Chapter 5: Performance and Optimization of the Everglades Stormwater Treatment Areas

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SUMMARY

As part of Everglades restoration, the construction and operation of six large freshwater treatment wetlands, known as the Everglades Stormwater Treatment Areas (STAs), are mandated by the Everglades Forever Act (EFA) (Section 373.4592, Florida Statutes). To date, the total area of the STAs, including infrastructure components, is around 65,000 acres with approximately 45,000 acres of effective treatment area currently operational. These areas have been created south of Lake Okeechobee to remove excess total phosphorus (TP) from surface waters prior to entering the Everglades Protection Area (EPA) (**Figure 5-1**). Stormwater Treatment Areas 1 East, 1 West, 2, 3/4, 5, and 6 (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6, respectively) are managed by the South Florida Water Management District (District or SFWMD). This chapter and related appendices (Appendices 5-1 through 5-5) summarize the short- and long-term STA performance analyses, evaluation of conditions relevant to STA performance, facility status, operational challenges, and enhancements during Water Year 2011 (WY2011) (May 1, 2010–April 30, 2011). A detailed analysis of the annual performance in terms of permit compliance is reported in Volume III, Appendix 3-1. A summary of individual components identified in the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) (Burns and McDonnell, 2003) is also covered in this chapter. More information on the STAs is also available at www.sfwmd.gov/sta. Key highlights of STA performance and optimization during WY2011 are presented below.

- In WY2011, the STAs received 735,165 acre-feet of water and retained 67.5 metric tons of TP (see Volume III, Appendix 3-1). This equates to a 79 percent TP load reduction and a decrease in flow-weighted mean (FWM) TP concentration from 94 to 20 parts per billion [ppb, or micrograms per liter (μg/L)]. STA-3/4 maintained its excellent long-term performance with 16 ppb FWM outflow TP and performance of the other five STAs was generally a dramatic improvement from the previous water year. The FWM outflow TP concentrations were 22, 25, 15, 47, and 25 ppb for

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STA-1E, STA-1W, STA-2, STA-5, and STA-6, respectively. STA-5 achieved its lowest concentration over its period of operation.

- The outstanding performance can be attributed to the low hydraulic and phosphorus (P) loading during WY2011, effective operational management, and continued enhancements in various areas of the STAs. Further details on the STA condition, operational status, management activities, and enhancements are discussed within this chapter.
- Construction of STA Compartments B and C is in progress, and these projects were flow-capable by December 2010. While the District has not been issued authorization to operate Compartments B and C, initial assessment on environmental conditions (soil, vegetation, topography) have been initiated. Vegetation start-up is under way and will continue in WY2012.
- For STA-1E, the District continues to coordinate key issues with the U.S. Army Corps of Engineers (USACE). The operation and performance of STA-1E continued to be impacted by structural, elevation, and Eastern Flow-way restrictions (Periphyton Stormwater Treatment Area) issues in WY2011. Repairs and enhancements to resolve these issues are being planned and led by the USACE. During the reporting period, repairs of major structures also continued in STA-1E, including S-375.
- STA enhancements continued in WY2011, including vegetation conversion in STA-3/4 and STA-2, extensive bulrush (*Scirpus acutus*) planting in areas that are too deep for cattail (*Typha* spp.) to thrive and in areas where there is visible short-circuiting. An old remnant canal in STA-1W was plugged to correct a short-circuiting problem and improve flow in Cell 3. Cell performance after this enhancement will continue to be evaluated in WY2012. In STA-3/4, Cell 1A water level was drawn down to encourage cattail reestablishment in this cell impacted by chronic deep water conditions.
- With proper and cautious review of hydration priorities through implementation of the Drought Contingency Plan, many STA cells remained hydrated despite the prolonged and severe drought in WY2011. Approximately 21,700 acre-feet of water from Lake Okeechobee was delivered from December 8, 2010, to April 30, 2011, to hydrate priority cells. Initial evaluation of drought-related impacts to the STAs has been done (see the *Effects of Drought Conditions* section of this chapter). Further assessment of these effects and post-drought recovery is continuing in WY2012.
- Avian protection surveys during the 2011 nesting season were completed, as required under the Avian Protection Plan. Utilizing the survey results, operational priorities were adjusted during black-necked stilt (*Himantopus mexicanus*) nesting. The presence of Everglade snail kite (*Rostrhamus sociabilis plumbeus*) nests in STA-5 also impacted STA-5 and STA-6 operations.

The STAs are highly managed systems requiring concerted coordinated efforts among agency staff. Discussions and prioritization of flow-way operation, based on weekly hydrologic and P data, as well as vegetation condition, construction activities, and wildlife issues, help ensure that the STAs are operated and maintained optimally. Additional short- and long-term data analysis and field surveys were continued as part of research to identify ways to improve and sustain STA performance.

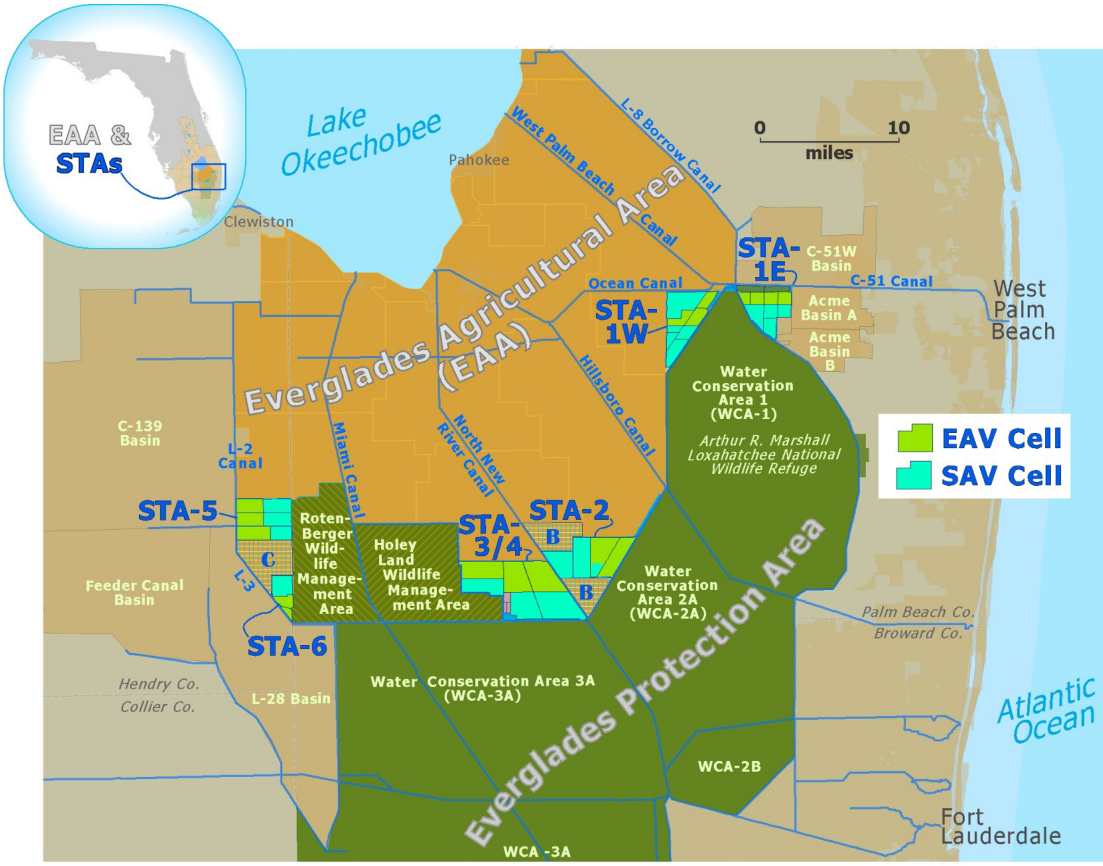


Figure 5-1. Location of the six Everglades Stormwater Treatment Areas (STAs) in relation to the Everglades Protection Area (EPA), their dominant vegetation community [emergent vegetation (EAV) or submerged aquatic vegetation (SAV)], and the major basins south of Lake Okeechobee.

INTRODUCTION

As a major component of Everglades restoration, the Everglades Construction Project Stormwater Treatment Areas (STAs) were built and operated to remove excess total phosphorus (TP) from surface waters prior to those waters entering the Everglades Protection Area (EPA). STAs are constructed wetlands that retain nutrients through several mechanisms including plant nutrient uptake and litter decay, settling and sorption, sedimentation, and microbial activities.

This chapter describes the performance and condition of the six STAs (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6, respectively), the highlights, and operational challenges as they relate to the STAs' and individual cell's treatment performance and capabilities (**Figure 5-1**). All data analyses related to permit compliance, such as the Everglades Forever Act (EFA) and National Pollutant Discharge Elimination System (NPDES) permits and Administrative Orders (AOs), are included in Volume III, Appendix 3-1.

Varying in size, configuration, and period of operation, the STAs are shallow freshwater marshes divided into treatment cells by interior levees (**Figure 5-2**). Managed by the South Florida Water Management District (SFWMD or District), water flows through these systems via water control structures, such as pump stations, gates, or culverts. The dominant plant communities in the treatment cells are broadly classified as (1) emergent aquatic vegetation (EAV), (2) submerged aquatic vegetation (SAV), and (3) floating aquatic vegetation (FAV). Interspersed among this vegetation, where conditions are favorable, are periphyton communities.

Treatment performance, which varies temporally and among STAs, depends on several factors including (1) antecedent land use, (2) nutrient and hydraulic loading, (3) vegetation condition, (4) soil type, (5) cell topography, (6) cell size and shape, (7) weather conditions, (8) construction activities to improve performance (enhancement activities), and (9) regional operations. STA managers use an adaptive approach and weekly data analyses. An analysis of short- and long-term performance incorporates the latest stage and water quality information and compares the actual flow and TP loads to the long-term average annual values anticipated for each STA. Other weekly analyses examine stage levels and compare those with target stages. General operational strategies employed in the STA operations help to ensure that inflows (flows and TP loads) are within the design operational envelope, that the flows are distributed among flow-ways when possible, and that the water levels in the cell stay within target stages. Other factors are considered as they arise, including restrictions due to enhancements, revegetation, or the presence of nests of protected or endangered species.

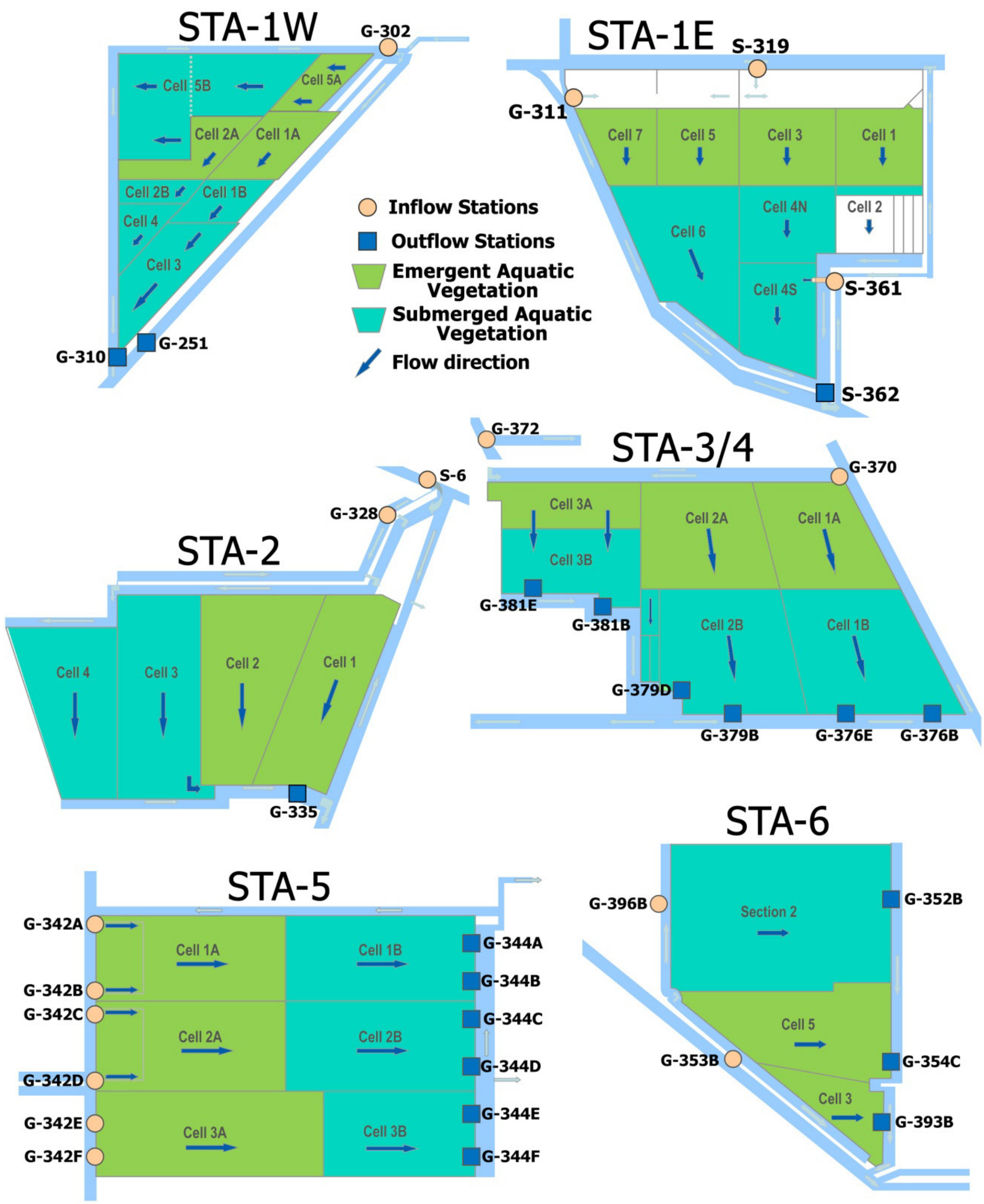


Figure 5-2. STA schematics showing configurations of the treatment cells, flow direction, dominant vegetation type, and locations of permitted inflow and outflow stations. The southern section of STA-2, Cell 2, is currently undergoing a vegetation conversion from emergent to SAV.

STA PERFORMANCE

INTRODUCTION

A summary of WY2011 and period-of-record performance for each STA, as required by permits, is included in Volume III, Appendix 3-1. In WY2011, the STAs received over 735,000 acre-feet (ac-ft) of water and retained 67.5 metric tons (mt) of TP from runoff water, which equates to a 79 percent load reduction. TP concentration was reduced from an annual flow-weighted mean (FWM) of 94 parts per billion [ppb, or micrograms per liter (μg/L)] at the inflow to 20 ppb at the outflow.

This section of the chapter discusses the condition and action plan related to any STA that did not meet the regulatory criteria established in the permit, individual STA's WY2011 versus historical performance, performance of each flow-way, characterization of pattern of treatment along selected STA flow-way inflow-outflow transects, analysis of treatment performance against phosphorus loading rates (PLR) and inflow TP concentration, and STA-3/4 Periphyton-Based Stormwater Treatment Area (PSTA) project performance. A detailed analysis of the cell-by-cell performance and water budget is also presented in Appendix 5-1.

PERMIT-RELATED PERFORMANCE ISSUES AND ACTION PLANS

In WY2011, the STA-1E and STA-5 outflow FWM TP concentrations exceeded the interim effluent limits (IELs) contained in the EFA permits. The STA-1E outflow FWM TP concentration was 22 ppb (IEL=20 ppb) and STA-5 outflow FWM TP concentration was 47 ppb (IEL=40 ppb) (Volume III, Appendix 3-1). As required by the permits, the causes were investigated and documented, and action plans were developed accordingly.

In STA-1E, the reasons that the IEL was exceeded included anomalous rainfall conditions, several structure failures and repairs, vegetation failure in both Cell 7 (cattail mortality, poor density, and poor condition) and Cell 6 (hydrilla die-off in WY2010), and Eastern Flow-way restrictions and dryout due to drought. During the extended dry season, STA-1E received supplemental water from Lake Okeechobee for hydration maintenance, and temporary pumps were installed to move water from Cell 6 to Cell 4N. The U.S. Army Corps of Engineers (USACE) is leading long-term action plans related to this STA, including structural repairs, raising the ground elevation and leveling Cell 7, and decommissioning the PSTA project in Cell 2.

Following the extensive hydrilla loss in Cell 6 in WY2010, the District initiated efforts to plant bulrush in Cells 6 and 7, inoculate Cell 6 with SAV, improve flow distribution through degrading sections of elevated berm along the southern end of Cell 5, and plant bulrush in Cell 5 to reduce hydraulic short circuiting. **Figure 5-3** shows that TP spikes occurring in a short period, (i.e., May to July 2009) for STA-1E resulting from vegetation failure in the Western Flow-way, have major impacts on the 12-month moving average data. With minimal flow to the Western Flow-way (restricted flow condition in WY2011), the outflow TP moving average slowly decreased with a sudden decline towards the end of the water year.

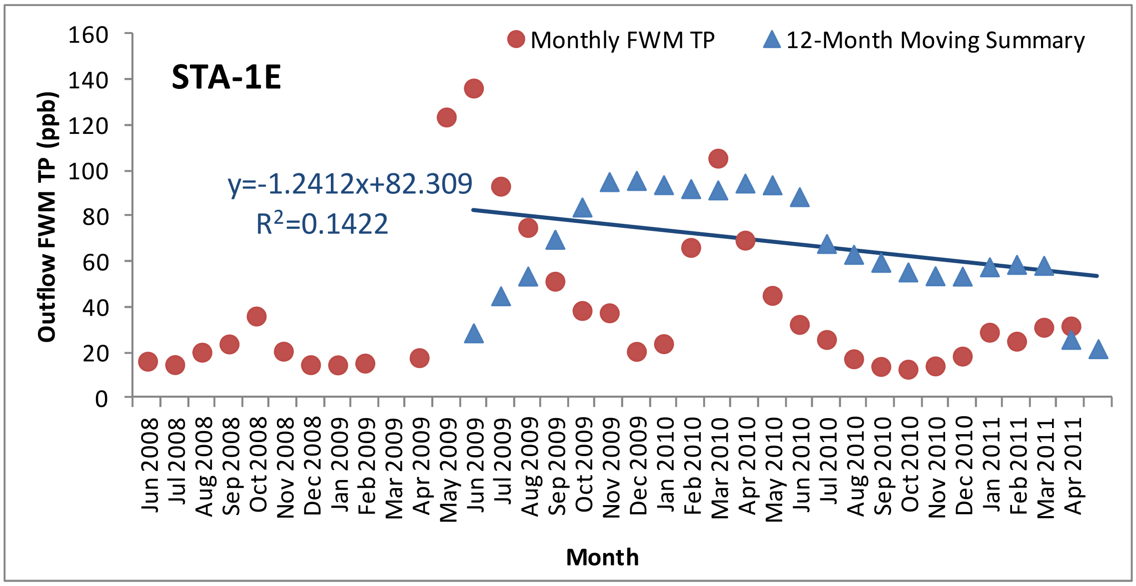
In STA-5, vegetation in Cell 1A continued to improve, particularly after the rehabilitation effort in WY2009, and hydrilla in Cells 1B and 2B remained stable despite low water conditions during early 2011. By December 2010, the EAV cells dried out, while the SAV cells stayed hydrated through the dry season by implementing tactical measures to bring water in from the Miami Canal when water was available. Flow-way 3 had very little flow, due to restrictions related to Compartment C Build-out construction. There were also operational impacts from the presence of snail kite nests in Cell 1A early in the water year (see the *Facility Status and*

Operational Issues section of this chapter). The District continued to plant bulrush in open and deep areas of STA-5, and plans are under way to plug degraded vegetation strips in Cell 1B and plant bulrush on those strips to remedy short-circuiting that has been observed in this part of the cell. It is also anticipated that once Compartment C Build-out construction is completed and the expanded STA is operational, water can be distributed among the different flow-ways.

The 12-month outflow TP moving average in STA-5 shows the effects of reduction in flows, particularly during the WY2009 rehabilitation of Cell 1A, and a slight increase as affected by the rehydration of Cell 1A. Towards the end of WY2011, the moving average began declining again due to the lack of flow as a result of regional drought.

For STA-6, WY2011 inflow volume exceeded the maximum envelope inflow volume. This STA received additional inflows from the C-139 basin as a result of restrictions in STA-5 and dewatering for Compartment C Build-out construction. These additional flows were unforeseen and were not accounted for in the 2007 and 2010 operational envelope calculations. Despite exceeding the maximum inflow volume target, the flow-weighted annual outflow TP values remained less than the interim TP limits for STA-6; therefore, no action plan is required.

The status of WY2010 STA issues and actions reported in the 2011 SFER are incorporated within the *STA Condition Assessment* and *Vegetation Enhancements* sections of this chapter.



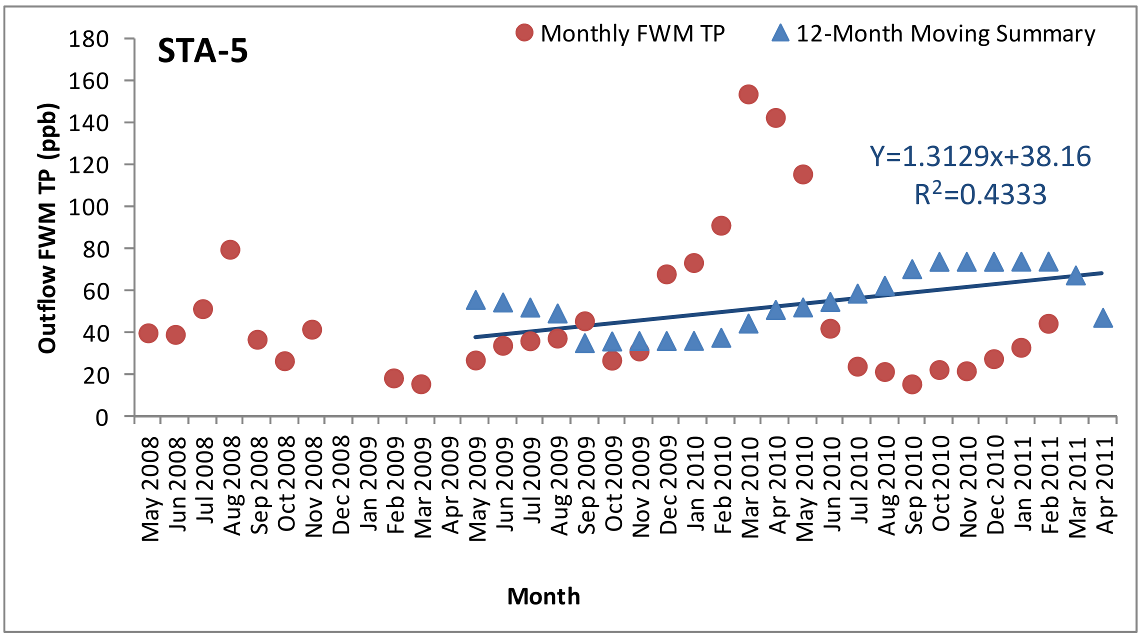


Figure 5-3. Twelve-month moving outflow flow-weighted mean (FWM) TP concentrations for STA-1E (top) and STA-5 (bottom). The 12-month moving average trend reflects that that the 12-month moving average TP concentrations are highly influenced by short-term spikes occurring during the year.

ANALYSIS OF INDIVIDUAL STA AND FLOW-WAY TREATMENT PERFORMANCE

A summary of the flow volume and phosphorus (P) removal performance for each flow-way is presented in **Table 5-1**. The annual water and TP mass balance budgets for individual STA treatment cells or flow-ways were developed in WY2011. The assumptions and methods used in computing the water and TP budgets are provided in Chapter 5 of the *2008* and *2009 South Florida Environmental Reports* (SFERs) – *Volume I*. The water and TP mass balance analyses and cell by cell analyses for WY2011 are reported in Appendix 5-1 of this volume.

Like previous water budget analyses, the WY2011 STA cell water budgets were dominated by surface flow, comprising over 80 percent of both inflow and outflow for most cells; these values are much less in STA-5 and STA-6 (Appendix 5-1). The WY2011 TP mass budget was also dominated by surface water inflow and outflow TP. Previous SFERs have documented the influence of inflow TP concentration and load on STA outflow TP concentration. Further analysis showing this correlation is presented later in this chapter. In general, cell treatment performance has been consistent with how other treatment wetlands respond to increasing inflow TP (Kadlec, 2006).

Table 5-1. Water Year 2011 (WY2011, May 1, 2010–April 30, 2011) performance for each STA flow-way.

