SOUTH FLORIDA WATER MANAGEMENT DISTRICT

July 12, 2016

Mr. Ed Smith
Director
Office of Ecosystem Projects
Florida Department of Environmental Protection
3900 Commonwealth Boulevard, MS 24
Tallahassee, FL 32399-3000

Subject: Submittal of After-Action Report for Emergency Authorization for Temporary Operational Changes to Address High Water Conditions in the South Florida Region (OGC Case No. 00-0889)

Dear Mr. Smith:

In compliance with the requirements of Emergency Final Order issued by the Florida Department of Environmental Protection (Department) on Feb 11, 2016, the South Florida Water Management District (SFWMD) is pleased to submit the attached After-Action Report.

Water levels in Water Conservation Area 3A rose alarmingly high after extraordinary rainfall in December 2015 and January 2016, influenced by *El Niño* conditions. SFWMD and the U.S. Army Corps of Engineers operated the regional water management system under emergency provisions for 90 days during emergency conditions and beyond, successfully reducing the WCA-3A water level below dangerous levels and mitigating for downstream high water effects experienced by local businesses and residential areas. This report summarizes the water management and field operations that took place and provides a comprehensive summary of hydrologic and water quality conditions in the region during the emergency operations period.

If you have any questions regarding the report, please contact Seán Sculley, P.E., Principal Engineer, Compliance Assessment and Reporting Section, Water Quality Bureau by telephone at (561) 682-6109 or email at ssculley@sfwmd.gov.

Sincerely,

Ernie Marks
Division Director
Everglades Policy and Coordination

EM/am
Enclosure

Emergency Operations After Action Report

High Water Conditions in the South Florida Region

February 12–May 11, 2016

Prepared for

Florida Department of Environmental Protection

Prepared by

South Florida Water Management District

3301 Gun Club Road

West Palm Beach, FL

July 12, 2016

ACKNOWLEDGEMENTS

The South Florida Water Management District gratefully acknowledges the contributions of the professionals in the agency who participated in the production of this document. Contributors were Wossenu Abtew, Matahel Ansar, Jesus Carrasco, Thomas Dreschel, Patricia Gorman, Seyed Hajimirzaie, Kathleen Haunert, Nirmala Jeyakumar, Stephen Kelly, Christopher Madden, Amanda McDonald, Cheol Mo, José Otero, Chelsea Qiu, Armando Ramirez, Jorge Rivas, Seán Sculley, John Shaffer, Cassondra Thomas, Robert Verrastro, Andrew Wolf, Mike Worley and Shi Kui Xue. Reviewers were Teresa Coley, Suelynn Kirkland, Julianne LaRock, Paul Linton, Jonathan Madden and Brenda Mills.

The South Florida Water Management District also acknowledges the Clewiston, Miami, Homestead and Okeechobee field stations whose outstanding effort and public service significantly contributed to the success of the emergency operations.

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ACRONYMS, ABBREVIATIONS AND UNITS OF MEASUREMENT

µg/L	micrograms per liter
BCNP	Big Cypress National Preserve
cfs	cubic feet per second
EA	environmental assessment
EFO	emergency final order issued February 11, 2016
ENP	Everglades National Park
ERTP	Everglades Restoration Transition Plan
ET	evapotranspiration
F.S.	Florida Statutes
FDEP	Florida Department of Environmental Protection
FONSI	finding of no significant impact
FWC	Florida Fish and Wildlife Conservation Commission
FWM	flow-weighted mean
MWD	Modified Water Deliveries to Everglades National Park
NGVD29	National Geodetic Vertical Datum of 1929
ppb	parts per billion
RECOVER	Restoration, Coordination and Verification
SFWMD	South Florida Water Management District
STA	stormwater treatment area
TP	total phosphorus
USACE	United States Army Corps of Engineers
WCA	Water Conservation Area
WY	Water Year

EXECUTIVE SUMMARY

Rainfall in the South Florida Water Management District (SFWMD) from November 2015 through January 2016 was the wettest since records began in 1932. SFWMD basins received more than 300 percent of average rainfall or more in January, most of which occurred between January 27 and 29. Rainfall over Water Conservation Area 3A (WCA-3A) in January 2016 was 9.5 inches, more than 400 percent of average January rainfall. WCA-3A is only expected to receive this amount or more on average only once every 100 years.

Water levels in WCA-3A crested at elevation 11.50 feet National Geodetic Vertical Datum of 1929 (NGVD29) in mid-February and returned to below the highest zone (Zone A) of the regulation schedule by May 9. Approximately 681,000 acre-feet of water was discharged from WCA-3A during the 90-day emergency operations period, February 12–May 11, 2016. Everglades National Park (ENP) received more than one-half million acre-feet of water during the emergency operations period. Approximately 60 percent went to Western Shark River Slough and 40 percent went to Northeast Shark River Slough.

SFWMD field station staff and crews and contractors constructed numerous temporary features to move water and to mitigate effects of higher water levels in the region that affected local businesses and residents of the Las Palmas community. Construction activities included deployment of temporary pumps next to S-355B, rehabilitation of six earthen plugs in the L-28 borrow canal, installation of ramps, walkways with safety handrails and creation of dry land refuge for alligators and crocodiles for airboat vendors along Tamiami Trail, installation of temporary pumps in the C-358 seepage collection canal south of the Las Palmas community, construction of C-358 berm improvements and Richmond Drive ditch plugs to inhibit surface water flows to the C-358 canal, excavation of a temporary open connection between the C-358 and C-57 canals, installation of gated culverts with risers at the south end of the 8.5-Square Mile Area detention area, and securing authorization to degrade a portion of the S-327 weir in the S-332D detention area.

SFWMD submitted $1.314 million of field operations expenses for the S-355B temporary pumps, Las Palmas community mitigation, and L-28 canal plug rehabilitation conducted during the emergency operations period to the Florida Department of Environmental Protection (FDEP) for reimbursement. Funds were made available by FDEP through a release of funds from the Land Acquisition Trust Fund for the Grants and Aids to Water Management Districts Wetlands Protection special category.

The WCA-3A and WCA-3B flow-weighted mean (FWM) total phosphorus (TP) outflow concentration during the emergency operations period was 8 micrograms per liter (µg/L) or parts per billion (ppb), significantly lower than the 2007–2015 historical average of 13 ppb. The WCA-3A water level was between elevations 9.5 and 11.5 feet NGVD29 during the emergency operations period. The relatively low FWM TP concentration is consistent with previous observations of lower TP concentrations associated with high WCA-3A water levels.

TP concentrations measured during the emergency operations period throughout the region were at or below average concentrations for this time of year. The estimated FWM TP concentration of total inflows to Northeast Shark River Slough calculated with provisional data for tracking compliance with the 1991 Settlement Agreement is 6.9 ppb through June 6, 2016. It is not certain at this time whether the annual FWM TP, based on the federal water year ending September 30, 2016 (WY2016), will be below the long-term limit. Based on current and anticipated flows, it is expected that the limit will be 7.6 ppb. The estimated FWM TP concentration for Taylor Slough and Coastal Basins appears to be on a trajectory for 5–6 ppb, well below the compliance limit of 11 ppb.

Following a large S-197 discharge event in early December 2015, subsequent smaller releases during the emergency operations period did not appreciably reduce downstream salinity further, though the cumulative effect maintained desired salinity levels. It is unknown how much direct precipitation from above-average rainfall contributed to salinity reduction. From visual observations in Barnes Sound and Manatee Bay, it appears that bottom vegetation was unaffected by S-197 releases between December 2015

and May 2016, with *Thalassia* and *Halodule* continuing to maintain moderate bottom cover. No evidence of fish kills or high chlorophyll concentrations were observed and the waters in both basins remained mostly clear throughout the study period.

Lake Okeechobee releases to the St. Lucie Estuary (297,000 acre-feet) accounted for two-thirds of all inflows to the St. Lucie Estuary during the emergency operations period. Flows from Lake Okeechobee to the Caloosahatchee River Estuary (578,000 acre-feet) accounted for three-fourths of all Caloosahatchee River Estuary inflows for the same period. Salinity conditions in both estuaries improved for oysters and submerged aquatic vegetation during the emergency operations period.

INTRODUCTION

Extreme rainfall events in December 2015 and January 2016 caused by extraordinary natural phenomena resulted in water levels in WCA-3A rising dramatically and severe impacts to natural resources. WCA-3A flooding imperiled avian and mammal species. Immediate action beyond what was allowed under existing regulatory criteria was necessary to move significant volumes of water out of WCA-3A.

On February 11, 2016, FDEP issued an emergency final order (EFO) authorizing SFWMD and the United States Army Corps of Engineers (USACE) immediate action to deviate from permitted water management practices to move significant volumes of flood water out of WCA-3A to ENP through Shark River Slough. Under this EFO, operation of six projects[1] permitted by FDEP were temporarily modified and remedial means necessary to redress the emergency were authorized. In addition, Florida Governor Rick Scott requested USACE to implement a deviation from the *Central and Southern Florida Project Water Control Plan for Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System* (USACE 2012) in WCA-3A. The EFO directed USACE and SFWMD to continue water quality and hydrologic monitoring of their respective existing permitted project features and to identify and evaluate water quality and hydrologic conditions in the affected areas. Monitoring and reporting requirements, including the production of this after action report, are articulated in Paragraph 18, Specific Conditions, of the EFO.

On February 12, 2016, USACE signed the *Finding of No Significant Impact, L-29 Canal and South Dade Conveyance System Temporary Emergency Deviation to Affect Relief of High Water Levels within Water Conservation Area 3A (WCA-3A), Broward and Miami-Dade County, Florida* (USACE 2016) and initiated the temporary emergency deviation on February 15. The temporary emergency deviation of the *Central and Southern Florida Project Water Control Plan for Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System* (USACE 2012) was in effect for 90 days and allowed water levels in the L-29 canal to be raised in order to allow more water to flow from WCA-3A to ENP. The L-29 canal runs along the north side of the Tamiami Trail (US Highway 41) between WCA-3A and ENP. The WCA-3A Water Control Plan limits L-29 canal stages to elevation 7.5 feet (NGVD29). USACE concurrently issued an Environmental Assessment (EA) and FONSI of this federal action (USACE 2016).

The central change in operations was to lower WCA-3A stage by relaxing the allowable maximum water level in the L-29 Canal (the canal that receives flows from WCA-3A through the S-333 and from WCA-3B through S-355 A and B) from elevation 7.5 feet NGVD29 up to 8.5 feet NGVD29. USACE and

[1] FDEP issued permits to SFWMD for the C-111 Spreader Canal Project (including the S-199 and S-200 pump stations and the S-18C water control structure), the Non-Everglades Construction Project Discharge Structures Project (including the S-334 water control structure), and the S-197 Control Structure Project. FDEP also issued permits to the USACE for the WCA-3 Decompartmentalization and Sheetflow Enhancement Physical Model Project (including the S-152 water control structure), the Modified Water Deliveries to Everglades National Park Project (including the S-355A and S-355B water control structures), and the Ninth Amended Emergency Final Order to Operate the S-332B, S-332C, and S-332D Pump Stations and Appurtenant Structures.

SFWMD made temporary operational changes and constructed temporary water control features in order to achieve the objective of lowering WCA-3A more rapidly while preserving the authorized flood mitigation level of service for the Las Palmas development (also known as the 8.5 Square Mile Area) adjacent to Northeast Shark River Slough in ENP and areas served in the C-111 basin.

FDEP issued an Emergency Measures – High Water Scenarios Order on May 11, 2016. This second order granted authority to SFWMD and USACE to complete construction and continue operation of five projects undertaken as part of the EFO until November 30, 2016: 1) temporary pumps adjacent to the S-355B structure; 2) WCA-3A Decompartmentalization and Sheet Flow Enhancement Physical Model project including the S-152 structure; 3) Modified Water Deliveries to ENP project; 4) degradation of a portion of the S-327 weir within the S-332D detention basin; and 5) rehabilitation of six earthen plugs in the L-28 borrow canal and operation of S-344 structure.

WATER CONSERVATION AREA 3A

ECOLOGY

WCA-3A, the largest Everglades WCA (786 square miles), is located in western Miami-Dade and Broward counties. Originally one conservation area, in 1962 WCA-3 was divided into WCA-3A and WCA-3B by construction of two interior levees (L-67A and L-67C) so that water losses due to levee seepage could be reduced. WCA-3A is predominately a vast sawgrass marsh dotted with tree islands, wet prairies, and aquatic sloughs. A cypress forest fringes its western border along the L-28 Gap and expands south to the Tamiami Trail. WCA-3A is not entirely enclosed by levees. A 7.1-mile stretch, the L-28 Gap, was left open on the mid-western side of WCA-3A to allow overland flows into Big Cypress National Preserve (BCNP). **Figure 1** shows location, inflow and outflow structures, and water level gauges of WCA-3A. WCA-3A receives most of its water from direct rainfall. Surface water inflows to WCA-3A are from the Everglades Stormwater Treatment Areas (STAs) to the north, WCA-2A and WCA-2B to the east, and agricultural lands to the west. Water leaves WCA-3A primarily through evapotranspiration (ET), the combined effect of evaporation and uptake of water by plants. A significant amount of water also leaves WCA-3A by groundwater seepage. Surface water is discharged west to BCNP, south to ENP, and east and south to Miami-Dade County for water supply during dry times and to tide during wet periods. Ownership is mixed with state, SFWMD, and private interests. The state leases portions of its land to the Miccosukee Tribe of Indians. The Florida Fish and Wildlife Conservation Commission (FWC) manages the areas and manages hunting for waterfowl, deer, and small game.

Water levels in WCA-3A rose dramatically as a result of record rainfall. The rapid rise, especially since it occurred during a time of year when water levels are historically low (dry season), inundated tree islands and other wildlife habitat. According to FWC, flooding eliminates nesting opportunities that can inhibit recovery of imperiled bird species. Sustained flooding would seriously impact and reduce population levels of white-tailed deer, nesting birds, and wading birds.

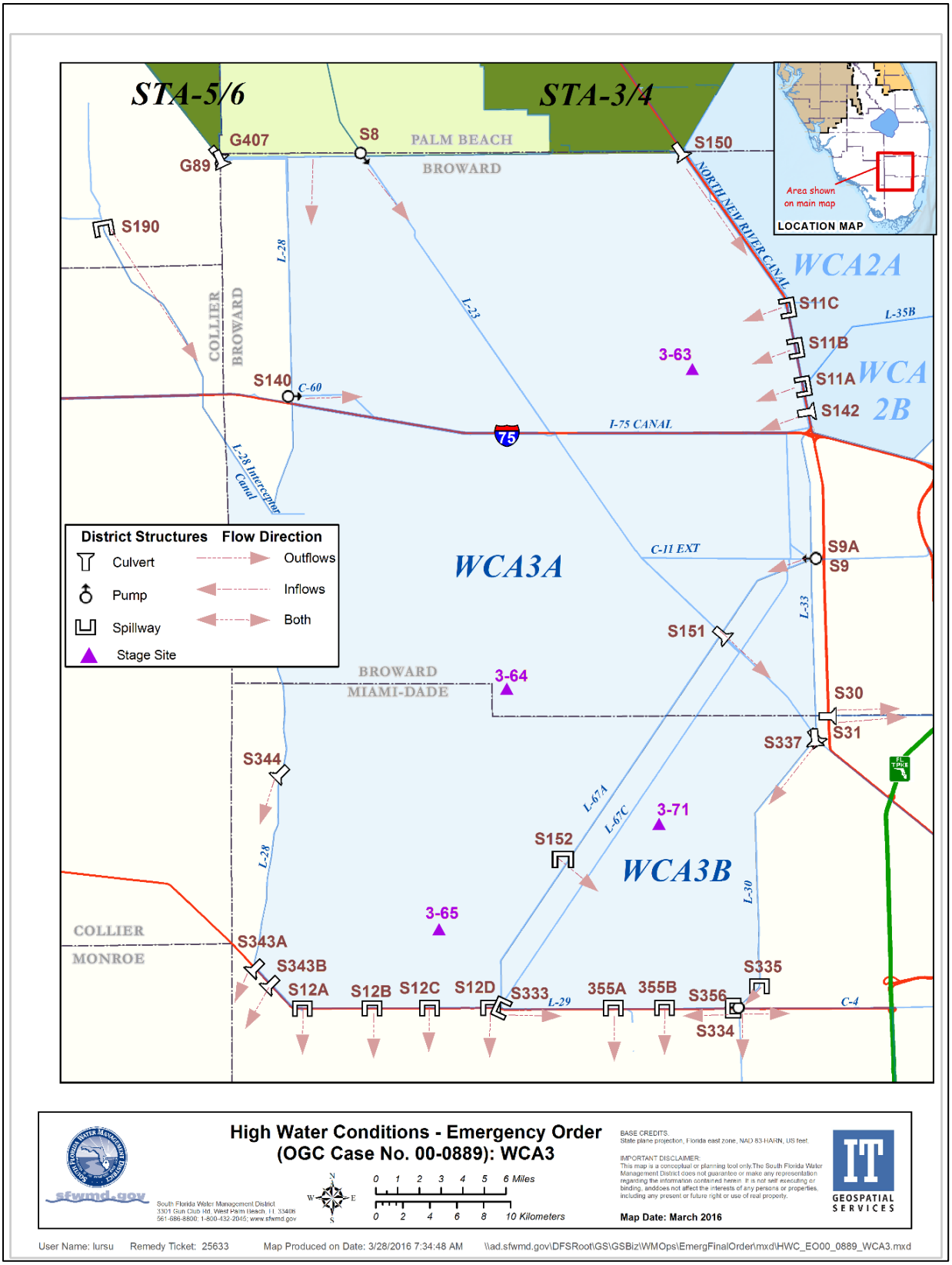


Figure 1. WCA-3A and WCA-3B with water control structures and water level recorders.

REGULATION SCHEDULE

Water levels in WCA-3A are managed in part by operation of several water control structures that discharge from WCA-3A to canals downstream. Rules that govern operation of these structures are developed by USACE and are codified in a regulation schedule that is part of the water control plan. The regulation schedule prescribes (or prohibits) discharges through specified water control structures based on WCA-3A water level and time of year. **Figure 2** shows the current regulation schedule for WCA-3A, modified in 2012 to include the operational guidance for the Everglades Restoration Transition Plan (ERTP). This WCA-3A regulation schedule is interim because it will be modified again at the conclusion of the USACE series of incremental tests that will result in a comprehensive operating plan that will be incorporated into the WCA, ENP, and ENP-South Dade Conveyance water control plan for operation of the Modified Water Deliveries to ENP (MWD) and C-111 South Dade projects.

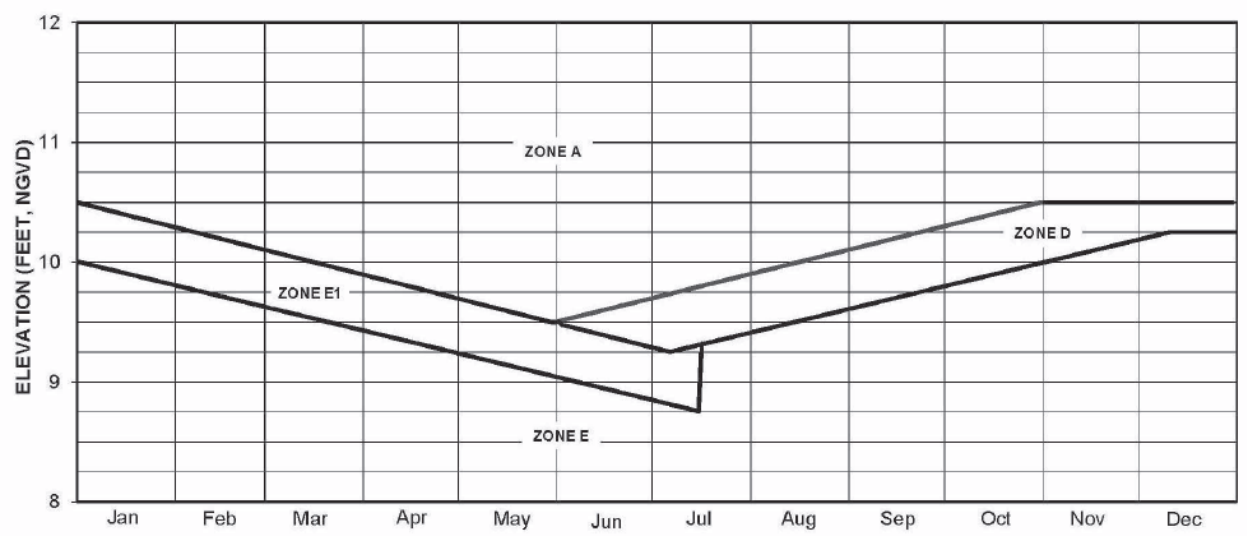


Figure 2. WCA-3A interim regulation schedule (USACE 2012).

The regulation schedule has the calendar year along the horizontal axis and WCA-3A water level along the vertical axis. The lines of the regulation schedule define regions or zones, in which a series of specific operational rules are to be followed. The uppermost region is called Zone A. If the WCA-3A stage[2] is in this zone, flood control releases, subject to constraints, is authorized. The middle zones (D and E1) are transitional and include the desirable WCA-3A water levels to be maintained. The lowest region of the regulation schedule, Zone E, prescribes discharges to ENP that mimic what would have flowed under the natural system (pre-construction of levees, canals, etc.) based on rainfall in the region.

Under the ERTP water control plan, operation of the S-333 water control structure is constrained by the L-29 canal stage and the water level reading from the G-3273 gauge in Northeast Shark River Slough. The L-29 constraint requires S-333 to be closed when the stage exceeds 7.5 feet NGVD29; the G-3273 constraint requires S-333 to be closed if the gauge reading is above 6.8 feet NGVD29. The G-3273 constraint was relaxed beginning October 15, 2015, as part of the USACE Increment 1 Field Test, implemented with a temporary deviation. The key provision of the temporary emergency deviation implemented in accordance with the EFO issued May 11, 2016, was to relax the L-29 constraint (from 7.5 feet NGVD29 up to 8.5 feet NGVD29) in order to allow more discharge from WCA-3A through S-333.

[2] USACE and SFWMD use the arithmetic average of three water level gauges (3-63, 3-64, and 3-65 shown in **Figure 1**) to indicate WCA-3A stage and use it with the WCA-3A regulation schedule and other hydrologic information to make operational decisions for the discharge structures.

EMERGENCY OPERATIONS

COORDINATION AMONG AGENCIES

In accordance with Specific Condition 19 of the EFO, SFWMD maintained close coordination with the USACE, FDEP, and other interested stakeholders in order to address in a timely manner any potential water quality, flood protection, or environmental resource issues. Interested stakeholders included the United States Department of Interior, the Florida Department of Agriculture and Consumer Services, FWC, and the Miccosukee Tribe of Indians of Florida.

SFWMD obtained state approval for field operations activities in support of accomplishing the EFO objective. SFWMD submitted project activity forms to the FDEP Office of Ecosystem Projects for review and authorization to conduct the proposed work. This is presented in more detail in the next section.

ACTIVITIES

This section includes descriptions of water management operations (operation of water control structures) and field operations (construction activities, pump deployments, etc.) conducted by USACE and SFWMD to expedite lowering WCA-3A water stages and mitigate for higher water stages downstream. The actions that took place subsequent to the issuance of the EFO were generally as follows:

- USACE and SFWMD consulted with potentially affected parties in advance of emergency operations to seek concurrence and secure temporary flowage easements.
- USACE issues National Environmental Policy Act documentation to support a temporary emergency deviation February 12, 2016.
- USACE implements a temporary emergency deviation to the current ERTP governing operations in the project area on February 15, 2016. The key provision of this deviation is relaxing the L-29 canal water level constraint from 7.5 feet NGVD29 up to 8.5 feet NGVD29 for the purpose of providing high water relief in WCA-3A.
- SFWMD maximizes WCA-3A discharges through multiple water control structures including temporary pumps.
- SFWMD initiates rehabilitation of the L-28 canal plugs with commensurate S-344 structure operation to provide additional WCA-3A outflow capacity to BCNP.
- SFWMD mitigates for higher L-29 canal water level effects immediately downstream of the L-29 canal.
- Sustained higher water levels in the L-29 canal result in larger discharges into and higher stages in Northeast Shark River Slough. This in turn results in more seepage into the L-31N canal and higher stages in the 8.5 Square Mile Area.
- SFWMD operates the South Dade Conveyance System structures to account for higher flows into the C-111 basin resulting from WCA-3A discharges and increased seepage from Northeast Shark River Slough.
- SFWMD mitigates for higher water levels in the Las Palmas community, formerly known as the 8.5 Square Mile Area.
- USACE and SFWMD implement an operational strategy for a transition from the temporary emergency deviation for up to 60 days beginning May 12, 2016, after WCA-3A water levels were lowered below Zone A.