STA	Flow-way or Cell	PLR ($g/m^2/yr$)	HLR (cm/day)	Surface Water Inflow (ac-ft)	Inflow FWM TP (ppb)	Surface Water Outflow (ac-ft)	Outflow FWM TP (ppb)
1E	Central FW	0.13	0.29	6,859	120	10,594	45
	Western FW	0.02	0.06	1,390	77	472	142
1W	Eastern FW	0.47	1.03	30,896	125	34,267	24
	Western FW	1.13	2.10	32,590	148	24,890	25
	Northern FW	1.10	2.04	69,759	148	75,898	21
2	Cell 1	0.40	1.24	26,605	88	32,269	12
	Cell 2	0.89	2.42	65,697	101	68,712	19
	Cell 3	0.76	2.57	69,891	81	67,747	15
	Cell 4	0.01	0.05	1,168	44	12,071	35
3/4	Eastern FW	0.37	1.20	93,679	84	102,716	17
	Central FW	0.28	1.47	95,680	53	90,663	21
	Western FW	0.39	2.06	112,832	51	122,832	13
5	Flow-way 1	0.42	1.36	33,483	84	16,926	41
	Flow-way 2	0.21	0.38	9,381	149	4,618	54
	Flow-way 3	0.10	0.08	2,005	317	2,775	77
6	Cell 3	0.65	1.92	5,629	93	4,496	16
	Cell 5	0.47	1.33	9,941	97	7,863	17
	Section 2	1.48	3.45	57,274	118	62,233	27

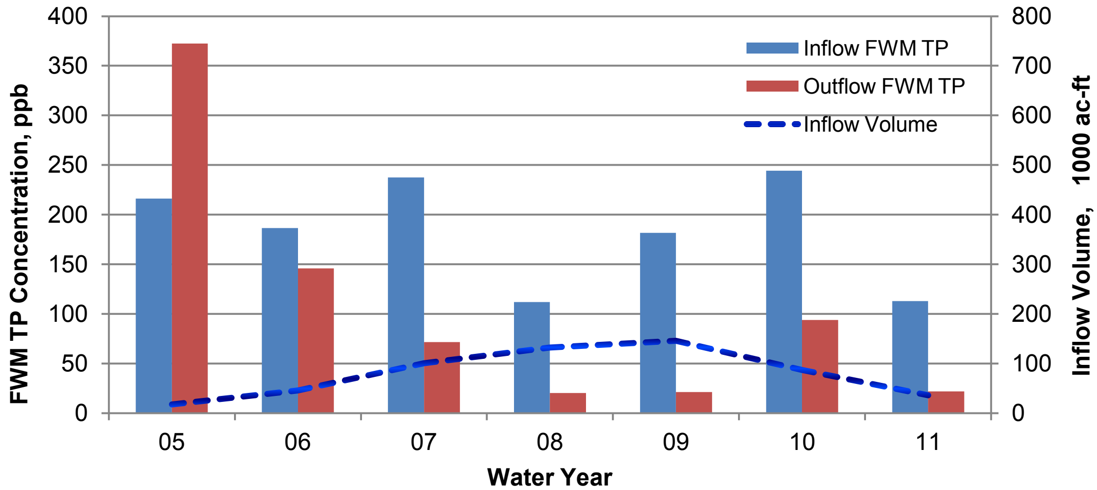
Note: PLR = phosphorus loading rate; HLR = hydraulic loading rate; $g/m^2/yr$ = grams per square meter per year; cm/day = centimeters per day; ac-ft = acre-feet; ppb = parts per billion; FW = flow-way. STA-2 Cell 4 and STA-6 Section 2 were operational only part of the water year. Complete TP cell by cell budgets are found in Appendix 5-1.

STA-1E

In WY2011, only the Central Flow-way of STA-1E was fully operational. The Western and Eastern flow-ways were under restricted operations and received little or no flow. As mentioned earlier in this chapter, this STA, with an outflow TP concentration of 22 ppb, did not meet the IEL required by the EFA permit. However, the annual rainfall amount is also below the simulation average that was one of the bases for setting the IEL. In addition, STA-1E continues to be operated under various challenging conditions, including structural failures, persistent deep water condition resulting in poor vegetation establishment in Cells 5 and 7, and slow recovery of Cell 6 from extensive SAV loss during WY2010.

Compared to the period-of-record performance since STA-1E began operation in WY2005, the WY2011 outflow concentrations were some of the lowest observed for this STA, and was comparable to the outflow TP levels observed in WY2008 and 2009 (**Figure 5-4**). The relatively low outflow TP concentration, despite the operational issues in STA-1E, can be attributed to various factors, including the low inflow volume (approximately 26,000 ac-ft), low inflow TP concentration, correspondingly low hydraulic loading rates (HLR) [less than 0.3 centimeters per day (cm/day)] and PLR [0.25 grams per square meter per year ($g/m^2/yr$)], and influence of seepage (approximately 12 percent of total outflow volume). Structural repairs were under way during WY2011. Additional improvements, including leveling of low elevation areas and grading in the Eastern Flow-way, are in the planning stage and are being coordinated by the USACE.

The resulting outflow FWM TP concentrations in the Central Flow-way was 45 ppb, higher than the reported outflow concentration at S-362 (outflow discharge structure), primarily due to the contribution of seepage in flow and load to S-362. It is also likely that varying uncertainties in the data between the flow-way and main discharge structures contributed to this observed difference. Data for the Western Flow-way are not presented because it has been offline for most of the water year and the volume of flow is minimal (<500 ac-ft of outflow). The Western Flow-way has not performed as well as the Central Flow-way in terms of P retention since the beginning of operation. Since WY2007, Cells 5 and 7 have had low or negative TP reduction in terms of both load and concentration (**Figure 5-5**). Cell 6 had a positive trend in TP removal in the first three years and peaked in WY2008, but due to the hydrilla die-off in May–June 2009, its performance declined and the system is still recovering, despite reestablishment of hydrilla in this cell as visually observed through WY2011. Outflow TP concentration remains high, prompting restriction of flow through the Western Flow-way.



Water Year	Key Events in STA-1E
2005	Hurricanes Frances and Jeanne; emergency operations only.
2006	Hurricane Wilma. Western and Central flow-ways were operational. Eastern Flow-way was off-line for PSTA.
2007	Tropical Storm Ernesto. Regional drought resulted in dryout of Cells 3 and 5. Western and Central flow-ways were operational. Eastern Flow-way was off-line for PSTA.
2008	Regional drought resulted in dryout of Cells 3 and 5. All flow-ways were operational. Additional inflow source (runoff from Wellington Acme Basin B). Structural failures.
2009	Regional drought resulted in dryout of Cell 3. Tropical Storm Fay. Western and Central flow-ways were operational. Eastern Flow-way was off-line for PSTA structural failures.
2010	Cattail decline in Cell 7; hydrilla die-back in Cells 4N, 4S, and 6. Western Flow-way was placed offline following hydrilla loss for rehabilitation. Eastern Flow-way was off-line for PSTA. Cells 3, 4N and 5 dried out during the dry season.
2011	Regional drought. Western Flow-way continued to be offline. Eastern Flow-way was on restricted operation for PSTA. Repair of S-375 was initiated.

Figure 5-4. Period of record summary of inflow and outflow phosphorus concentrations, inflow volume, and key events in STA-1E.

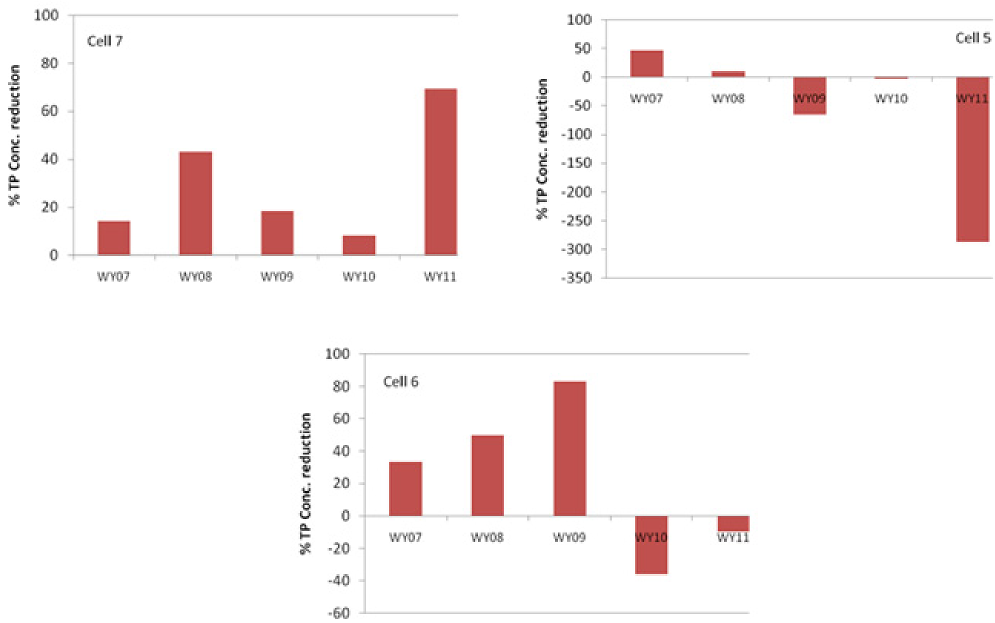
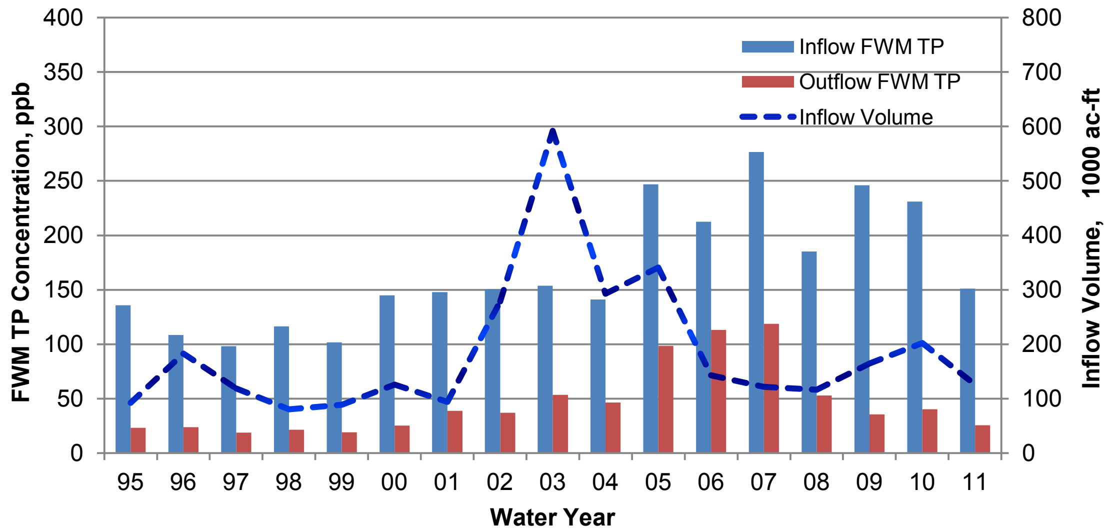


Figure 5-5. Analysis of Western Flow-way (Cells 5, 6, and 7) TP concentration reduction from inflow to outflow for WY2007–WY2011.

STA-1W

Figure 5-6 shows that STA-1W performance, in terms of outflow TP concentration, has improved since the construction enhancements and rehabilitation work in 2005−2007. WY2011 outflow FWM TP concentration of 25 ppb was comparable to the levels found in the initial five years of operation of the Everglades Nutrient Removal (ENR) project. Aside from the benefits of enhancements and rehabilitation, WY2011's successful performance can be attributed to the decrease in hydraulic and P loading and relatively lower inflow concentration (137–148 ppb) compared to the previous six years. It can also be attributed to an effective operational management, including maintaining hydration of the cells despite the regional drought and managing flows despite receiving more flows due to operational issues in STA-1E.

The Eastern, Western, and Northern flow-ways of STA-1W had HLRs and PLRs greater than 2 cm/day and 1 $g/m^2/yr$, respectively (**Table 5-1**). For the Northern Flow-way, long-term monitoring indicates that Cell 5A provides minimal treatment, likely due to a lack of vegetation in a large portion of the cell, short-circuited flow, and a short flow path. Bulrush has been planted in some of these areas and is expected to expand with time. Additional planting or encouragement of deep water tolerant plants (e.g., bulrush) and improvement of flow conditions are being evaluated to further improve performance of this cell. Cell 5B, with a diverse SAV population and healthy EAV strips, has performed effectively since rehabilitation in 2006 following the 2004–2005 hurricane damage. Similarly, the Eastern and Western flow-ways have performed steadily and produced outflow concentrations at the levels observed in the early years of ENR Project operation. In WY2011, a remnant canal in Cell 3 was plugged in an effort to block approximately 50 percent of flow that was preferentially flowing through the canal; the outcome of this effort will be evaluated in WY2012.



Water Year	Key Events in STA-1W
1994-1998	ENR Project: Eastern and Western flow-ways were operational.
1999	Northern Flow-way was added; project was changed to STA-1W.
2000-2002	Cells 5A and 5B dried out as a result of regional drought (October 1999–August 2001).
2003	High inflows from Lake Okeechobee regulatory releases.
2004	Eastern and Western flow-ways were operational. Tussock removal and plant rehabilitation in Cell 2.
2005	Hurricanes Frances and Jeanne. Only the Eastern Flow-way was operational. Cell 2 divide levee construction. Degraded Cell 5 limerock berm. Hurricane repairs. Plant establishment in Cell 5. Cells 2 and 4 dried out. STA1W Recovery Plan initiated in December 2004.
2006	Hurricane Wilma. Western Flow-way plant establishment. Northern Flow-way enhancements construction. Continued rehabilitation activities in Cell 5. Cells 2, 4, 5A and 5B dried out as a result of construction and rehabilitation activities.
2007	Tropical Storm Ernesto. Regional drought. All flow-ways were impacted by either rehabilitation activities, construction, or vegetation conversion. All cells dried out.
2008	Regional drought. Enhancement-related construction, vegetation conversion, and continued rehabilitation activities. All cells dried out (except for Cell 5B).
2009	Regional drought. Tropical Storm Fay. All flow-ways were operational; Cell 3 remained dry part of the year for vegetation conversion purposes
2010	Hydrilla and musk grass die-back in Cells 2B, 4 and 5B. All flow-ways were operational
2011	All flow-ways were operational. Regional drought. Supplemental water delivery from Lake Okeechobee helped maintain hydration of all cells through the drought season. Earthen plug was installed in Cell 3 discharge canal.

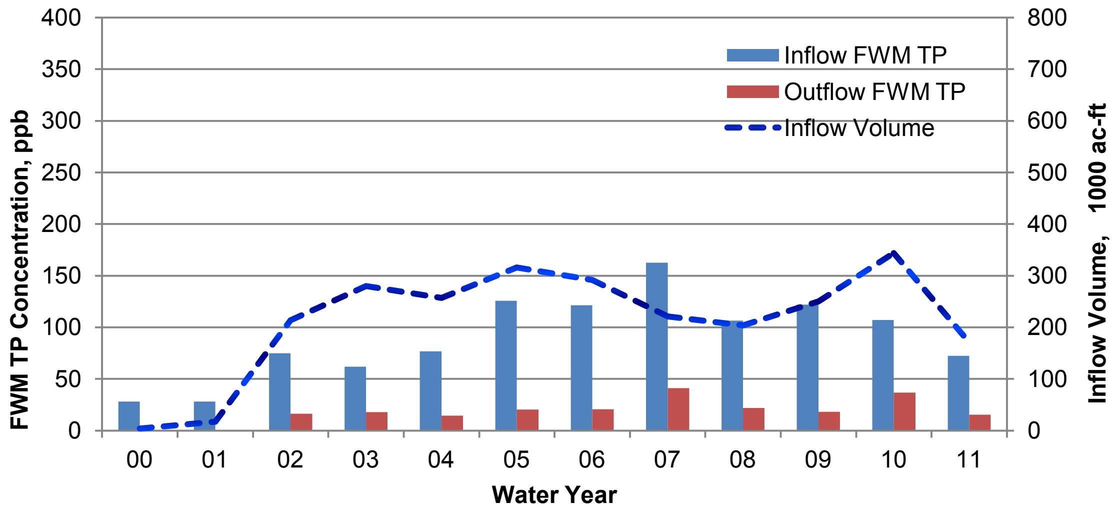
Figure 5-6. Period of record summary of inflow and outflow phosphorus concentrations, inflow volume, and key events in STA-1W.

STA-2

In WY2011, STA-2 outflow TP concentration (15 ppb) was among the lowest observed during this STA's period of operation (**Figure 5-7**). Similar to the other STAs, this excellent performance can be attributed partially to the lower loading rates in this water year, and relatively lower inflow TP concentrations compared to the previous six years. Although Cell 1 and parts of Cell 2 dried out briefly during the drought, the cells recovered quickly upon receiving flows during a brief rain event and supplemental water from Lake Okeechobee. In WY2010, dryout and rehydration in Cell 1 resulted in elevated outflow TP concentrations that lasted for more than six months before returning to pre-dryout level.

In addition, the performance of STA-2 can be attributed to the vegetation in Cells 1, 2, and 3 which remained stable with excellent coverage except for the southern portion of Cell 2, which has been undergoing vegetation conversion. As of the end of WY2011, SAV [musk grass (*Chara* sp.)] has colonized only a portion of the southwest area of Cell 2. In Cell 4, which was online with restriction part of the year and hydraulically separated from the rest of STA-2 in November 2010, there was little inflow (1,168 ac-ft) and little reduction in TP concentration (annual FWM concentration of 44 ppb at the inflow and 35 ppb at the outflow). Despite the lack of SAV in the southern portion of Cell 2, the cell achieved an outflow concentration below 20 ppb.

Like previous years, Cell 1 achieved the lowest outflow TP concentration (12 ppb) (**Table 5-1**), compared to Cells 2 and 3. This can be attributed to the HLR and PLR that are almost half of the values for Cells 2 and 3 in WY2011 and the fact that Cell 1 was never farmed prior to becoming an STA.

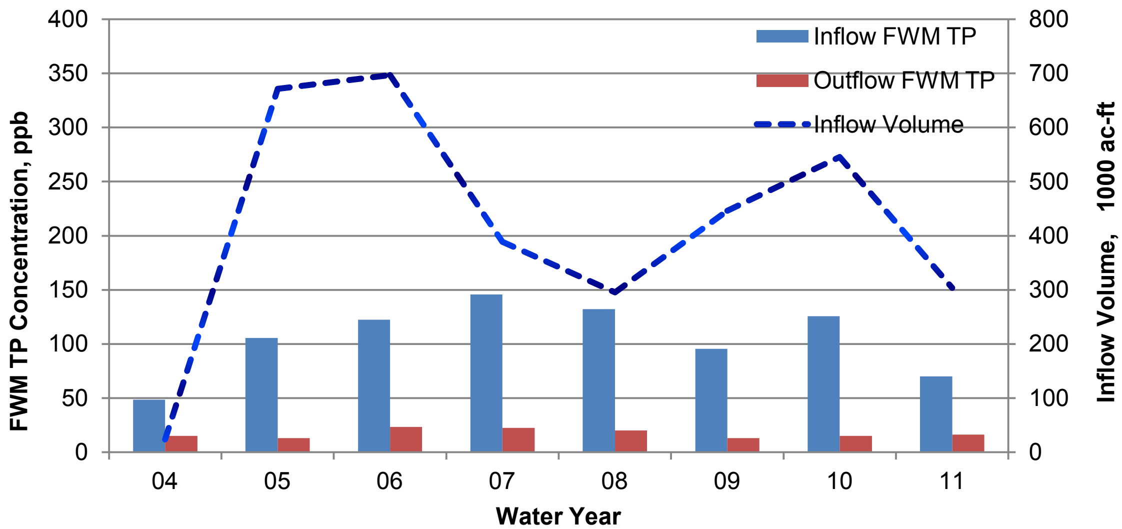


Water Year	Key Events in STA-2
2000	Cells 2 and 3 were operational; Cell 1 was offline due to high mercury levels.
2001	Cells 1–3 were operational. Despite regional drought, cells remained hydrated.
2002	Cells 1 and 2 dried out during the dry season.
2003	Cell 1 dried out during the dry season and passed mercury start-up (December 2002).
2005	Hurricanes Frances and Jeanne.
2006	Hurricane Wilma; SAV in Cell 3 was damaged.
2007	Tropical Storm Ernesto. Despite regional drought, cells remained hydrated. Cell 4 was flow-capable.
2008	Regional drought resulted in dry out of Cells 1 and 2.
2009	Regional drought resulted in dry out of Cells 1 and 2. Tropical Storm Fay. Vegetation conversion was initiated in the southern portion (~400 ac) of Cell 2
2010	Hydrilla die-back in the northern portion of Cell 3 and in Cell 4 (December 2009).The southern portion of Cell 2 (conversion area) remained devoid of SAV. Cells 1 and 2 dried out during the dry season.
2011	Regional drought resulted in a brief dry out of Cell 1. Cell 4 was partially operational then offline from November to April 30 due to Compartment B construction. Cell 4 also dried out.

Figure 5–7. Period of record summary of inflow and outflow phosphorus concentrations, inflow volume, and key events in STA-2.

STA-3/4

STA-3/4 continues to be one of the best performing STAs, achieving very low outflow TP concentration as it has over the years of operation (**Figure 5-8**). The STA has maintained an excellent TP removal despite extreme weather conditions and high flows over the years. In WY2011, this STA achieved 16 ppb outflow FWM TP concentration and a 76 percent reduction of the TP load. The STA received low hydraulic and P loads and lower inflow TP concentrations compared to previous years, thus resulting in low outflow TP concentration. The three flow-ways received moderate loading relative to the other STA flow-ways with an HLR between 2 and 3 cm/day and PLR less than 1 g/m^2/yr (**Table 5-1**). The inflow FWM TP concentrations were low (51–84 ppb) and the outflow FWM TP concentrations were 13–21 ppb, with the Western Flow-way achieving the lowest outflow TP concentration. This flow-way has a dense establishment of cattail, which was not impacted by deep water conditions like the other two cells, and has a thick coverage of chara throughout Cell 3B. In the Eastern Flow-way, Cell 1B vegetation conversion continued in WY2011, while Cell 1A was dewatered to allow cattail to reestablish. The 400-acre PSTA project within Cell 2B is described later in this chapter.



Water Year	Key Events in STA-3/4
2003	One flow-way was operational.
2004	Two flow-ways were operational. Cell 2B vegetation conversion was initiated
2005	Hurricanes Frances and Jeanne. Two flow-ways were operational while the Western Flow-way divide levee construction
2006	Hurricane Wilma. Two flow-ways were operational. Phased vegetation conversion in Cell 1B was initiated.
2007	All flow-ways were operational. Tropical Storm Ernesto. Cell 1A dried out as a result of regional drought. PSTA Implementation Project was in flow-through operation. Vegetation conversion in Cells 1B continued and vegetation conversion in Cell 3B was initiated.
2008	All flow-ways were operational. Cell 1A dried out as a result of regional drought. vegetation conversion continued in Cell 1B
2009	All flow-ways were operational. Cell 3A dried out as a result of regional drought. Tropical Storm Fay resulted in high flows and deep water conditions. Vegetation conversion continued in Cell 1B.
2010	All flow-ways were operational. Water level was drawn down in Cell 1A for vegetation rehabilitation.
2011	All flow-ways were operational. Cell 1A was dewatered for cattail rehabilitation; regional drought accelerated dry out of Cell 1A

Figure 5-8. Period of record summary of inflow and outflow phosphorus concentrations, inflow volume, and key events in STA-3/4.

STA-5

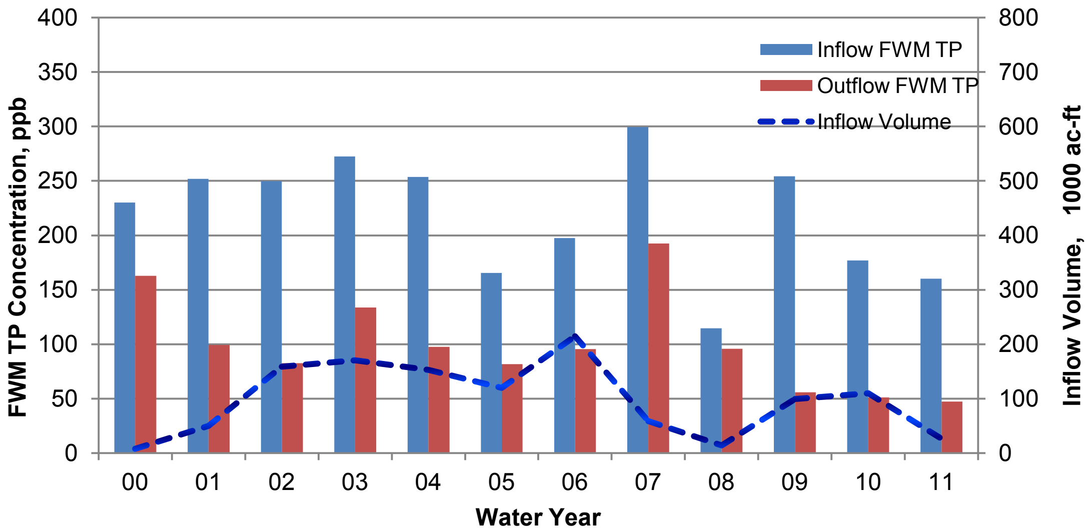
STA-5 had the lowest HLR (0.39 cm/d) and PLR (0.23 $g/m^2/yr$) but the highest FWM inflow TP concentration (160 ppb) in WY2011 compared to the other STAs. The resulting STA outflow FWM TP concentration was 47 ppb, highest among all the STAs. This is, however, the best performance achieved by this STA over its period of operation (**Figure 5-9**). The outflow concentration has declined dramatically since WY2009. This decline can be attributed to various factors, including reduction in hydraulic and P loading particularly as influenced by recent drought events, decrease in soil P flux with years of STA operation and peat formation, decrease in inflow TP concentrations, enhancements including sediment dredging from the STA inflow canal (L3) and filling of a slough area in Cell 1A in 2009, and good vegetation establishment through most of the STA.

For the flow-ways, there was relatively low loading during WY2011, with 1.36 and 0.38 cm/day HLR in the Northern and Southern flow-ways, respectively, and less than 0.5 $g/m^2/yr$ PLR in these flow-ways (**Table 5-1**). These two flow-ways' performance continues to improve in terms of outflow TP concentration (41 and 54 ppb, respectively, in WY2011). Initial assessment of the effects of the slough fill effort indicates that flow distribution through Cell 1A has improved, thus resulting in utilization of most of the cell during normal operations, while in the past, a large part of the area was not utilized as water flowed through the slough area. With improved hydrologic conditions, vegetation in Cell 1A also continues to improve, with more cattail recruitment in areas that had facultative and upland vegetation prior to rehabilitation. Bulrush has also been planted in previously open areas. SAV, which has historically been primarily hydrilla, in Cells 1B and 2B has also been stable in the recent water years, although it had previously experienced large-scale vegetation loss over its period of operation. The Southern Flow-way had very little flow due to restrictions related to Compartment C Build-out construction.

STA-6

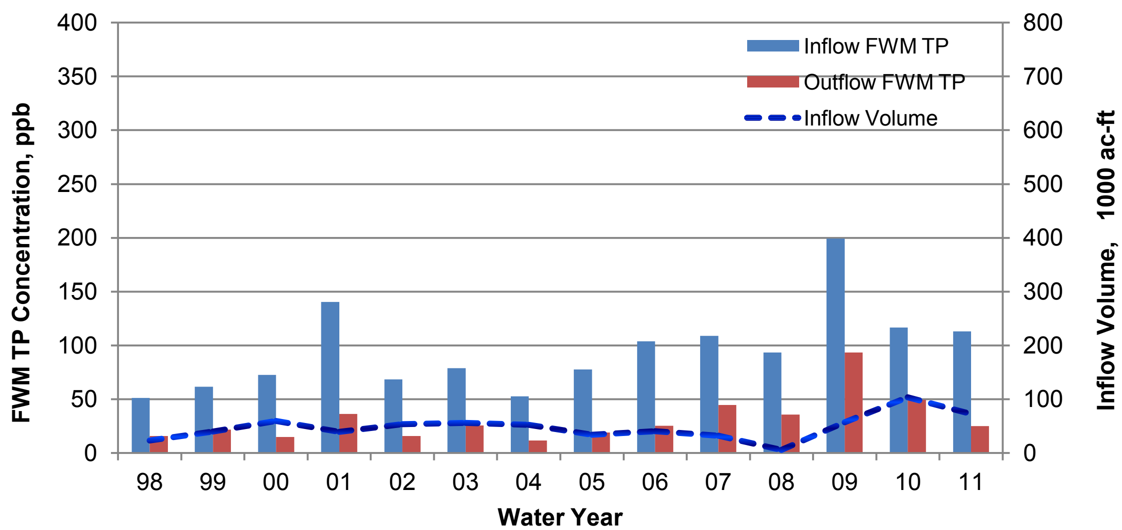
The outflow TP FWM concentration in WY2011 was 25 ppb, which is significantly lower than values achieved in WY2010 and WY2009 (**Figure 5-10**). This excellent performance was achieved despite this STA receiving additional flows due to STA-5 restrictions and from Compartment C construction-related dewatering. Previous investigation into this STA indicated that the frequent cycles of extended dryout (as a result of drought or lack of flows during the dry season) and reflooding has resulted in high outflow P concentration. During dryouts, organic material in the soil is oxidized at a much more rapid rate than when flooded. This process results in release of P, which then fluxed to the overlying water column upon reflooding. Since WY2010 was a wet year and the STA did not dry out, it is likely that this contributed to the lower annual TP observed in WY2011 outflow.

Of the flow-ways, Cell 3 and Section 2 received the highest HLR (3.5 cm/day) in this water year (**Table 5-1**). The inflow FWM TP concentrations to the three flow-ways in this STA were moderate (94–118 ppb), and the resulting outflow FWM TP concentrations were 16–27 ppb.



Water Year	Key Events in STA-5
1999	Northern and Central flow-ways were operational
2000-2001	Cells 2A and 2B dried out as a result of regional drought
2005	Hurricanes Frances and Jeanne. Central Flow-way was operational. Northern Flow-way divide levee construction; degraded high ground areas.
2006	Hurricane Wilma. Central Flow-way divide levee construction continued. Cells 1A, 1B, 2A, and 2B dried out during the dry season.
2007	Tropical Storm Ernesto; Cells 1A, 2A, and 2B dried out as a result of regional drought; Southern Flow-way was constructed and flow-capable.
2008	All cells dried out as a result of regional drought. Inflow canal (L3) dredging to remove enriched canal sediment.
2009	Northern Flow-way was offline for rehabilitation of Cell 1A. Cells 1A, 2A, 2B, 3A, and 3B dried out as a result of regional drought.
2010	Central Flow-way was operational. Northern and Southern flow-ways were operational with restrictions. Cells 1A, 2A, 3A, and 3B dried out during the dry season. Snail kite nests were present in Northern and Central flow-ways, necessitating closer management of water levels and sending excess flows to STA-6.
2011	Northern Flow-way was online with restrictions for the first half of the water year. Southern Flow-way was offline May 18 to July 25, 2010, and then online with restrictions for the remainder of the water year due to Compartment C construction. Cells 1A, 2A, 3A, and 3B dried out as a result of regional drought. Impacts of snail kite nesting continued in the early part of this water year.

Figure 5-9. Period of record summary of inflow and outflow phosphorus concentrations, inflow volume, and key events in STA-5.



Water Year	Key Events in STA-6
1998	Cells 3 and 5 were operational.
2000-2001	Cells 3 and 5 dried out as a result of regional drought.
2002-2004	Cells 3 and 5 were operational.
2005	Hurricanes Frances and Jeanne; Cells 3 and 5 dried out during the dry season.
2006	Hurricane Wilma. Inflow source switched from US Sugar operations to C-139 basin runoff. Vegetation conversion in the eastern portion of Cell 5. Cells 3 and 5 dried out during the dry season.
2007	Tropical Storm Ernesto. Cells 3 and 5 dried out as a result of regional drought. Section 2 was flow-capable but remained offline.
2008	Entire STA dried out as a result of regional drought. Unable to hydrate Section 2 due to lack of flow.
2009	Entire STA dried out as a result of regional drought.
2010	High rainfall volume. STA-6 dried out during the dry season.
2011	Cells 3 and 5 were operational. STA received additional flow from Compartment C dewatering. Section 2 was offline part of the year for Compartment C construction. STA-6 dried out as a result of regional drought.

Figure 5-10. Period of record summary of inflow and outflow phosphorus concentrations, inflow volume, and key events in STA-6.

Evaluation of Phosphorus Treatment along Transects at Selected STA Flow-ways

The District and the Everglades Agricultural Area (EAA) Everglades Protection District (EPD) continue to investigate ways to improve TP reduction in the STAs. Understanding the environmental condition and treatment pattern along individual flow-ways provides information to help in these investigations. Within several STA flow-ways, water quality sampling stations have been established along inflow to outflow transects representing the inflow-to-outflow gradient. This internal water quality sampling allow scientists to monitor P uptake and potential release within the STA flow-ways under various operational and environmental conditions. Over time, data collected from these transects provides needed insight about key processes such as internal P transformations and spatial relationships between vegetation type/health and P retention or sediment P release. For example, Dierberg and DeBusk (2008) utilized data from five internal sampling events in STA-2 Cell 3 to help characterize particulate P transformations in STA-2 Cell 3. Similarly, data from 26 internal sampling events in this same flow path, collected over a six-year period, were used as evidence of background P concentrations in SAV-dominated wetlands (Juston and DeBusk, 2011).

Previous investigations have observed that non-ideal hydraulic conditions (i.e., short-circuits and preferential flow-ways) within a wetland can create difficulties in the interpretation of internally collected constituent concentration data (Kadlec, et al., 1993; Carlton, 2002). Several factors suggest that this was not a confounding factor in the analyses of internal transect data performed by Juston and DeBusk (2011) for STA-2 Cell 3. For example, time series of normalized differences between station values and transect mean values were evaluated for each of the 25 internal stations with grab sample time series available, and this assessment revealed that internal stations contributed high and low values to transect mean calculations randomly over time. One would expect stationary bias in contributions (consistently higher or consistently lower values than means) if stations were in areas of preferential or consistently low flows. This analysis agrees with results of a prior tracer study conducted in this wetland, which indicated generally excellent hydraulic performance and a lack of strong preferential flow paths.

Potential factors affecting P changes along the flow-way under various scenarios in this and other STA flow-ways will continue to be investigated further. Factors that significantly contribute to an increase in P along the flow-way, such as short-circuits or resuspension, could be critical in optimizing P reduction in treatment cells.

The transect information included below contains those with surveys completed in WY2010. Other transect studies and results have been reported in previous SFERs. Comprehensive use of these, previously reported, and future transect data will be incorporated in various analysis describing STA performance and treatment mechanisms.

STA-1W Eastern Flow-way

Water samples were collected along internal transects in the Eastern Flow-way on September 30, 2009, and September 16, 2010. Transect locations A–C (north to south within each cell) for the flow-way are depicted in **Figure 5-11**. For the 2009 sampling event, the flow rates on the day of collection and two weeks prior to the sampling event were low, at 112 and 75 ac-ft per day, respectively. Flows during the 2010 sampling were moderate, at 285 and 453 ac-ft per day at the inflow and outflow, respectively.

During the 2009 low-flow sampling event, TP concentrations along the nutrient gradient increased from 98 ppb at the inflow of Cell 1A to 228 ppb at the inflow of Cell 3, primarily due to an increase in particulate P (PP). However, the dissolved organic P (DOP) and soluble reactive P (SRP) fractions also increased and then sharply declined to 60 ppb at the outflow of Cell 3 (**Figure 5-12**). In September 2010, under moderate flow, the internal TP concentrations quickly declined from 122 ppb at the Cell 1B inflow to 16 ppb at transect B (Cell 1B) and remained at around this level along the remainder of the flow-way (**Figure 5-12**).

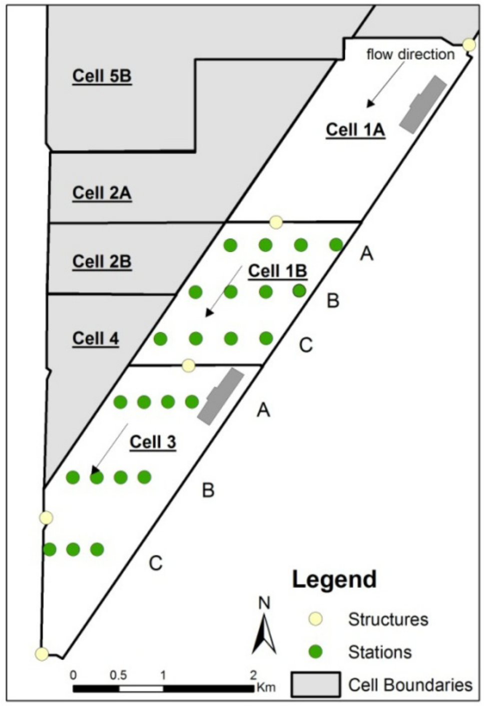


Figure 5-11. Location of internal water quality sampling stations within STA-1W Cells 1B and 3 on September 30, 2009, and September 16, 2010. Transects are identified alphabetically along the north-to-south flow-way.

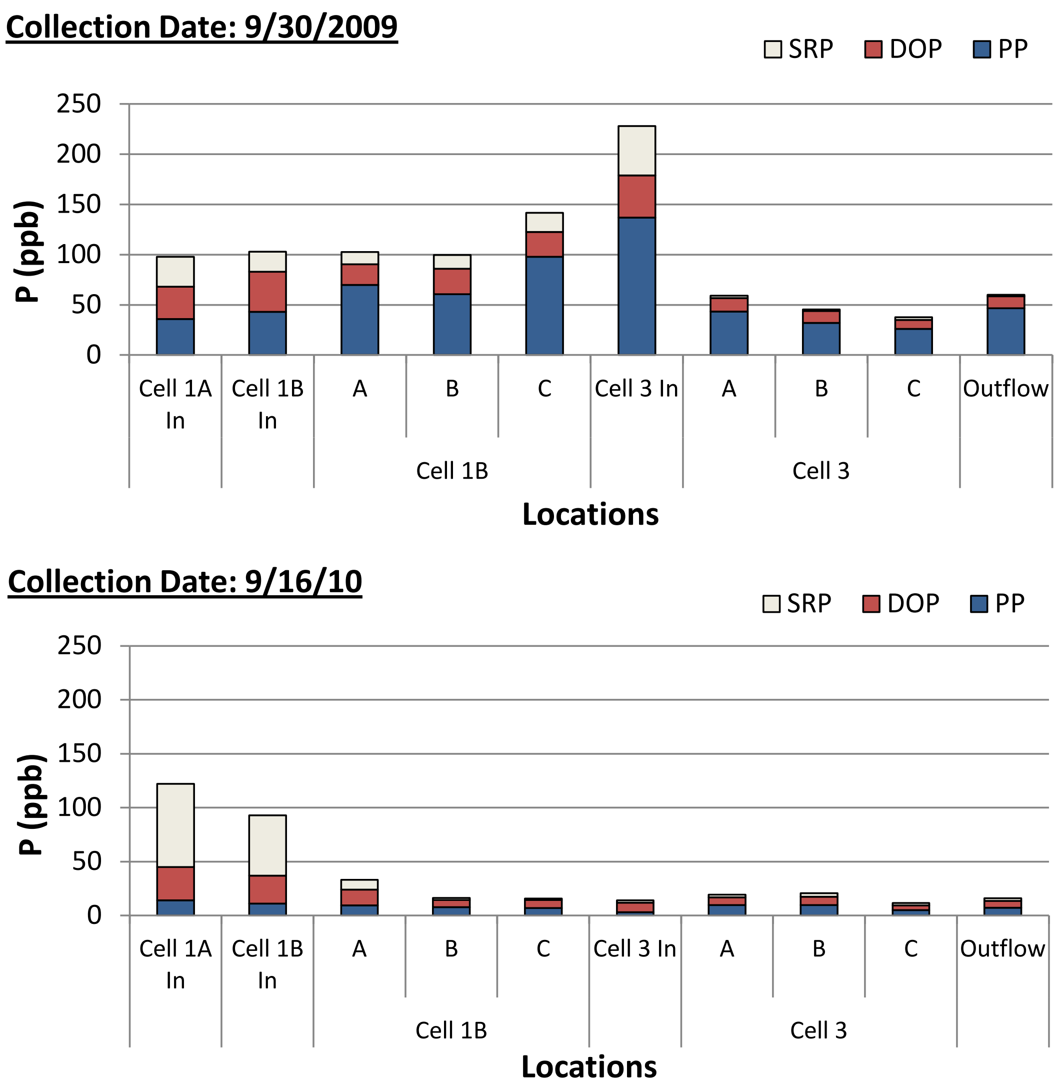


Figure 5-12. Phosphorus species concentration profiles along the inflow/outflow gradient for the Eastern Flow-way of STA-1W on September 30, 2009 (upper), and September 16, 2010 (lower) [Note: soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), particulate phosphorus (PP)].

Water Quality Transect: STA-2 Cell 1

Water quality samples were collected along internal transects in Cell 1 on December 17, 2009, and August 13, 2010. Transect locations A–J (north to south) for the flow-way are depicted in **Figure 5-13**. The December 2009 sampling event occurred three days after the initiation of high flows into the cell, but before discharges began on December 18, 2009. Except for one day (November 27, 2009) that had an inflow of 309 ac-ft per day, there was no flow in or out of the cell for 39 days prior to December 14, 2009. The cell experienced a severe dry-down in spring 2009. During the sampling event on August 13, 2010, there was no inflow to the cell, whereas the outflow was 115 ac-ft per day. Mean daily flows for the two weeks prior to the sampling event were 109 and 11 ac-ft per day at the inflow and outflow, respectively.

The internal water quality sampling results depict P profiles reflecting the different flow and environmental conditions during and prior to December 2009 and August 2010 (**Figure 5-14**). During the December 2009 sampling event, the inflow TP concentration of 92 ppb was reduced to 46 ppb at transect A, with the largest reduction observed in the SRP and DOP fractions. Throughout the remainder of the cell, TP concentrations fluctuated between 26 and 45 ppb, primarily driven by PP concentrations. TP levels exiting the cell were 21 ppb. Eight months after the December 2009 sampling event, the internal TP profile of this cell depicted reduced internal P loading within the cell. The inflow TP was 57 ppb and remained comparable at transect A. Further down the flow-way, TP concentrations decreased to 17 ppb at transect D, then remained low, exiting the cell at 13 ppb.

Water Quality Transect: STA-2 Cell 4

Water quality samples were collected along internal transects in Cell 4 on December 15, 2009 and August 24, 2010. Transect locations A–F (north to south) for the flow-way are shown in **Figure 5-13**. The two sampling events illustrate how internal performance of the cell can change during flowing and low or non-flowing conditions. During the December 2009 sampling event, flow on the day of collection was 109 and 5 ac-ft at the inflow and outflow, respectively. Except for two days, inflow to this cell was zero during the two weeks prior to collection. However, during the August 2010 sampling event, inflow and outflow averaged 513 and 219 ac-ft per day, respectively. The mean daily inflow over the two weeks prior to collection was 337 ac-ft per day.

While the inflow TP concentrations during both sampling events were comparable (76 and 78 ppb for the 2009 and 2010 sampling events, respectively), the P species comprising the inflow waters were markedly different (**Figure 5-15**). During the December 2009 sampling (no/low flow conditions) the inflow TP concentration was dominated by the PP fraction (82 percent); in August 2010 (moderate flow) the dominant fractions were SRP and DOP (47 and 39 percent, respectively). The TP concentrations along the nutrient gradient during the December 2009 sampling event depict a gradual decline to 36 ppb at the outflow, primarily due to the reduction of the PP fraction. By contrast, in the August 2010 sampling event, the majority of the SRP and DOP fractions were removed by the cell at transect A with no additional removal occurring through the remainder of the cell.

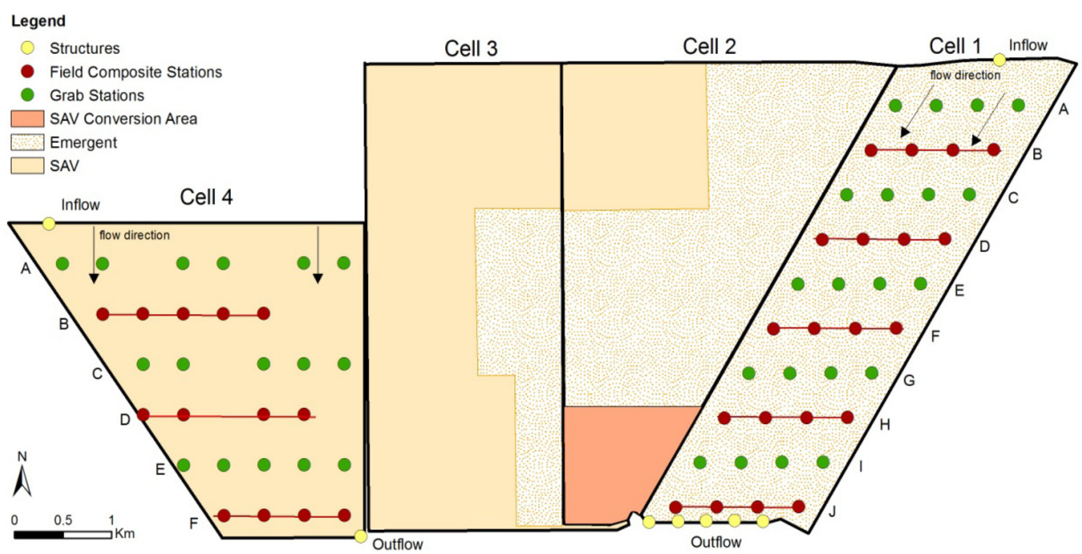


Figure 5-13. Location of surface water sampling stations in STA-2 Cells 1 and 4 in December 2009 and August 2010. Transects are identified alphabetically along the flow-way. Grab samples (green) were analyzed individually, while the samples collected along the red transects were composited in the field prior to analysis.

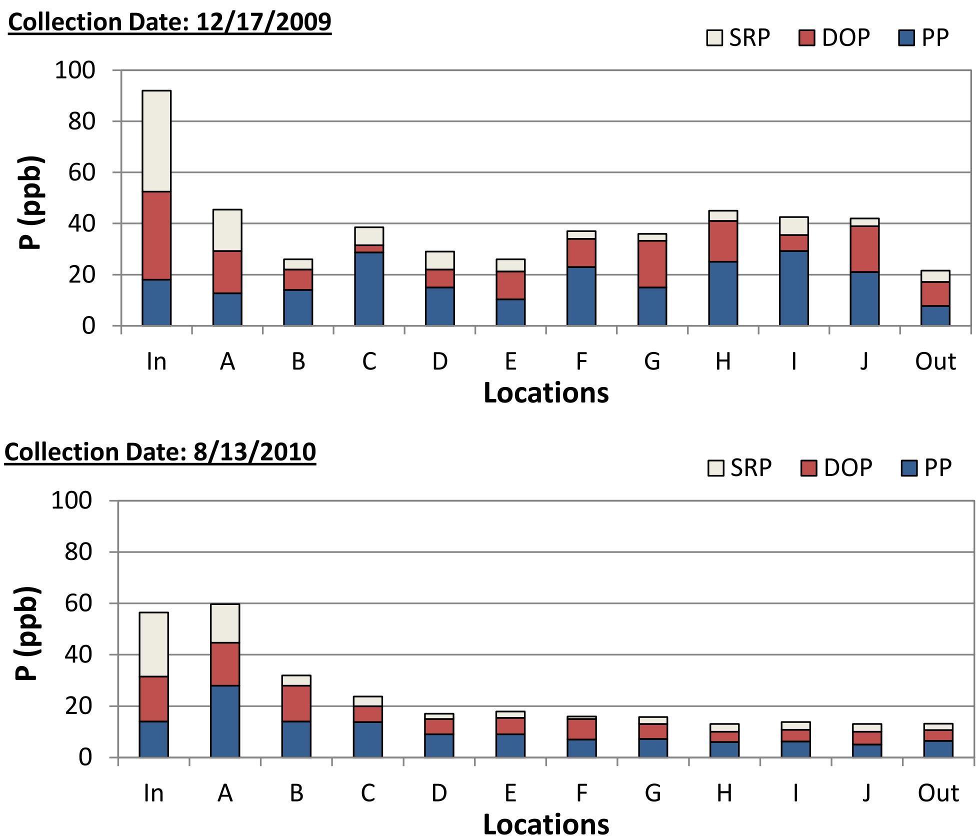


Figure 5-14. TP concentration profiles along the inflow/outflow gradient for STA-2 Cell 1 during December 2009 (upper) and August 2010 (lower).