The WCA-3A stage rose above the Zone A line of the regulation schedule on December 5, 2015, to an elevation of 10.50 feet NGVD29 and remained fairly constant until late January 2016. Throughout December, the WCA-3A stage remained within a tenth of a foot above the Zone A line (10.50 feet NGVD29) but was nearly three-tenths of a foot above the line by January 26, 2016, due to the Zone A line lowering beginning in January to prepare for the following wet season. By January 29 (after the extreme rainfall event), WCA-3A stage had risen to elevation 11.00 feet NGVD29, seven-tenths of a foot above the Zone A line. Furthermore, the L-29 canal stage rose above elevation 7.5 feet NGVD29 on January 29, 2016, requiring the S-333 water control structure to be closed. This significant constraint persisted ten days until February 5, 2016.

By February 11, the WCA-3A water level had risen to 11.35 feet NGVD29, was rising approximately 0.02 feet per day and was 1.12 feet above the Zone A line. Between the time the WCA-3A stage crested at an elevation of 11.50 feet NGVD29 on February 18, 2016, and the time it remained below the Zone A line on May 9, 2016,more than 800,000 acre-feet of water was either discharged (681,000 acre-feet) or lost due to net ET and seepage (120,000 acre-feet) from this water body.

SFWMD and USACE implemented emergency operations in accordance with Exhibit A of the EFO and in a manner that minimized harmful impacts, including flooding and degradation of water quality, to the environment, the public, adjacent properties, and downstream receiving waters. SFWMD and USACE ensured that adverse off-site water resource related impacts did not occur as a result of this EFO and fully monitored conditions related to the activities authorized by the order. The emergency operations were implemented in a manner that minimized detrimental impacts (including harmful flooding and degradation of water quality) to the environment, the public, adjacent properties, and downstream receiving waters to the greatest extent practicable. SFWMD and USACE implemented emergency operations that maximized beneficial impacts to the environment to the greatest extent practicable consistent with the hydrological and biological restoration goals of the Everglades Forever Act (Section 373.4592, Florida Statutes [F.S.]) and the Florida Bay Restoration Act (Section 373.4593, F.S.).

All emergency operation activities were conducted using appropriate best management practices. Best management practices for activities conducted in or discharging to wetlands or other surface waters included properly installed and maintained erosion and turbidity control devices to prevent erosion and shoaling and to control turbidity. Turbidity and erosion controls were installed prior to clearing and excavation and placement of fill material, and were maintained in effective conditions at all locations until construction was completed, disturbed areas were stabilized, and turbidity levels fell below 29 nephelometric turbidity units above background for flows to Class III waters and to background levels for flows to Outstanding Florida Waters. USACE and SFWMD ensured that erosion control devices and procedures were inspected and maintained during all phases of construction. This applies to the S-355B temporary pumps, C-358-C-357 connection, C-358 berm work, Richmond Drive berm work, S-360W weir culverts, and S-327 weir modification. SFWMD and USACE corrected for any erosion, shoaling, water quality, or flooding problems that resulted from the operation of the structures authorized by the EFO.

Secure Authorization to Conduct Field and Water Management Operations

USACE and SFWMD secured agreements with affected parties along the L-29 canal prior to water levels being raised. Extensive coordination took place with the Miccosukee Tribe of Indians of Florida and separate agreements were reached with Everglades airboat tour operators (vendors) and the Florida Power & Light Company whose lands received flows due to higher water levels in the L-29 canal. SFWMD also provided mitigation measures that restricted flows from coming into the vendors' properties. Raising the L-29 canal stage limit increased the available discharge capacity through S-333. Most of these flows in turn, flowed into Northeast Shark River Slough between the S-333 and S-334 structures.

SFWMD submitted project activity forms to the FDEP Office of Ecosystem Projects for state approval for emergency field operations that are described in this section. **Table 1** below lists activities for which

project activity forms were submitted and received FDEP approval. Activities listed in **Table 1** were also coordinated with the USACE Miami Regulatory Section for federal government approval. USACE staff verified by email that activities were either non-jurisdictional and therefore did not require a permit or where approval was required, a nationwide permit was issued.

Table 1. FDEP project activity form approvals.

Feature	FDEP Approval
C-358 Berm & Richmond Drive Plugs	3/30/2016
S-344 Emergency Operations	3/30/2016
L-28 Plugs & S-344 Operations	3/30/2016
C-358 Extension to C-357	4/15/2016
Culverts Near S-360W	4/15/2016
S-327 Weir Degradation	4/22/2016
Tower Road maintenance	5/10/2016
Culverted C-358 Crossings	5/19/2016

Maximize Use of WCA-3A Outflow Structures

Surface water can be discharged from WCA-3A through 10 water control structures that are listed in **Table 2**. Each water control structure has its own operating criteria. Operating criteria were modified for some of the structures during the emergency period.

Increase S-333 Discharge

Prior to issuance of the EFO, operation of the S-333 single-gated spillway water control structure was governed by the ERTP water control plan and the WCA-3A regulation schedule. Discharge through the structure was constrained by the water level in the L-29 canal between S-333 and S-334 structures (10.7 miles east of S-333). S-333 must close if the L-29 canal stage (computed as the average of S-333 tailwater and S-334 headwater elevations) was above 7.5 feet NGVD29.

With issuance of the EFO and subsequent USACE implementation of a temporary emergency deviation that included a provision to allow the L-29 canal stage to rise up to 8.5 feet NGVD29, it was necessary to secure agreements (temporary flowage easements) with and provide mitigation for federally recognized tribes, landowners, and commercial interests along the Tamiami Trail before L-29 canal water levels were allowed to rise resulting from increased S-333 discharges. For the week prior to the additional opening of the S-333 spillway gate, discharge averaged 520 cubic feet per second (cfs) with the gate opening generally ranging between 1.6 and 2.0 feet. On February 15, 2016, the spillway gate was opened substantially more and for the following week, flows averaged 1,230 cfs. Since February 16, 2016, S-333 discharges averaged 1,300 cfs, with most of the time at maximum discharge (e.g., the spillway gate completely out of the water).

Table 2. WCA-3A discharge structures and operating constraints prior to the emergency period.

Structure	Type/Flow	Destination	Constraints
S-151	Gated Culverts (6) 1,105 cfs (design)	WCA-3B or for water supply (when used together with S-31 and S-337)	
S-152	Gated Culverts (10) 750 cfs (max)	WCA-3B	Operation is restricted to November through January
S-344	Gated Culverts (2) 135 cfs (design)	BCNP and ENP	Opened when WCA-3A is above schedule; Loop Road gauge kept below 8.5' NGVD29; Closed November 1–July 14 to protect Cape Sable seaside sparrow habitat.
S-343A	Gated Culverts (3) 195 cfs (design)	Tamiami Trail Canal and BCNP	Regulatory releases only; Closed November 1–July 14 to protect Cape Sable seaside sparrow habitat.
S-343B	Gated Culverts (3) 195 cfs (design)	Tamiami Trail Canal and BCNP	Regulatory releases only; Closed November 1–July 14 to protect Cape Sable seaside sparrow habitat.
S-12A	Gated Spillway (6) 8,000 cfs (design)	Western Shark River Slough in ENP	Closed November 1–July 14 to protect Cape Sable seaside sparrow habitat.
S-12B	Gated Spillway (6) 8,000 cfs (design)	Western Shark River Slough in ENP	Closed January 1 – July 14 to protect Cape Sable seaside sparrow habitat.
S-12C	Gated Spillway (6) 8,000 cfs (design)	Western Shark River Slough in ENP	
S-12D	Gated Spillway (6) 8,000 cfs (design)	Western Shark River Slough in ENP	
S-333	Gated Spillway (1) 1,350 cfs (design)	Eastern Shark River Slough or South Dade Conveyance System	Closed if L-29 canal stage > 7.5 feet NGVD29 or if G-3273 gauge > 6.8 feet NGVD29; under Increment 1, closed if L-29 canal > 7.5 feet NGVD29.

Operate S-152 Culverts

S-152 is a set of ten manually operable gated culverts adjacent to the L-67A canal that USACE is allowed to operate on a limited basis from November through January under a permit issued by FDEP for the WCA-3 Decomp Physical Model project. The structure was closed January 28, 2016, at the conclusion of the most recent project test cycle. The structure was opened for a brief period in February (19–22) and was closed due to WCA-3B having insufficient discharge capacity through the S-355A and S-355B spillways that discharge by gravity. Their discharge capacity was greatly reduced by the higher tailwater stage in the L-29 canal. For this reason, SFWMD deployed temporary pumps to provide WCA-3B discharge capacity (see next section). When the temporary pumps were close to becoming operational, S-152 was opened again. SFWMD opened S-152 (75 percent opening; all 10 gates opened 3.5 feet) March 9, 2016, to increase WCA-3A outflows. All 10 culverts were closed May 3, 2016, because WCA-3A stage was no longer in Zone A of the regulation schedule. Approximately 37,000 acre-feet of water was discharged from WCA-3A through the S-152 culverts during the emergency operations period.

S-355A and S-355B

These two gated spillways are located on the south end of WCA-3B and discharge into the L-29 canal. Both S-355A and S-355B operated only briefly during the emergency operations period (March 1–11, 2016) largely because the discharge capacity of these two structures was reduced greatly by higher water levels in the L-29 canal. For this reason, temporary pumps were deployed next to the S-355B structure to provide sufficient WCA-3B discharge capacity during emergency operations.

Deploy Temporary WCA-3B Pumps

SFWMD deployed four temporary pumps adjacent to the S-355B water control structure in WCA-3B that were used in conjunction with S-152 in order to move water from WCA-3A through WCA-3B then into the L-29 canal and into ENP (Northeast Shark River Slough).

Deployment of temporary pumps to "lift" water from WCA-3B into the L-29 canal was necessary because water could not be discharged by gravity through the S-355A and S-355B structures. Water levels in the L-29 canal rose by 0.5 feet or more due to the increased S-333 discharges. This created water levels downstream of the S-355 structures that were roughly equal to or higher than the water level on the upstream (WCA-3B) side. Four 30-inch diameter diesel pumps were installed with 185-foot long discharge pipes over the L-29 levee. Flow through each pump was rated at 50 cfs for a total of 200 cfs pumping capacity. The pumps began operation March 12, 2016. Occasionally, one or more pumps were shut down for maintenance, repair, or low water conditions. For the 63 days of their operation, the pumps operated 76 percent of the time. All pumps were secured on May 13, 2016.

Rehabilitate L-28 Plugs and Operate S-344

On March 24, 2016, SFWMD requested authorization from USACE to rehabilitate six earthen plugs in the lower L-28 borrow canal and to temporarily operate the S-344 water control structure to aid in relieving high water levels in WCA-3A. The L-28 plugs were originally put in place by USACE to prevent over-drainage of the eastern portion of BCNP during dry conditions. The plugs are located adjacent to tree islands and other areas of high ground to the west. The rehabilitated plugs will help direct S-344 discharge from WCA-3A as sheet flow to the eastern portion of BCNP. Flow through S-344 started after the 90-day emergency operations period on May 19, 2016 when rehabilitation of the northernmost plug was complete. S-344 gate openings were increased as work was completed on the remaining five plugs, working from south to north.

Operate S-12C and S-12D

USACE operated the S-12C and S-12D structures in accordance with the ERTP water control plan; no deviations from their operating criteria were necessary. These two structures discharged 280,000 acre-feet of water from WCA-3A into Western Shark River Slough during the emergency operations period.

S-12A and S-12B

S-12A and S-12B virtually remained closed in accordance with the ERTP water control plan as the 90 days of emergency operations was within the closure period to protect Cape Sable seaside sparrow habitat. Due to the high headwater elevation at the S-12A spillway, gates were opened February 22–March 10, 2016, just enough to prevent overtopping of the gates. Flow averaged 250 cfs and a total of 9,000 acre-feet was discharged through S-12A during the 18 days.

Mitigate for Higher L-29 Canal Water Levels

Affected Businesses along Tamiami Trail

SFWMD Miami Field Station staff met with representatives of Coopertown Airboats, Everglades Safari Park, and Gator Park businesses to mitigate for effects higher L-29 canal water levels would have on their properties. These businesses are located off of Tamiami Trail and their properties have surface water connections to the L-29 canal.

On February 17, 2016, Miami Field Station staff met with Coopertown Airboats to evaluate the rising water around their boat docks. If the water reaches elevation 8.5 feet NGVD29, the docks that Coopertown Airboats uses to load customers onto their boats would be flooded. Customers would then have to walk through standing water to get to the boats. The team decided to remove the docks from their anchor points and reattach them to new ramps. The new ramps were fabricated from ten-foot wide deck boards and fastened together with two-inch by six-inch stringers. Three docks were modified. This raised the docks by seven inches and kept the ramps and docks dry.

On February 23, 2016, SFWMD Miami Field Station staff met with a representative of Everglades Safari Park on-site to discuss ways of addressing a large trip hazard on their walkway and reduced dry land for their alligators due to high water on their property resulting from higher L-29 Canal water levels. It was agreed that SFWMD would attach three diamond-plate sheets to the existing hinged walkway. SFWMD purchased the plates that day and fabricated and installed the plates February 25. Also on February 25, 2016, SFWMD Miami Field Station staff moved 400 bags of sand, each weighing 40 pounds, to the alligator enclosures and spread the material in 3.5 hours to provide dry land. SFWMD created a staging area next to Tamiami Trail and used sand bags to transport the sand to the enclosures. The sand bags were loaded onto Jon boats and moved to the side of the island closest to the enclosures. From there the bags were transferred to wheelbarrows and the sand was dumped into the alligator enclosure. This was labor intensive but provided the cleanest and fastest way of getting material to the enclosure.

Everglades Safari Park also had walkways to their outside exhibits that were starting to flood. With the water scheduled to go up to 8.5 feet NGVD29, the walkways would be under water. Customers would have to walk through water to get to the exhibits. The Miami Field Station constructed 500 feet of eight-foot wide wooden walkways with safety handrails over existing walkways (**Figure 3**). All wood was loaded onto Jon boats and transported to the island. It was a labor intensive operation to elevate the walkways by eight inches and out of the water.

In April 2016, as the water level in the L-29 canal was approximately 8.3 feet NGVD29, Everglades Safari Park needed more sand placed in their crocodile exhibit. Four hundred more bags of sand were deployed by Miami Field Station staff. Coopertown Airboat had the same issue with their alligator enclosure. High water eliminated any dry land for the alligators. Four hundred bags of sand were spread in the enclosures providing alligators dry refugia (**Figure 3**).

Figure 3. SFWMD installation of raised walkway with handrails at Everglades Safari Park.

Gator Park Airboat was concerned with high water near electrical conduit. The electrician from Miami Field Station inspected the conduit and found only security camera wiring in the conduit. It was deemed safe for water to be in the conduit and presented no danger to the public. Gator Park Airboat also had flooding in their pedestrian walk area. The Field Station placed ten sheets of plywood down next to their docks and secured them to the docks. The plywood provided dry, safe access on to which customers walked (**Figure 4**).

Figure 4. Before and after placement of sand to provide dry refugia for crocodiles at Everglades Safari Park.

Maintenance of Communication Tower Access Roads in ENP

SFWMD coordinated with ENP to conduct maintenance work on approximately one-half mile of tower access roads that became impassable as a result of the higher L-29 canal water levels. The roads are immediately south of Tamiami Trail and approximately ten miles west of Krome Avenue. SFWMD staff began to place clean crushed limestone on the inundated road sections (approximately ten-feet wide) to a depth of approximately one foot on May 9, 2016. This amounted to 900 cubic yards of fill. SFWMD installed silt fences prior to placement of fill as a best management practice to control turbidity. It took eleven days to complete this work.

Mitigate for Higher Water Levels in the Las Palmas Community

SFWMD initially requested approval from FDEP to construct features to alleviate high water levels in the southwest portion of the Las Palmas community (formerly known as the 8.5 Square Mile Area): 1) installation of one temporary pump at the eastern terminus of the C-358 seepage collection canal to lift water from the C-358 canal to the C-357 canal upstream of the S-357 pump station (later revised to two temporary pumps); 2) rehabilitation of the west end of the C-358 berm; 3) construction of a temporary berm connecting the C-358 berm to the ditch along the south side of Richmond Drive (SW 168th Street); and 4) placement of plugs in ditches on the north and south sides of Richmond Drive in the vicinity of SW 213th Avenue. The last three features were to prevent surface water from entering the C-358 seepage collection canal.

Staff from Homestead and Clewiston field stations worked during the week of February 29, 2016, to install a temporary pump to move water from the C-358 seepage canal (also known as the Richmond Drive seepage collection canal) into the C-357 canal (**Figure 5**). A temporary pump (40-cfs) was used to keep the adjacent Las Palmas community from flooding as a result of raised groundwater levels. The temporary

pump installation included transportation and deployment of a power unit, pump, fuel tank, and 240 feet of pipe. SFWMD field crews constructed a transition ramp, an earthen bridge over the pipe and removed an earthen plug upstream. Installation was completed within three days.

Figure 5. SFWMD transportation of power unit, pump, fuel tank, and pipe (left); connecting pipe (center); and removal of earthen plug (right).

During the week of March 7–11, 2016, a contractor installed power poles and made the necessary tie-ins for new service and removed the existing S-357 service line and poles. Rehabilitation of the C-358 berm, construction of a temporary berm between C-358 and Richmond Drive and placement of ditch plugs on each side of Richmond Drive (adjacent to the L-357 levee) was completed (**Figure 6**) and a second 30-inch diameter 40-cfs temporary pump was installed the week of March 1. Pumping with the second pump began March 5, 2016. While the two 40-cfs temporary pumps were able to stem the rate of rising water levels in the affected area, they did not provide sufficient relief. SFWMD removed the temporary pumps and created an open connection between the C-358 and C-357 canals on April 9, 2016.

SFWMD requested USACE approval to excavate a temporary open channel to connect C-358 to C-357 in lieu of the two deployed temporary pumps. While the temporary pumps were effective in stemming the rate of rise of water levels in the area, they were not able to lower water levels as desired. The USACE Engineering and Design Branch approved the SFWMD request on April 20, 2016, conditioned upon SFWMD restoring the temporary connection and the C-358 canal crossing at SW 207th Avenue (USACE contractor haul road to a disposal area) by May 7, 2016. SFWMD created the open connection April 9, 2016. Stages in adjacent areas declined by 0.5 feet NGVD29 or more over the next few weeks with continued operation of the S-357 pump station and the open connection.

Figure 6. Las Palmas community mitigation (left to right): ditch plug on north side of Richmond Drive; berm connecting C-358 seepage collection canal berm to Richmond Drive; and culverted crossing of C-358 seepage collection canal.

Staff from the Okeechobee and Homestead field stations began excavation to open the C-358 seepage canal to the C-357 canal and remove the two temporary pumps the week of May 5, 2016. Additionally, two 72-inch culverts were installed by staff from the Homestead Field Station at both 207th Avenue and 205th Avenue (a total of four 72-inch culverts) to facilitate the USACE contractor's haul route ingress and egress to the USACE projects.

Construct Temporary Culverts at 8.5 Square Mile Area Detention Area

SFWMD requested approval from USACE on April 11, 2016, to install temporary culverts in the southwest corner of the 8.5 Square Mile Area Detention Area (just west of the S-360W weir). USACE approved the SFWMD request conditioned upon SFWMD discontinuing discharge through the temporary culverts by May 7, 2016. The three 36-inch corrugated metal pipe culverts with removable flash boards were used to maintain the 8.5 Square Mile Area detention area water depths similar to what would occur when construction of the C-111 northern detention area is complete.

Staff from the Okeechobee Field Station construction crew and the Homestead Field Station began installation on April 14 and completed work April 15. The intent was to have the culvert inverts placed at elevation of 5.25 feet NGVD29 but the construction crew could not excavate to a sufficient depth for this vertical placement. The three culverts were set at elevations ranging from approximately 5.75 to 5.90 feet NGVD29.

Figure 7 shows the location of the temporary culverts relative to the C-358 seepage collection canal, the S-357 pump station, and the existing concrete weirs at the southern end of the detention area (S-360E and S-360W). The culverts were placed just east of S-360W.

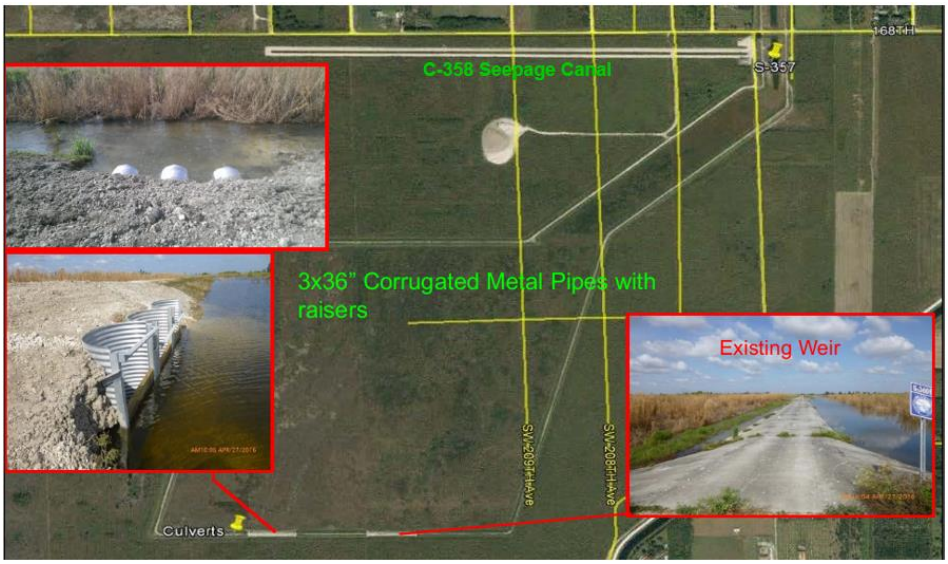


Figure 7. Temporary culverts at south end of the 8.5 Square Mile Area detention area.

Modify S-327 Weir

SFWMD submitted a project activity form to FDEP on April 20, 2016, proposing to degrade a portion of an existing concrete broad-crested weir (S-327) located west of the S-332D pump station in the northern end of the S-332D detention area.

The degraded length of weir would provide conveyance for the full design discharge capacity of S-332D (575 cfs), while the existing S-329 berm located between Cell 2 and the flow-way cell of the S-332D detention area will maintain sufficient stages within the northern portion of the S-332D detention area. It would also accommodate continued use of S-332DX1 for water deliveries from the S-332D detention area high head cell north to the south detention area. FDEP issued a letter to SFWMD on April 22, 2016, acknowledging that the temporary modification would minimize return seepage to the L-31N canal, which will in turn help mitigate effects of increased stages in the L-29 canal and other measure that will lower water levels in WCA-3A.

By the end of the emergency operations period, SFWMD had not yet received USACE permission to proceed as this was considered an alteration to a civil works project. Therefore, USACE was required to

consider the request in accordance with Section 14 of the Rivers and Harbors Act of 1899 and codified in 33 United States Code 408 (commonly referred to as "Section 408").

Reduce Inflows to the Water Conservation Areas

Activate Hillsboro Canal Aquifer Storage and Recovery

SFWMD communicated with FDEP that operation of the Hillsboro aquifer storage and recovery system would be initiated under an underground injection control permit that had been issued in December 2015. An inspection of the facility took place in February 2016 by FDEP, and authorization to proceed with operation was received in March 2016. The authorization included a reduction in the monitoring parameters and frequencies to allow more flexibility in site operations during the period of the EFO. The aquifer storage and recovery system began withdrawing water from the Hillsboro Canal on May 26, 2016, at a rate of 5 million gallons of water per day, equivalent to 8 cfs. Water from the canal was treated via mechanical filtration and ultraviolet disinfection prior to injection into the Floridan aquifer, at a depth of approximately 1,000 feet below land surface. The underground injection control permit allows withdrawal from the canal for a period of 60 days, although SFWMD is considering requesting an extension of the recharge duration.

Activate Kissimmee Basin Aquifer Storage and Recovery

SFWMD initiated an electrical and mechanical assessment of the Kissimmee aquifer storage and recovery system during February 2016, with the intent of placing the system back into operation, after a hiatus of approximately 3 years. The system is currently undergoing that evaluation and is anticipated to be rehabilitated during the remainder of calendar year 2016. SFWMD received a draft underground injection control operating permit from FDEP on May 25, 2016, allowing withdrawal from Lake Okeechobee at a rate of 5 million gallons of water per day (equivalent to 8 cfs) for a period of 6 months. Water from Lake Okeechobee will be treated via media filtration coupled with ultraviolet disinfection prior to injection into the Floridan aquifer, at a depth of approximately 800 feet below land surface.