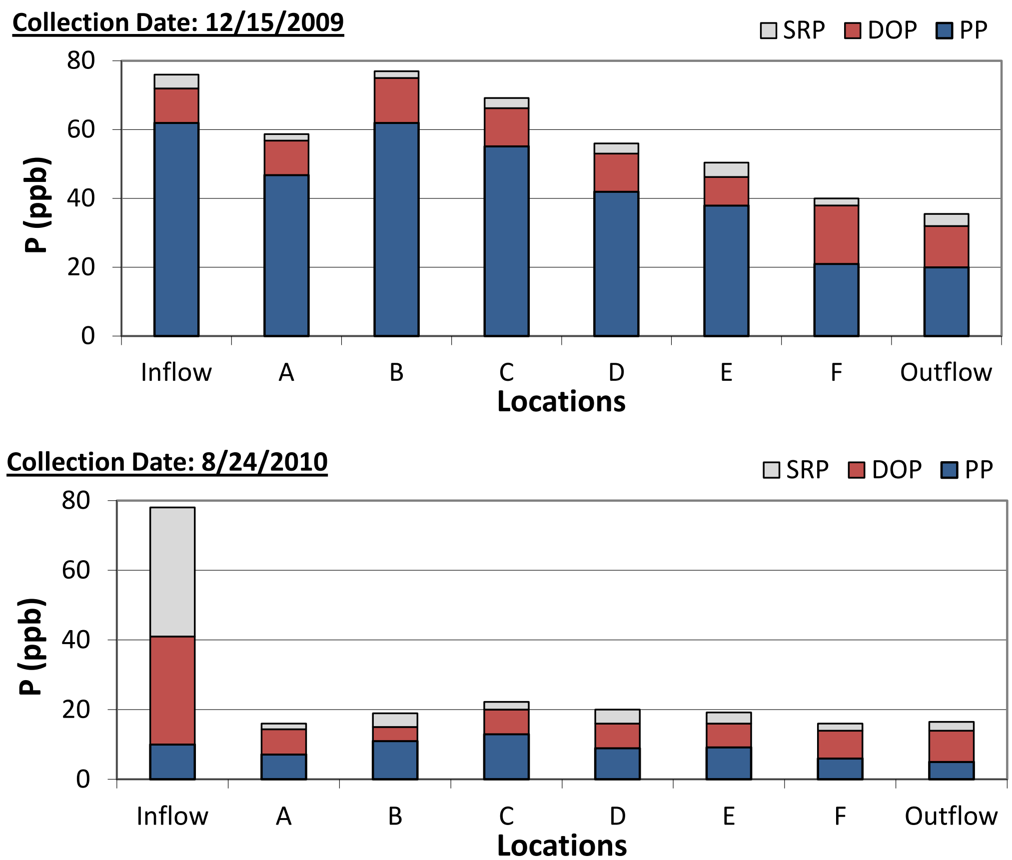


Figure 5-15. TP concentration profiles along the inflow/outflow gradient for STA-2 Cell 4 during December 2009 (upper) and August 2010 (lower).

Water Quality Transect: STA-6

Water quality samples were collected along internal transects in STA-6 Cells 3 and 5 and Section 2 on July 30, 2010. This was the first internal water quality sampling event performed in this STA using this approach. Transect locations A– E (west to east) for Section 2 and Cell 5 and transects A–C for Cell 3 are depicted in **Figure 5-16**. On the day of sample collection, Section 2 was receiving the highest flow among the flow-ways at 270 ac-ft per day, while Cells 3 and 5 were receiving relatively low flows (6 and 24 ac-ft per day, respectively). Prior two-week mean flows were 562, 44, and 46 ac-ft per day for Section 2, and Cells 3 and 5, respectively.

Data collected along each transect were averaged to produce TP and P species concentration gradient profiles for each cell (**Figure 5-17**). On the day of collection, the inflow TP concentrations were 94, 85, and 66 ppb for Section 2 and Cells 5 and 3, respectively. The TP concentration profiles in Section 2 showed a 60 percent increase at transect A (primarily SRP and DOP), then a marked decrease at transect B. Along the remainder of the wetland, TP gradually declined, exiting the cell at 33 ppb. For both Cells 3 and 5, 90 percent of the P was removed before transects B and C, respectively, and exited the cell at 15 ppb.

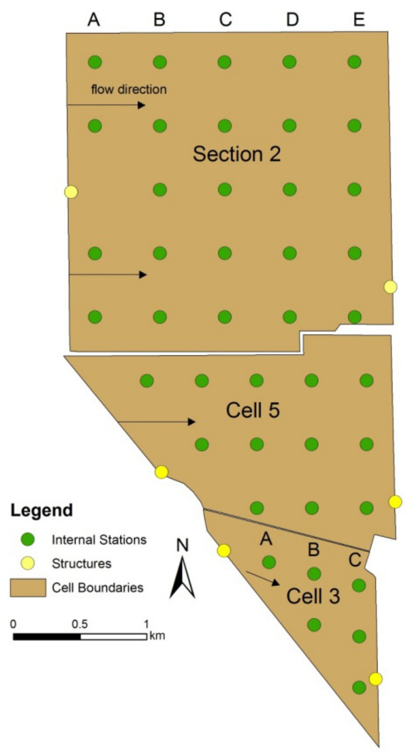


Figure 5-16. Location of internal water quality sampling stations in STA-6 Cells 3 and 5, and Section 2 on July 30, 2010. Transects are identified alphabetically along the west-to-east flow-way.

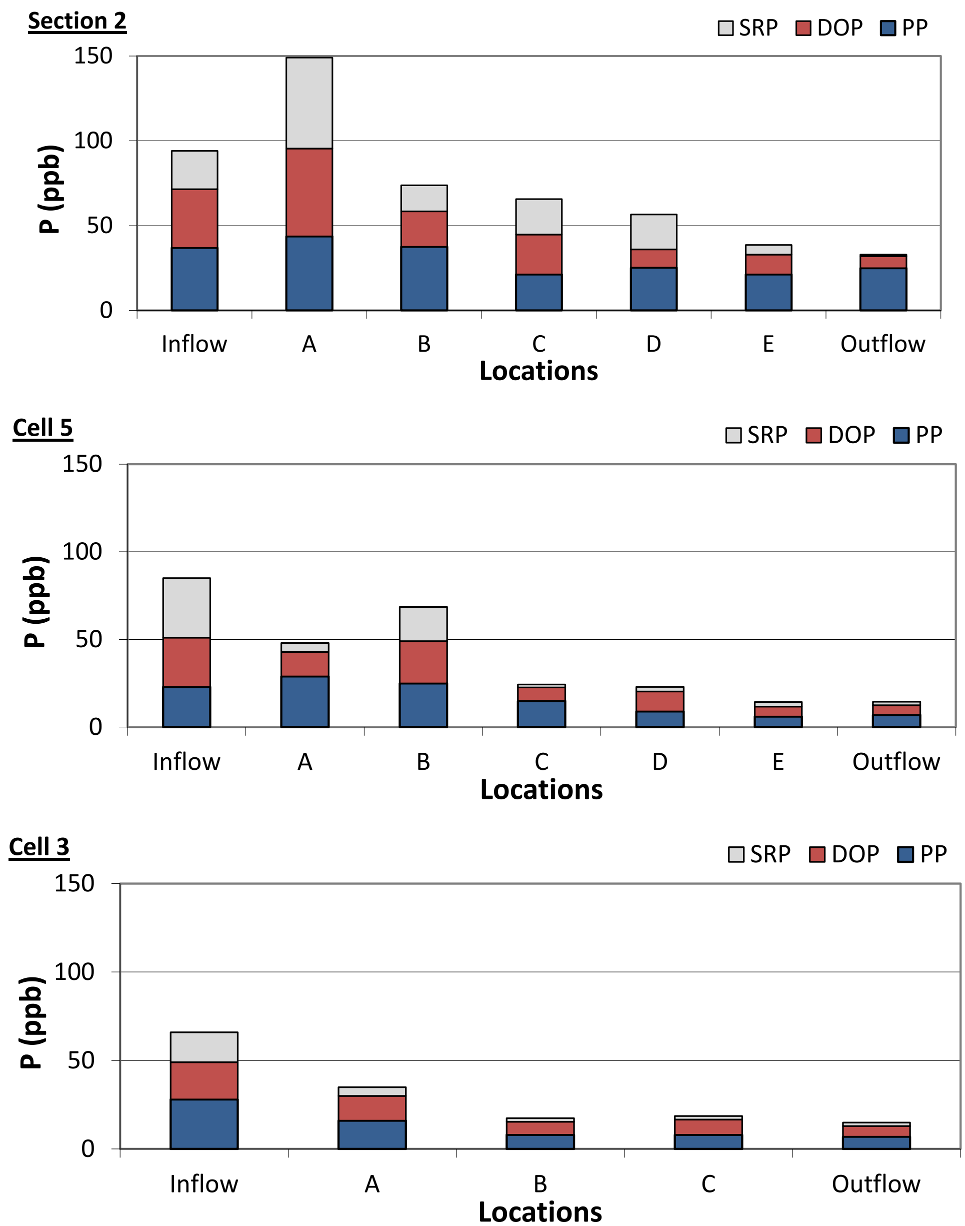


Figure 5-17. Time series of flow into and out of each treatment cell from July 1–31, 2010, for STA-6 Cells 3 and 5 and Section 2.

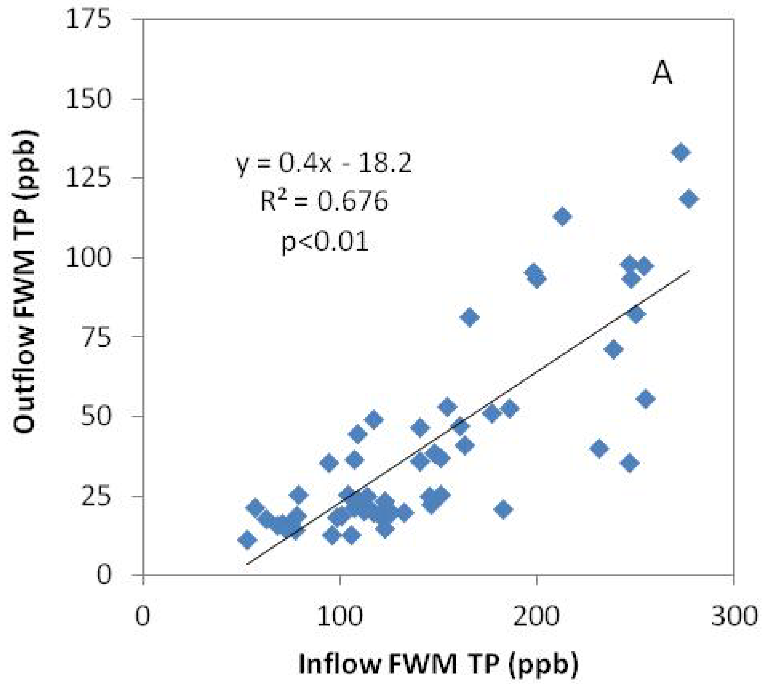
EFFECTS OF INFLOW CONCENTRATION AND PHOSPHORUS LOADING RATE ON STA PERFORMANCE

TP removal in the STAs is a complex process and is affected by a number of variables, including PLR, HLR, hydraulic residence time (HRT), hydrologic pattern (flow, changes in depth), hydroperiod (periods of dryout), inflow TP concentration, vegetation type and condition, treatment cell size and configuration, and soil characteristics and P content. Additionally, extreme weather events (e.g., drought, storms), STA operational phases (start-up, routine operation, or recovery), and management activities (e.g., drawdown, vegetation conversion and control, cell rehabilitation) also influence treatment performance.

Previous SFER reports (SFWMD, 2008 and 2009) and other publications (Juston and DeBusk, 2006; Kadlec 2006) have presented analyses of the influence of inflow HLR, PLR, and TP concentration on outflow TP concentration in the STAs. The analysis included in this chapter incorporates recent data from the STAs and further evaluates the influence of two key variables (inflow PLR and TP concentration) on outflow TP concentration. Analyses were done using period of record data and were performed at STA and individual treatment cell levels. Additional analysis was done to determine differences in relationships among dominant vegetation types (EAV versus SAV). Since, PLR is highly correlated to both HLR and inflow TP concentration ($p<0.01$), and there is no significant correlation between HLR and inflow TP concentration ($p>0.05$), PLR and inflow TP concentration were used as two independent variables to correlate against outflow TP concentration. This approach is consistent with analyses performed in evaluating the performance of other treatment wetlands (Kadlec and Wallace, 2009). Published analyses indicate an ‘S’ shaped trend that is observed when outflow TP concentration is plotted against inflow TP loading yields, with an upper transition from no removal to measurable removal as P loading is lowered (Kadlec, 1999; Richardson et al., 1997; Richardson, 2008). The upper end of the curve may be described as the threshold or saturation point for long-term P assimilative capacity (Richardson et al., 1997; Richardson, 2008). For the STAs, the relationship between PLR and outflow TP concentration may not be linear, depending on the range of TP loading rates.

Prior to plotting the data, the period of record data were screened and outliers were excluded, based on unusual operational conditions and extreme events such as regional drought. PLR data were first log-transformed to reduce the heterogeneity of variance. Transformed data were then plotted against outflow flow-weighted mean P concentration. The correlation between PLR and outflow TP concentration was found to be statistically significantly ($r^2 = 0.539$, $p<0.01$) (**Figure 5-18**). When the PLR is greater than 1.0 $g/m^2/yr$, there was a dramatic increase in outflow TP concentrations. In STA-1W and STA-5, for example, when PLRs exceed 1.6 $g/m^2/yr$ ($\log_{10}$ PLR>0.2), outflow TP concentrations greater than 75 ppb were observed. At the STA level, there was a moderate linear correlation between inflow and outflow TP concentrations ($r^2 = 0.676$, $p<0.01$) (**Figure 5-18**).

A similar trend was observed at the treatment cell level. **Figure 5-19** shows that treatment cell outflow TP concentration was positively correlated with increasing inflow TP concentration ($r^2 = 0.515$, $p<0.01$) and PLR ($r^2 = 0.375$, $p<0.01$).



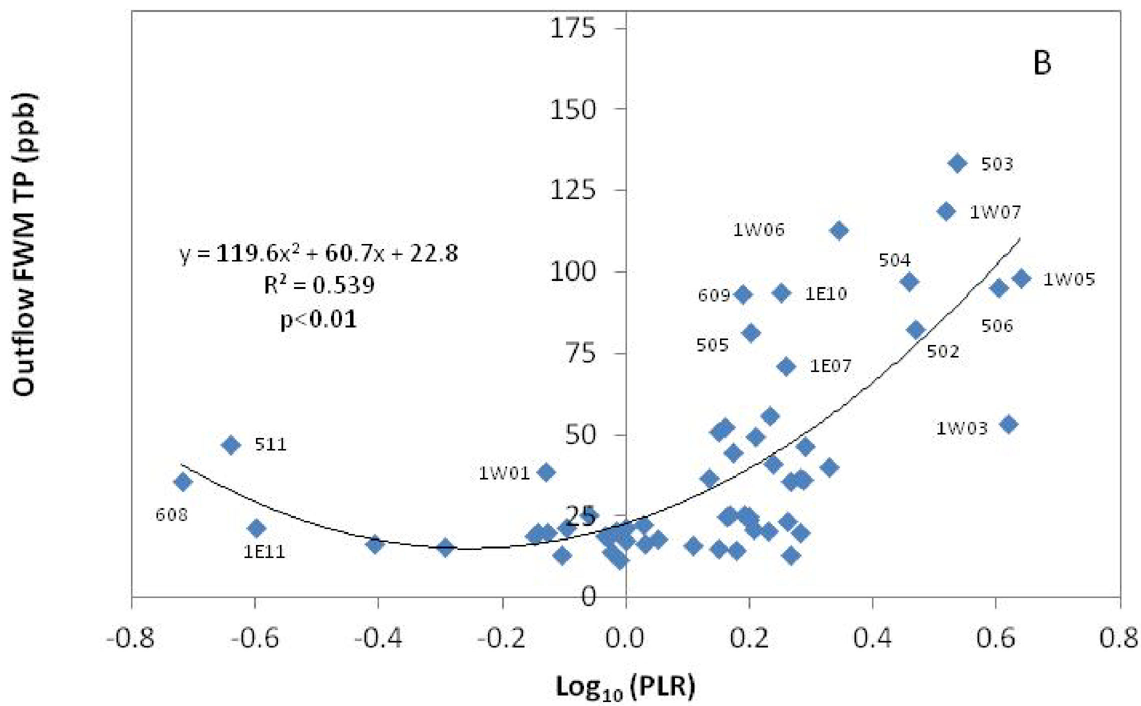


Figure 5-18. Relationship between annual inflow TP concentration and (A) annual inflow TP concentration or (B) phosphorus loading rate (PLR) (log PLR value) in the six STAs (STA-1W, STA-1E, STA-2, STA-3/4, STA-5, and STA-6). Data presented are for period of record. Some data points are labeled with STA identifications in panel B. For example, code "503" represents STA-5 in WY2003.

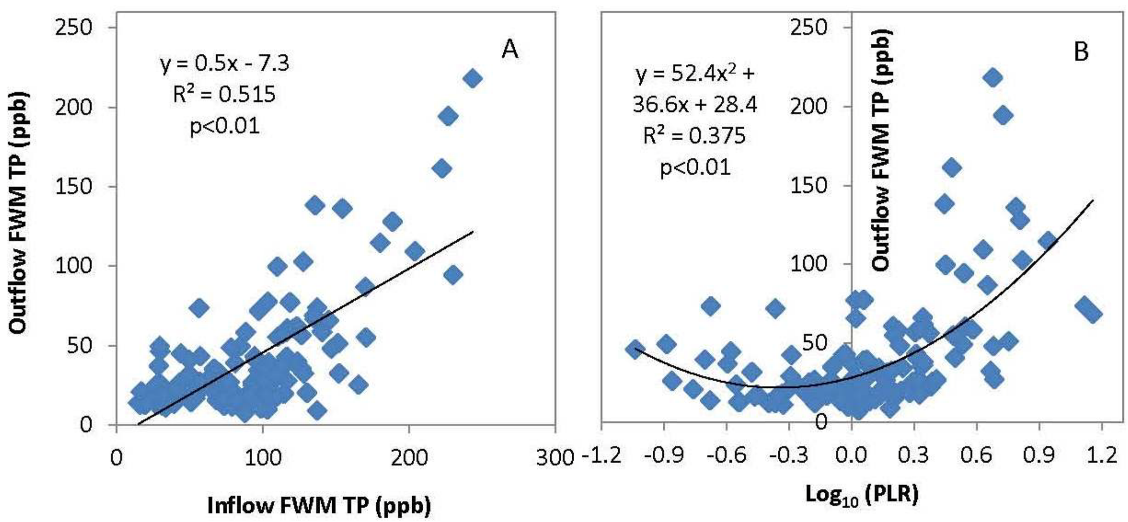


Figure 5-19 Relationship between annual outflow TP concentration for the period-of-record in STA cells and inflow TP concentration (A) or PLR ($\log_{10}$ PLR value) (B).

Further analysis was performed to evaluate the relationships between PLR or inflow TP concentration and outflow TP concentration between the two dominant vegetation types in the STA (**Figures 5-20** and **5-21**). It should be noted that, realistically, no cell in any of the STAs is purely SAV, considering the presence of EAV on vegetation strips and in sporadic areas between herbicidal treatments, particularly during the dry season. There are currently no quantitative criteria for the optimal amount of EAV allowed to establish in an SAV-targeted cell. Similarly, in EAV cells, there are open areas with other vegetation types including FAV and SAV. The size of EAV and SAV + open water areas is estimated annually using aerial imagery (**Appendix 5-3**). Depending on when the aerial imagery was taken, the coverage may change. In WY2011, for example, according to the aerial imagery taken during the middle of the drought period, Cell 1B of STA-3/4, Cell 3B of STA-5, and Section 2 of STA-6 contained more than 50 percent EAV coverage. The analysis indicates a difference in outflow TP concentration response with increase in inflow concentration between EAV and SAV cells. Increase in inflow TP concentration resulted in a substantially greater increase in outflow TP concentration in EAV cells (slope=0.7) than in SAV cells (slope=0.2).

At PLRs greater than 1 $g/m^2/yr$ (log PLR >0), there was a notable difference in response of outflow TP concentration between EAV and SAV cells, with a more dramatic response in EAV cells than in SAV cells. Based on the regression equations in **Figure 5-21**, at log PLR of 0 or PLR = 1.0 $g/m^2/yr$, outflow TP concentration in the treatment cells is 23 ppb for SAV and 28 ppb for EAV. At loading rates of around 2.5 $g/m^2/yr$ ($\log_{10}$ PLR=0.4), in an EAV cell, the expected outflow TP concentration is 60 ppb.

These analyses suggest that to achieve a low outflow TP concentration, the PLR must be maintained at a low level. For example, a PLR of less than 1.0 $g/m^2/yr$ for SAV cells can be expected to produce an outflow TP concentration of 23 ppb or lower, and keeping PLR in the EAV cell (front end treatment for STAs in a sequential EAV-SAV layout) at below 2.5 $g/m^2/yr$ will help attain lower than 60 ppb TP in the front end outflow, correspondingly helping control the loading in the downstream SAV cell. Richardson et al. (1997; 2008) proposed a threshold PLR of 1 $g/m^2/yr$ for most freshwater wetlands although Kadlec (1999) criticized the over-simplification of "the one-gram rule." However, they both agree that wetlands continue to retain additional P as PLR increases at the cost of increasing outflow P concentrations. Similarly, Juston and DeBusk (2006) reported that a PLR below 1.3 $g/m^2/yr$ in an STA provided a high likelihood of achieving outflow TP concentrations less than 30 ppb.

Data analysis efforts will continue in WY2012 to better understand the influence of loading rates and other factors on TP removal and make further recommendations in managing the STAs. Future analyses will include an evaluation of seasonal effects (dry and wet seasons) on performance and on the relationships between PLR or inflow TP concentration versus outflow TP concentration and influence of soil TP on outflow concentration (internal cycling). Multivariate techniques may be useful to examine the effects of multiple factors on TP removal because of the many environmental and anthropogenic drivers influencing STA performance.

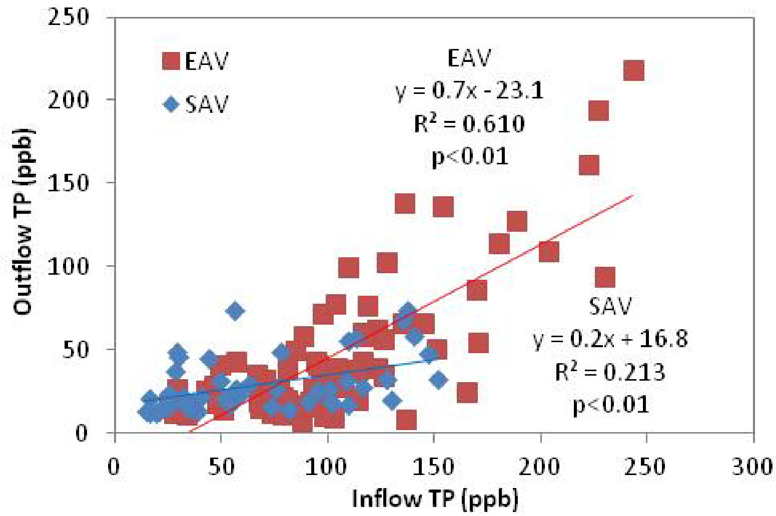


Figure 5-20. Relationship between annual cell inflow and outflow TP concentrations in EAV versus SAV cells (period of record).

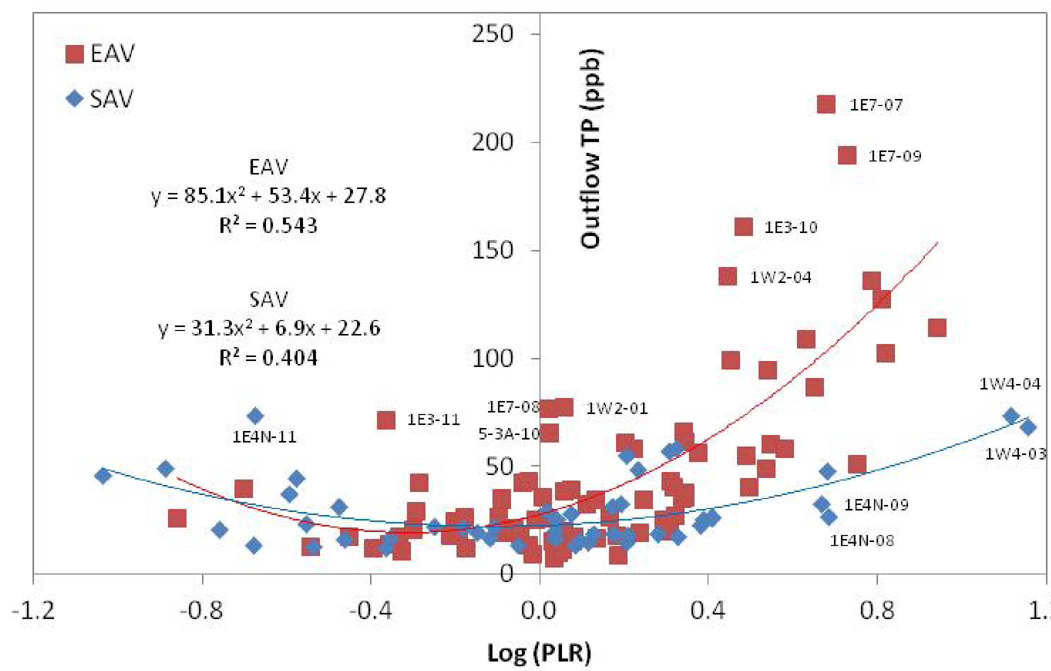


Figure 5-21. Relationship between log PLR and outflow TP concentration in EAV and SAV cells in the STAs (period of record). Some data points are labeled with cell identifications. For example, code "1E7-07" represents STA-1E Cell 7 in WY 2007.