Deploy Temporary Pumps near S-7 Pump Station

On March 18, 2016, SFWMD requested FDEP authorization to install four 42-inch diameter temporary diesel pumps, each with a nominal capacity of 100 cfs, adjacent to the S-7 pump station due to failure of one of the three 830-cfs pumping units. On April 26, 2016, SFWMD transported and unloaded pipes, air compressor, and hardware and completed earthwork for the site. Assembly began April 27. This action reduced the need to use pump station S-8 as a back-up, since use of this facility is currently limited by the high water conditions in WCA-3A. S-7 pumps into WCA-2A as will the four temporary pumps. S-8 pumps into WCA-3A. **Figure 8** shows the temporary pumps assembly, intake, and discharge.

Figure 8. Temporary pumps assembly, intake, and discharge near S-7.

FIELD OPERATIONS EXPENSES

FDEP made $1.55 million available to reimburse SFWMD for field operations expenses incurred as part of emergency operations. SFWMD submitted $1.31 million of eligible expenses incurred through June 15, 2016. This amount includes $327,000 of SFWMD field operations staff time, $854,000 in contractual, fuel, and materials expenses, $120,000 for use of SFWMD equipment, $10,000 of capital equipment (installation of two staff gauges to better monitor water levels near the Las Palmas community), and $4,000 of operating expenses (SFWMD survey work and travel costs). Activities for which expenses were reimbursed include the following:

- Deployment and operation of temporary pumps next to S-355B ($553,000)
- Mitigation for high water levels in the Las Palmas community ($245,000)
- Rehabilitation of L-28 canal plugs ($516,000)

TRANSITION PERIOD

Rather than implementing an abrupt conclusion to temporary emergency operations, SFWMD and USACE developed a transition operations plan to return to Increment 1 operations. The 60-day transition (May 12–July 11, 2016) centered around gradually lowering the L-29 canal constraint to an elevation slightly above 7.5 feet NGVD29 to allow increased flows to Northeast Shark River Slough compared to what could be achieved with the constraint at 7.5 feet NGVD29. The L-29 constraint was set low enough to maintain the authorized level of flood mitigation for the Las Palmas community and varied during the transition period to compensate for variation in rainfall. Despite significant rainfall over WCA-3A on May 4, the WCA-3A water level dropped out of Zone A by May 11, the end of the 90-day emergency operations period.

The objectives of the transition period are to 1) maintain as practicable WCA-3A discharges as prescribed by the rainfall plan (part of the WCA-3A regulation schedule); 2) maximize discharge from WCA-3A the east (through S-333) rather than through S-12C and S-12D; 3) maintain rates of discharge to L-31N and C-111 consistent with Increment 1 criteria and 4) use S-356 pump station to maintain L-31N stage using Increment 1 criteria.

HYDROLOGIC SUMMARY

SFWMD and USACE continued hydrologic monitoring of existing permitted features during emergency operations. The system was closely monitored to maximize intended benefits and avoid unintended consequences. SFWMD and USACE implemented emergency operation activities that maximized beneficial impacts to the environment to the greatest extent practicable consistent with hydrologic and biological restoration goals of the Everglades Forever Act (Section 373.4592 F.S.) and the Florida Bay Restoration Act (Section 373.4593 F.S.).

RAINFALL

Dry season (November through May) rainfall in South Florida through January 2016 was extreme as a result of strong El Niño conditions. SFWMD rainfall from November 2015 through January 2016 and in January 2016 was the most since 1932. SFWMD basins received more than 300 percent of average rainfall or more in January, most of which occurred between January 27 and 29, 2016. Rainfall for January 2016 in WCA-3A averaged 9.5 inches, more than 400 percent of average with an exceedance probability of one percent (100-year return period). **Table 3** lists January 2016, average, deviation from average and percent of average rainfall for SFWMD basins and for the entire SFWMD.

Table 3. January SFWMD rainfall.

SFWMD Basin	January 2016 Rainfall (inches)	Average January Rainfall[a] (inches)	Rainfall in Excess of Average (inches)	% of Average
Upper Kissimmee	6.56	2.25	4.31	292
Lower Kissimmee	8.24	1.85	6.39	445
Lake Okeechobee	8.83	1.85	6.98	477
East Everglades Agricultural Area	9.67	2.04	7.63	474
West Everglades Agricultural Area	11.12	2.48	8.64	448
WCA-1 and WCA-2	10.64	2.25	8.39	473
WCA-3	9.54	2.25	7.29	424
Martin/St Lucie	9.09	2.48	6.61	367
Eastern Palm Beach	9.09	3.03	6.06	300
Eastern Broward	7.79	2.18	5.61	357
Eastern Miami-Dade	6.38	2.09	4.29	305
East Caloosahatchee	10.23	1.76	8.47	581
Big Cypress Preserve	9.60	1.92	7.68	500
Southwest Coast	11.54	1.92	9.62	601
Everglades National Park	6.38	1.64	4.74	392
Keys[b]	6.5	1.5	5.0	425
SFWMD	9.18	2.20	6.98	417

a. From Ali 1999.

b. From SFWMD Operations Bureau

The SFWMD extreme amount of rainfall from November 2015 through February 2016, occurring in SFWMD Water Year 2016 (WY2016) influenced by strong El Niño conditions was comparable to that from November 1997 through February 1998 (WY1998). Departure from average rainfall was more pronounced in the WCAs and in the Lower East Coast Service Area whereas for the same period in WY1998, the most extreme rainfall occurred in the Kissimmee basins. **Table 4** compares SFWMD basin rainfall amounts for these two El Niño-influenced portion of dry seasons and shows rainfall amounts in excess of historical averages.

Table 4. 1998 and 2016 El Niño year four-month SFWMD rainfall (November–February).

SFWMD Basin	November–February Rainfall (inches)			Rainfall in Excess of Average (inches)	
	1998	2016	Average	1998	2016
Upper Kissimmee	27.74	12.34	9.08	18.66	3.26
Lower Kissimmee	24.71	17.08	7.49	17.22	9.59
Lake Okeechobee	17.96	17.41	6.94	11.02	10.47
East Caloosahatchee	20.89	18.18	6.76	14.13	11.42
Big Cypress Preserve	18.96	17.66	7.05	11.91	10.61
Southwest Coast	18.96	19.47	7.05	11.91	12.42
Martin/St. Lucie	17.31	20.36	10.09	7.22	10.27
East Everglades Agricultural Area	15.41	17.85	7.75	7.66	10.10
West Everglades Agricultural Area	20.84	19.18	8.67	12.17	10.51
Eastern Palm Beach	21.11	21.53	12.01	9.10	9.52
WCA-1 and WCA-2	17.07	23.30	9.50	7.57	13.80
WCA-3	17.07	20.55	9.50	7.57	11.05
Eastern Broward	17.92	23.67	9.74	8.18	13.93
Eastern Miami-Dade	16.72	24.84	8.63	8.09	16.21
Everglades National Park	17.96	17.99	7.12	10.84	10.87
SFWMD	19.72	18.80	8.76	10.96	10.04

A significant rainfall event occurred on May 4, 2016, in portions of Collier and Miami-Dade counties. The heavy rainfall caused a minor reversal in WCA-3A stage. Northeast Shark River Slough, the Las Palmas development, and portions of south Miami-Dade County received between four and five inches of rain in 24 hours.

WATER LEVELS AND FLOWS

WCA-3A

At the beginning of the SFWMD WY2016 dry season (November 1, 2015), the water level in WCA-3A was 10.22 feet NGVD29 and in a desirable zone of the regulation schedule (**Figure 9**). As a result of above normal rainfall in November through early December and subsequent inflows, the WCA-3A stage rose above the Zone A line of the regulation schedule. The water level ascended into Zone A of the regulation schedule on December 5, 2015, and reached a maximum elevation of 11.50 feet NGVD29 on February 18, 2016, due to extreme January 2016 rainfall. This was almost two feet above the historical average for this day and more than one foot above the regulation schedule line requiring regulatory discharges. Prior to emergency operations, the S-333 structure was closed January 26–February 5, 2016, in accordance with the ERTP regulation schedule due to the L-29 canal stage being above an elevation of 7.5 feet NGVD29. On February 5, when the L-29 canal stage receded below 7.5 feet NGVD29, a limited opening of S-333 was made. Discharge remained limited (less than 650 cfs) until the first decision meeting to review conditions pertaining to the WCA-3A regulation schedule (conducted on a weekly basis by USACE) was held after the emergency order and emergency temporary deviation were issued. At this time, the WCA-3A stage was more than one foot above the Zone A line.

Figure 10 shows the WCA-3A water level during the WY2016 dry season. This stage hydrograph is plotted with statistical information compiled for each day of the year based on WCA-3A water levels from 1962 to 2013. Statistical data plotted for each day are maximum (Max), median stage (50th percentile, P50), 75th percentile (P75) and 90th percentile (P90) of historical values. **Figure 10** shows that WCA-3A stage was slightly below the 51-year median stage at the beginning of the dry season. Because of heavy December 2015 rainfall, by January 1, 2016, the WCA-3A stage rose to a level observed less than 10 percent of the time (stage was higher than the P90 value). This occurred during a time of year when water levels are normally receding, as evidenced by the declining P50 trace. By mid-February, the WCA-3A stage began to exceed period of record daily maxima and did so for 30 consecutive days.

Figure 11 illustrates the effect of the key provision of emergency operations on WCA-3A stage—relaxation of the L-29 canal water level constraint. Prior to emergency operations and especially during January 2016 as shown on the left side of **Figure 11**, S-333 discharge was limited by the L-29 constraint. In fact S-333 was closed for nine consecutive days in late January to early February—when the area received 9.5 inches of rain—because of the L-29 constraint. After the L-29 stage fell below 7.5 feet NGVD29 in early February, S-333 discharge resumed, but only at a rate of 400 to 500 cfs.

In contrast, when emergency operations affecting S-333 were implemented (relaxation of the L-29 constraint) on February 15, 2016, S-333 discharge increased almost threefold to more than 1,300 cfs. S-333 was discharging the maximum hydraulically possible (the spillway gate was completely out of the water) for most of the emergency period. **Figure 11** shows the increased S-333 discharge and L-29 canal stage and the decreasing WCA-3A stage during the emergency period (shaded). After the WCA-3A water level receded below Zone A on May 9, 2016, after the slight reversal due to heavy rainfall on May 4, S-333 discharges were reduced and the L-29 canal stage began to transition back to 7.5 feet NGVD29.

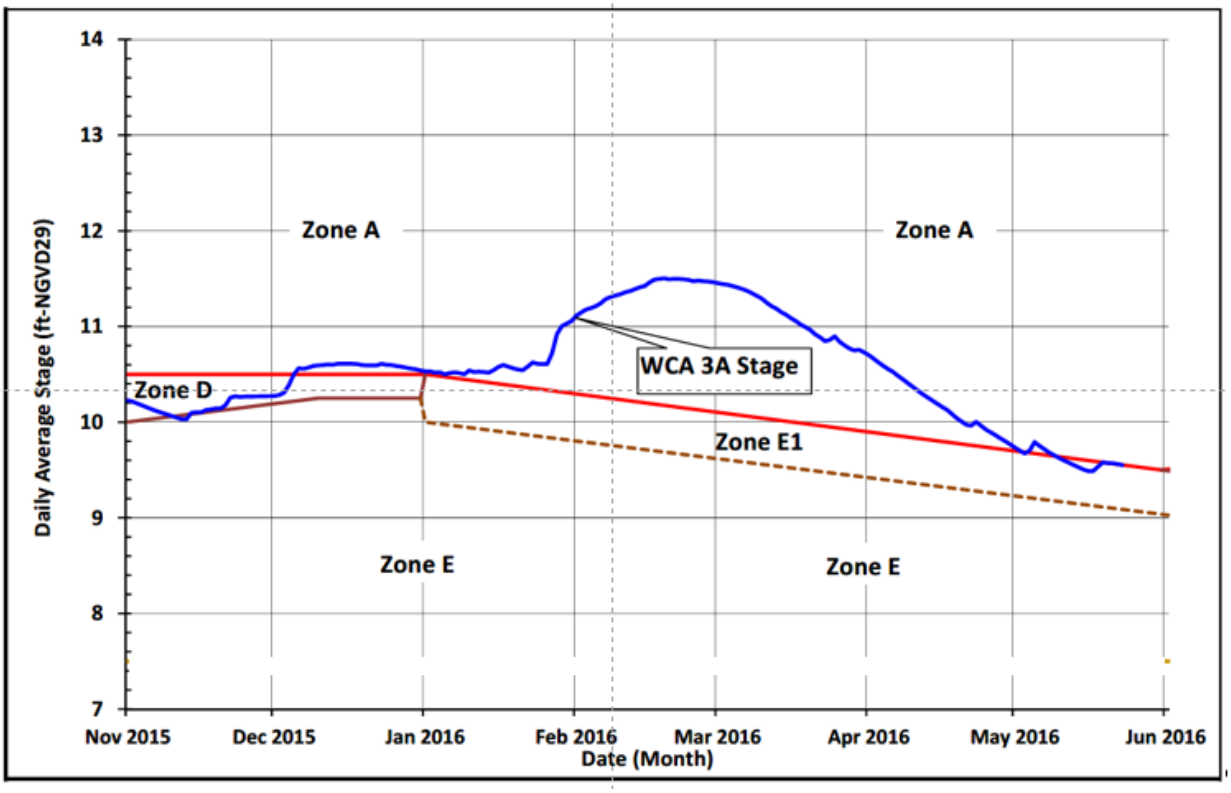


Figure 9. WCA-3A stage and regulation schedule zones, November 2015–May 2016.

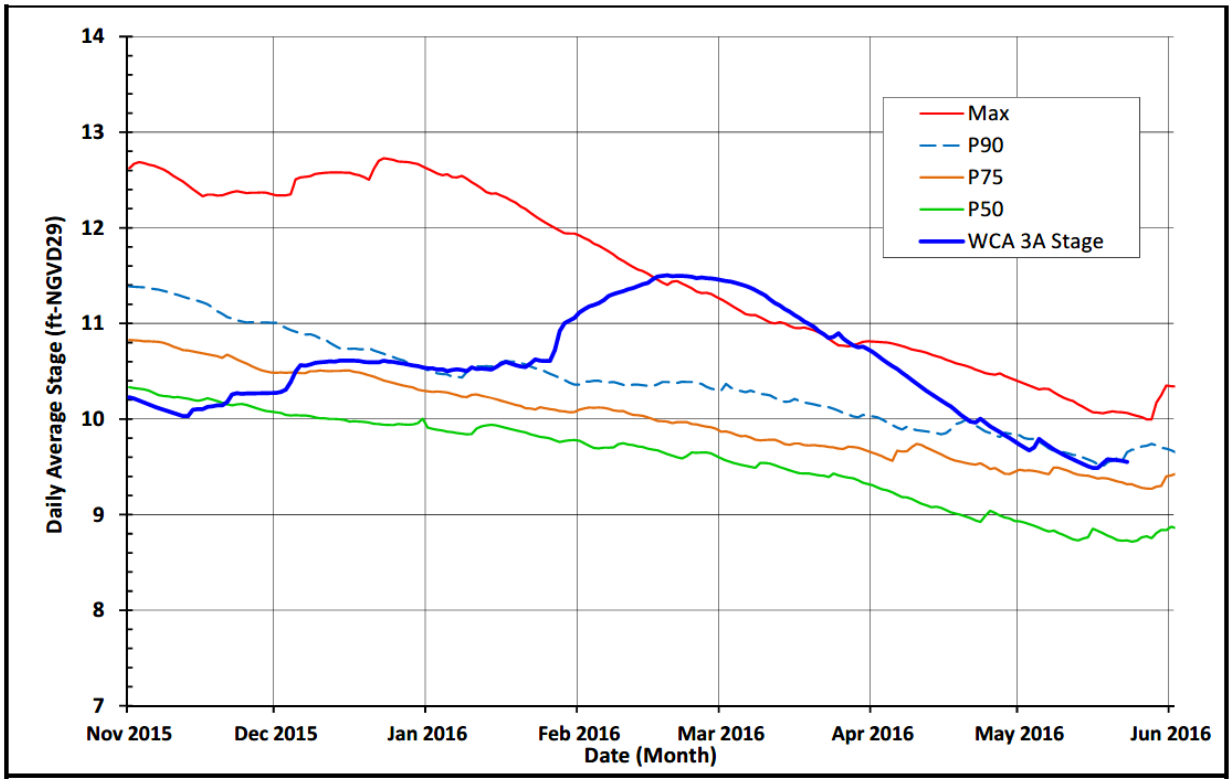


Figure 10. WCA-3A stage with historical stage exceedance percentiles.

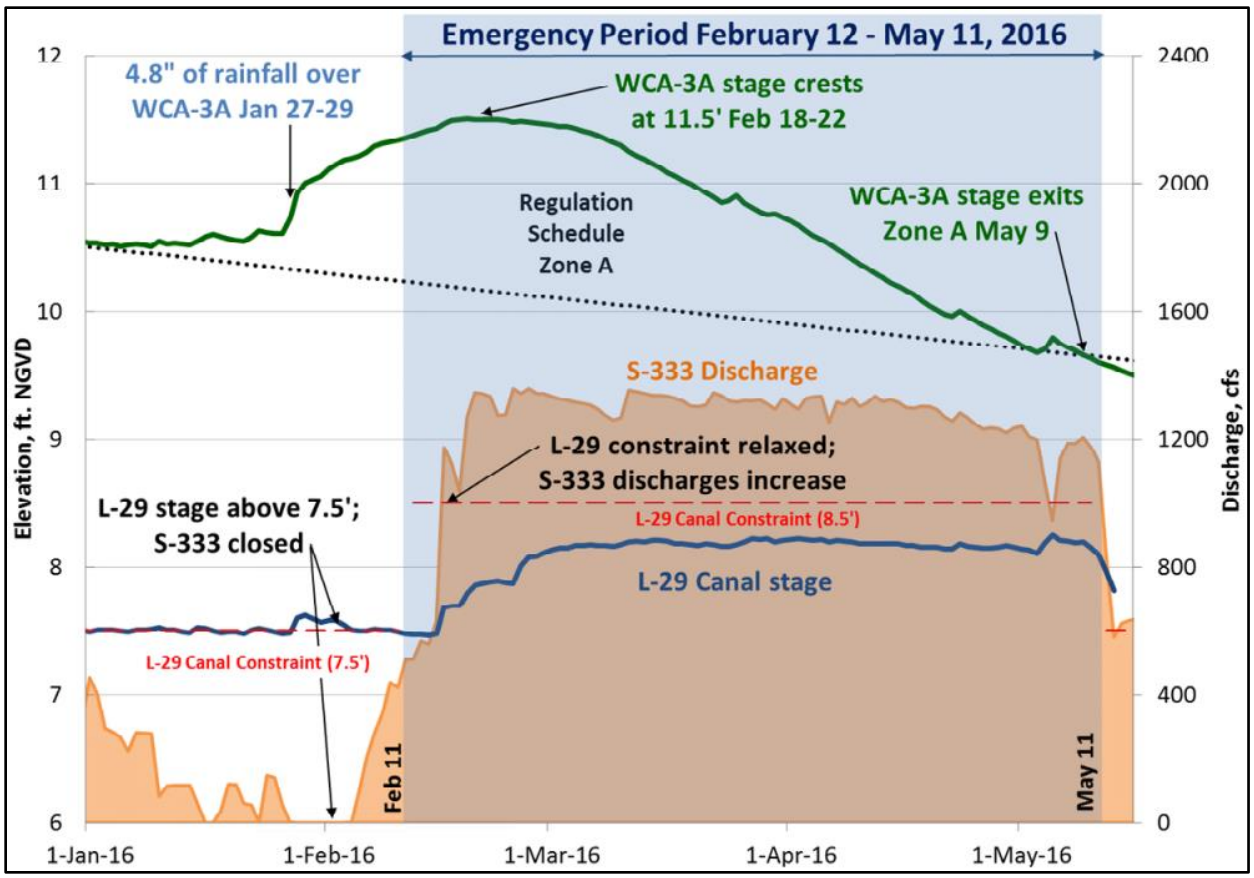


Figure 11. WCA-3A water level and S-333 discharge, January 1 – May 31, 2016.

Approximately[3] 681,000 acre-feet was discharged through WCA-3A outflow structures during the 90-day emergency operations period. Discharge through the S-12C and S-12D structures accounted for 295,000 acre-feet (43 percent); the S-333 structure discharged 223,000 acre-feet or about one-third of the total amount; S-151, a series of gated culverts on the east side whose discharge can either go to WCA-3B or to tide, discharged 117,000 acre-feet (17 percent); and S-152, also a series of gated culverts that convey water from WCA-3A to WCA-3B, discharged 37,000 acre-feet (5 percent). The emergency operations period occurred during the closure period for structures S-12A and S-12B. S-12A, however, was opened briefly to avoid overtopping of spillway gates due to high water in WCA-3A. This flow volume accounted for about 1 percent of WCA-3A structure outflows (approximately 9,000 acre-feet). WCA-3A structure outflows during the emergency period are shown in **Figure 12**. The WCA-3A structure inflow volume during the emergency operations period was approximately 280,000 acre-feet. This is about twice the average inflow volume for the previous eight years. The WCA-3A structure outflow volume, however, was about eight times the 2007–2015 average of 84,000 acre-feet (**Figure 13**).

[3] Hydrologic data presented in this report are preliminary and based on best available information.

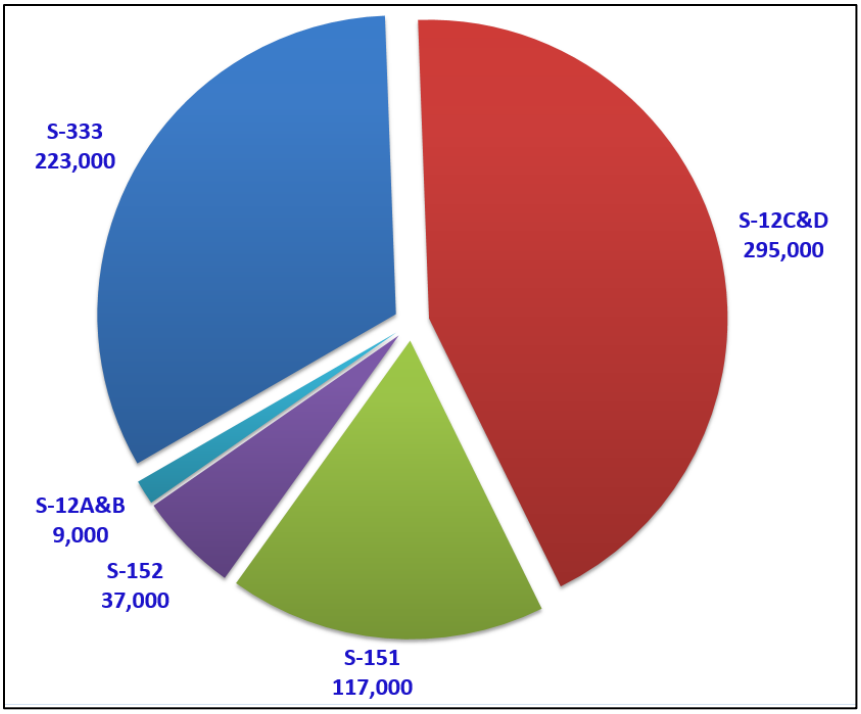


Figure 12. WCA-3A outflow structure discharge volumes (acre-feet) during the 90-day emergency period.

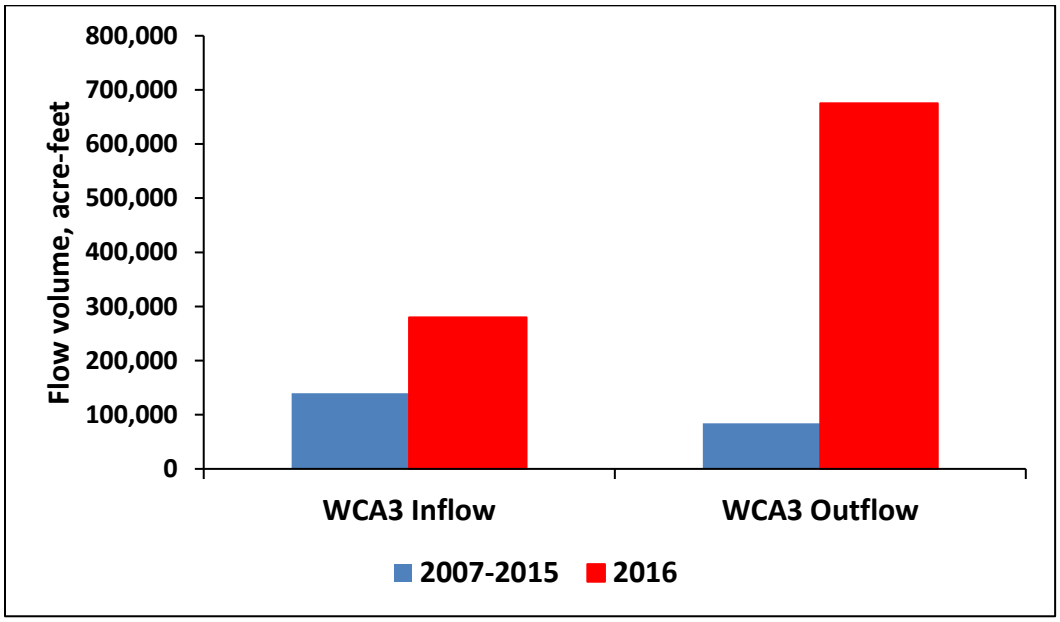


Figure 13. WCA-3A inflow and outflow volumes (acre-feet) during emergency operations period compared to recent historical (2007–2015) averages.