STA-3/4 PERIPHYTON-BASED STA IMPLEMENTATION PROJECT

The PSTA project in STA-3/4 was constructed to investigate the performance of a periphyton-dominated treatment system, which is a component of the Long-Term Plan. The project comprises 400 acres of STA-3/4 within Cell 2B that was delineated by the construction of new levees to form an upstream 200-acre cell (Upper SAV Cell) and two adjacent parallel downstream 100-acre cells (Lower SAV and PSTA cells) (**Figure 5-22**). All cells have been managed to promote an SAV community and associated periphyton assemblage through repeated herbicide applications to suppress EAV establishment except in the vegetation strips. The Upper SAV Cell provides the SAV component of an EAV–SAV treatment train and delivers water with low TP concentrations to the Lower SAV and PSTA cells. Further information on the history, design considerations, layout, and operating plan of this project are available in the *2008–2011 SFERs – Volume I, Chapter 5*.

The PSTA project has been in operation since WY2008, and annual summaries of the hydraulic and P removal performance have been presented in the SFER. The WY2011 outflow FWM TP concentration for the PSTA Cell was 11 ppb, comparable to the values found in previous years. These outflow FWM TP concentrations were consistently lower than those of the Lower SAV Cell, and Cell 2B in the past four water years, regardless of the differences in operational days (**Table 5-2**). Arithmetic means of annual TP concentration for the inflow (G-390A and G-390B) and outflow (G-388) of the PSTA Cell during WY2011were 24 and 10 ppb, respectively (**Table 5-3**).

A detailed review of the PSTA project's period of record data, conducted in 2010, revealed significant problems with the flow data for some of the project structures. While the project is performing very well with respect to the outflow concentrations, the large uncertainties with the flow data cast uncertainty on the annual performance summaries that have been reported in previous years' SFERs. To more accurately assess the PSTA performance, the District is modifying PSTA structures and operation to improve the accuracy of the flow measurements. In addition, the District is initiating an enhanced scientific investigation that will focus on the dynamics of the PSTA system, periphyton P uptake and decomposition, soil accretion, and P stability in accreted soil. The objectives of the studies will be to (1) evaluate dynamics of physical and biological characteristics under different hydraulic scenarios and/or extreme events, (2) understand major vegetation and sedimentation processes, and (3) explore alternatives to organic soil removal for achieving low P levels.

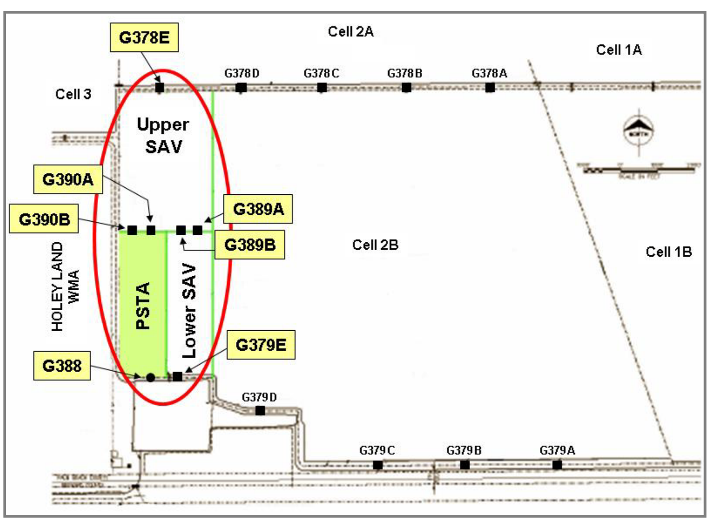


Figure 5-22. Location of Upper and Lower SAV cells, PSTA Cell, and related water control structures.

Table 5-2. Summary of treatment performance of the PSTA Cell, the Lower SAV Cell, and Cell 2B in STA-3/4 during the past four water years.

Water Year	Period of Operation	Cell	Surface inflow volume (ac-ft)	Surface inflow FWM TP (ppb)[2]	Surface outflow volume (ac-ft)	Surface outflow FWM TP (ppb)[2]
2008	July 5 – Dec. 12, 2007 (161 days)	PSTA	3,322	28 (4)	5,201	12 (2)
		Lower SAV[1]	6,691	26 (2)	2,096	32 (6)
		Cell 2B[1]	14,767	27 (4)	20,238	25 (3)
2009	July 9 – Dec. 23, 2008 (168 days)	PSTA	3,958	14 (1)	6,102	8 (<1)
		Lower SAV[1]	15,002	32 (9)	18,106	13 (1)
		Cell 2B[1]	55,270	15 (1)	80,850	13 (1)
2010	May 25, 2009 – Apr. 30, 2010 (341 days)	PSTA	7,957	20 (3)	10,795	10 (1)
		Lower SAV[1]	47,986	22 (3)	20,838	14 (2)
		Cell 2B[1]	114,285	24 (1)	168,599	17 (1)
2011	May 1-June 1; Aug. 3-Dec. 7, 2010 (159 days)	PSTA	3,827	20 (3)	3,958	11 (1)
		Lower SAV[1]	1,922	18 (3)	1,625	24 (2)
		Cell 2B[1]	81,845	20 (1)	75,613	25 (1)

[1] calculations based only on positive flow through water control structures
[2] values represents period of operation mean; values in parentheses represent standard error

Table 5-3. Summary statistics for water TP (in ppb) in grab samples at water control structures in the STA-3/4 PSTA project (May 1, 2010–December 13, 2010).

	G-378E	G-379E	G-388	G-389A&B	G-390A&B
Min	13	13	5	10	10
Max	27	60	20	42	47
Mean[a]	20	29	10	21	24
Median	19	27	10	21	23
CV (%)	22	40	41	37	43
N	32	32	32	64	64

[a] Arithmetic mean

FACILITY STATUS AND OPERATIONAL ISSUES

OPERATIONAL STATUS OF EXISTING FLOW-WAYS

The operational status of each STA flow-way during WY2011 is summarized in **Table 5-4**. Details on vegetation conditions, drought effects, and supplemental water deliveries to the STAs are covered in the *STA Condition Assessment* section of this chapter. Information specific to drought and the strategies to minimize impact to the STAs are presented at the end of that section. Details on enhancements and rehabilitation activities for each STA are included in the *Management Strategies and Implementation* section of the chapter. A summary of the operational status of the flow-ways is as follows:

- **STA-1E:** The Central Flow-way was fully operational while the Eastern Flow-way remained online with restrictions due to operation of the USACE PSTA Demonstration Project in Cell 2. The Western Flow-way, which had been offline in WY2010 due to structural failures and vegetation decline, was brought back online with restrictions on May 10, 2010. Cell 7 vegetation continues to decline due to chronic deep water conditions. Recovery of SAV in Cell 6 continued in WY2011 following a cell-wide hydrilla die-off in the early part of WY2010. Temporary pumps were installed to move water from Cell 6 to Cell 4, as needed, due to the Cell 6's inability to treat water.
- **STA-1W:** All flow-ways were operational. Due to structural, hydrologic, and vegetation issues in STA-1E, STA-1W received additional flow in WY2011.
- **STA-2:** Cells 1, 2, and 3 were fully operational; Cell 4 was online with restrictions from May 4–November 22, 2010, and off-line from November 23, 2010–April 30, 2011, due to construction activities in Compartment B, and the cell was dry by December 2010. In March 2011, one of the three pumps in S-6 failed, limiting the structure's pumping capacity. Temporary pumps were put in place to deliver water to STA-2 past the end of WY2011.
- **STA-3/4:** The Western and Central flow-ways were fully operational. The Eastern Flow-way was online from May 2010 to early March 2011 and then online with restrictions from March to past WY2011 due to vegetation enhancement activities in Cell 1A.
- **STA-5:** Flow-way 1 continued to be on restricted operation from WY2010 due to presence of snail kite nests. In May 2010, despite low water levels in Cells 1B and 2B, water in the affected flow-ways had to be maintained at optimal depths to protect the nests; excess water was sent to STA-6. The snail kite-related restriction was lifted in Cell 1A on October 27, 2010, and in Cell 2A on November 9, 2010. Flow-way 2 was fully online during WY2011. Beginning on May 18, 2010, Flow-way 3 was offline because flow into the G-342E and G-342F structures stopped due to Compartment C construction. This flow-way was brought back online from July 25–September 18, 2010 and was online with restrictions from September 19, 2010, to the end of WY2011 to allow vegetation to reestablish. Cells 1A, 2A, 3A, and 3B dried out beginning in December 2010 and remained dry for the remainder of the water year as a result of drought.
- **STA-6:** Cells 3 and 5 were operational in WY2011. Section 2 was online from May–November 2010 and has been off-line since for Compartment C construction. Water sent from Compartment C dewatering activity increased the hydraulic load to this STA; these were unforeseen flows into the STA. This

additional volume was not accounted for during the development of 2007 and 2010 operational envelopes. From late October to late December 2010, G-351 was closed and water was pumped from G-600 into the intake canal north of the structure. By December 2010, this cell, along with the rest of STA-6, dried out.

COMPARTMENT B BUILD-OUT

The Compartment B Build-out Project is located in Palm Beach County, west and south of the existing STA-2 (**Figure 5-1**). Construction of this STA and its three pump stations began in WY2010 and the system was flow-capable by December 2010. Construction of two inflow canal bridges, initiated in August 2009, was completed in May 2011. Construction of pump stations G-434, G435, and G-436 is expected to be complete in May 2012 (**Figure 5-23**). Operation of the Compartment B Build-out Project is dependent on the acquisition of state and federal discharge permits.

COMPARTMENT C BUILD-OUT

The Compartment C Build-out Project is located in Hendry County between existing STA-5 and STA-6 (**Figure 5-1**). The EFA permit for construction of the Compartment C Build-out was issued on January 12, 2009; construction activities started in April 2009, and pump station construction began in September 2009. The project was flow-capable as of December 2010. Construction of the G-508 inflow pump station is scheduled to be complete by March 2012 (**Figure 5-24**). Final design of a second inflow pump station to the Rotenberger Wildlife Management Area (G-708) has also been completed, but environmental permit authorizations are delayed until the second quarter of Fiscal Year 2012 (FY2012, October 1, 2011–September 30, 2012). This pump station will augment the inflow capacity provided by the existing G-410 inflow pump station and allow additional deliveries of treated STA water into the Rotenberger Wildlife Management Area. Operation of the Compartment C Build-out Project is dependent on the acquisition of state and federal discharge permits.

Environmentally Sensitive Areas in Compartment C

The District continues to work with the Seminole Tribe of Florida, USACE, Florida's State Historic Preservation Office, and Advisory Council on Historic Preservation toward resolution of the environmentally sensitive cultural resource areas in Flow-way 5 of the Compartment C Project. Permanent protective measures, which will be designed to ensure that on-site environmentally sensitive areas within Compartment C boundaries will be preserved and protected from inundation, are expected to be in place by June 2012. It is anticipated that rainfall and limited stormwater inflows (depending on water availability) will begin to establish wetland vegetation within Flow-way 5 during the 2012 wet season. Sensitive area preservation work is scheduled to begin during the 2012 dry season and to be completed by June 2013. Flow-way 5 will not be placed into normal operation until the permanent protective measures have been implemented. Once the measures are in place, the District plans to continue to monitor and evaluate operations in a concerted effort to maintain preservation and protection of these areas.

Table 5-4. Timeline of operational status for each STA flow-way in WY2011.

<table>
<tr><th rowspan="2">STA</th><th rowspan="2">Flow-way or Cell</th><th colspan="8">2010</th><th colspan="4">2011</th></tr>
<tr><th>May</th><th>June</th><th>July</th><th>Aug</th><th>Sept</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th></tr>
<tr><td rowspan="3">STA-1E</td><td>Eastern</td><td colspan="12">Online with restrictions</td></tr>
<tr><td>Central</td><td colspan="12">Online</td></tr>
<tr><td>Western</td><td colspan="12">Online with restrictions</td></tr>
<tr><td rowspan="3">STA-1W</td><td>Northern</td><td colspan="12">Online</td></tr>
<tr><td>Eastern</td><td colspan="12">Online</td></tr>
<tr><td>Western</td><td colspan="12">Online</td></tr>
<tr><td rowspan="4">STA-2</td><td>Cell 1</td><td colspan="12">Online</td></tr>
<tr><td>Cell 2</td><td colspan="12">Online</td></tr>
<tr><td>Cell 3</td><td colspan="12">Online</td></tr>
<tr><td>Cell 4</td><td colspan="7">Online with restrictions</td><td colspan="5">Offline</td></tr>
<tr><td rowspan="3">STA-3/4</td><td>Eastern</td><td colspan="10">Online</td><td colspan="2">Online with restrictions</td></tr>
<tr><td>Central</td><td colspan="12">Online</td></tr>
<tr><td>Western</td><td colspan="12">Online</td></tr>
<tr><td rowspan="3">STA-5</td><td>Northern</td><td colspan="6">Online with restrictions</td><td colspan="6">Online</td></tr>
<tr><td>Central</td><td colspan="12">Online</td></tr>
<tr><td>Southern</td><td colspan="3">Offline</td><td colspan="2">Online</td><td colspan="7">Online with restrictions</td></tr>
<tr><td rowspan="3">STA-6</td><td>Cell 3</td><td colspan="12">Online</td></tr>
<tr><td>Cell 5</td><td colspan="12">Online</td></tr>
<tr><td>Section 2</td><td colspan="7">Online</td><td colspan="5">Offline</td></tr>
</table>

Note: Refer also to Volume III, Appendix 3-1, Table 11.

Figure 5-23. Construction of the G-436 outflow structure in the Compartment B South Build-out in April 2011 (photo by the SFWMD).

Figure 5-24. Construction of the G-508 structure in the Compartment C in April 2011 (photo by the SFWMD).

IMPACTS OF AVIAN NESTING ON STA OPERATION

In accordance with the 2008 Avian Protection Plan (APP), the District conducted black-necked stilt nesting surveys from April to July 2011. Results of these surveys are presented in Appendix 5-2. Low water conditions in the STAs, particularly in the summer, make it ideal for ground nesting birds. Preferential nesting habitat for black-necked stilts can vary greatly with some stilts choosing higher and drier locations near water, while other nests are built in locations where the base of the nest is underwater.

Based on the results of nesting surveys, operation and maintenance activities were adjusted to reduce impacts to nests within the STAs (**Table 5-5**). This includes prioritization of flow according to the APP to avoid disturbing areas with nests, adjustment of mowing and grading schedules for levee and canal maintenance, and placing visible markers (e.g., bean bag markers) to mark nests on levees that could potentially be impacted by vehicular traffic.

While the mowing schedule within the STAs was modified based mostly on the black-necked stilts' nesting season, it also includes other protected migratory bird species such as killdeer (*Charadrius vociferus*) and common nighthawks (*Chordeiles minor*). More than a dozen black-necked stilts, common nighthawks, and killdeer were observed nesting on STA levee roads between April and June. These nests were marked to minimize any impacts on nests from traffic and other activities in the STAs. In close coordination with the U.S. Fish and Wildlife Service, the District also adjusted the operations of STA-5 Cells 1A and 2A to minimize impacts to the Everglade snail kites such that no incidental takes occurred during 2010.

Table 5-5. Modified operational and levee and canal maintenance activities implemented during the 2011 ground-nesting migratory bird breeding season.

STA	Type of Action	Date Implemented	Strategies Implemented to Reduce Impact on Ground Nesters
All	Operational	Throughout Breeding Season	Prioritized operation of flow-ways that were not impacted with black-necked stilt nests.
All	Maintenance	Throughout Breeding Season	Modified mowing and grading schedule to reduce impacts to ground nesters and young on levee roads and embankments.
Operational Changes to Individual STAs			
1E	Operational	06/06/2011	Avoided impacting five black-necked stilt nests in STA-1E until July 11 when all eggs were either hatched or flooded by rising water solely caused by rainfall.
1W	Operational	06/26/2011	Avoided impacting two black-necked stilt nests in STA-1W Cell 2B by avoiding flows into STA-1W Western Flow-way until July 5 when all eggs were either hatched or flooded by rising water solely caused by rainfall.
3/4	Operational	06/26/2011	Avoided impacting eight black-necked stilt nests in STA-3/4 Cell 2B and one black-necked stilt nest in Cell 3B by prioritizing water flows away from flow-ways within these STA cells.
2	Maintenance	05/24/2011	One ground-nesting killdeer was marked on the south levee road of STA-2 Cell 2 with bean bags and reported to District staff. Mowers avoided area until nesting was completed in mid-June.
1W	Maintenance	05/25/2011	Twelve ground-nesting black-necked stilts were marked on both the north and south levee roads of STA-1W Cell 2B with bean bags and reported to District staff. Mowers avoided area until nesting was completed in early July.
3/4	Maintenance	06/17/2011	One ground-nesting killdeer was marked on the levee road near the G-370 pump station in STA-3/4 with bean bags and reported to District staff. Mowers avoided area until nesting was completed in early July.
Comp C	Construction	05/05/2011	Two ground-nesting migratory birds (one killdeer and one common nighthawk) were observed in a portion of the Compartment C construction area. The area was marked and District staff was notified about the presence of these nests. Construction activities avoided the area until all eggs were hatched and chicks moved out of the area.
Comp B	Construction	07/12/2011	One ground-nesting common nighthawk was marked on a levee road near the G-343 structure in the Compartment B construction area.

Table 5-6. Modified operational target stages (in feet) in STA-5 Cells 1A and 2A during the 2010 Everglade snail kite breeding season to minimize impacts on nests.

Date	Cell 1A		Cell 2A	
	Max	Min	Max	Min
April 12, 2010	Normal operation	Normal operation	Normal operation	Normal operation
April 19, 2010	14.0	13.7	14.0	13.7
May 10, 2010	14.0	13.7	14.0	13.7
June 8, 2010	15.5	13.7	15.5	13.7
June 23, 2010	14.0	13.7	15.0	13.7
July 8, 2010	15.0	13.7	15.0	13.7
July 23, 2010	16.0	13.7	15.0	13.7
August 9, 2010	17.0	13.7	14.5	13.7
August 18, 2010	17.0	13.7	14.5	13.7
September 2, 2010	Normal operation	Normal operation	14.5	13.7
September 16, 2010	Normal operation	Normal operation	15.5	13.7
September 30, 2010	Normal operation	Normal operation	15.5	13.7
October 21, 2010	Normal operation	Normal operation	Normal operation	Normal operation

Note: The normal operation target stage for these cells is 14 feet in relation to the National Geodetic Vertical Datum of 1929 (NGVD29).

STA CONDITION ASSESSMENT

Managing each STA requires knowledge of its condition and its ability to remove P from runoff water. This includes information on P storage and the stability of the different forms of P in the system. Currently, the Long-Term Plan requires an estimate of vegetation coverage through aerial imagery and an estimate of P storage in floc and surface soil layers.

OVERVIEW OF DATA UTILIZATION

Data obtained from these surveys and sampling are currently utilized in documenting STA conditions, in investigating a poor-performing cell, and in developing or evaluating management strategies for a cell. In the 2006–2007 STA-1W rehabilitation, for example, soil information played a major role in deciding the proper management strategy for each affected cell. Cell 1B, with documented high levels of P in the southern portion of the cell, was scraped and the material was removed. In Cell 4, the highly inorganic accreted soil material was scraped and removed. In Cell 2B, however, the more organic soil was disked in (instead of removal). The resulting vegetation establishment and performance in these three cells attest to the success of the chosen soil management strategy.

Another example of when soil information was used was in troubleshooting performance of STA-5 and STA-6. These two STAs have had performance issues; STA-5 had high outflow TP concentrations until WY2009 while in STA-6 outflow TP concentration was slowly increasing since it started operation, but more dramatically after WY2004. Through understanding the type of soil in these areas and the amount of P stored in soil, soil P flux was identified as a key contributor to observed outflow TP concentrations. In STA-5, the highly variable topography and presence of a slough area in Cell 1A was resulting in frequent dryout of higher areas, and consequently soil oxidation and P flux. In STA-6, frequent dryout and rehydration of the soil likely contributed to the observed high P in the outflow. As in the other STAs, other factors affect performance, and since these were not controlled experiments, the actual contribution of soil P flux cannot be quantified. However, separate laboratory studies utilizing soils from the different STAs indicated a large amount of P flux from soils subjected to cycles of draining and reflooding.

Since vegetation is a key component for P removal in the STAs, vegetation information is useful in many different investigations. Unvegetated areas, for example, indicate problems with short circuiting or unfavorable growing areas. Vegetation information has helped identify areas that need bulrush planting, identify areas that need SAV inoculation, support the request for drawing down the water level in STA-3/4 Cell 1A, explain the poor performance in STA-1E Cell 7, and assess the progress of vegetation conversion projects. Aerial imagery has been helpful not just for estimating area coverage for each cell, but also in estimating and temporal evaluation of cattail density in problem areas. Specifically, managers have tracked the decline in cattail density in STA-1E Cell 7 and STA-3/4 Cell 1A using aerial images.

Ground SAV surveys have been similarly useful in identifying areas that may have issues, i.e., absence of SAV indicates reduced P treatment from the water column. It is also an opportunity to observe the health of SAV, which is critical for P removal. These types of observations are not currently possible using aerial imagery at a 1:24,000 scale due to interference and the resolution of the images.

In WY2012, further analysis of the data will include correlating soil characteristics with the vegetation type and density and P pattern. Future uses of these data can include utilization of ecological models in predicting P treatment performance under different scenarios of hydrologic conditions, soil and P accretion, vegetation coverage, and vegetation density.

SOIL SURVEYS

Soil Sampling

Soil cores are collected once every three years at 1,330-foot x 1,330-foot grid locations and samples are analyzed for TP, total nitrogen (TN), total carbon (TC), bulk density (BD), and ash-free dry weight (AFDW). Intact soil cores were collected by driving a 10-cm diameter stainless steel corer into the soil profile. When appropriate, while driving in the corer, a serrated knife was used to cut around the outside perimeter of the corer to reduce soil compaction. The floc material was poured into a graduated clear butyrate tube, depth was recorded, and the sample was placed in prelabeled watertight zipped plastic bags. The uppermost 10 cm-soil layer was then extruded into a separate sample bag. All samples were cleared of vegetation, roots, rocks, and shells, and then placed in waterproof plastic bags. The bags were then packaged in an ice cooler for transport to the laboratory where they were stored at 4ºC prior to analysis. Intact cores were collected using a 4-inch diameter stainless steel corer. For this report, soil information for STA-1W and STA-3/4 and baseline soil characterization of Compartments B and C, as required by the Long-Term Plan, are also included. This past water year, additional soil cores were collected and analyzed for carbon (C) and nitrogen (N) isotopes to obtain a more accurate estimation of soil and P accretion in the STAs.

STA-1W

Surface (0–10 cm) soils in STA -1W are generally highly organic, with mean AFDW of 79 percent and relatively low BD (less than 0.3 g/cm^3) (**Table 5-7** and Appendix 5-4). Bulk density in surface soil of SAV cells was slightly higher than in EAV cells. Soil TP increased slightly between WY2011 (650 mg/kg) and previous sampling events (2007–2008), with a mean TP concentration of 550 mg/kg. TC and TN within the upper soil layer were comparable with the previous sampling. TC in the soil layer was generally higher than in the floc layer while TP was generally higher at the floc layer.

The floc layer had an average AFDW of 56 percent. The floc TP concentration was similar to that found in the 2007–2008 sampling event at approximately 1,200 mg/kg. Although floc P storage was slightly higher than in the 2007–2008 sampling event, there appears to be little to no change in P storage in the surface (0−10 cm layer) over the last three years.