S-333

The S-333 structure discharged 223,000 acre-feet of water from WCA-3A during the emergency operations period. As a result of allowing the L-29 canal constraint to be relaxed as part of the emergency operations, an additional 60,000 acre-feet was discharged through S-333 during the 90-day emergency period. **Figure 14** (top panel) is the S-333 discharge hydrograph (top), headwater (red line) and gate opening (green line) from February 1 through mid-May 2016. S-333 discharge averaged 1,247 cfs and exceeded 1,200 cfs 83 percent of the time. S-333 discharged 202,000 acre-feet during the three-month period of February through April 2016 (**Figure 14** [bottom panel]), by far the largest amount in the last 39 years.

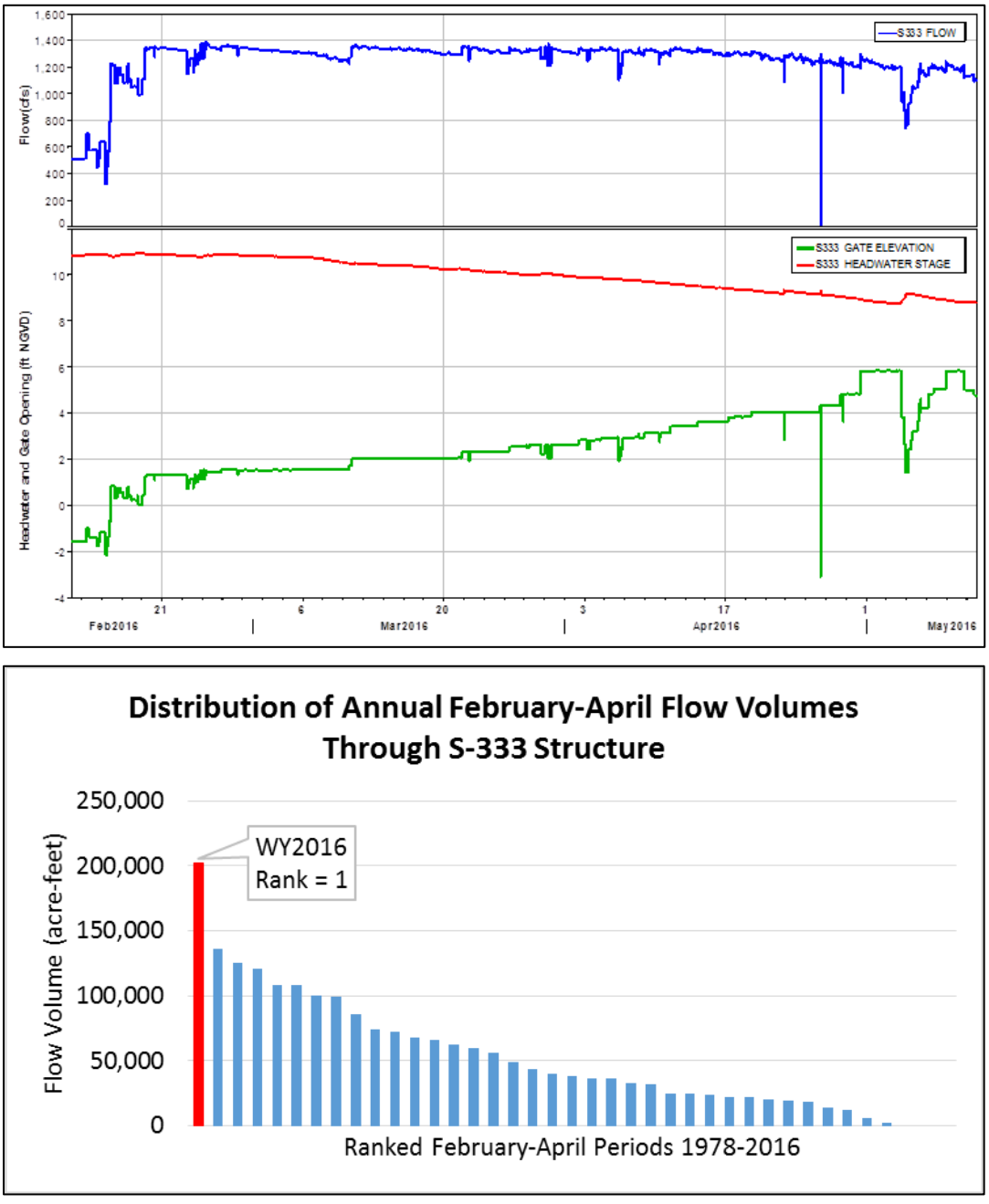


Figure 14. S-333 discharge hydrograph February 1–May 15, 2016 (top) and S-333 rank-ordered February–April flow volumes (bottom).

WCA-3B

Operation of the S-152 structure was coupled with WCA-3B outflow operations. The primary WCA-3B outlets, the S-355A and S-355B spillways located in the L-29 levee, only discharged a small amount (approximately 2,000 acre-feet between March 1 and March 11 according to an estimate provided by USACE) during the emergency period because of the higher tailwater elevation in the L-29 canal. SFWMD deployed temporary pumps (see the Activities subsection under the Emergency Operations section) to "lift" water from WCA-3B into the L-29 canal in order to pass WCA-3A discharge through WCA-3B. The temporary pumps operated soon after a mid-March deployment and pumped a total of 18,000 acre-feet during the emergency period. Water levels in WCA-3B were maintained in a desirable range during this period; the net inflow (S-152 inflow minus S-355B temporary pump outflow) was offset by seepage out of WCA-3B and ET.

Figure 15 shows the S-152 discharge (WCA-3B inflows from WCA-3A) and S-355B temporary pump discharge (outflow from WCA-3B) hydrographs from February 1 to May 15, 2016. Approximately 18,000 acre-feet of water was discharged from WCA-3B between March 12 and May 13, 2016. These discharges accounted for approximately one-half the S-152 inflow volume; seepage and net ET accounted for the balance of the WCA-3B water budget.

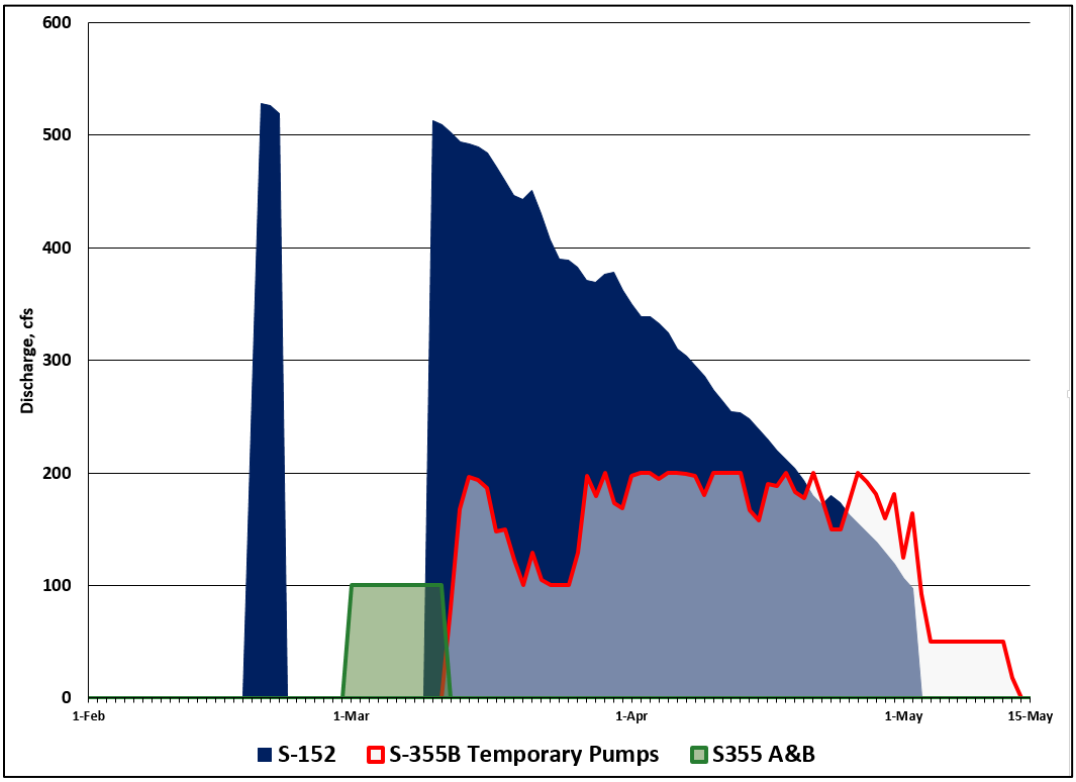


Figure 15. WCA-3B inflow (S-152 from WCA-3A) and outflow (S-355B and temporary pumps to the L-29 canal) structure discharge hydrographs.

WCA-3A and WCA-3B Discharge Destinations

Although not a precise accounting of WCA-3A and WCA-3B outflows by destination, the following flow volumes were estimated from concurrent flow volumes of downstream structures to give a general idea of "where the water went". The majority of WCA-3Aand WCA-3B outflows, 510,000 acre-feet, during the emergency operations period went to ENP. Of this amount, approximately 60 percent went to Western Shark River Slough and 40 percent went to Northeast Shark River Slough. Approximately 143,000 acre-feet of water was discharged to east coast basins in Miami-Dade County during the emergency operations

period. This amount is the summed discharge volumes through structures S-31 (50,000 acre-feet), S-338 (48,000 acre-feet), S-194 (26,000 acre-feet), and S-196 (19,000 acre-feet). The S-334 structure discharged 34,000 acre-feet "around the corner", south to the L-31N canal.

Seepage from Northeast Shark River Slough into the L-31N canal from the L-29 canal to structure G-211 (approximately 57,000 acre-feet) was expectedly higher because of the increased water levels in ENP. Although authorized to operate during the emergency operations period under certain conditions, the S-356 pump station (designed to return ENP seepage) did not operate. The S-334 spillway is adjacent to the S-356 pump station in the L-29 canal. S-356 is designed return seepage from Northeast Shark River Slough collected in the L-31N canal when S-333 does not have priority. S-356 did not operate during the emergency period because S-333 had priority during the entire time. S-334 discharged L-29 canal water to the east in order to maintain the L-29 stage below 8.3 feet NGVD29. The volume pumped into the C-111 South Dade project detention areas and toward Taylor Slough was 214,000 acre-feet. This large volume includes a significant amount of water that was likely pumped more than once due to seepage east from the created hydraulic ridge in the detention areas.

Flows toward the Eastern Panhandle and Barnes Sound (54,000 acre-feet) were estimated as the difference between structures S-18C and S-197 flow volumes. About 9,000 acre-feet was discharged through S-197 during the emergency operation period.

Shark River Slough

More than one half million acre-feet of water was discharged into Shark River Slough during the 90-day emergency period. Sixty percent flowed into Western Shark River Slough through the S-12 structures (304,000 acre-feet); 40 percent (206,000 acre-feet) flowed into Northeast Shark River Slough from the L-29 canal through culverts under the Tamiami Trail and under the One-Mile Tamiami Trail Bridge. The 510,000 acre-feet discharged to Shark River Slough during this 90-day period is 73 percent more than Shark River Slough receives in an average dry season. In the three-month period from February through April 2016, 545,000 acre-feet was discharged to Shark River Slough, more than any previous February–April period in the previous 39 years (**Figure 16**).

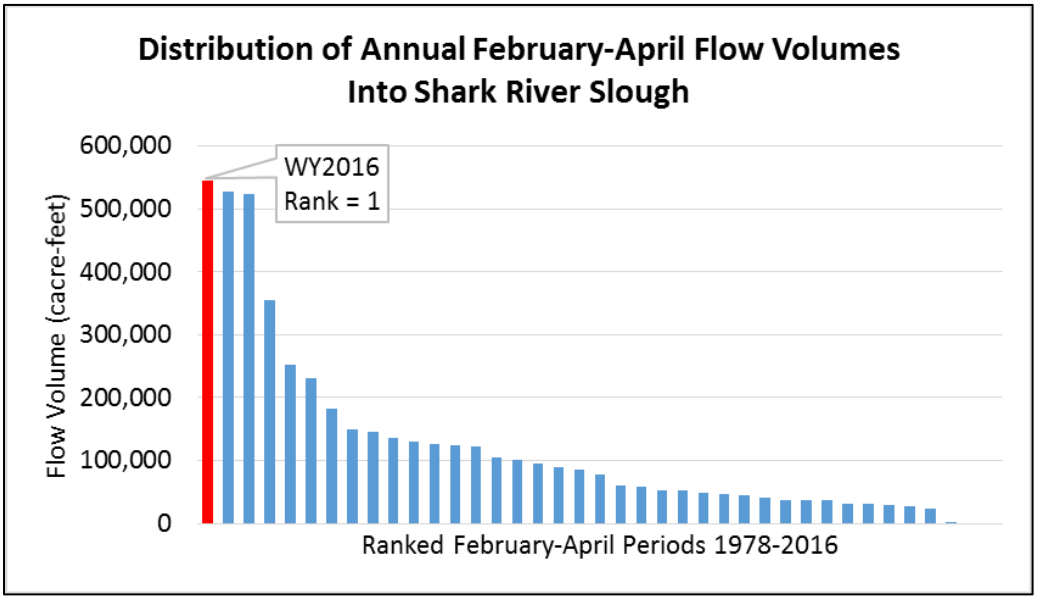


Figure 16. Rank-ordered February–April flow volumes to Shark River Slough, 1978–2016.

Water entering the L-29 canal from S-333 and the S-355B temporary pumps discharges either into Northeast Shark River Slough or east through spillway structure S-334. S-334 was opened to moderate

L-29 canal stage during the emergency period, preventing the stage from exceeding 8.3 feet NGVD29. Approximately 34,000 acre-feet was discharged through S-334 during the emergency period. This water joined discharges from S-335 in the L-30 canal then flowed south in the L-31N canal.

Las Palmas Community

The Las Palmas community, formerly known as the 8.5 Square Mile Area, is located west of Krome Avenue (SW 177th Avenue) and north of Richmond Drive (SW 168th Street) in southwestern Miami-Dade County. This community experienced high water levels, especially in the southwest corner, due to increased flows to Northeast Shark River Slough. The community also received between four and five inches of rainfall in a 24-hour period on May 4, 2016. Activities undertaken to mitigate for the higher water levels are described in the Emergency Operations section of this report. **Figure 17** shows the location of the Las Palmas community, 8.5 Square Mile Area project features, and two gauges indicative of conditions in the area, G-3273 and Angel's Well.

The G-3273 gauge is approximately 2.5 miles west of the Las Palmas Community and is an indicator of water depths (above and below ground) in Northeast Shark River Slough in ENP. Under the ERTP water control plan and WCA-3A regulation schedule, the S-333 structure must close if the water stage at this gauge is greater than elevation 6.8 feet NGVD29. This was intended to provide residents of the Las Palmas community the intended level of flood protection afforded by the features of the 8.5 Square Mile Area component of the USACE Modified Water Deliveries to Everglades National Park project. The G-3273 constraint was relaxed as part of the USACE Increment 1 field test and was also not in effect during the emergency operations period. **Figure 18** shows G-3273 being consistently above elevation 6.8 feet NGVD29 after the start of the Increment 1 field test on October 15, 2015. Responses to rainfall events can be seen in December 2015, January 2016, and in early May 2016. The effect of the large Northeast Shark River Slough inflows is also shown with sustained elevations above 7.0 feet NGVD29 and water levels exceeding the 95 percent exceedance band from early January through May 2016.

Angel's Well gauge is closer to Las Palmas, approximately 0.25 miles west of the protective levee surrounding the community, along the theoretical extension of SW 152nd Street. **Figure 19** is a similar hydrograph for the Angel's Well gauge and shows more pronounced responses to the noted rainfall events. Water levels began to recede in early April 2016 after SFWMD replaced temporary pumps with an open connection designed to remove water from the C-358 seepage collection canal on the south side of Richmond Drive. The Angel's Well stage steadily declined as a result of SFWMD operations and mitigation efforts in the area (described in the next section), with one reversal due to heavy May 4, 2016, rainfall.

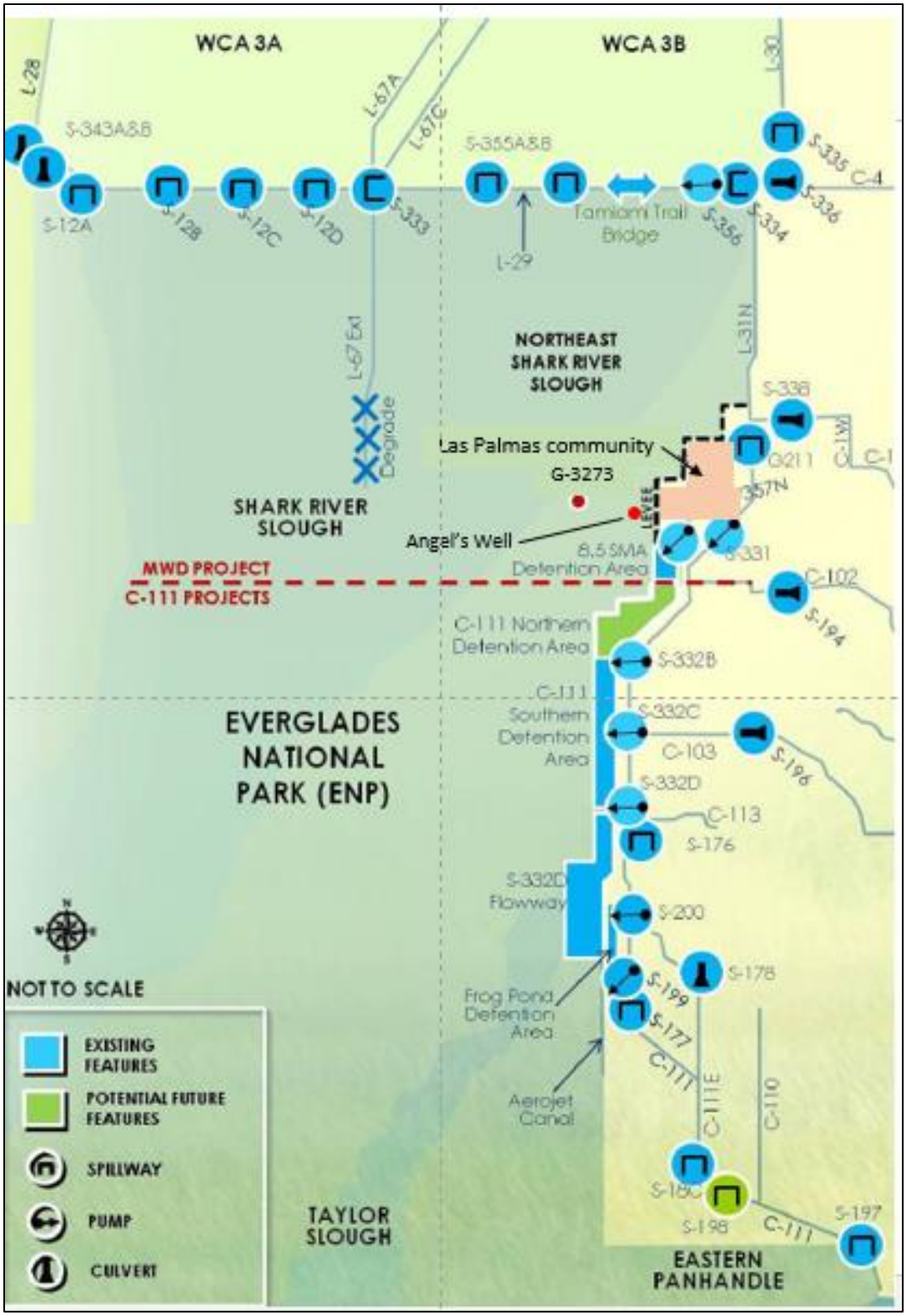


Figure 17. Location map of Las Palmas community G-3273 gauge and Angel's Well gauge.

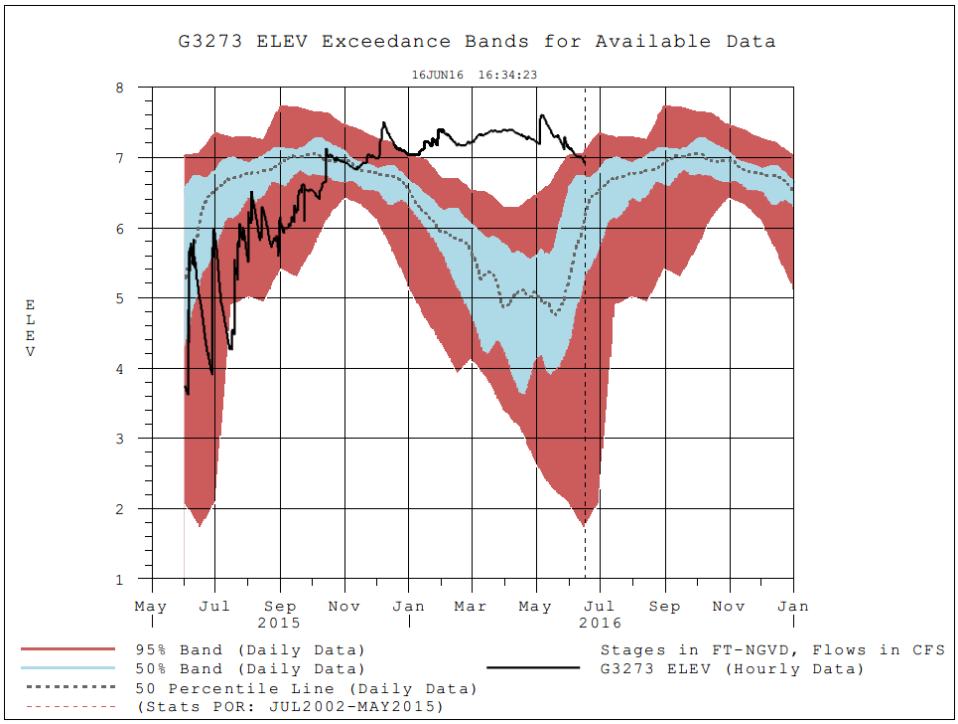


Figure 18. G-3273 gauge stage hydrograph plotted with exceedance percentiles (courtesy of USACE).

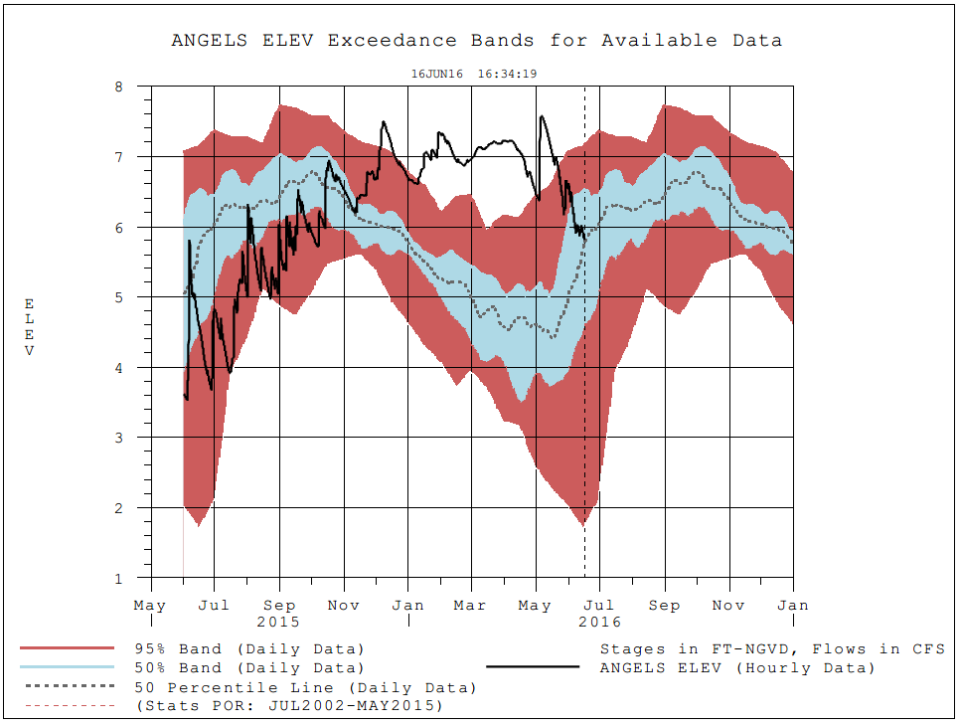


Figure 19. Angel's well gauge stage hydrograph plotted with exceedance percentiles (courtesy of USACE).

Eastern Panhandle and Barnes Sound

Flows toward the Eastern Panhandle and Barnes Sound (54,000 acre-feet) were estimated as the difference between structures S-18C and S-197 flow volumes. About 9,000 acre-feet was discharged through S-197 during the emergency operation period. S-197 is the coastal water control structure at the southern end of the C-111 canal. Water discharged through S-197 enters Barnes Sound. During the emergency operations period, S-197 was open 41 days for four events and discharged a total of 8,500 acre-feet. In comparison, S-197 was open in December 2015 for 16 consecutive days and discharged 17,800 acre-feet. **Table 5** shows the number of days open, discharge volume, average discharge rate, and maximum flow rate for the mentioned events. **Figure 20** is the S-197 discharge hydrograph from December 1, 2015 to May 4, 2016 (S-197 was closed April 21 was not opened again until May 18).

Table 5. S-197 Discharge events from December 2015 through April 2016.

Date Opened	Date Closed	Duration (days)	Average Discharge Rate (cfs)	Discharge volume (acre-feet)	Maximum Daily Average Discharge rate (cfs)
12/4/2015	12/19/2015	16	1112	35300	1601
1/28/2016	2/10/2016	13	76	2100	94
2/23/2016	3/3/2016	10	140	2800	195
3/17/2016	3/28/2016	12	146	3500	231
3/31/2016	4/12/2016	13	40	1000	52
4/16/2016	4/21/2016	6	101	1200	129

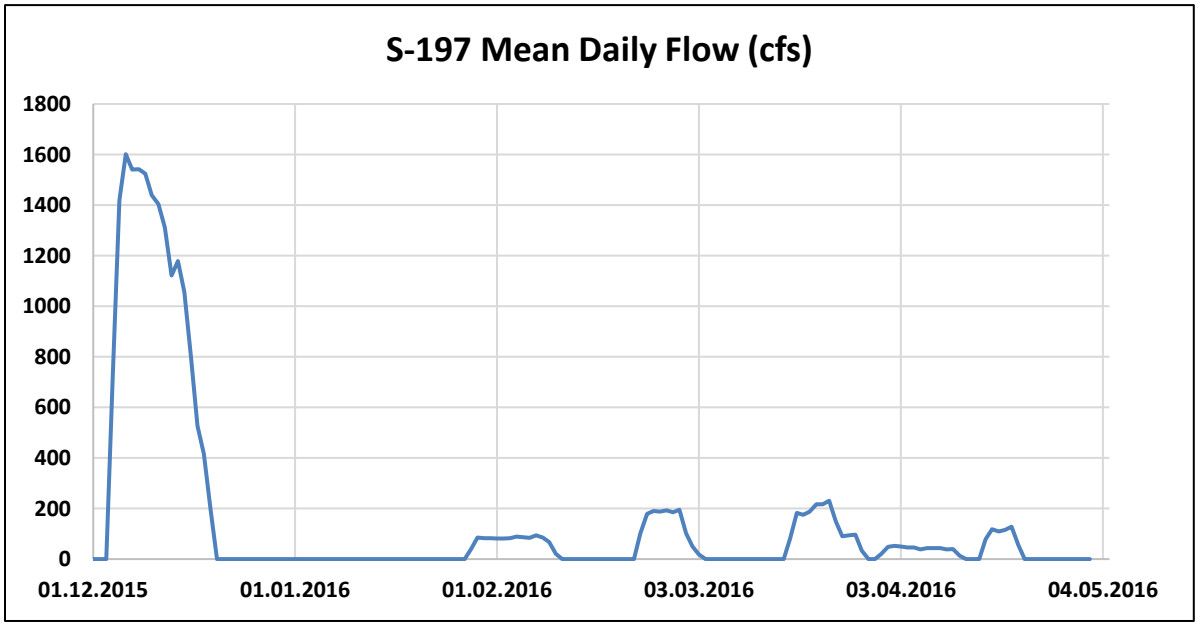


Figure 20. S-197 Discharge hydrograph from December 2015 through April 2016.

C-111 SEEPAGE MONITORING RESULTS

The EFO required an estimate of seepage in a segment (reach) of the C-111 canal between the S-176 water control structure and the S-199 pump station. The C-111 basin consists of three reaches of the C-111 canal from north to south: a northern reach, a 5.5-mile reach from S-176 to S-177 (immediately downstream of the S-199 pump station); a central reach, from S-177 to S-18C; and a southern reach from S-18C to S-197 (see **Figure 17**). Based on an analysis performed by the SFWMD Operational Hydraulics Unit using data collected during the emergency operations period, approximately 37,800 acre-feet of net seepage entered the C-111 northern reach of the C-111 canal. This volume represents approximately 70 percent of the corresponding pumped volume from this reach for the same period.

The S-332D pump station is located immediately upstream of the C-111 northern reach. It removes water from the L-31N canal and discharges into the S-332D detention area. Pump station S-200 is located in the C-111 northern reach 2.7 miles downstream of S-176 and discharges into the Frog Pond Detention Area. A substantial portion of the S-332D and S-200 pumped discharge is assumed to return to the C-111 northern reach as seepage. Pump station S-199 discharges into the Aerojet Canal.

The estimation of seepage into and out of a canal by a water budget requires consideration of several terms including rainfall, ET, inflows, outflows, and evaluation of the water levels in the vicinity of the canal. A simplified water budget equation assuming several terms of the full equation to be negligible was used to estimate the net seepage into and out of the northern C-111 reach. This estimation only considers structural inflows and outflows, as follows:

$$\textit{Structural flow out} - \textit{Structural flow in} = (S177+S199+S200) - S176 = \textit{Net Seepage} \qquad (1)$$

Net seepage is defined as the groundwater flux into the canal from the detention areas to the west. It also includes the groundwater flux into the canal from the agricultural areas to the east. The net seepage term is dominated by seepage from the west because of the higher water level on the west side of the canal. Direct precipitation on the canal and ET from the canal are assumed to be insignificant or offset each other. The change in storage in the canal over the period of the analysis is also assumed to be negligible. **Figure 21** shows the estimated net seepage based on **Equation 1**. The net seepage from February 11, 2016, through May 11, 2016, is 37,800 acre-feet, is shown in **Table 6**.

The portion of the water pumped at S-332D and S-200 that returns to the northern C-111 canal as seepage was quantified. It is assumed that a major contribution to seepage into the northern C-111 canal originates from pumping at S-332D and S-200. It is assumed that pumping from S-199 does not contribute significantly to seepage into the northern C-111 canal, and instead contributes to seepage into the next reach downstream, which is the middle C-111 canal between S-177 and S-18C. The ratio of net seepage into the northern C-111 canal to pumping volume from S-332D and S-200 is 70 percent, as shown in **Table 6**. The majority of that net seepage originates from water pumped into the detention areas by S-332D and S-200, but the exact amount is not known.

Figure 21. Net seepage into the northern C-111 canal.

Table 6. Net seepage into the northern C-111 canal.

From 2/11/2016 to 5/11/2016	Volume (acre-feet)
Net seepage into the northern C-111 Canal	37,800
Pumping volume at S332D and S200	54,000
Net Seepage as a fraction of pumping volume	70%

WATER QUALITY

An extensive water quality monitoring network was in place prior to the EFO associated with several existing permit requirements and a cooperative agreement between ENP and SFWMD (for the duration of the USACE G-3273 Relaxation and S-356 Pump Station Incremental Field Test). No additional water quality monitoring was conducted because of the EFO. This report contains results for total phosphorus (TP) and salinity. SFWMD and USACE continued water quality monitoring of permitted features during the emergency operations period. The system was closely monitored to maximize intended benefits and avoid unintended consequences.

TOTAL PHOSPHORUS

TP is the water quality parameter of most interest. TP concentrations and loads from SFWMD water quality monitoring stations (from water control structures, canal locations, and groundwater wells) in the area addressed by the EFO are summarized in this section. All water quality parameters monitored by SFWMD can be found in its corporate database, DBHydro.

The flow-weighted mean (FWM) TP inflow concentration to WCA-3A and WCA-3B during the emergency operations period was 18 micrograms per liter (µg/L) or parts per billion (ppb), which was

equivalent to the recent historical (Calendar Years 2007–2015) average TP FWM inflow concentration for the same 90-day period (**Figure 22**). The corresponding outflow FWM TP concentration from WCA-3A and WCA-3B during the emergency operations period was 8 ppb, which was significantly lower than the 2007–2015 historical average of 13 ppb. This is consistent with observations of generally lower TP concentrations being associated with higher WCA-3A water stages.

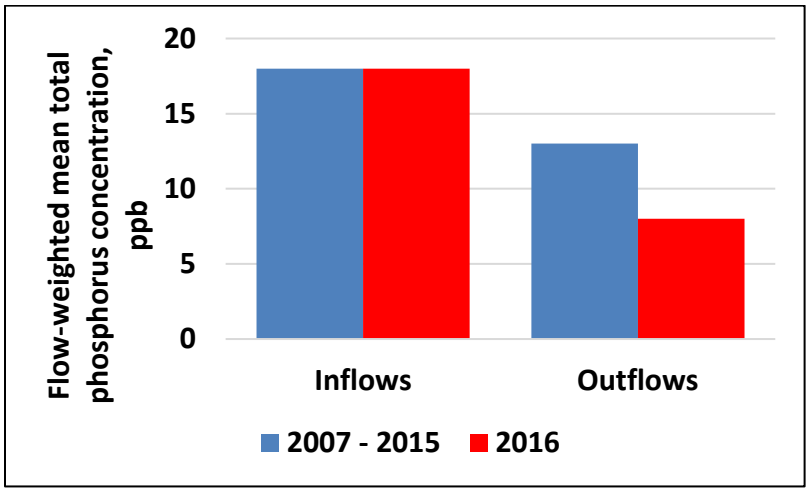


Figure 22. WCA-3A and WCA-3B FWM TP concentrations during 90-day emergency operations period compared to recent historical averages for the same 90-day period.

Figure 23 identifies the water control structures for which TP concentration data are presented in this report. FWM TP concentrations were computed at each structure for the 90-day emergency operations period. FWM TP concentrations for the previous nine February–May periods were computed for comparison purposes.

TP concentrations from WCA-3A outflow structures S-12C, S-12D, S-333, and S-152 and WCA-3B temporary pumps S-334 and S-151 are shown in **Figure 24**. Mean TP concentrations at S-355B, S-334, and at WCA-3A outflow structures were equal to or below their respective historical (2007–2015) averages. Mean TP concentrations during the emergency operations period ranged between 5 and 10 ppb, below the 2007–2015 average range of 9–15 ppb. Mean TP through the S-12C and S-12D structures were 6 and 5 ppb, respectively. S-333 mean TP was less than 10 ppb. A geometric mean TP concentration was calculated for S-152 because flow data was not readily available. The FWM TP concentration for S-355B represents the flows from the temporary pumps. S-355B (and S-355A) do not have a historical average for the 2007–2015 period since they were only authorized to operate in June 2015.

Similar data for structures S-357, S-360W (temporary gated culverts), S-332B, S-332C, S-332D, S-200, S-199, S-18C, and S-197 are shown in **Figure 25**. Mean TP concentrations for these structures ranged from 3 to 9 ppb; historical average TP concentrations ranged between 5 and 9 ppb. The geometric mean TP concentration from the temporary gated culverts installed next to the S-360W weir was 9 ppb. FWM TP concentrations through the C-111 detention basin structures were between 5 and 7 ppb.

Figure 23. Location of water control structures with reported FWM TP concentration data.

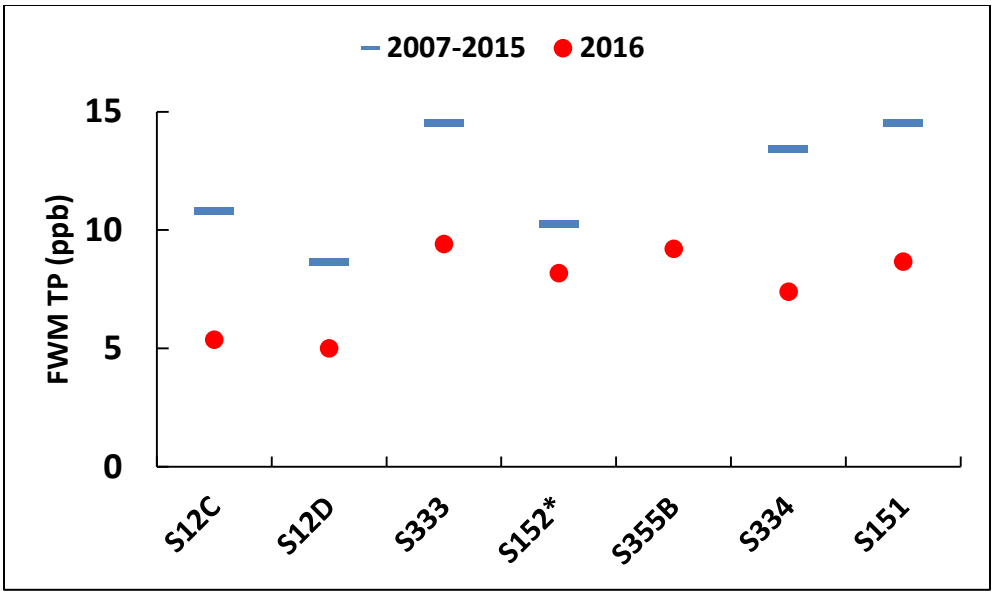


Figure 24. WCA-3A outflow structures S-355B and S-334 FWM TP concentrations during 90-day emergency operations period compared with corresponding 2007–2015 averages (S-152 is the geometric mean).

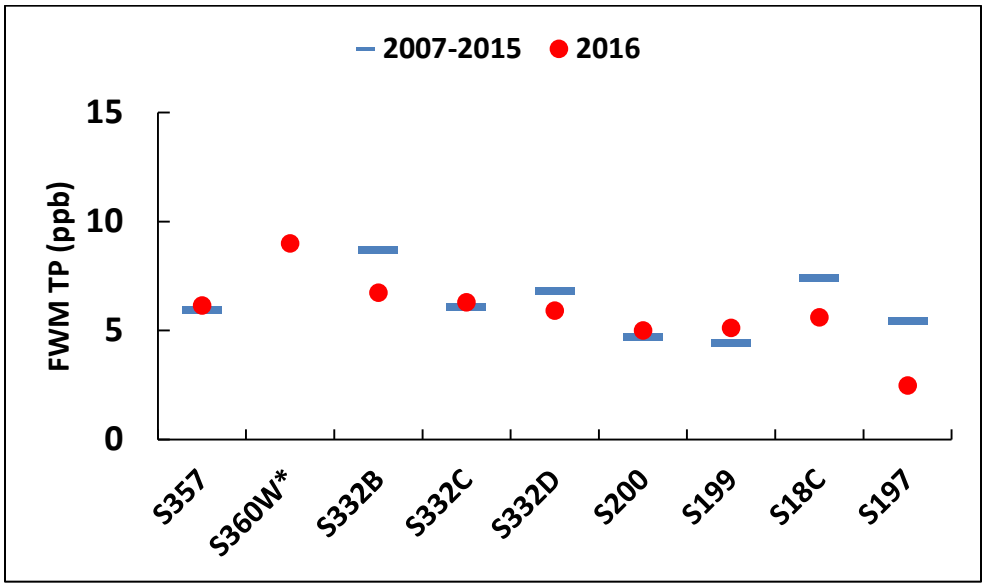


Figure 25. FWM TP concentrations during 90-day emergency operations period compared with corresponding recent historical averages for MWD project and C-111 basin structures (S-360W is the geometric mean).

The long-term phosphorus concentration limit for Northeast Shark River Slough contained within the Settlement Agreement to the Federal Everglades Lawsuit Consent Decree (Case Number 88-1886) is based on the federal water year (October 1–September 30) and is dependent on total flow. The long-term limit decreases linearly with increasing total flow and reaches the minimum of 7.6 ppb with a total flow of 1,061,000 acre-feet. Although compliance for WY2016 will not be determined until early 2017 (after the water year is over and all flow and water quality data are processed and analyzed), a comparison of a partial-

year (through June 6, 2016) FWM TP concentration with the present calculation of the TP limit is presented below.

As of June 6, 2016, the estimated total flow to Northeast Shark River Slough in WY2016 was 1,043,600 acre-feet. This corresponds to a long-term limit of 7.7 ppb. With four wet season months remaining in the federal water year, it is likely the long-term limit will be 7.6 ppb for WY2016. The estimated FWM TP concentration for the partial WY2016 through June 6, 2016, is 6.9 ppb. **Figure 26** compares WY2016 with the previous two water years in terms of WCA-3A stage, total flow to Northeast Shark River Slough, long-term limit, and FWM TP concentration. **Figure 26** shows that lower TP concentration measurements have been generally associated with higher WCA-3A water levels and vice versa. A slight upward trend in WY2016 TP concentrations can be seen as the WCA-3A water level declined.

Figure 27 compares the partial WY2016 FWM TP concentration with the long-term limit and the previous eight water years. From this figure, lower FWM TP concentrations appear to be correlated with higher flows. The partial WY2016 figures show the flow is already the second largest annual total flow volume discharged to Northeast Shark River Slough in the past nine years with four wet season months remaining and presently has the lowest FWM TP concentration.

Compliance for Taylor Slough and Coastal Basins is based on an annual FWM TP concentration. The TP limit for Taylor Slough and Coastal Basins is fixed at 11 ppb. **Figure 28** shows Taylor Slough and Coastal Basins flow and TP trends for WY2015 and (partial) WY2016. The WY2016 FWM TP concentration appears to be on a trajectory for 5–6 ppb, well below the limit.

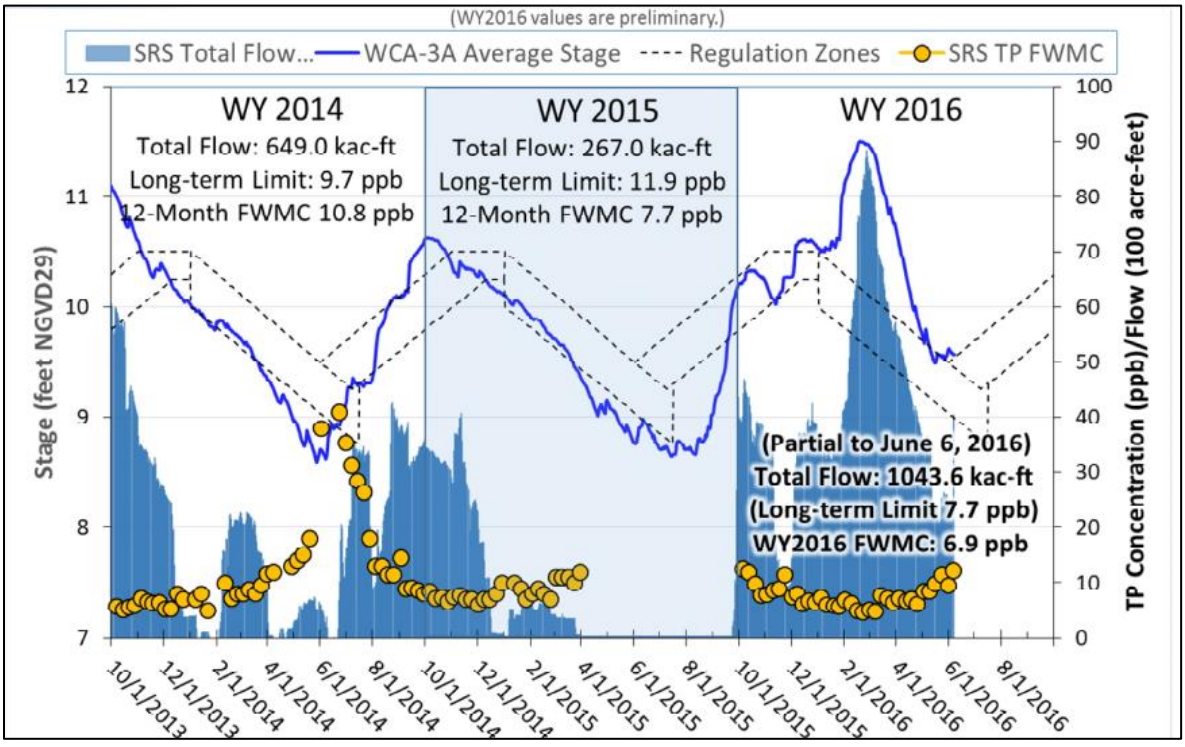


Figure 26. Water level, flow, and TP trends for Shark River Slough for WY2014–WY2016.

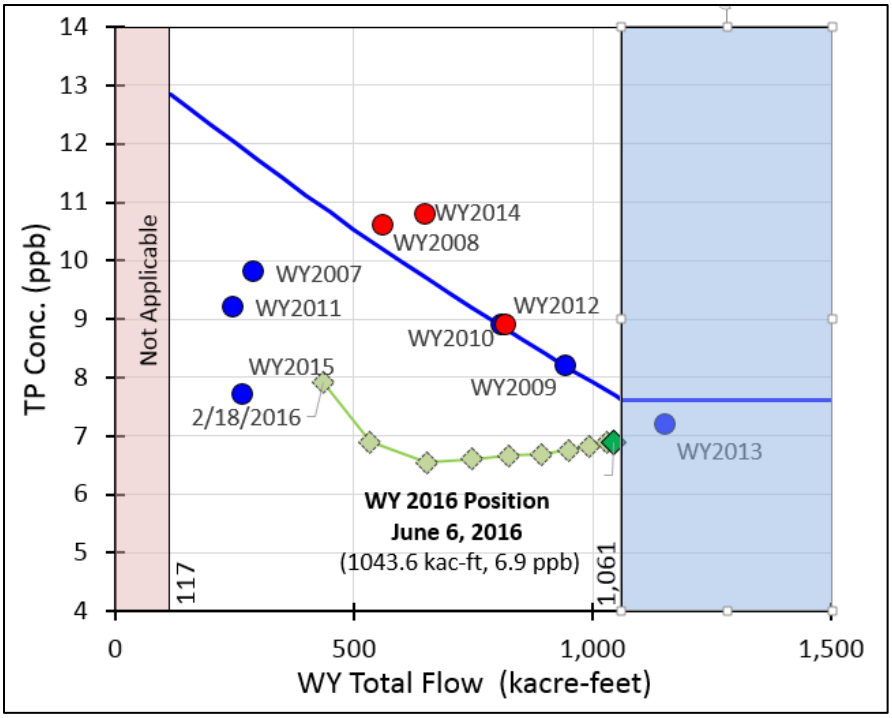


Figure 27. Shark River Slough water year total flow in thousand acre-feet (kacre-feet) and TP FWM concentration with the long-term limit.

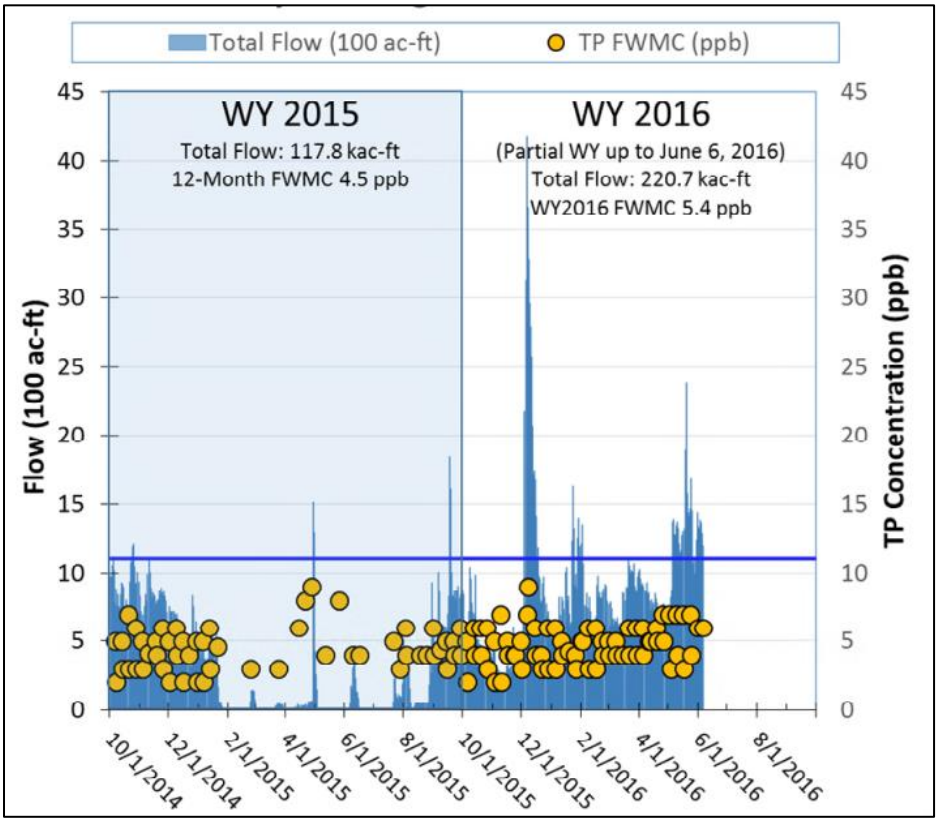


Figure 28. Flow in 100 acre-feet (ac-ft) and TP FWM concentrations to Taylor Slough and Coastal Basins.