During the 2006 and 2007 rehabilitation of STA-1W, the accrued soil layer from Cells 1B and 4B was scraped and removed, while in Cell 2B, the accrued layer was disked in. The reported floc results for Cells 1B and 4B are likely characteristics of material accreted over a three-year period. Floc layer TP for Cells 1B, 2B, and 4 was much lower than the average floc TP concentration for the entire STA and in cells that did not undergo any soil removal or modification (**Table 5-7**). In contrast, results reported for the 0–10 cm layer in Cell 2B may be characteristics of a mixture of old accreted material and pre-STA peat soil.

Table 5-7. Selected physico-chemical characteristics of the floc and surface soil (0−10 cm) layers in the STA-1W, based on WY2011 sampling. Values are means ± standard deviation.

Cell	Layer	Ash Free Dry Weight (%)	Bulk Density (g/cm^3)	Total Carbon (g/kg)	Total Nitrogen (g/kg)	Total Phosphorus (mg/kg)
Cell 1A	Floc	58.7±9.7	0.06±0.02	326±44	22.6±2.9	1326±293
	Surface Soil	68.2±11.7	0.22±0.06	381±59	240±3.6	727±306
Cell 1B	Floc	59.1±16.9	0.11±0.06	327±58	21.8±4.3	992±466
	Surface Soil	77.1±9.8	0.25±0.07	433±49	27.3±2.6	487±277
Cell 2A	Floc	63.2±10.6	0.051±0.02	358±46	24.4±3.3	1240±390
	Surface Soil	80.3±8.8	0.21±0.05	449±47	27.2±2.5	432±198
Cell 2B	Floc	52.5±13.5	0.13±0.02	310±60	16.2±5.0	673±84
	Surface Soil	72.6±11.9	0.27±0.02	415±28	23.4±1.9	539±294
Cell 3	Floc	70.2±15.0	0.07±0.01	392±63	26.3±4.6	1124±235
	Surface Soil	82.9±5.7	0.20±0.04	460±31	28.0±1.4	517±218
Cell 4	Floc	48.7±3.5	0.10±0.02	302±16	16.4±1.1	572±65
	Surface Soil	70.8±11.9	0.30±0.04	398±48	21.4±3.2	373±88
Cell 5A	Floc	63.4±10.6	0.05±0.03	349±50	25.4±4.9	1617±602
	Surface Soil	74.4±13.0	0.28±0.07	419±66	25.6±4.4	559±147
Cell 5B	Floc	48.0±9.7	0.07±0.03	298±54	18.5±3.6	1195±347
	Surface Soil	70.0±11.7	0.32±0.06	433±49	27.3±2.6	836±1887
STA Mean	**Floc**	**56.0±7.29**	**0.071±0.03**	**327±30**	**21.3±3.7**	**1180±321**
	Surface Soil	**78.8±3.43**	**0.27±0.04**	**416±25**	**25.0±2.2**	**650±145**

STA-3/4

The results of the WY2011 soil survey for STA-3/4 are summarized in **Table 5-8** and Appendix 5-4. The surface (0–10 cm) soil layer was highly organic, with an AFDW greater than 70 percent and BD below 0.3 g/cm^3. Mean surface soil TP was 666±247 mg/kg. TP concentrations in Cell 3A were higher than that found in 2007, but comparable to the results from 2005. Total N and TC concentrations in the surface soil layer were also comparable with the 2007 sampling event, indicating little to no change over the three-year period. The widest range in soil TP variability was found in Cells 2A (272–2,455 mg/kg) and 1B (253–1,785 mg/kg). The result reflects, generally, a soil TP gradient within each cell, with high levels on the front end and low levels on the back end of the cell.

The floc characteristics are also comparable among the different cells, including low BD values (less than 0.1 g/cm^3) and 50 percent AFDW (**Table 5-8**). The floc TP concentration was almost twice as much as that found in the surface soil layer and was also generally higher in EAV cells than SAV cells, indicating a higher TP enrichment in the front end of the flow-way. The differences in TP concentrations among the EAV cells were not significant, and similarly, there was also no significant difference in TP among the SAV cells (Scinto and Johnson, 2010). Floc BD from WY2011 was generally lower than from 2007, but TP, TN, and TC concentrations were comparable, indicating little change over the three-year period.

Table 5-8. Physico-chemical characteristics of floc and surface (0–10 cm) soil layer in STA-3/4 Cells 1A and 1B in WY2011. Values are means ± standard deviation.

Cell	Layer	Ash Free Dry Weight (%)	Bulk Density (g/cm^3)	Total Carbon (g/kg)	Total Nitrogen (g/kg)	Total Phosphorus (mg/kg)
Cell 1A	Floc	53.5±11.5	0.06±0.05	302±56.8	18.3±4.0	1365±367
	Surface Soil	70.0±14.1	0.27±0.10	362±63.5	21.7±4.5	653±194
Cell 1B	Floc	53.4±14.0	0.05±0.02	316±52.1	17.8±4.2	1146±365
	Surface Soil	74.6±11.2	0.27±0.08	371±67.2	21.6±4.0	536±208
Cell 2A	Floc	56.1±13.0	0.03±0.03	303±52.6	20.4±4.7	1477±356
	Surface Soil	64.3±13.9	0.26±0.10	340±69.2	21.8±4.5	750±370
Cell 2B	Floc	42.6±16.2	0.07±0.03	279±65.5	16.0±6.2	1025±479
	Surface Soil	72.5±10.0	0.36±0.10	388±53.4	22.8±3.8	636±164
Cell 3A	Floc	50.1±14.8	0.03±0.02	282±53.1	17.7±4.3	1550±361
	Surface Soil	61.9±14.2	0.27±0.08	333±66.8	20.2±5.0	801±216
Cell 3B	Floc	45.0±24.7	0.04±0.03	279±91.6	17.0±8.0	1003±387
	Surface Soil	71.4±9.8	0.24±0.06	364±55.1	23.1±4.1	649±213
STA Mean	**Floc**	**50.3±16.6**	**0.05±0.03**	**295±64.3**	**17.9±5.5**	**1245±435**
	Surface Soil	**69.3±13.1**	**0.28±0.09**	**360±65.3**	**21.8±4.4**	**666±247**

Compartment B

Within Compartment B, 38 sampling stations were selected from the grid locations to obtain soil baseline information in the new cells. These locations will serve as benchmark points for future soil evaluations. Soil samples were collected within a 20-meter radius of the sampling station. Within this radius the samplers actively chose a sample site located (1) in an undisturbed location (i.e., avoiding dirt roads and other infrastructure) and (2) away from large, woody vegetation. Soils were analyzed for various inorganic P fractions to determine the labile inorganic phosphorus (Li-P; KCl extraction), iron and aluminum-bound P (FeAl-Pi; NaOH extraction), and the calcium and magnesium-bound P (CaMg-Pi; HCL extraction). The organic P fraction (Po) was calculated as the difference between the NaOH-TP extractable and the NaOH-Pi extraction associated with the Fe- and Al-bound P. Residual P was calculated by the difference between TP and the sum of the extractable fractions.

Surface soils in this area are organic, with AFDW greater than 70 percent and low BD (0.3 ± 0.08 g/cm^3), which is typical of the STA-2 area (Wetlands Biogeochemistry Laboratory, 2009) (**Table 5-9**). Mean TP concentration was 666 ± 150 mg/kg, which was higher than the baseline and current 0–10 cm soil TP levels at STA-2 Cells 1, 2, and 3. TC, TN, and total calcium (TCa) levels found in baseline Compartment B soils were comparable to the baseline data and results of 2004–2007 soil surveys in STA-2.

Approximately 50 percent of the soil TP pool in Compartment B was in highly resistant P forms, which indicates that they are highly stable and likely from the old peat formation (**Figure 5-25**). The other half consisted of both labile inorganic and inorganic P pools, and moderately labile P forms (Ca- and Fe-bound P). The labile P pool was less than 1 percent of soil TP. It is anticipated that as the area is flooded, the labile soil phosphorus will be released into the water column. Aside from the concentration of labile P in the soil, the duration of net flux will also depend on vegetation and microbial P uptake (Reddy and D'Angelo, 1994; Wetzel, 1999). As these new cells become operational and new material accretes, the distribution of the different P fractions on the soil surface is expected to change.

Table 5-9. Baseline soil characteristics for the surface soil layer (0–10 cm) in Compartment B (mean ± SD).

Cell	n	Ash Free Dry Weight (%)	Bulk Density (g/cm^3)	Total Carbon (g/kg)	Total Nitrogen (g/kg)	Total Phosphorus (mg/kg)	Total Calcium (g/kg)
Cell 5	12	67.7±14.5	0.4±0.1	371±87	24±4.9	714±206	40.2±11.7
Cell 6	9	78.5±12.5	0.3±0.05	439±704	26.5±4	626±125	39±8.7
Cell 7	8	72.6±8.2	0.3±0.05	403±442	25.5±2.8	724±90	41.9±9.7
Cell 8	9	82.6±1.5	0.3±0.03	462±15	30.2±8.4	595±96	38±2.7
STA Mean	38	75.0±12.0	0.34±0.09	419±71	27.1±6.9	669±149	39.7±8.6

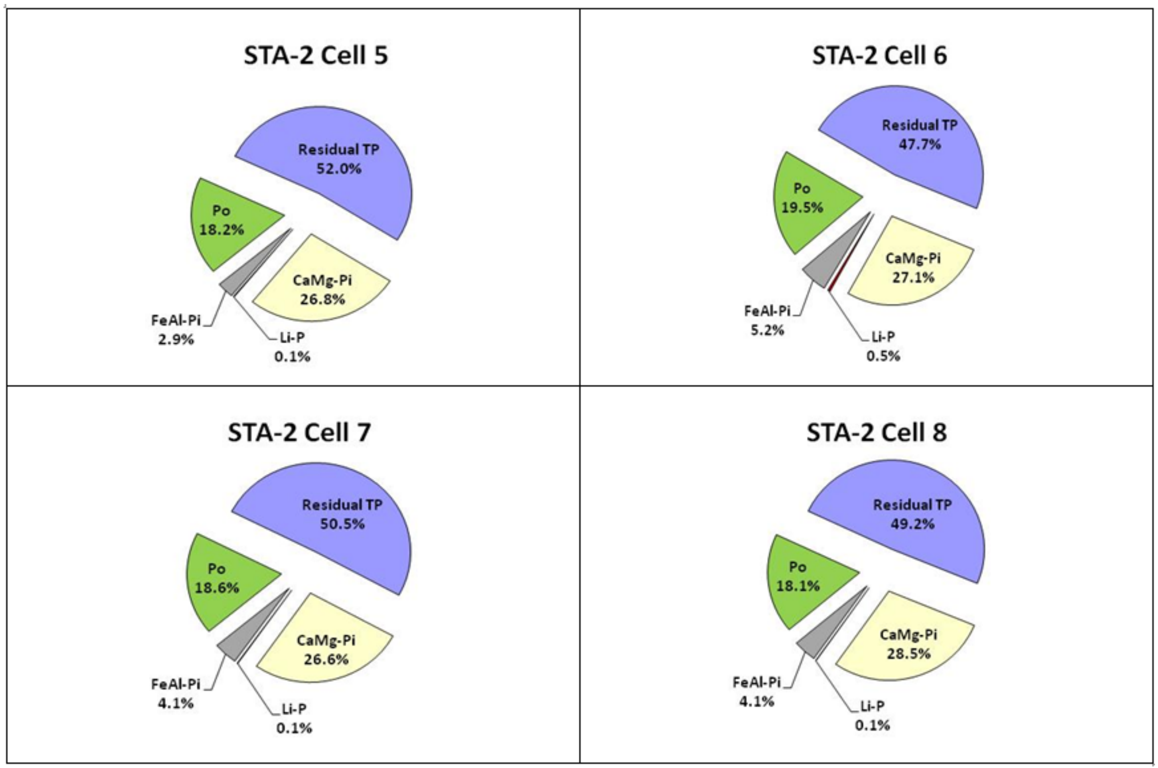


Figure 5-25. Distribution of labile and non-labile phosphorus fractions in the upper 10 cm soil layer of Compartment B cells. [Note: organic phosphorus (Po), aluminum-bound phosphorus (FeAl-Pi), labile inorganic phosphorus (Li-P), calcium- and magnesium-bound phosphorus (CaMg-Pi)].

Compartment C

Compartment C soils are primarily mineral with sandy clay loam texture, less than 20 percent AFDW, and high BD of around 1 g/cm^3. The exception to this is Cell 5B, which contained 47 percent AFDW and had a BD of 0.5 g/cm^3 (**Table 5-10**). The average TP concentration in this area is 320 ± 251 mg/kg, with Cell 5B having higher TP (534 ± 129 mg/kg) than the rest of the new cells. TC and TN concentrations in this area averaged 101 ± 101 g/kg and 7.6 ± 7.3 g/kg, respectively. Cell 5B exhibited different characteristics from the other cells in Compartment C, with approximately four times as much organic matter (AFDW), and higher TP, TN, TC, and TCa. Based on these observations, it seems that Cell 5B soil characteristics is similar to the currently operational STA-5 cells, while the other new Compartment C cells are similar to STA-6.

Compartment C soils are highly inorganic, with less than 20 percent AFDW and BD close to 1 g/cm^3 in most cells, except in Cell 5B. Highly resistant forms of P accounted for approximately 50 percent of soil TP, and the labile P was less than 1 percent in Compartment C Cells (**Figure 5-26**). The moderately labile pool (CaMg-Pi) is also generally small, except for Cell 4A with 24 percent of the TP in the moderately labile pool. This suggests a short period of initial flux upon reflooding. However, the rate of breakdown and release from the moderately labile and organic fractions will depend on the environmental condition in the cells, such as the frequency and duration of cycles of dryout and reflooding. Oxidation of organic substrate is accelerated at aerobic condition, which consequently releases phosphorus into the overlying water column upon reflooding. Repeated cycles of dryout and reflooding have been identified as one of the factors contributing to high outflow in STA-5 and later in STA-6. High P flux has also been observed in other STAs and wetlands immediately upon reflooding previously dried or drained soils.

Table 5-10. Baseline soil characteristics for the surface soil layer (0–10 cm) in Compartment C Stormwater Treatment Area (mean ± SD).

Cell	n	Ash Free Dry Weight (%)	Bulk Density (g/cm^3)	Total Carbon (g/kg)	Total Nitrogen (g/kg)	Total Phosphorus (mg/kg)	Total Calcium (g/kg)
STA-5 Cell 4A	7	14.5±12.3	1.0±0.4	82.1±62.9	6.31±4.64	370±288	6.1±5.4
STA-5 Cell 4B	2	17.3±14.8	0.8±0.4	85.9±69.4	6.14±5.08	258±139	9.3±2.3
STA-5 Cell 5A	9	11.7±17.4	1.1±0.3	61.5±91.5	4.67±6.66	230±281	4.2±6.3
STA-5 Cell 5B	4	46.7±21.0	0.5±0.1	246±113	18.2±8181	534±129	15.8±7.7
STA-6 Cell 4	3	13.6±10.8	1.0±0.4	83.5±67	6.48±5.13	235±76	6.1±2.4
STA Mean	25	19.3±18.6	0.97±0.40	102±98.5	7.65±7.20	316±245	8.0±7.7

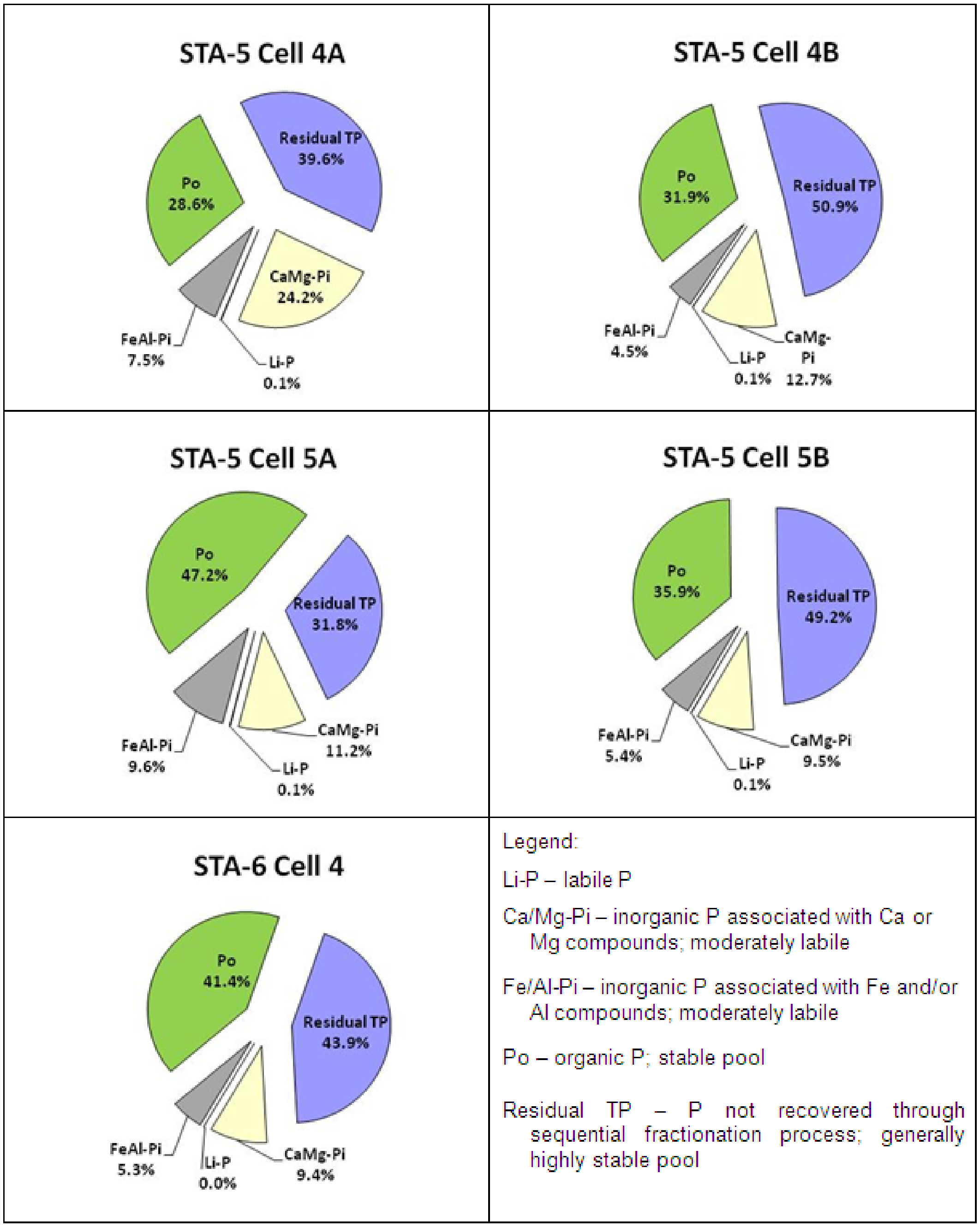


Figure 5-26. Distribution of labile and non-labile phosphorus fractions in the upper 10 cm soil layer of Compartment C cells [Cells 4A, 4B, 5A, and 5B (STA-5), and Cell 4 (STA-6)].

Soil Accretion Estimation

Accretion rates are influenced by various factors, including vegetation, nutrient levels in soil and inflow water, and frequency and duration of dryout. The type of vegetation, such as cattail or SAV species, determines the type and quantity of residue accretion per unit time. While cattail areas accrue primarily organic soils, SAV cells accrue primarily mineral residues. The rate of accretion depends on the rate of turnover of vegetation. For example, under normal operations and when conditions are favorable to the specific vegetation, plant turnover and litter production could be slow (Mitsch and Gosselink, 1993; Kadlec and Wallace, 2009). During extreme weather events that impact vegetation, such as storms or drought, vegetation litter production or accretion of SAV residues could be accelerated. During dryout, vegetation mortality could occur, and any recently accreted soil mass is subject to consolidation, oxidation, and compaction. Frequent cycles of dryout and reflooded conditions have been shown to accelerate soil loss (Reddy and Patrick, 1984; Morris et al., 2004). For these reasons, the STAs are operated to avoid dryout to the maximum extent possible.

A study to estimate the depth of accreted soil material in selected STAs was completed in January 2011. Intact soil cores were collected from preselected locations in STA-1W, STA-2, and STA-3/4. The cores were sectioned into 2-cm intervals and analyzed for physico-chemical characteristics, such as BD, TC, TP, TN, and isotopic ratios of C to N. Based on this information, the breakpoint (the layer that separates the pre-STA soil and STA accreted soil) was estimated and used as a basis for soil accretion estimation (Wetlands Biogeochemistry Laboratory, 2009). A summary of the results for each cell examined, including estimation of soil and P accretion rates, is presented in **Table 5-11**. The mean depth of accreted soils in Cells 1A, 2A, and 3 of STA-1W was 16 cm whereas for the Northern Flow-way, it was 12 cm. This could be attributed to the differences in years of operation. Cells 1A, 2A, and 3 were part of the former ENR Project, which began operation in WY1995, while the Northern Flow-way (Cells 5A and 5B) began operation six years later (WY2000). These cells were selected because they were the least disturbed during the 2005-2007 rehabilitation efforts. These cells were dewatered during construction and rehabilitation in 2006 and 2007 and part of the cells also dried out during recent drought years. It was expected that soil loss due to oxidation, compaction, and consolidation has occurred during the dewatering and dryout periods. Some earthwork also occurred in Cells 1A and some areas of Cell 5B. In the Northern Flow-way, Cell 5B (SAV cell) had a thicker accrued layer (13 cm) than Cell 5A (EAV cell, 10 cm). Average soil and P accretion rates for Cells 1A, 2A, and 3 of STA-1W were 1.0 ± 0.4 cm/yr and 1.5 ± 0.7 g/m^2/yr, respectively. For the STA-1W Northern Flow-way (Cells 5A and 5B), soil and P accretion rates were 1.2 ± 0.6 cm/yr and 2.0 ± 1.2 g/m^2/yr, respectively. Both the soil and P accretion rates were comparable between Cells 5A and 5B, despite having different dominant vegetation communities.

In STA-2, the mean depth of accreted soils was 11 cm. Accreted soil depths in the SAV cells (Cells 3 and 4) were higher than what were observed in the EAV cells. Soil and P accretion rates for STA-2 were found to be 1.1 ± 0.3 cm/yr and 1.9 ± 0.9 g/m^2/yr, respectively. While soil accretion rates were comparable among STA-2 cells, the P accretion rates in SAV cells were also consistently higher for the SAV cells (Cells 3 and 4) than the EAV cells (Cells 1 and 2). This could have been influenced by the frequent dryout in the EAV cells, particularly as a result of dry conditions in recent years. Based on observations in this STA and in STA-1W Cells 5A and 5B, vegetation type may have less influence with the observed differences in accretion depth and P accretion rates, unless the cell is subjected to dryout and reflooding cycles.

In STA-3/4, the mean depth of accreted soil was 10 cm. Soil and P accretion rates were 1.7 ± 0.8 cm/yr and 3.3 ± 2 g/m^2/yr, respectively. This was higher than either STA-1W or STA-2. There was no clear difference in accreted soil depths, soil accretion rates, and P accretion rates among the different cells and vegetation communities. Cell 1B is still undergoing conversion to

SAV and more than half of the cell continues to be EAV. Similarly, a large portion of Cell 2B has cattail communities.

Further analysis of the soil and P accretion data is under way, including statistical analysis and additional laboratory testing to determine the stability of P in the accrued layer.

Table 5-11. Soil and phosphorus accretion rates in selected STA cells based on stable isotopic analysis and bulk density data.