SALINITY

The EFO required this report to include "salinity and ecological monitoring at the S-197 water control structure in accordance with Appendix C, 'G-3273 Constraint Relaxation/S-356 Field Test and S-357N Operational Strategy Monitoring Plan'". SFWMD entered into a cooperative agreement with ENP in June 2015 to conduct monitoring and modeling in support of the USACE S-356 Field Test. As a component of monitoring, SFWMD installed benthic salinity and temperature monitoring probes downstream of S-197 to supplement the ability of the existing network to capture the eco-hydrologic response to openings of S-197. Salinity and temperature readings are taken every 30 minutes from probes distributed along a salinity gradient from S-197 to the saline waters of Barnes Sound. SFWMD conducted event-driven (S-197 opening) deployment of a high-resolution surface water quality mapping unit when S-197 was operated as part of the field test and the structure remained opened for more than three days. A spatial analysis of the output was used to estimate freshwater plume dynamics in Barnes Sound and evaluate the potential for ecological impacts, both positive and negative. Five mapping trips have been conducted so far: December 1 and 16; January 12, March 8, and April 5, 2016. Details of this effort will be published by SFWMD in its first annual performance report to be submitted to ENP in July 2016. **Figure 29** shows the location of the deployed sondes and the permanent SFWMD sonde in Barnes Sound.

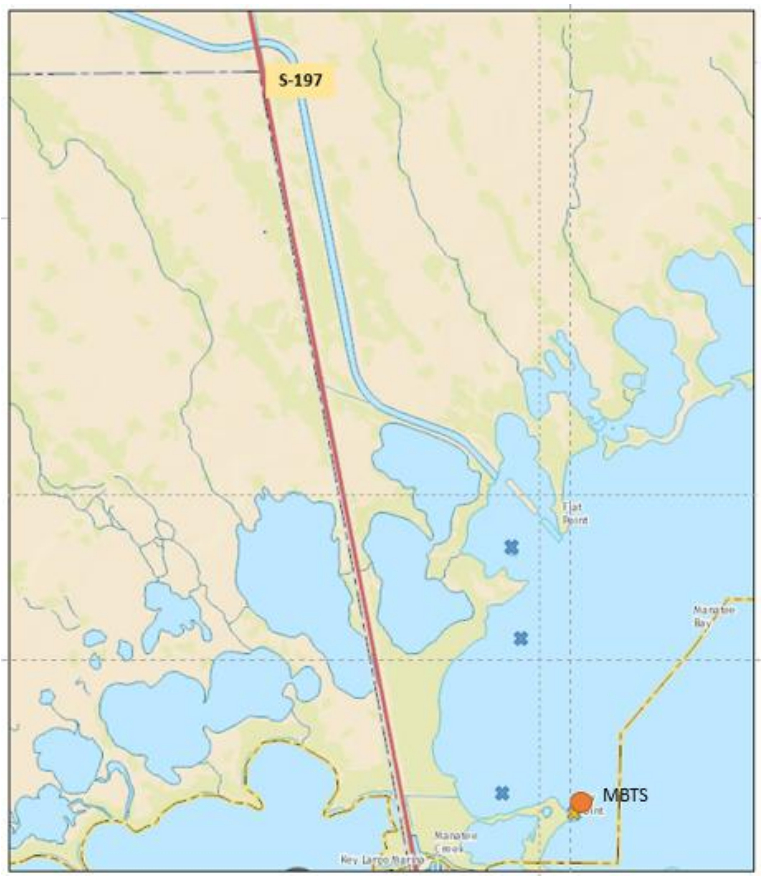


Figure 29. Location of deployed sondes (marked with an X) in Manatee Bay and SFWMD's permanent site MBTS (marked with a circle).

Instantaneous salinity and temperature from the MBTS site is shown in **Figures 30** and **31**. The boxes in this and all subsequent figures represent the times when S-197 was open. The red box indicates an opening prior to the emergency operations period and green boxes denote openings during the emergency operations period. The large releases in December 2015 can be clearly seen in **Figure 30**; even the subsequent smaller releases are reducing salinity[4] in the surface waters.

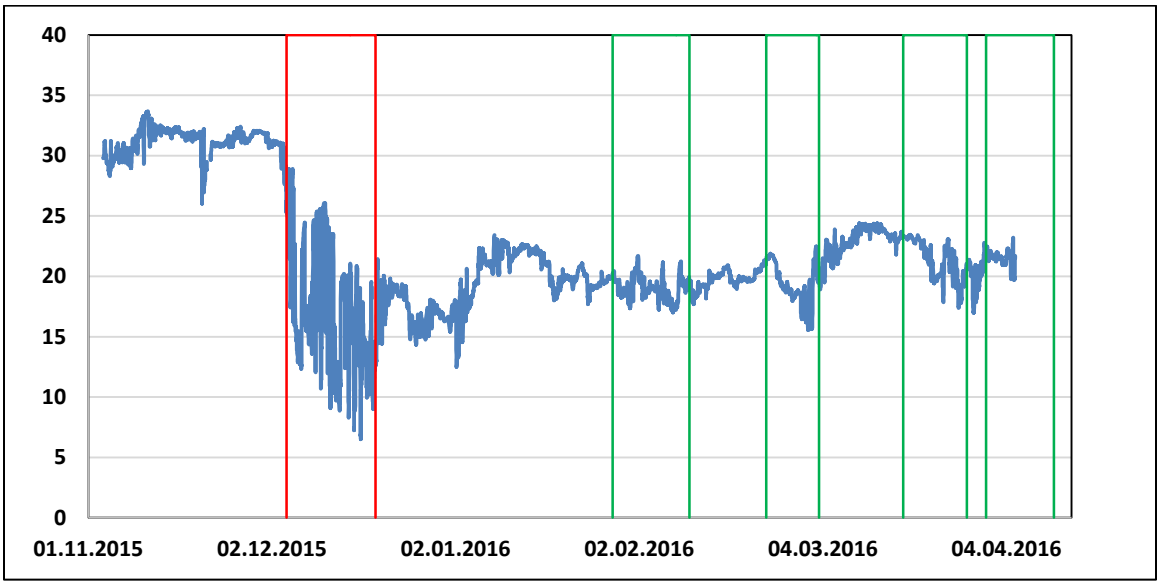


Figure 30. Instantaneous salinity of the surface water from the MBTS site.

The effects of water releases on the temperature signal are difficult to interpret as temperatures also have a seasonal signal. However, the smaller releases associated during the emergency operations period all exhibit a drop in temperature during openings (**Figure 31**).

Surface and bottom water measurements of salinity (**Table 7**) showed stratification in December 2015 at two of three sites (Man 3 not measured) and again at Man 1 in January 2016. The impacts of fresh water on the benthos may be mitigated somewhat by stratification, which allows higher salinity water on the bottom to buffer the osmotic shock on biota as the water masses gradually mix, leading to a mesohaline regime. Freshwater discharges associated with opening of S-197 are having the effect of lowering the salinity in the bottom waters most times. Another effect, especially at the Man 1 sites, is an increase in the variability of the salinity. Man 1 is closest to the mouth of the C-111 canal and this could explain this increase in the variability (**Figures 32** and **33**).

[4] Salinity, the ionic salt mass per kilogram of seawater, is dimensionless.

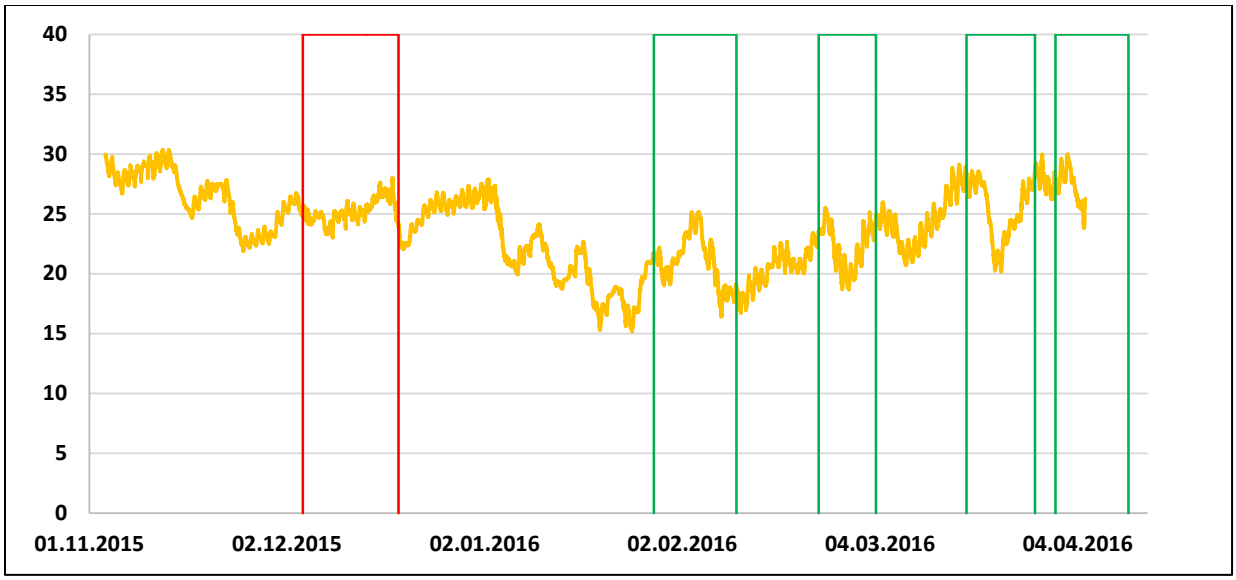


Figure 31. Instantaneous temperature in degrees Celsius in the surface water from the MBTS site.

Table 7. Temperature and salinity measurements made during S-197 gate openings.

		Temperature (degrees Celsius)		Salinity	
Site	Date	Surface	Bottom	Surface	Bottom
Man 1	12/16/2015	27.08	27.76	3.79	5.92
Man 2	12/16/2015	26.60	27.66	4.53	21.76
Man 3	12/16/2015	not available	not available	not available	not available
Man 1	1/13/2016	18.25	18.37	18.04	19.80
Man 2	1/13/2016	19.42	19.46	22.24	22.32
Man 3	1/13/2016	18.87	19.00	22.00	22.20
Man 1	3/8/2016	22.15	22.22	21.72	21.72
Man 2	3/8/2016	22.10	22.08	21.49	21.50
Man 3	3/8/2016	22.23	22.22	22.14	22.14

Surface water salinity mapping is shown in **Figure 34**. During the five water release events from S-197 structure on the C-111 canal between December 2015 and March 31, 2016, salinity decreased downstream in both Manatee Bay and Barnes Sound. The horizontal impact of the releases extended into Barnes Sound reducing salinities throughout. The initial salinity level in both basins was 30–35 and declined to 20–25 during and following releases. The salinity map sequence (**Figure 34**) shows that, following an initial large release in early December 2015, subsequent small releases did not appreciably reduce salinity further, though the cumulative effect was to maintain reduced salinity throughout the dry season to date. It is unknown how much the direct precipitation from greater than average rainfall during this El Niño season contributed to salinity reduction. Most recently, higher salinity water is reentering Barnes Sound from Card Sound.

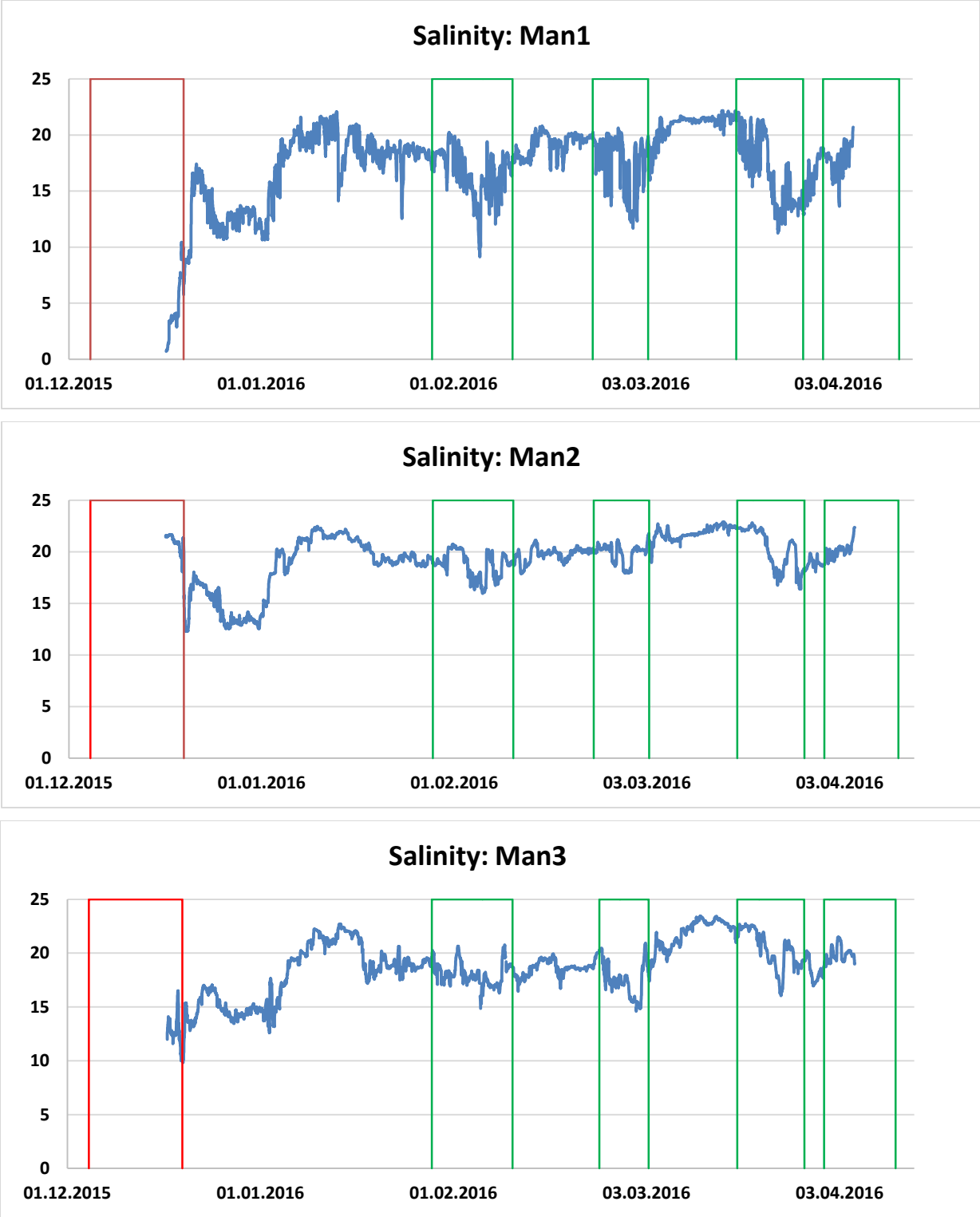


Figure 32. Instantaneous salinity in bottom waters at three sonde sites in Manatee Bay. (Boxes represent the times when S-197 was open. Green boxes are openings during emergency operations period.)

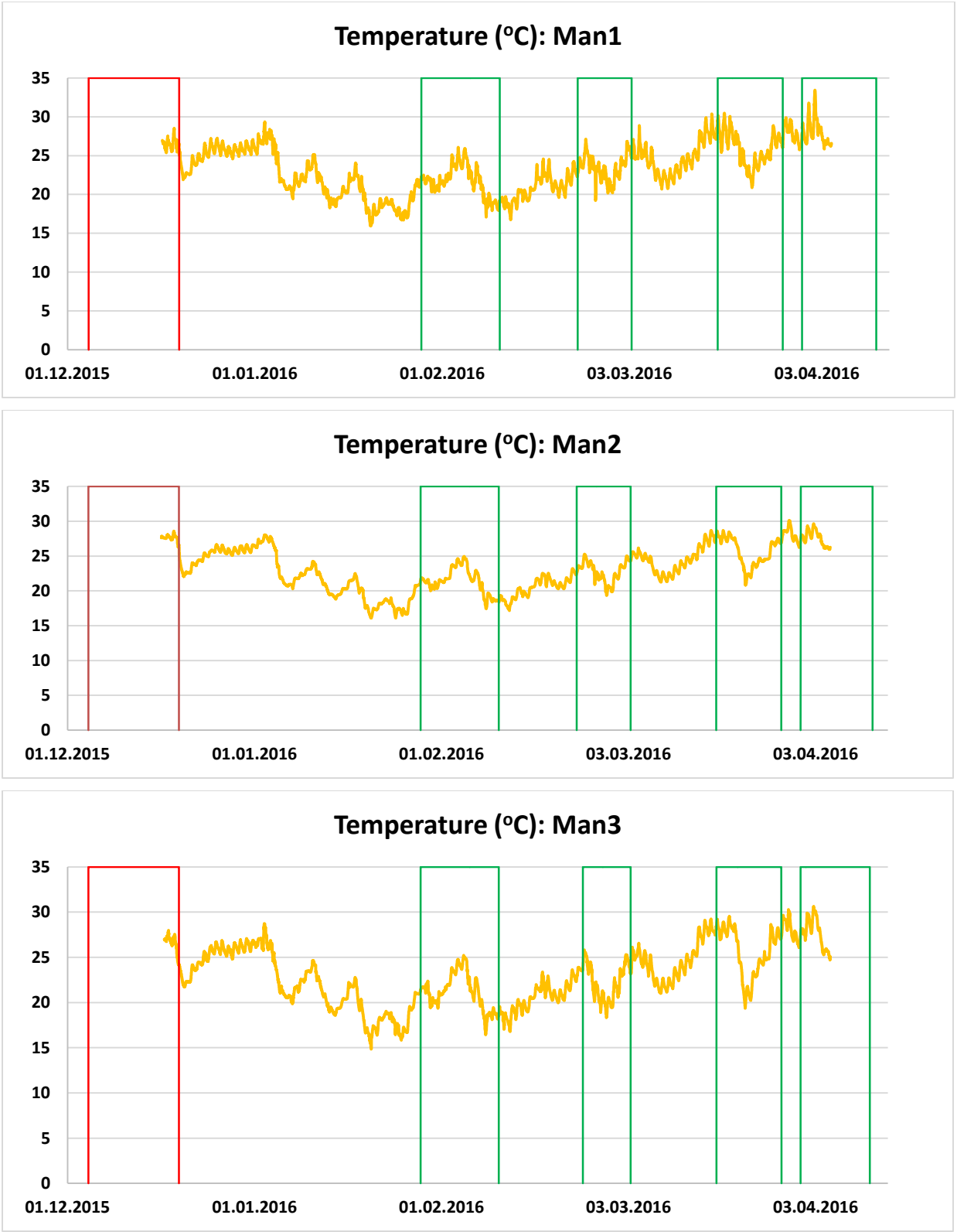


Figure 33. Temperature in degrees Celsius (°C) in bottom waters at three sonde sites in Manatee Bay. (Boxes represent the times when S-197 was open. Green boxes are openings during emergency operations period.)

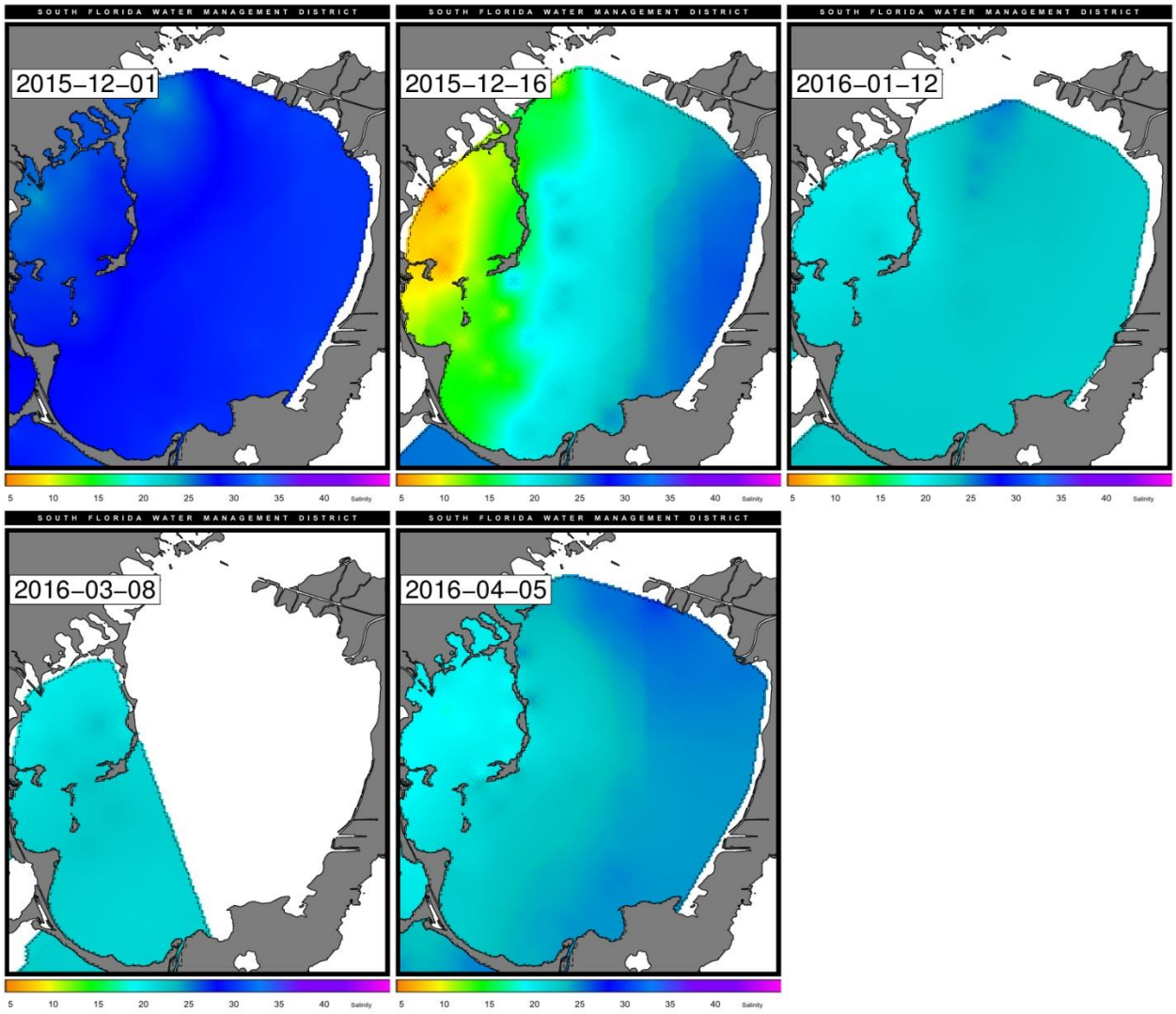


Figure 34. Salinity distribution in Manatee Bay and Barnes Sound.

Although no benthic assessments were conducted for this study, it can be reported from visual observations that bottom vegetation seems unaffected by the releases, with *Thalassia* and *Halodule* continuing to maintain moderate bottom cover. No evidence of fish kills or high chlorophyll concentrations were observed and the waters in both basins remained mostly clear throughout the study period.

ADDITIONAL INFORMATION

Although not required to be included in this report, concurrent information about the St. Lucie and Caloosahatchee estuaries is presented in this section.

ST. LUCIE ESTUARY FLOWS AND SALINITIES

The St. Lucie Estuary is on the eastern side of Lake Okeechobee and receives lake releases through S-308 (**Figure 35**). Lake releases historically (SFWMD WY1997–WY2015) account for 37 percent of total flow to the St. Lucie Estuary through S-80 during the dry season. However, during the emergency operations period (February 11–May 11, 2016), 65 percent of total flow originated from the lake (**Table 8**). The majority of this flow occurred in February and early March 2016, with flow from the lake averaging

3,557 cfs between February 11 and March 4, 2016. Flow then declined to a constant release averaging 1,628 cfs from March 5 to 17, 2016 when pulsed releases began, which averaged 851 cfs for the remainder of the emergency operations period (**Figure 36**).

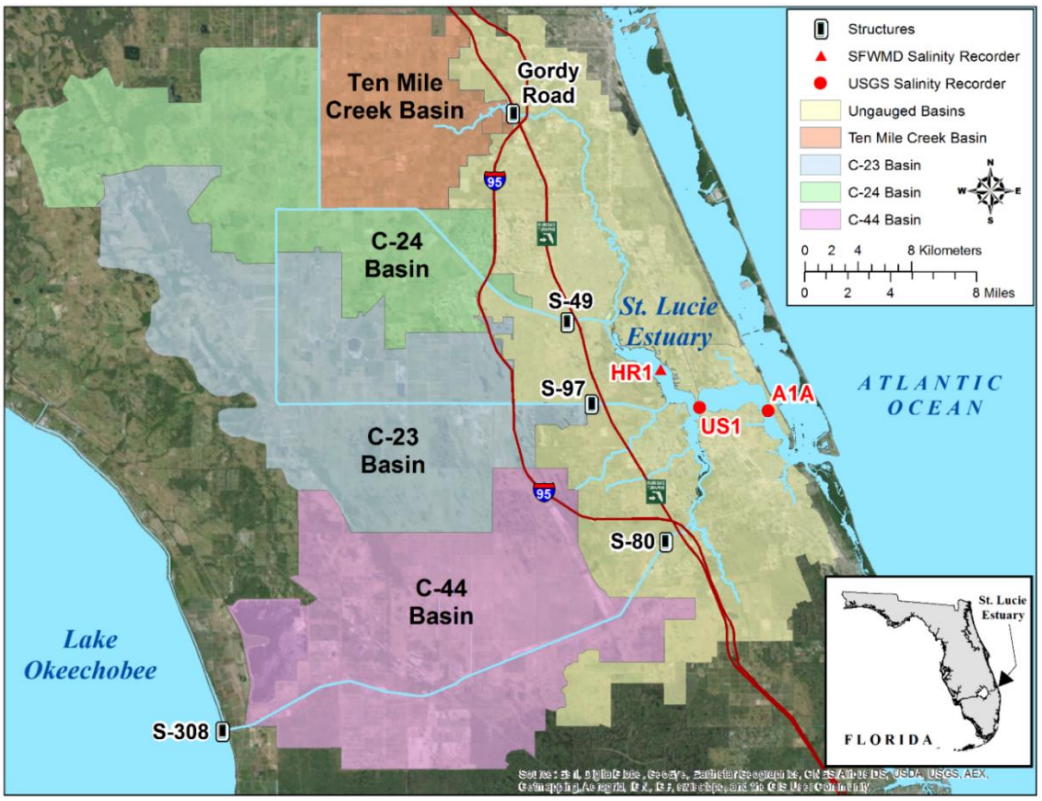


Figure 35. St. Lucie Estuary basins, water control structures and salinity monitoring sites.

Table 8. St. Lucie Estuary flow summary (February 11–May 11, 2016).

Source	Flow Volumes (acre-feet x 1000)		Average Flow Rate, cfs
Lake Okeechobee	297	65%	1646
C-44 Basin	62	14%	345
Tidal (Ungauged) Basin	37	8%	207
C-23, C-24 and Ten Mile Creek basins	62	14%	346
Total	458	100%	2544

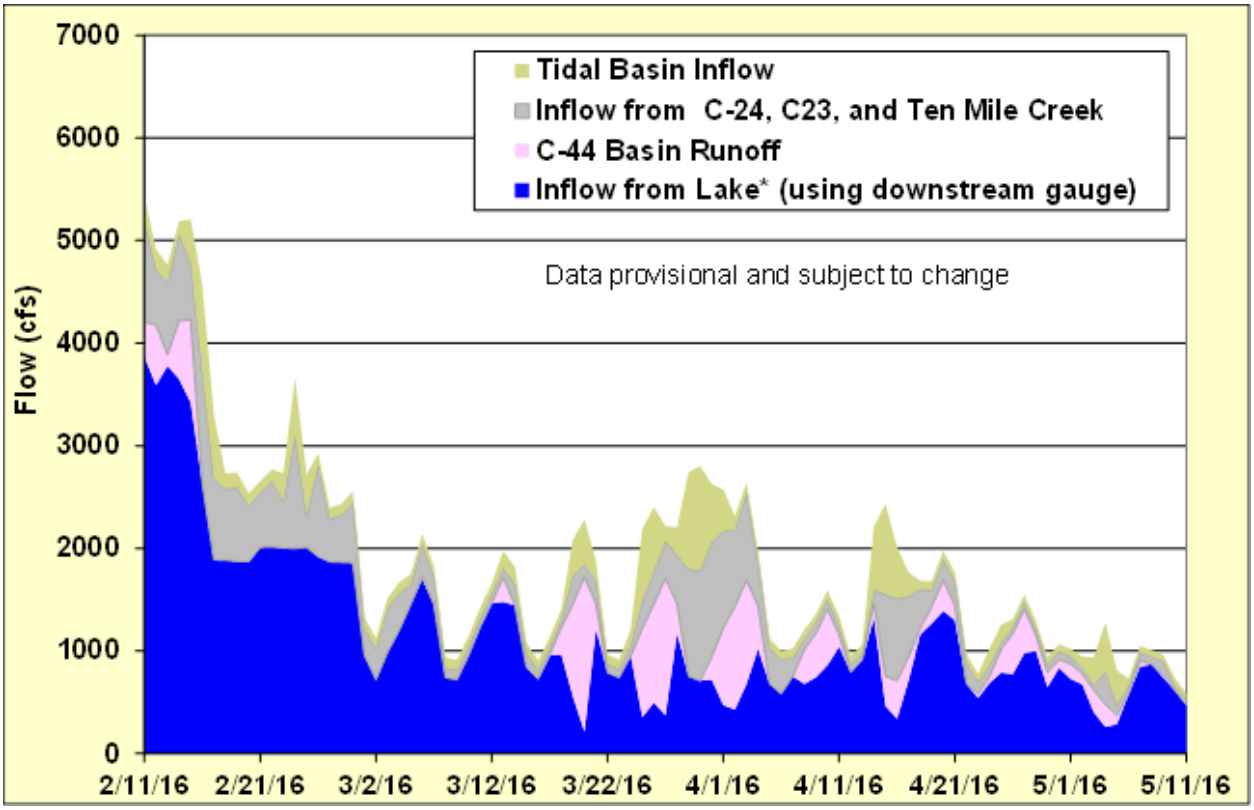


Figure 36. Estimated surface freshwater inflows from Lake Okeechobee and runoff from the C-44, C-23, C-24, Ten Mile Creek, and tidal basins into the St. Lucie Estuary.

Salinity is monitored in the surface and bottom waters at the US Highway 1 Bridge to assess potential stress on adult oysters (**Figure 37**). The seven-day average water column salinity is assessed and compared to salinity envelopes developed for adult oysters. During the emergency operations period, salinity was in the poor range (< 5) for 38 days. On March 20, 2016, salinity began exceeding 5 and continued to increase through the fair range into the good range for the remainder of the emergency operations period (**Figure 38**). Mortality for adult oysters is expected to occur after 28 days of salinity < 5. Live oyster density, measured on April 7, 2016, per routine biannual Restoration, Coordination and Verification (RECOVER) sampling, was lower compared to the previous spring, but higher compared to the spring 2014 (**Figure 39**). Mortality was 18 percent, which is lower than the long-term average of 27 percent. It is believed that oysters are more tolerant of low salinities during the cooler temperatures of winter, which possibly explains why there was lower mortality than expected during the emergency operations period.

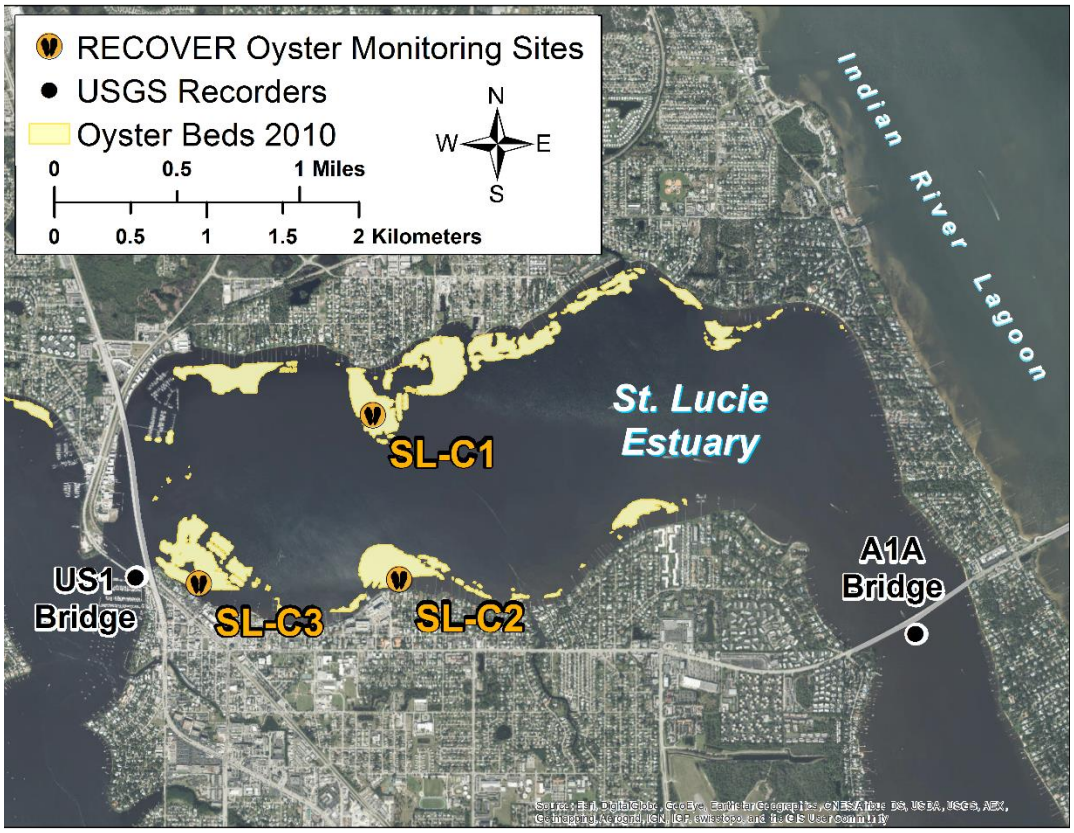


Figure 37. RECOVER oyster monitoring sites in St. Lucie Mid-Estuary.

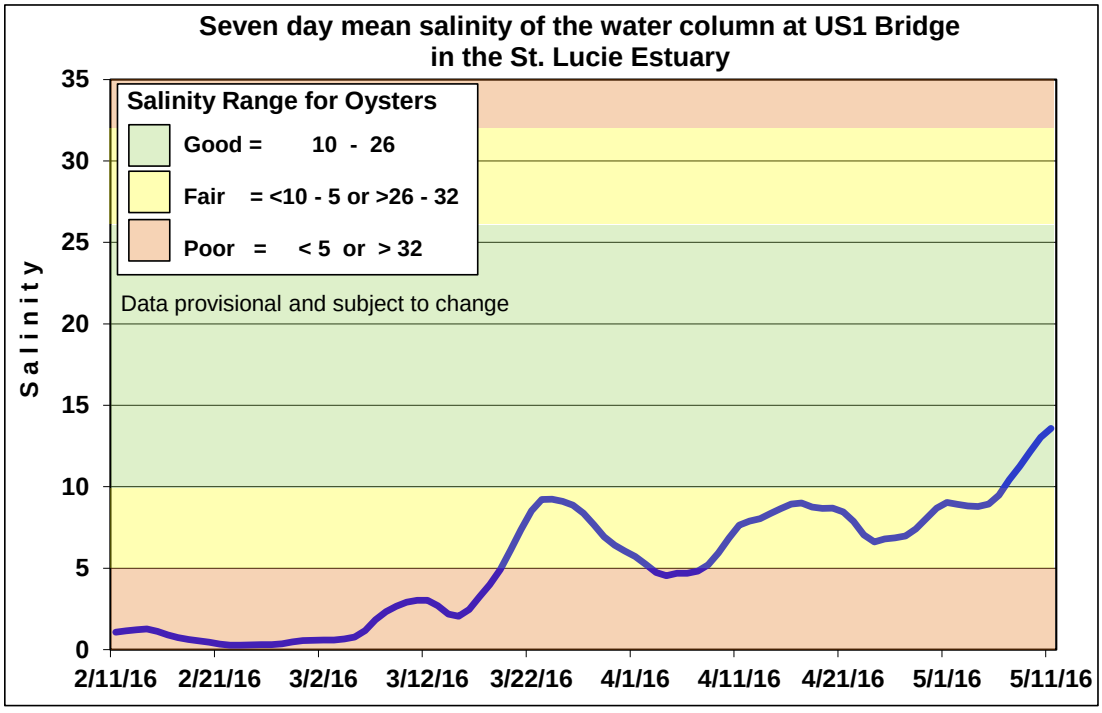


Figure 38. Seven-day mean salinity of the water column at the U.S. Highway 1 Bridge.

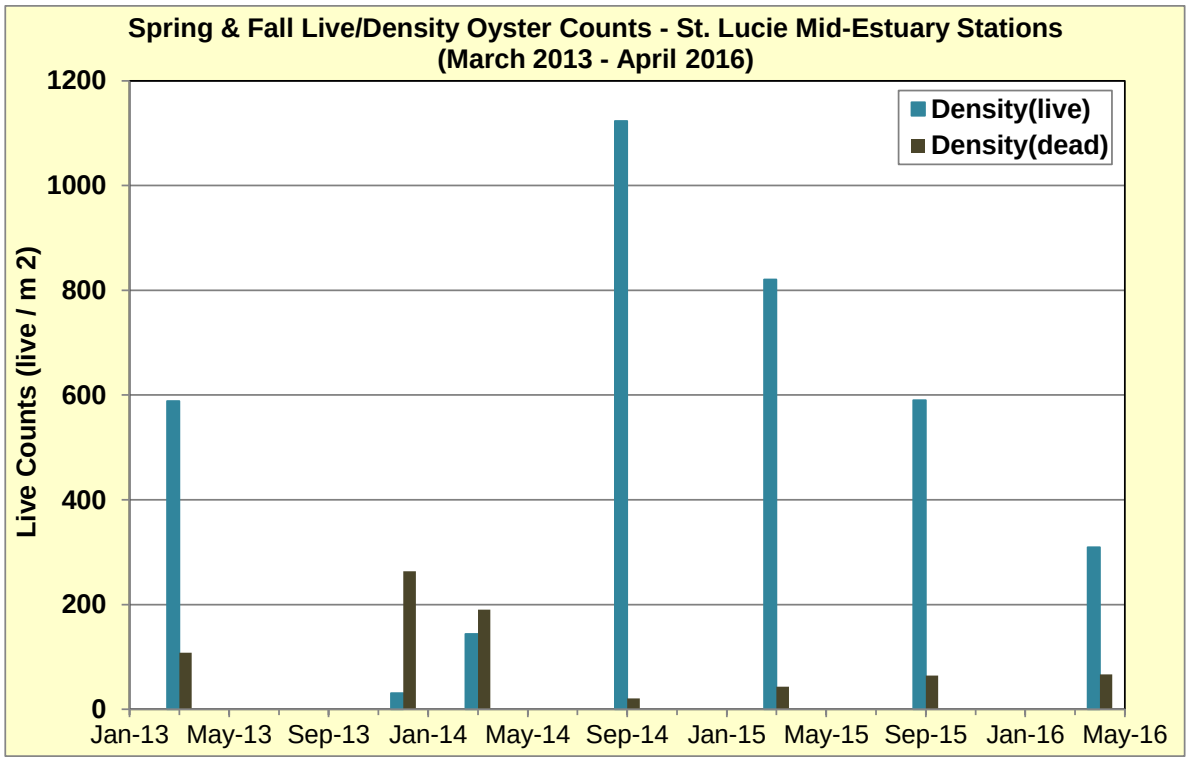


Figure 39. Oyster density counts in live oysters per square meter (m 2) in the St. Lucie Mid-Estuary, March 2013–April 2016.

Seagrasses are also sensitive to salinity; lower salinities cause leaf mortality. Seagrass biomass is routinely monitored in the lower St. Lucie Estuary as part of RECOVER monitoring (**Figure 40**). During the emergency operations period, seagrass biomass was assessed three times at both Willoughby Creek and Boy Scout Island sites (**Figures 41** and **42**, points highlighted in green). The Willoughby Creek site is dominated by Johnson's seagrass (*Halodule johnsonii*) and shoal grass (*Halodule wrightii*), two low-salinity tolerant species that can recover relatively quickly. The biomass index was relatively high at the beginning of the emergency operations period but then declined (**Figure 40**). However, biomass has begun to recover. It is not known if this variability in biomass is in response to the emergency operations as the measurements fell within what appears to be natural variability of the site.

Manatee grass (*Syringodium filiforme*) is the dominant species at Boy Scout Island. It is sensitive to low salinity and can take a long time to recover (as much as 5 years). Manatee grass biomass has been declining since its peak in 2011 (**Figure 42**) and was very low immediately preceding the emergency operations period. Therefore, it is difficult to assess what, if any, impact the high Lake Okeechobee releases had on seagrass biomass at this site.

Figure 40. RECOVER seagrass monitoring sites in the St. Lucie Estuary.

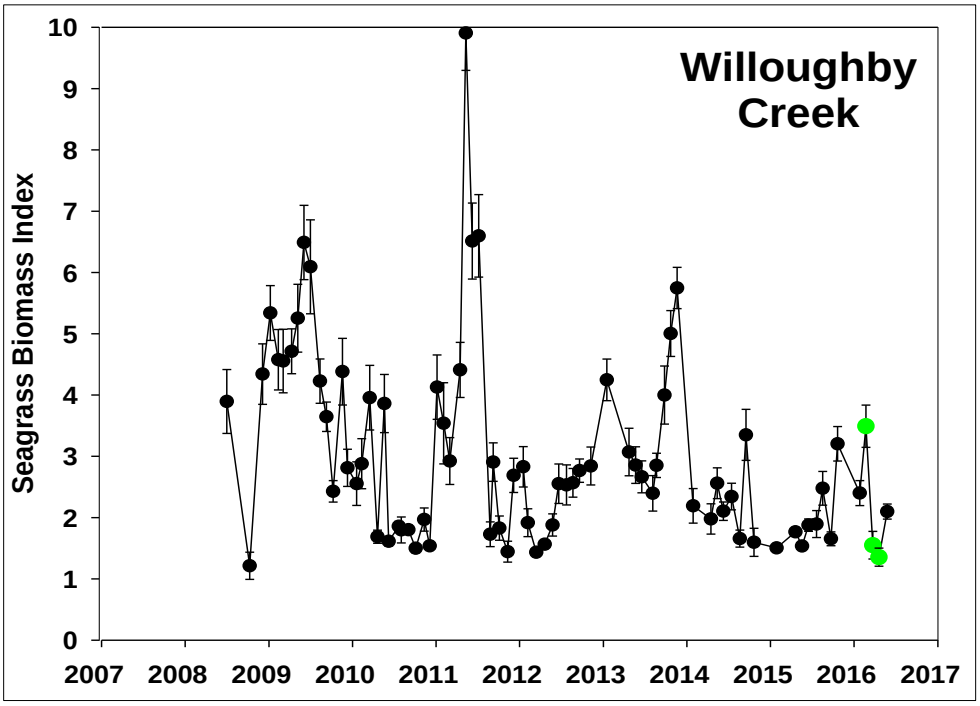


Figure 41. Seagrass biomass index at Willoughby Creek in the St. Lucie Estuary. Green points represent samplings during emergency operations.

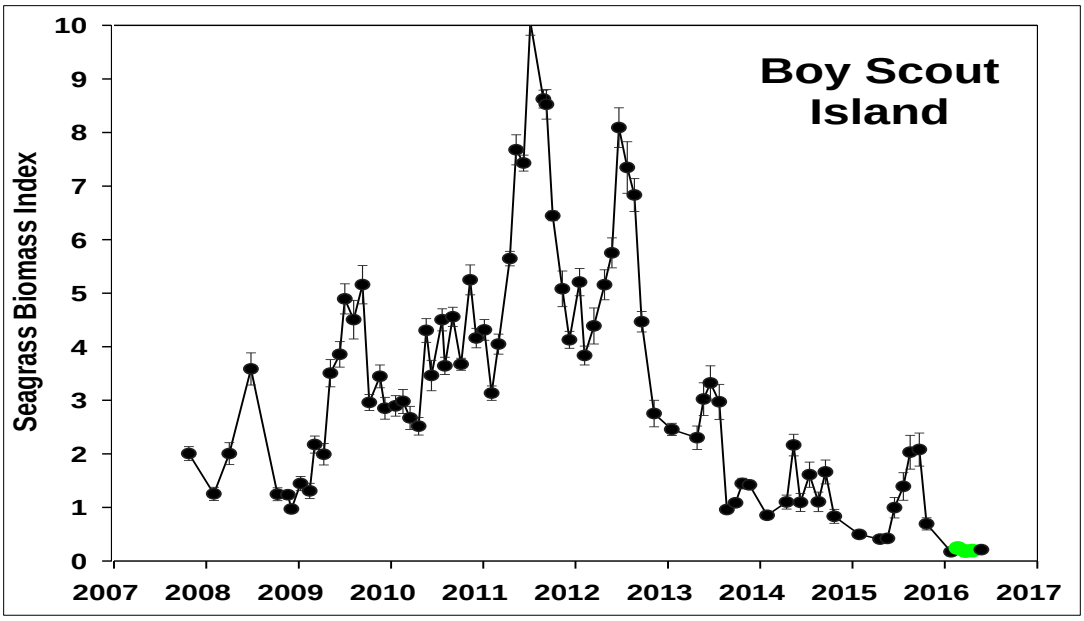


Figure 42. Seagrass biomass index at Boy Scout Island in the St. Lucie Estuary. Green points represent samplings during emergency operations.

CALOOSAHATCHEE ESTUARY FLOWS AND SALINITIES

The Caloosahatchee Estuary is on the western side of Lake Okeechobee and receives lake releases through the S-77 structure (**Figure 43**). Lake releases historically (SFWMD WY1997–WY2015) account for 52 percent of total flow to the Caloosahatchee Estuary through the S-79 structure during the dry season. However, during the emergency operations period, 74 percent of total flow originated from the lake (**Table 9**). The majority of this flow occurred in February and early March 2016, with flow from the lake averaging 5,836 cfs between February 11 and March 3, 2016. Flow then declined to a constant release averaging 3,404 cfs from March 4 through 17, 2016 after which pulse releases began averaging 2,095 cfs for the remainder of the emergency operations period (**Figure 44**).

Table 9. Caloosahatchee River/Estuary inflows (February 11, 2016–May 11, 2016).