STA	Cell	Accretion Depth (cm)	Soil Accretion (cm/yr)	Phosphorus accretion (g/m^2/year)	Comments
STA-1W	Cell 1A	19	1.2±0.46	1.6±0.88	Dewatered and tussock removal in 2006-2007; soil compaction due to heavy equipment in the cell
	Cell 2A	16	1±0.1	2±0.21	Dewatered in 2006-2007
	Cell 3	13	0.9±0.3	1.2±0.5	Dewatered, cattail stands chopped and litter left in place in 2007. Converted to SAV vegetation.
	Former ENR Mean	16.2±5.7 (n=14)	1.0±0.4	1.5±0.7	
	Cell 5A	10	1.0±0.42	2.0±1.4	Dewatered in 2006
	Cell 5B	13	1.2±0.65	2.1±1.1	Dewatered in 2006; disking and soil removal in some areas of 5B
	Northern Flow-way Mean	12±5.5 (n=12)	1.2±0.55	2±1.2	
STA-2	Cell 1	9	1.0±0.26	1.0±0.13	Frequent dryout during dry season, and water loss due seepage to adjoining cells.
	Cell 2	10.5	1.0±0.26	1.6±0.41	
	Cell 3	12.5	1.2±0.4	2.5±1	
	Cell 4	12.9	1.3±0.94	2.7±0.94	Operational for approximately 2 years prior to this analysis.
	Mean	11±3.3 (n=29)	1.1±0.3	1.9±0.9	
STA-3/4	Cell 1A	8	1.4±0.48	2.7±0.9	Chronic deep water condition resulted in peat pop-ups in previous years.
	Cell 2A	12	2.0±1.1	5.5±4.2	Chronic deep water condition resulted in peat pop-ups in previous years.
	Cell 1B	12	2.0±0.83	2.4±0.97	
	Cell 2B	8	1.5±0.46	3.8±1.5	
	Mean	10±4.6 (n=39)	1.7±0.77	3.3±2 .0	

ENR: Everglades Nutrient Removal Project

VEGETATION COVERAGE AND CONDITION

Vegetation coverage in the individual treatment cells is monitored for various purposes and using different techniques. To track temporal changes in cell vegetation coverage, aerial imagery at a 1:24,000 scale is done annually. This technique allows for estimation of EAV, but does not distinguish between areas occupied by SAV and open water areas. Based on the aerial imagery, coverage is estimated using unsupervised classification utilizing ERDAS Imagine (ESRI, Redlands, CA) software. An initial classification scheme with 40 classes was reduced to two groups: SAV/open water and EAV. These two groups are further processed using other ERDAS software tools. The resulting image is prepared for analysis, display, and acreage calculation. To obtain a more detailed classification of dominant EAV, ground-truthing via helicopter is conducted within a few days of aerial imagery processing. Mapping at the dominant species level is done only case-by-case, such as when major changes in environmental conditions occur and is suspected of causing significant changes in vegetation types in the cell.

A summary of vegetation coverage, based on aerial imagery done in WY2011, is presented in **Table 5-12** and Appendix 5-3. The percent change in vegetation was estimated based on vegetation coverage comparison between WY2010 (April 16, 2009) and WY2011 (May 23, 2010) (**Figures 5-27** and **5-28**). To assess coverage of SAV, ground surveys are conducted at least annually. For these surveys, a rake method is used for qualitative assessment of SAV relative density. SAV survey results for selected STAs are included in this report. Additional surveys, including qualitative and quantitative assessments are done for other reasons and purposes. For example, photo documentation via helicopter was conducted before and during the drought in WY2011. Findings are discussed in the drought section of this chapter. A more in-depth quantitative survey was completed to assess the benefits of lowering the water level in areas where cattails have been stressed by deep water conditions. This particular study was setup in STA-3/4 Cells 1A and 2A. Initial results are discussed in the *Management Strategies and Implementation* section.

Areal Coverage of STA Vegetation

The following discussion on vegetation coverage is based primarily on the 2010 aerial imagery flight data. Due to the time required to process and analyze acquired images, there is a lag in reporting for the SFER. At the time of this reporting, processing and analysis of the 2011 imagery is in progress. While aerial imagery is acceptable for capturing and documenting annual vegetation coverage in the STAs, the difference in time of taking aerial imagery from year to year, which usually spans between March and May depending on weather conditions, could make a difference in the results. The extent of differences depends on the seasonality of vegetation dynamics and hydrologic condition in the STAs.

STA-1E

Cells 1 and 2 were not included in this analysis because they are still under restricted operation. In Cells 3 and 5 (EAV cells), the estimated EAV coverage was 85 percent, and the remaining 15 percent had SAV, open water, or a combination of both (**Table 5-12**). These results are comparable to 2009 (**Figure 5-27**; Appendix 5-3). In Cell 7, EAV coverage was 56 percent, which was 5 percent lower than in 2009; the decrease could be attributed to the chronic deep water conditions in this cell. The unfavorable conditions resulted in unhealthy cattail communities, with floating cattail mats in the southern part of Cell 7 covering approximately 25 percent of the area, and impacted but rooted cattail stands primarily in the northwestern portion with approximately 50 percent of the areal cover (Pietro et al., 2011). Floating cattail mats were also observed in the southwestern portion of Cell 5. Giant bulrush that was planted in short-circuited areas in Cells 5 and 7 are expanding and adding to the EAV coverage. A more detailed analysis of bulrush expansion is expected to be included in future reports.

Cell 4N and 4S had 60 and 89 percent SAV/open water area coverage, respectively. The coverage was 30 and 5 percent less than in 2009 for Cells 4N and 4S, respectively (**Figure 5-28**). In Cell 6, 2010 imagery indicated 17 percent coverage of EAV, an increase of approximately 8 percent from 2009 (**Figure 5-27**; Appendix 5-3). This cattail coverage increase could be attributable to an effort to encourage more EAV in this cell to allow for redundant treatment vegetation in case of any future large-scale SAV loss. The exact cause of significant uprooting of hydrilla in Cell 6 remains undetermined, although it is believed to be due to the plant being stressed under multiple environmental factors including high nutrient loading, a change in light penetration by over-growth, herbivory, and flow and wind action. The uprooting of hydrilla, combined with a high-flow event through Cell 6 resulted in the accumulation of massive amounts of vegetation at the outflow area of Cell 6 in July 2009 (**Figure 5-29**; Pietro et al., 2011).

STA-1W

In STA-1W, the 2010 imagery indicates that the EAV cells (Cells 1A, 2A, and 5A) were 80, 94, and 54 percent covered with EAV, respectively (**Table 5-12**; Appendix 5-3). Compared to the 2009 results, the EAV coverage increased by 18 percent and 6 percent in Cells 1A and 2A, respectively (**Figure 5-27**). The results in Cell 5A were comparable between the two water years and a large portion of this cell (46 percent) remains unvegetated. These areas are deemed too deep for cattail establishment. The lack of vegetation in almost half of this cell, plus suspected short-circuiting, is blamed for the lack of treatment performance in this cell. Bulrush has been planted in a portion of this cell to improve flow and performance, but the expansion of this vegetation will take time. SAV/open water coverage decreased by 5 percent in Cell 3, which showed approximately 45 percent EAV in this SAV-converted cell (**Figure 5-28**). EAV control has been performed since this imagery event. Vegetation coverage did not differ significantly in other cells.

STA-2

In STA-2 Cells 1 and 2, the EAV coverage was 97 and 62 percent, respectively (**Table 5-12**; Appendix 5-3). The southern end of Cell 2 was recently converted to SAV, hence the lower coverage of EAV in comparison to Cell 1 with a 14 percent decrease in EAV coverage between 2009 and 2010 (**Figure 5-27**). The conversion area is planned for expansion in the coming water year. SAV/open water coverage in Cell 4 was 88 percent, a 5 percent decrease from 2009 (**Figure 5-28**). There was little to no change in EAV versus SAV/open water coverage in the SAV cells (Cells 3 and 4).

STA-3/4

EAV coverage in Cells 1A, 2A, and 3A was 65, 78, and 95 percent, respectively (**Table 5-12**; Appendix 5-3). There was a 5 to 7 percent decrease in EAV coverage in Cells 1A and 2A from 2009, respectively (**Figure 5-27**). Vegetation coverage between 2009 and 2010 were comparable in other cells. In Cells 1B, 2B, and 3B (SAV cells), EAV coverage was 59, 26, and 34 percent, respectively (**Figure 5-28**). Cell 1B is still undergoing a phased SAV conversion. Based on ground surveys, these cells had a very successful coverage of SAV in areas where EAV was absent.

STA-5

In STA-5, EAV coverage in Cells 1A, 2A, and 3A was 65, 85, and 85 percent respectively (**Table 5-12**; Appendix 5-3). The lower EAV coverage in Cell 1A is attributed to the presence of a remnant slough, which was not filled during the 2009 rehabilitation of this cell. Efforts are under way to plant bulrush in this area and other open waters in this cell. EAV coverage in Cell

1A decreased by 35 percent and by 11 percent in Cell 2A between 2009 and 2010 (**Figure 5-27**). These cells have been experiencing dryout during the dry season; hence EAV areas include some woody and facultative species. In Cells 1B, 2B, and 3B (SAV cells), the EAV coverage was 12, 19, and 94 percent, respectively. Cell 3B was dry for a major portion of the past two water years, thereby resulting in the extensive areal coverage by EAV species. Vegetation coverage did not differ significantly in other cells within this two-year period (**Figure 5-28**).

STA-6

Cells 3 and 5 (EAV cells) had 61 and 83 percent EAV coverage based on 2010 imagery (**Table 5-12** and Appendix 5-3). This represents a 15 and 7 percent decrease from 2009, respectively (**Figure 5-27**). These cells also dried out frequently and the EAV areas were covered with a mixture of cattails, sawgrass, and woody species. Section 2, an SAV-targeted cell, had 61 percent EAV coverage, primarily due to dryout condition related to Compartment C construction (**Table 5-12** and **Figure 5-28**). Prior to dryout (2009), this cell had successful SAV coverage, although the highly variable topography has resulted in persistent growth of emergent species, including upland and facultative species.

Table 5-12. Estimated coverage of EAV versus SAV and open waters in each existing STA cell, based on 2010 aerial imagery.

STA	Cell	Cell Type	Treatment Area (acres)	SAV/ Open Water (%)	EAV (%)
STA-1E	1	EAV	534	7	93
	3	EAV	567	15	85
	5	EAV	541	15	85
	6	SAV	1043	83	17
	7	EAV	398	45	56
	4N	SAV	632	60	40
	4S	SAV	731	89	11
STA-1W	1A	EAV	702	20	80
	1B	SAV	579	80	20
	2A	EAV	705	6	94
	2B	SAV	313	96	5
	3	SAV	871	55	45
	4	SAV	365	82	19
	5A	EAV	605	46	54
	5B	SAV	2407	88	12
STA-2	1	EAV	2024	4	97
	2	EAV	2371	38	62
	3	SAV	2282	71	29
	4	SAV	1954	88	12
STA-3/4	1A	EAV	3018	35	65
	1B	SAV	3435	41	59
	2A	EAV	2506	22	78
	2B	SAV	2361	74	26
	3A	EAV	2410	5	95
	3B	SAV	2058	66	34
STA-5	1A	EAV	830	36	64
	1B	SAV	1211	88	12
	2A	EAV	839	15	85
	2B	SAV	1226	81	19
	3A	EAV	1051	17	83
	3B	SAV	937	7	94
STA-6	Section 2	SAV	1351	40	61
	3	EAV	243	17	83
	5	EAV	618	8	92

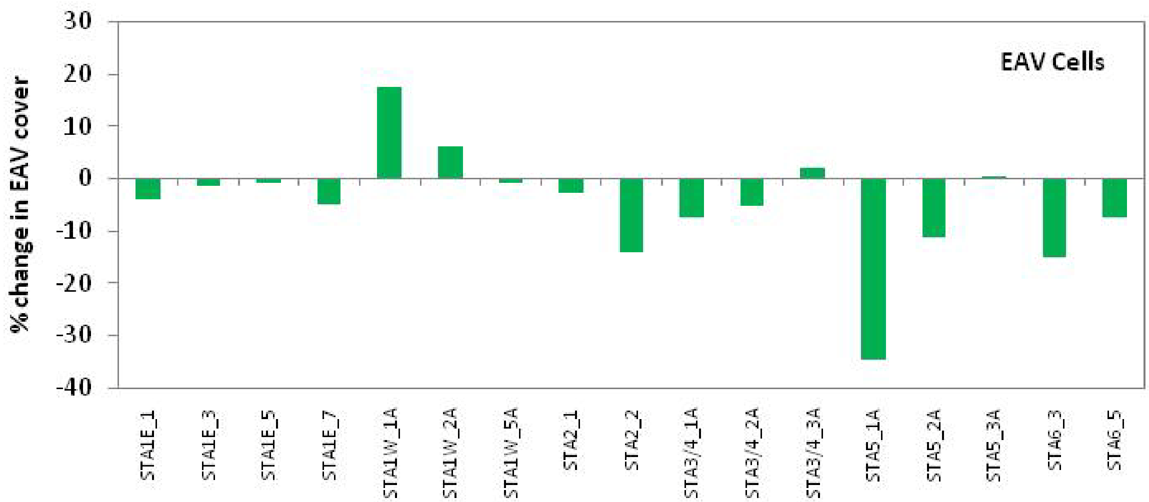


Figure 5-27. Changes in EAV in EAV-designated cells of the STAs based on aerial imagery acquired in April 2009 and May 2010.

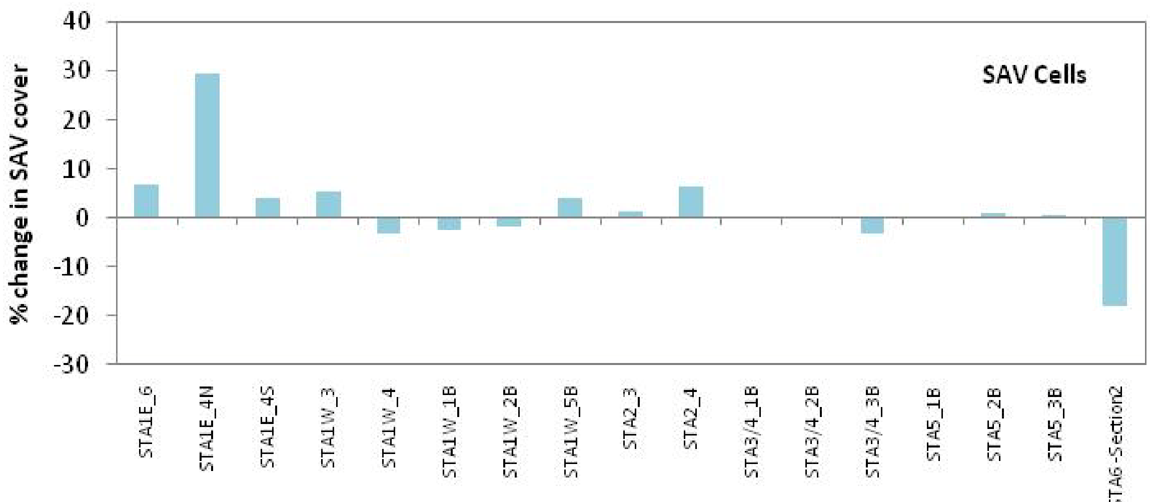


Figure 5-28. Changes in SAV and open area coverage in SAV-designated cells of the STAs based on aerial imagery acquired in April 2009 and May 2010.

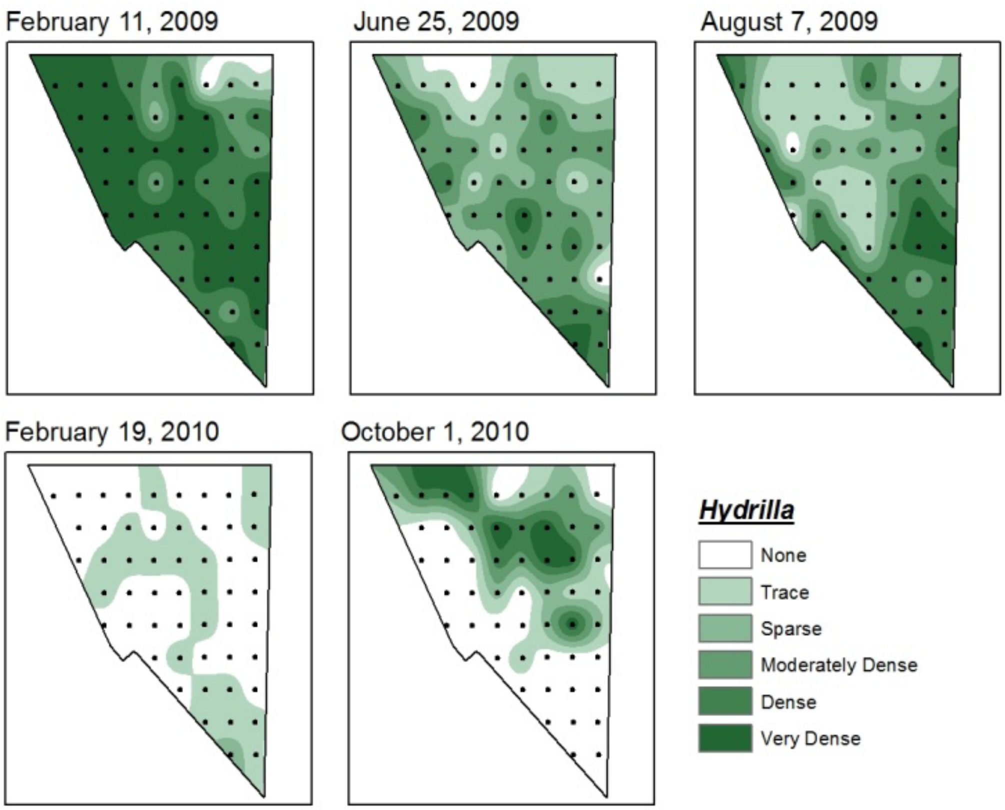


Figure 5-29. Hydrilla vegetation establishment in STA-1E Cell 6. A cell-wide die-off of Hydrilla occurred in May–June 2009.

Vegetation in Compartments B and C

A pre-operational vegetation survey of Compartments B cells was conducted on April 27, 2011, by helicopter to ground-truth aerial imagery produced earlier in the month. The southern build-out (Cells 7 and 8) of Compartment B is presently dominated by cattail. Other upland and facultative species are present. The northern build-out (STA-2 Cells 5 and 6) has predominantly upland vegetation including grasses and woody species such as dog fennel (*Eupatorium capillifolium*) and Carolina willow (*Salix* sp.), scattered cattail, and smartweed (*Polygonum* sp.). Compartment C was surveyed in May 2011. Prior helicopter and ground visual surveys of the area indicate that the area had predominantly upland vegetation including grasses, dog fennel, Carolina willow, and other upland species. Cell 4A had a large patch of willow in the northern portion and upland grasses in the rest of this cell. Cell 4B contained primarily upland grasses. Cell 5B was covered mainly by upland grasses. Cells 4 and 5A were dominated by upland vegetation including grasses and woody species, such as dog fennel and Carolina willow.

EFFECTS OF DROUGHT CONDITIONS

Maintaining optimal water levels is critical for the function and sustainability of the STAs. Prolonged dryout results in loss of SAV, stresses existing plant communities, and causes soil and litter oxidation, which then results in P flux upon cell rehydration. However, low water conditions encourage new cattail growth. When possible, rehydration of cells that have dried out should be done slowly to acclimate the plants, and discharge of water from affected cells should be delayed to the extent possible until the system has recovered from dryout impacts.

In most cases, under normal operation, the optimal water depth for EAV cells is 1.3 ft, which allows for maintaining healthy vegetation, and 1.3 to 2.0 ft for SAV cells. When drought is anticipated, the target stages are raised by another half foot (drought contingency target stages). In anticipation of the 2011 drought, contingency target stages were implemented beginning on January 18, 2011. Also, as part of the Drought Contingency Plan developed for the STAs, supplemental water from Lake Okeechobee and other sources was obtained when available. A list of outflows from Lake Okeechobee is included in Appendix 2-5, Table 3 of this volume. Between December 8, 2010, and April 30, 2011, a total of 21,700 ac-ft of water was delivered to the STAs during WY2011 for cell hydration purposes. Water depths for EAV and SAV cells of the STAs are presented in **Figures 5-30** and **5-31.** Aside from water supply-related flows, there was no other discharge from any of the STAs during the drought period.

STA-1E

Except for Cell 1, STA-1E cells remained hydrated through the drought season. A total of 600 ac-ft of lake water was delivered to this STA for hydration purposes.

STA-1W

With strategic planning and close coordination among the scientists and water control operators, all cells in STA-1W remained hydrated through the drought period. This STA received a total of 3,400 ac-ft of lake water in WY2011.

STA-2

Cell 1 began drying out in early December 2010 and was rehydrated in mid-January 2011 during a brief rain event. This cell remained hydrated for the remainder of the water year. Cells 2 and 3 remained hydrated at drought target stages through the drought season. Cell 4, which was offline for Construction B construction, was dry from December 2010 to February 2011, but was rehydrated for the remainder of the water year. A total of 6,800 ac-ft of lake water was sent to this STA primarily for hydration purposes.

STA-3/4

The water level in Cell 1A was purposely drawn down, beginning in March 2011, for vegetation recovery. Aided by regional drought, the cell dried out by the third week of April 2011. The other cells in this STA remained hydrated through the end of the water year. A total of 8,100 ac-ft of lake water was delivered to this STA. In late March 2011, G-376 structures were partially opened to allow backflow into Cell 1B to assist with SAV hydration. A temporary pump was also installed along the outflow levee between G-376E and G-376F to move water from the discharge canal into Cell 1B, but was not used until the end of the water year because water was not available.

STA-5

Due to lack of water, topographic variability, and rapid water loss through evapotranspiration and seepage, Cells 1A and 2A were dry by early March 2011. Cells 3A and 3B were dry through the water year due to Compartment C construction and also the drought. A total of 2,800 ac-ft of lake water was delivered to this STA. Cells 1B and 2B were kept hydrated through the use of the G-507 structure and later through G-350B, taking water from the Miami Canal when canal stage allowed it. During times of low water supply, it is more efficient to send water directly to the SAV cells rather than flowing water through the EAV cell. A temporary pump and the G-510 pump station were also used to move water into Cell 2B from the Miami Canal.

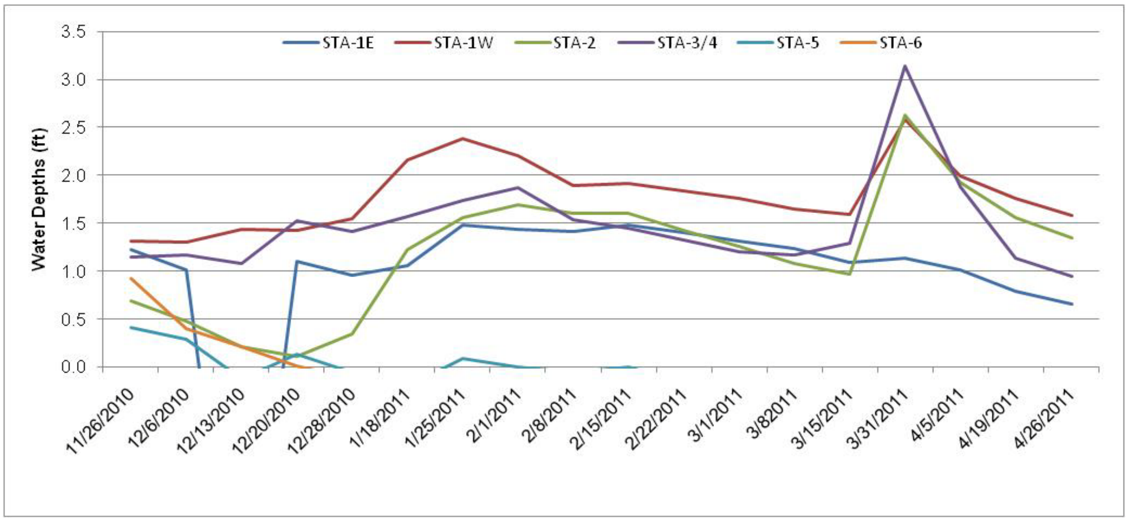


Figure 5-30. Water depths in EAV cells of the STAs during the WY2011 drought period.

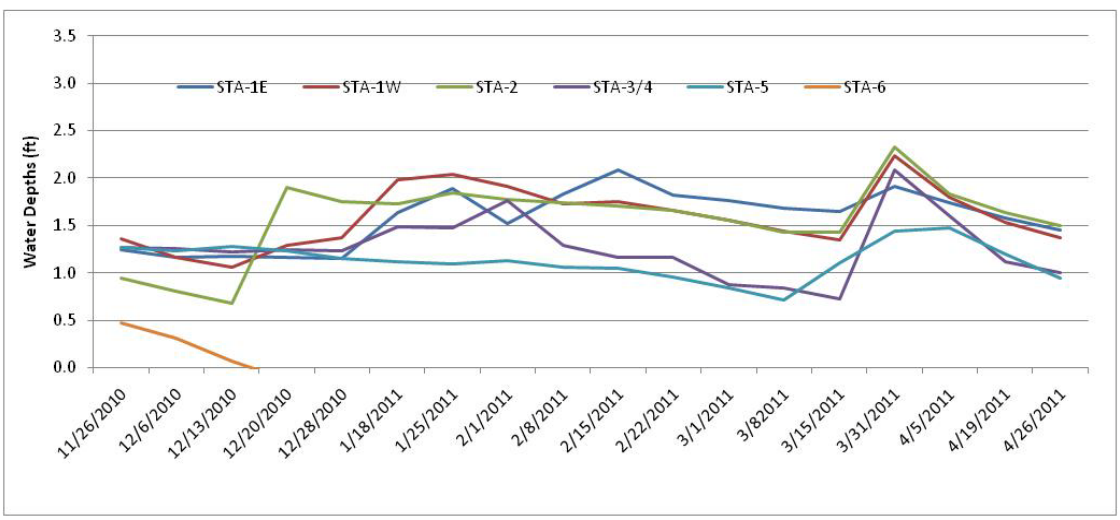


Figure 5-31. Water depths in SAV cells of the STAs during the WY2011 drought period.