	Flow Volumes (acre-feet x 1000)		Average flow rate, cfs
Lake Okeechobee	578	74%	3201
C-43 Basin	155	20%	856
Tidal Basin	48	6%	268
Total	781	100%	4325

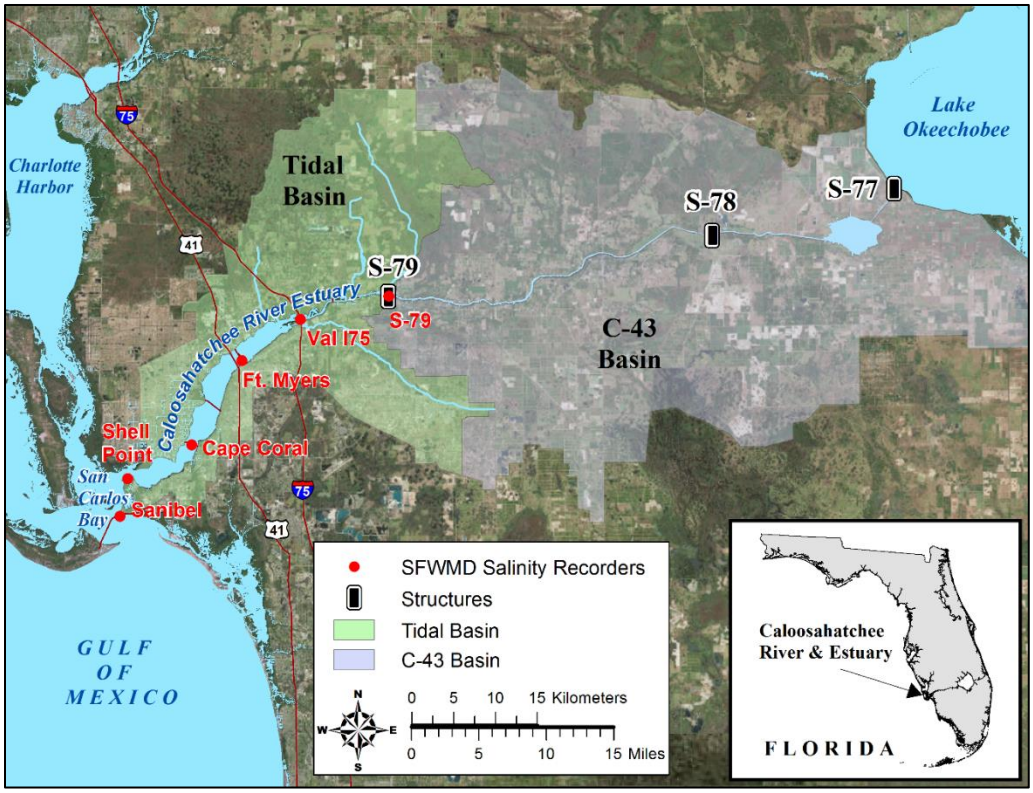


Figure 43. Basins, water control structures, and salinity monitoring for the Caloosahatchee Estuary.

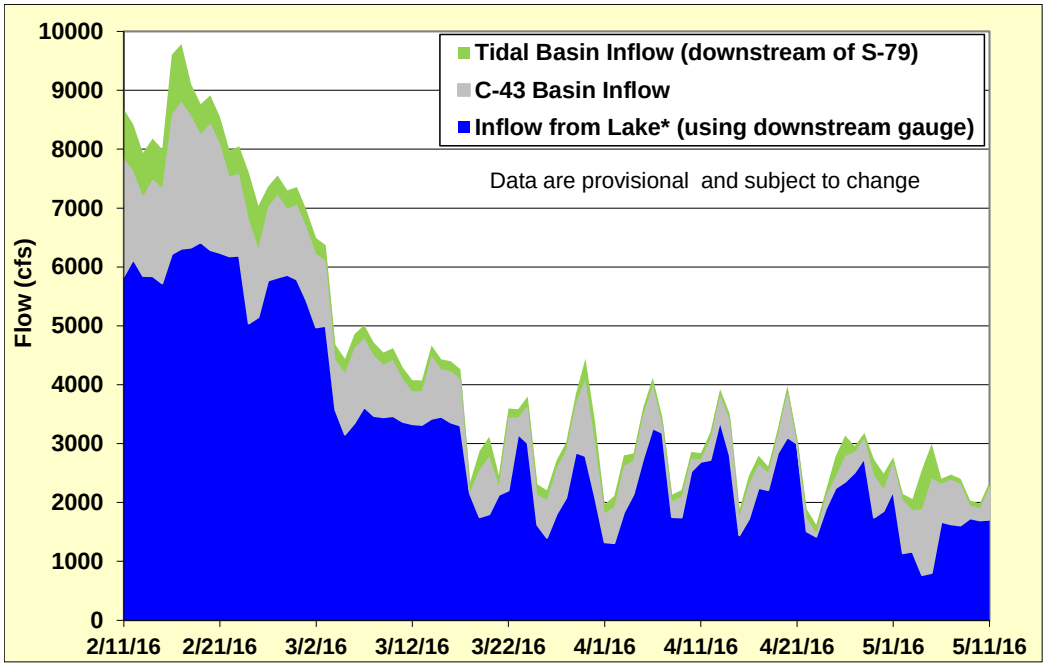


Figure 44. Freshwater inflows from Lake Okeechobee, runoff from the C-43 basin, and tributaries in the tidal basin into the Caloosahatchee River Estuary.

Salinity is monitored in the surface and bottom waters at three locations in the lower Caloosahatchee Estuary to assess potential stress on adult oysters: Cape Coral, Shell Point, and Sanibel (**Figure 45**). The

7-day average water column salinity is assessed and compared to salinity envelopes developed for adult oysters. During the emergency operations period, salinity at Cape Coral was in the poor range (< 5) for 56 days. On April 7, 2016, salinity began exceeding 5 and continued to increase through the fair range for the remainder of the emergency operations period (**Figure 46**). Salinity at Shell Point and Sanibel were in the fair to good range for the duration of the emergency operations period.

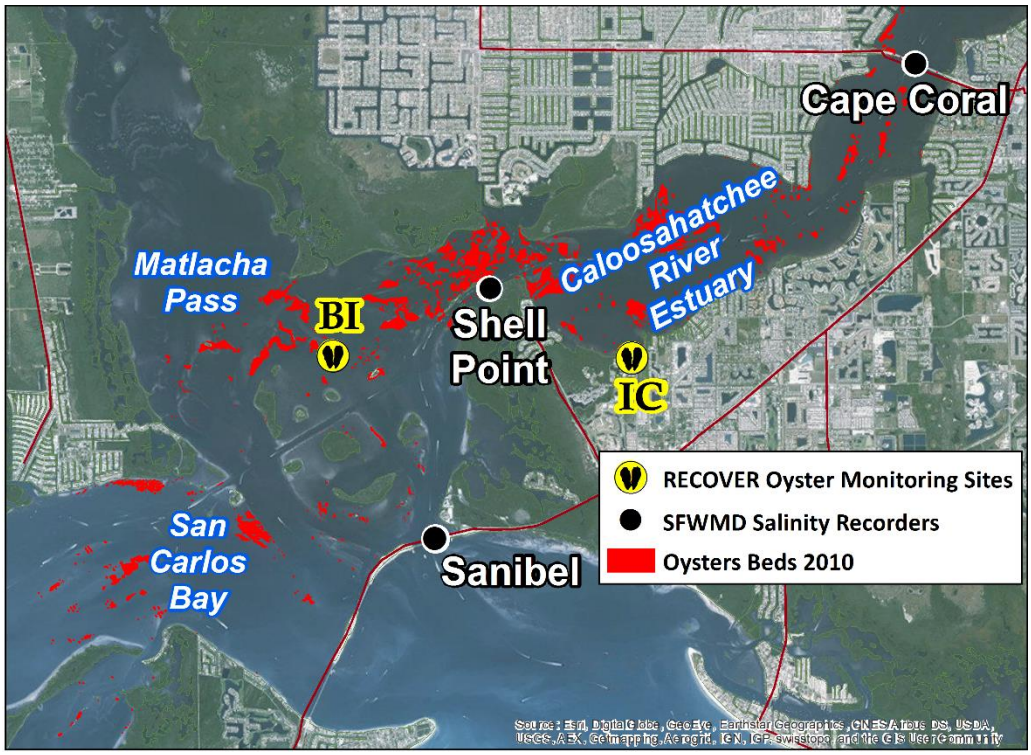


Figure 45. RECOVER oyster monitoring sites in Caloosahatchee River Estuary.

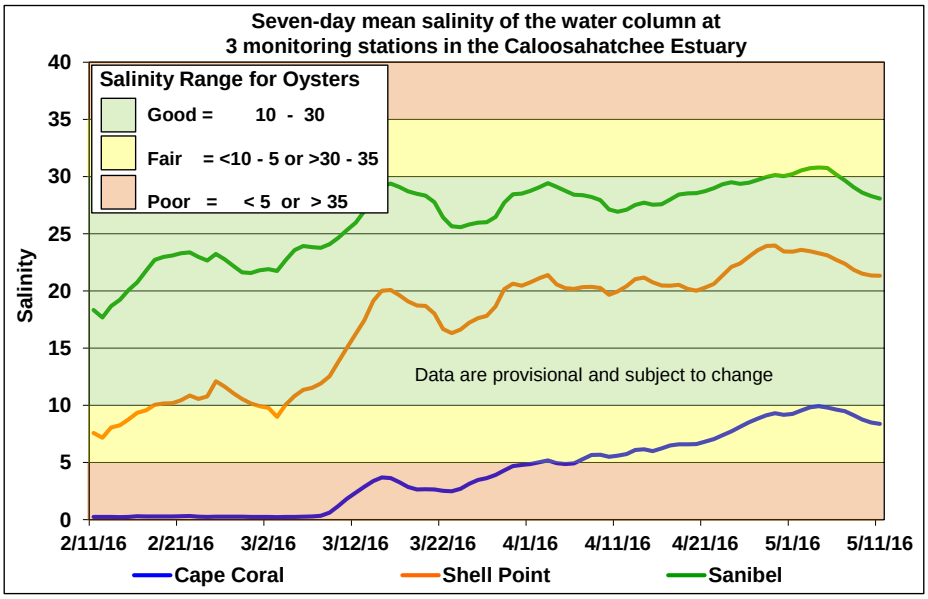
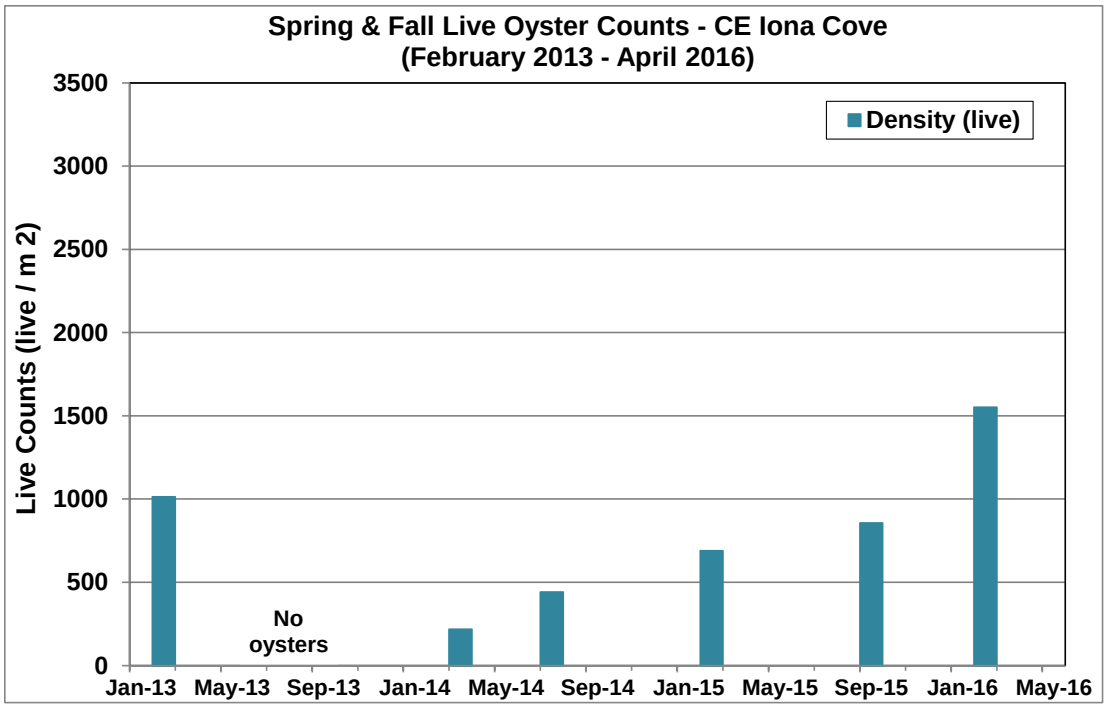


Figure 46. Seven-day mean salinity at Cape Coral Bridge, Shell Point, and Sanibel Bridge monitoring stations.

Mortality for adult oysters is expected to occur after 28 days of salinity < 5. Per routine biannual RECOVER sampling, live oyster density was measured on February 18, 2016 at Iona Cove located between Cape Coral and Shell Point and on March 8, 2016, at Bird Island located between Shell Point and Sanibel (**Figure 47**). Live density was higher compared to the previous spring at both locations. Mortality was 20 percent at Iona Cove and 9 percent at Bird Island, which was comparable to previous measurements made by a different method earlier in the year. It is unlikely that salinity was < 5 at either of these locations for any ecologically significant duration during the emergency operations period.



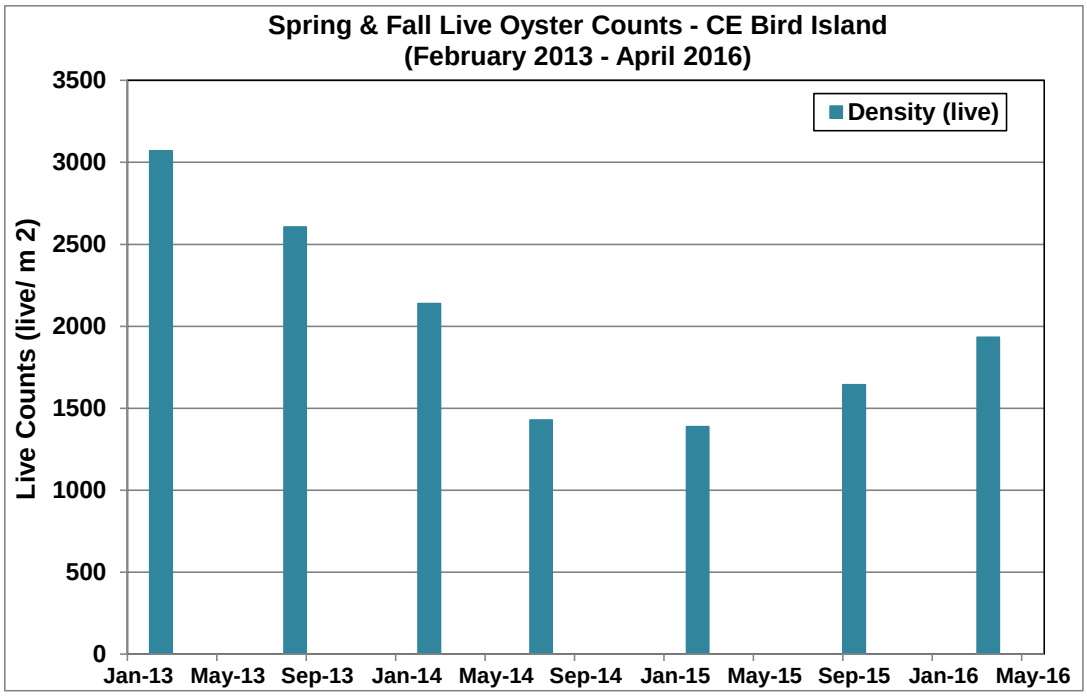


Figure 47. Oyster density counts in live oysters per square meter (m 2) at Bird Island and Iona Cove in the Caloosahatchee River Estuary.

In the upper portion of the Caloosahatchee Estuary, tape grass (*Vallisneria americana*), a species sensitive to salinity > 10, is monitored (CRE_2), and in the lower portion of the estuary, turtle grass (*Thalassia testudinum*) and shoal grass are monitored (CRE_8) (**Figure 48**). During the emergency operations period, biomass was assessed three times at both sites (**Figures 49** and **50**, points highlighted in green). Tape grass biomass at CRE_2 increased during the emergency operations period and was higher than most previous spring samplings (**Figure 49**). Seagrass biomass at CRE_8 also increased during the

emergency operations period and was near average compared to previous spring samplings (**Figure 50**). Submerged aquatic vegetation in the Caloosahatchee Estuary does not appear to have been negatively impacted by the increased Lake Okeechobee releases.

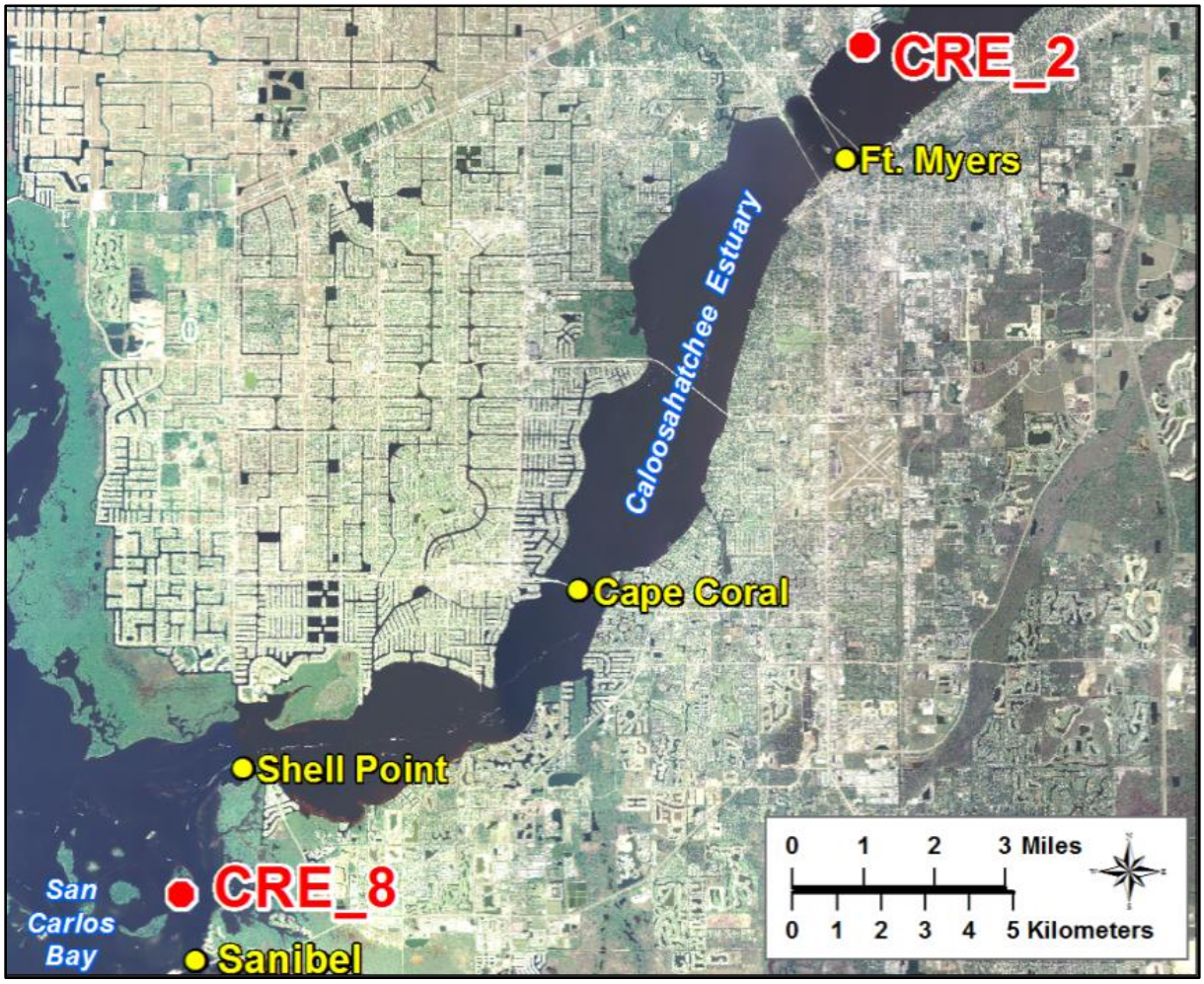


Figure 48. Submerged aquatic vegetation monitoring sites in the Caloosahatchee Estuary.

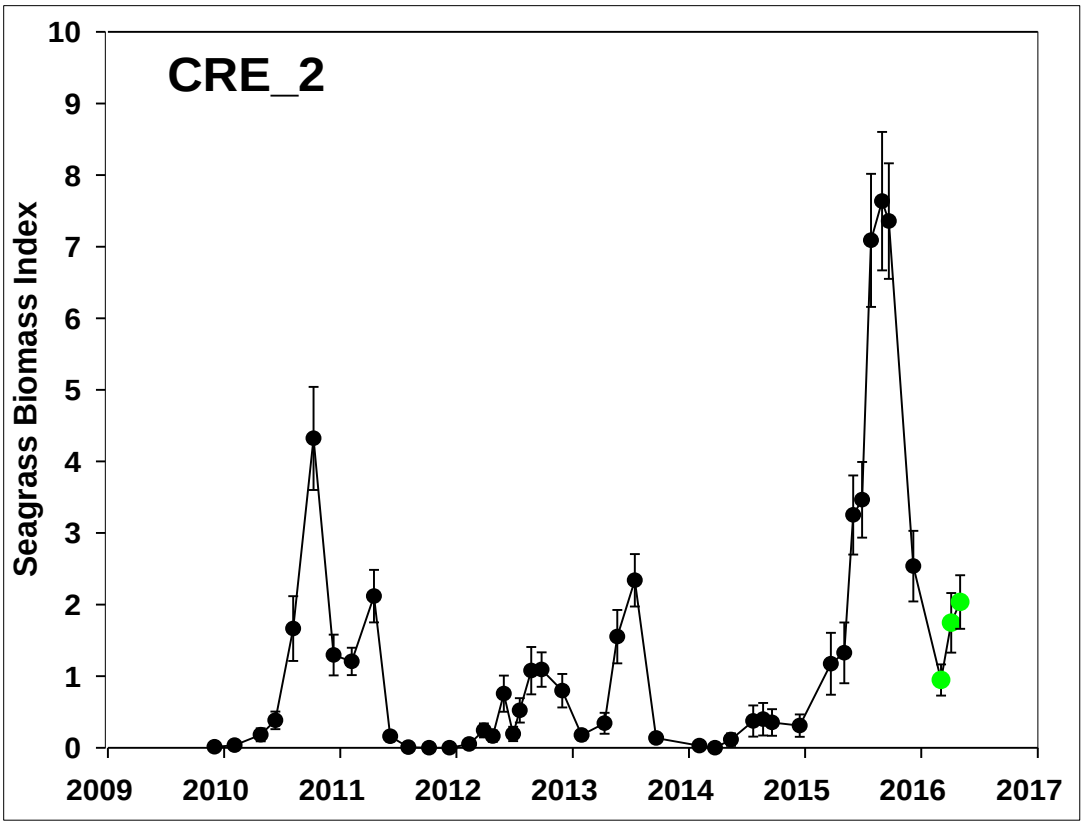


Figure 49. Seagrass biomass index at CRE_2 in the Caloosahatchee Estuary. Green points represent samplings during emergency operations.

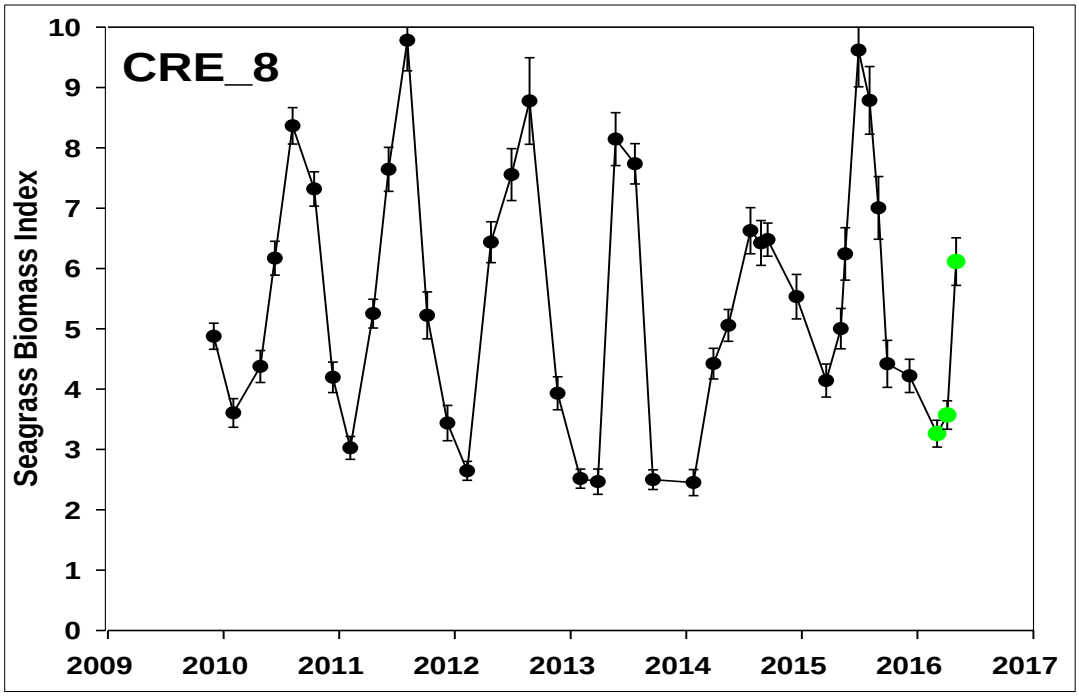


Figure 50. Seagrass biomass index at CRE_8 in the Caloosahatchee Estuary. Green points represent samplings during emergency operations.

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