STA-6

STA-6 did not receive supplemental water during the drought season, and by December 2010, Cells 3 and 5 were dry. Section 2, which was placed offline due to Compartment C construction, also dried out by December 2010.

MANAGEMENT STRATEGIES AND IMPLEMENTATION

Managing the STAs requires a concerted effort among scientists, engineers, water control operators, field station crews, and consultants. This involves routine maintenance, structural repairs, management of flows and loads, vegetation enhancements and control, and physical enhancements where needed. Data and field observations are constantly reviewed to provide a basis for short- and long-term management strategies.

WEEKLY OPERATIONAL EVALUATION

Using the most recent flow and TP data, the generation and review of STA weekly performance continued in WY2011. This report serves as a tool to manage flows and loads among the different flow-ways to optimize performance. This assessment includes comparing 7-day, 28-day, and 365-day TP and hydraulic loading values to the interim effluent limits, evaluating P loading against operational envelope targets, and comparing hydraulic loading among the different flow-ways. Data on stages, vegetation condition, and any operational constraints are also examined weekly. All this information serves as the basis for prioritizing water flow to and out of the different flow-ways of the STAs.

STA-1W ENHANCEMENTS

In WY2011, prioritization of cell discharges from Cells 3 and 4 was made to further improve performance by using the longest flow-way. Specifically, the use of G-251 was prioritized ahead of G-308 (Cell 3) and the use of G-307 was prioritized ahead of G-309 (Cell 4). In Cell 3, field surveys indicated that a remnant canal along the southwestern levee (south of G-308, north of G-259) has resulted in a short-circuit for approximately 50 percent of discharge through the southern third of the cell, thereby bypassing approximately 150 acres of potential treatment in the cell. The canal was plugged with soil material just upstream of G-259 during the last week of April (**Figure 5-31**).

STA-5 ENHANCEMENTS

The primary vegetation management measure undertaken in STA-5 in WY2011 was planting bulrush in unvegetated gaps in existing emergent vegetation strips in Cell 1B. These gaps were suspected to contribute to a hydraulic short circuit along the entire length of this SAV cell. By April 2011, planted bulrush was established and effectively eliminated gaps in the emergent vegetation strips. Earthen plugs were also placed in three 4-foot deep gaps adjoining vegetation strips along the south levee.

Figure 5-32. Remnant ENR canal in STA-1W Cell 3 before (top) and after (bottom) soil plug was installed to eliminate short-circuiting and improve flow (photos by the SFWMD).

VEGETATION ENHANCEMENTS

STA-2 Cell 2 Vegetation Conversion

STA-2 Cell 2, with approximately 2,270 acres of effective treatment area, has historically been an EAV cell with primarily cattail and patches of sawgrass. A deep area in the northwestern portion has SAV (predominantly hydrilla), the density of which seems to fluctuate widely. The 2003 Long-Term Plan included compartmentalization of this cell and conversion of the downstream portion to SAV to further improve P removal. In February 2009, the compartmentalization portion of the plan was postponed because the cell has been performing relatively well, producing an annual outflow FWM TP concentration of 20 ppb in WY2009 (pre-conversion) and 19 ppb in WY2011 (conversion in progress). Instead, the effectiveness of converting the southern portion of the cell to SAV without physical compartmentalization is being evaluated. In April 2009, approximately 300 acres of the cell was sprayed with herbicide to begin the conversion process. The goal was to eliminate cattail and encourage the establishment of desired SAV species, such as southern naiad (*Najas guadalupensis*) and pondweed (*Potamogeton* sp.). In July 2010, as the area was being cleared of standing cattail litter, the southwestern portion of the area was aerially inoculated with SAV material, primarily musk grass and southern naiad obtained from the adjacent Cell 3. As part of the monitoring effort, vegetation surveys were conducted regularly to assess SAV establishment in the conversion area and to evaluate the health of the SAV community in the northwestern portion. Surveys conducted in August 2010 indicated a slow gradual expansion of SAV from the inoculation area towards the rest of the area (**Figure 5-33**).

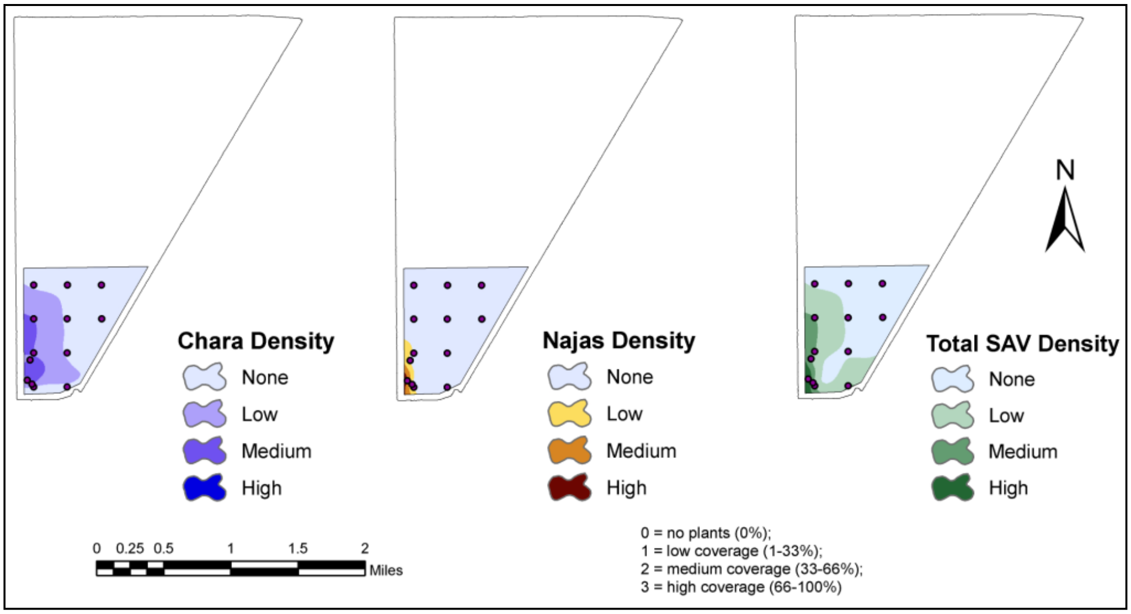


Figure 5-33. SAV coverage at the southern end of STA-2 Cell 2 in August 2010. This area is where emergent vegetation was converted to submerged aquatic vegetation beginning in April 2009. Ten locations in the conversion area with two additional points near the SAV inoculation areas were surveyed.

STA-3/4 Cell 1B Vegetation Conversion

Conversion of STA-3/4 Cell 1B from EAV to SAV was impeded by drought conditions during WY2011. Water levels in this cell, along with the other cells in this STA began dropping below target levels toward the end of WY2011. Further monitoring of drought effects and post-drought recovery, including evaluation of the status of vegetation conversion, will be reported in the future.

Bulrush Planting

Additional emergent vegetation planting was conducted to block hydraulic short circuits and optimize the distribution of flow and associated P removal in STA-1E, STA-1W, STA-3/4, and STA-5. Giant bulrush and cattail were planted in gaps in existing emergent vegetation strips and to establish new emergent vegetation strips in STA-1E Cell 4S, STA-1W Cells 2B, 4 and 5B, and STA-5 Cells 1B and 2B, which are maintained as SAV cells. New emergent vegetation strips were created near (i.e., immediately downstream of) inflows to these cells, and to increase compartmentalization of Cells 4S of STA-1E and 5B of STA-1W, where existing broad expanses of SAV are vulnerable to uprooting by high flows and wind and wave energy. Bulrush was planted to establish emergent vegetation in open water sections and sloughs in STA-1E Cell 5, the northern half of STA-3/4 Cell 1A, and throughout STA-1W Cell 5A (**Figure 5-34**).

Figure 5-34. A portion of STA-1E Cell 5 before (in 2008, left) and after (in April 2011, right) 80 cattail bales were strategically placed in WY2010 to block a hydraulic short circuit and improve flow distribution. The photo on the right shows successful establishment of planted bulrush (dark green vegetation) and floating aquatic plants trapped by the bulrush stands (photos by the SFWMD).

SAV Inoculation

In July 2010, 40 tons of southern naiad were harvested from STA-1W Cell 5B and used to inoculate STA-1E Cell 6 via helicopter. The harvested naiad was dropped at 56 points throughout Cell 6, which was devoid of SAV due to massive uprooting of hydrilla in spring 2009. Efforts to encourage establishment of SAV species will continue in this cell. Further compartmentalization with emergent vegetation strips is also planned for WY2012.

STA-2 Cell 2 was also inoculated with SAV material to accelerate plant establishment in the conversion area in the southernmost portion of this cell. Approximately 300 acres of cattail were sprayed in 2009 for the initial conversion. Monitoring of SAV establishment will continue and additional inoculation may be done as necessary.

STA-3/4 Cell 1A Vegetation Recovery Enhancement

STA-3/4, particularly Cells 1A and 2A, has been compromised by frequent deep water events, which has led to declining densities of cattail, particularly in the northern half of Cell 1A. Therefore, the District is revitalizing the cattail stand by managing a dry season drawdown of water levels to provide conditions for vegetative expansion, planting of bulrush, and colonization of new seedlings. A water-level drawdown, through the use of three temporary pumps was initiated on March 1 and will continue until early WY2012. Bulrush was planted in large unvegetated areas along the northeastern and northwestern sections in April 2011. Monitoring the effects of the drawdown will continue in the coming months.

APPLIED SCIENTIFIC STUDIES IN WY2011

Due to the complexity of the STAs, the many operational challenges, and the demand to achieve low outflow concentration, scientific investigations and research are continuing in the STAs. These studies include long-term and continuing surveys, short-term surveys, and controlled studies. In general, studies and surveys are conducted to address key issues such as: (1) understanding and documenting the condition of the STA during the water year reporting period, (2) evaluating proposed and completed enhancements, (3) evaluating impacts of extreme weather condition, (4) investigating failing or poor performance, and (5) finding ways to further improve performance. **Table 5-13** summarizes these studies grouped into two categories according to their primary purpose: (1) monitoring and documenting STA condition, and (2) evaluating ongoing or potential management strategies or technologies. Some of these studies or the rationale and objectives have been discussed earlier in the chapter. Some studies are directly linked to ongoing field implementation of management strategies (e.g., STA-3/4 Cell 1A drawdown evaluation), and some are directly linked to permit or Long-Term Plan requirements (e.g., vegetation surveys).

More importantly, in the coming months, scientists and engineers will continue to analyze period of record data for the STAs to better understand the mechanisms for phosphorus treatment, influence of various biogeochemical factors on STA performance, and correlating various management strategies and enhancements with STA performance. Results of these studies and data analyses are reported in the SFER or published in peer-reviewed journals or internal publications, whichever is most appropriate for reporting purposes, as the study is completed or as sufficient data is collected.

Table 5-13. Summary of Applied Scientific Studies including objectives and status in WY2011.

Study	Description and Objectives	Findings and Status, as of April 30, 2011
Purpose: *Evaluate different management strategies to improve treatment performance of the STAs*		
STA-1W Mesocosm P Study	This is a three-year study to investigate whether several species of native aquatic macrophytes (sawgrass, water lily, spikerush, and water lily + spikerush) can be used to enhance the treatment performance (TP removal) of the STAs. The TP removal capability of these species is being compared to that of cattail and SAV, plant communities that currently dominate the STAs. The study is being conducted at the STA-1W South Research Site.	This is the second year for the mesocosm study, the first year being a grow-in period, and a period of adjustment of controls and instrumentations. Initial findings indicate a long period of phosphorus flux from the soil material followed by flux from decomposing litter and detrital material, resulting in higher concentrations in the outflow than the inflow water (outflow from STA-1W). The amount of flux is gradually decreasing. Initial results also indicate lower outflow concentrations from water lily tanks and highest in tanks containing spikerush. Data collection is continuing in WY2012.
STA-3/4 PSTA Project	This project, which began in WY2007, is a field implementation of PSTA technology aimed at further lowering outflow TP concentration in STA-3/4. The outflow concentrations to date have been promising, but further evaluation of the data will aid in a better understanding of the mechanism of PSTA technology and allow a more accurate assessment of its performance.	The STA-3/4 PSTA project structures and its operation are currently being modified to enhance flow data accuracy. In addition, a more in-depth scientific evaluation is being initiated beginning WY2012. Aside from water quality, the following will be surveyed and tested: sediment, vegetation, periphyton, and enzyme activities. WY2011 PSTA project results are included in this chapter.
Purpose: *Document STA condition, success of STA enhancements, impact of extreme events, trends in treatment performance and other issues of critical importance to the STAs.*		
STA Vegetation Monitoring: Aerial Imagery	Aerial photographs (using high-contrast infrared film) of the STAs are taken annually during the summer to document vegetation coverage (emergent vegetation versus SAV+open water areas) in accordance with the Long-Term Plan and individual STA operating permits. Specific areas of interest in the STAs are mapped in more detail on an as-needed basis. Aerial photographs, together with ground-truthing data, have been used to evaluate vegetation density on a relative basis in selected areas. Vegetation mapping and GIS interpretation efforts are associated with this project, and findings are reported annually in the SFER.	Results of the 2010 imagery are presented in this chapter. The 2011 imagery is being processed and will be presented in the future. Further analysis of vegetation density index for selected areas in the STA is under way and results will be presented in a future SFER.
STA Vegetation Monitoring: Ground Surveys	Since infrared aerial photography does not image SAV in the STAs to any appreciable degree, ground surveys are conducted to assess SAV species coverage and relative abundance. Surveys are also conducted as part of extreme event assessments. Spatial species distributions are mapped and reported annually in the SFER and as needed for performance-related evaluations.	Results for STA-1E are presented in the chapter. Additional SAV maps will be presented in the future.

Table 5-13. Continued.

STA-3/4 Cell 1A Drawdown Evaluation	Evaluate baseline and post-drawdown condition of vegetation in STA-3/4 Cell 1A, which has been negatively impacted by extended periods of deep water. Results were compared with data from the adjoining cell (Cell 2A), which was not purposely drawn down. Monitoring includes site surveys and vegetation analysis. Results from this study will help in determining if lowering water levels can be incorporated as a routine management strategy to maintain healthy emergent vegetation in the STAs.	Initial results indicate that comparison between Cells 1A and 2A may have been complicated by drought and followed by heavy rains that affected both cells. There was a noticeable increase in juvenile cattail density between July 2010 (flooded condition) and February (dry season), but no difference in adult cattail density was observed. Additional measurements and surveys will be done in WY2012.
STA Water Quality Internal Transects Evaluation	Evaluate phosphorus removal from the water column along the flow path of selected flow-ways in STA-1E, STA-1W, STA-2 and STA-5. Data are being used to monitor P cycling within STA flow paths under various operational and environmental conditions. Over time, these data provide needed insight about key processes such as internal P transformations and spatial relationships between vegetation type/health and P retention or sediment P release.	Results of WY2011 transect sampling are presented in the chapter, under individual STAs. Further analyses of long-term transect data will be conducted as researchers obtain sufficient data sets representing various flow scenarios. Results have also been utilized to help characterize particulate P transformations in STA-2 Cell 3 (Dierberg and DeBusk, 2008) and as evidence of background P concentrations in SAV-dominated wetlands constructed on previously farmed muck soils (Juston and DeBusk, 2011).
STA-2 Cell 2 Partial SAV Conversion Evaluation	Emergent vegetation in the southern portion of STA-2 Cell 2 was treated with herbicide in April 2009 to allow for conversion of this area to SAV in accordance with the Long-Term Plan. Several different efforts are linked to this project, including SAV surveys, sampling along water quality transects and water level monitoring. This work is being conducted by both District staff and Everglades Agricultural Area (EAA) Everglades Protection District (EPD).	An update on the SAV establishment in the initial vegetation conversion area is presented in this chapter under *Vegetation Enhancements*. WY2011 vegetation surveys indicate that *Chara* sp. is beginning to colonize the southwestern portion of the cell. Additional inoculation study using naiad in selected areas was performed in the latter part of the water year; the success of this is being monitored in WY2012.
STA-5 Performance Evaluation	Evaluate the effectiveness of various enhancement activities in STA-5 Cell 1A. Aside from analysis of inflow and outflow TP concentrations, internal water quality transects, soil chemistry, soil processes, vegetation surveys, and water flow analysis are also conducted. These same parameters will also be examined for Cells 2A and 2B to determine ways to further improve this flow-way's performance.	Due to low water conditions, the evaluation in WY2011 was limited. Based on the outflow water quality, STA-5's overall performance continues to improve. However, this could be partly attributed to low loading into this STA. Results of the comprehensive evaluation will be presented in the future.
Cattail Sustainability Investigations	Mesocosm and field studies have been conducted to investigate cattail sustainability under extreme water depth conditions (both high water and low water conditions).	Deep water mesocosm study results have been published (Chen et al., 2010). Results from the mesocosm study indicate that water depths of 91 and 137 cm significantly stresses cattails, and that the impacts from 91 cm depths are reversible while impacts caused by 137 cm flooding are not reversible even when the system is brought back to 40 cm (approximate target water depth in the STAs). Results of evaluation of deepwater impacts in STA-1E cattail cells are currently being analyzed. Further studies are needed to validate findings at the field-scale level and investigate factors involved in cattail tussock formation and the impact of tussocks on treatment cell performance.

Table 5-13. Continued.

Investigation of Factors Influencing SAV Performance and Sustainability in STAs	A better understanding is needed of the individual factors (e.g., water chemistry, soil chemistry, soil physical characteristics, herbivory), and interactions among factors, that influence SAV species distribution, persistence, and colonization/recovery in STAs. This investigation will include (1) SAV distribution and speciation as a function of water depth; (2) an investigation on the potential impacts of bird herbivory on SAV communities; (3) a mesocosm study to determine the effects of mixed EAV and SAV communities on water quality and stability of sediment P; and, (4) a large sediment core evaluation study to assess impacts of sediment treatments (drydown, floc removal, etc.) on SAV recruitment and water column turbidity.	SAV surveys were conducted on potential bird herbivory study sites and based on findings, STA-1E Cell 4S and STA-1W Cell 5B were selected and exclosures were deployed. Biomass and bird count data have been collected monthly since deployment in January 2011. SAV mesocosms were set-up and initial testing and sampling was also initiated in the later part of WY2011. Initial findings indicate that birds were actively feeding in and around the plot areas and that SAV beds exhibited damage caused by grazing. The density of hydrilla and naiad in the exclosures increased relative to the biomass density in the open plots whereas chara exhibited a decline in density in the enclosed plots. Data collection for these studies is continuing and further interpretation on the findings will be conducted once sufficient data have been gathered.
Potential Water Quality Benefits and Constraints of "Front-end" FAV communities in the STAs	This test cell-scale study, initiated in 2008, and mesocosm-scale study, initiated in 2010, are being performed to document the P removal effectiveness of floating aquatic vegetation (FAV) as a front-end vegetation for the STAs, as well as to evaluate the influence of herbicide applications to FAV on water quality. Duplicate test cells were maintained with the following vegetation: cattail, cattail + FAV mix, and FAV.	Bi-weekly water quality sampling for SRP, TP, total soluble P, and pH was conducted at the test cell inflow and outflow until April 2011. Sampling for pH and TP at the S5A facility mesocosms was initiated in February 2011. Data collection is continuing and findings will be reported in the future.
Characterization of Hydraulic Resistance of Emergent Macrophytes in STA-2 Cell 2	Many of the emergent macrophyte-dominated STA cells now contain dense vegetation stands, consisting of both living and dead plant material. Under high flow events, hydraulic resistance by the dense vegetation could be contributing to the high water depths in the front-end of many of the STA flow-ways. For this effort, water stage monitoring devices were deployed throughout an EAV cell in 2008 to help characterize internal stage changes as a function of flow rate as well as vegetation community type and condition.	Data analysis, which includes the use of spatially-explicit hydrodynamic model, has been initiated utilizing spatial data (cell geometry, topography, vegetation type, and temporal data on inflow, rainfall, and evapotranspiration. The internal stage response to flow events was calibrated by assigning resistance factors to each of the five vegetation classes found in this cell [i.e., cattails (0.56), sawgrass and other emergents (0.42), open water with or without SAV (0.32), channels (0.05), and open conversion area (with little to no vegetation but has cattail litter from previous cattail stands, 0.38)]. The model was then validated by comparing simulated water levels to observed water levels. Further details on the outcome of this study and the modeling effort will be reported in the future.
STA Canal Sediment Study	The overall objective of this study is to determine the physical and chemical characteristics of STAs' outflow canal sediment and determine its role in STA outflow phosphorus composition and concentration. In addition, inflow canal sediment in STA-2 was also characterized due to concerns about the length of this inflow canal and the variability in TP concentration inflow sampling points.	WY2011 activities included an initial reconnaissance and lab-scale studies; results indicate that at certain flow conditions, canal sediment can be contributing to the overlying water column P. A field scale and more in-depth study are needed to validate findings from the initial study. Canal water will be sampled close to the structures at varying flow scenarios. More sediment sampling is needed at selected canal locations.

SUMMARY AND INTERPRETATION OF THE STATUS, CONDITION AND PERFORMANCE OF THE STAS

The six STAs performed well in WY2011 despite the various challenges. STA-1E and STA-5 minimally exceeded the interim effluent limit, but both still met the permit criteria. In the case of STA-1E, anomalous rainfall, structural failures and repairs, vegetation decline and loss, and PSTA restrictions influenced its performance. Treatment was provided almost entirely by the Central Flow-way due to restrictions in the Eastern and Western flow-ways. Despite this, the STA was able to achieve an outflow FWM TP concentration of 22 ppb, which is a significant improvement from WY2010 (94 ppb). However, it is estimated that seepage via S-361 has contributed approximately 12 percent in the final flow and load at the outflow structure, S-362. Additional water was also sent to STA-1W. While the USACE repairs major structures and continues to plan on other enhancements to this STA, operational decisions to maintain some treatment in the Western and Central flow-ways is continuing. Vegetation in Cell 7 continues to decline while Cell 5 continues to perform poorly compared to Cell 3. Vegetation coverage of Cell 6 continues to improve since it lost most of the SAV in the early part of WY2010, however, the P loading from the upstream EAV cell must improve for this flow-way to stabilize and perform effectively.

The performance of STA-1W (outflow FWM TP concentration of 25 ppb and 83 percent TP load reduction) was at the lowest range this STA ever achieved since it started operation in WY1995. Low flows and loads to this and other STAs in WY2011 helped achieve low outflow TP concentration. In addition, the steady improvement in STA-1W's performance is an indication of continued success in enhancements and rehabilitation in 2005–2007 and the effectiveness of a methodical process of operating the different flow-ways. Vegetation in both the EAV and SAV cells has remained stable, although Cell 5A continues to have open unvegetated areas.

STA-2 performance also improved, with the lowest outflow TP concentration (15 ppb FWM) and 80 percent P load removal in WY2011, despite a pause in operation of Cell 4, and ongoing vegetation conversion in the southern portion of Cell 2. Evaluation of the vegetation conversion in Cell 2 will continue in WY2012 and additional conversion will be evaluated based on the cell performance. Current operational condition (i.e., cell target stage versus static water level at the inflow supply canal and weir crest elevation at the cell outflow) limited the flows to Cell 1 in WY2011, and as a consequence, this cell had almost half the HLR and PLR of Cells 2 and 3. One of the operational goals for WY2012 is to distribute the flow more evenly among the functioning flow-ways.

STA-3/4 continues to be the best performing STA, having achieved outflow concentrations less than 20 ppb as it has in previous years. The biggest issue this STA faces is the inability to regulate the amount of flow within a short period. During heavy rain events, the STA receives high flows causing deep water conditions, particularly in EAV cells where resistance from dense cattail stands causes water depth to increase even higher. As a result, the condition and coverage of cattail in the northern regions of Cells 1A and 2A have been declining. Efforts to rehabilitate Cell 1A is under way, taking advantage of the dry season and using temporary pumps to draw the water down.

STA-5 had the lowest HLR (0.39 cm/d) and PLR (0.23 $g/m^2/yr$) but the highest FWM inflow concentration (160 ppb) in WY2011 compared to the other STAs. The resulting STA outflow FWM TP concentration was 47 ppb, which is the highest among all the STAs. However, this is the best performance achieved by this STA over its period of operation, an indication of improved performance**.** This can be attributed to various factors, including reduction in hydraulic and P loading particularly as influenced by recent drought events, decrease in soil P flux over years of

STA operation and peat formation, decrease in inflow TP concentrations, and various enhancements including sediment dredging from the STA inflow canal, filling of a slough area in Cell 1A in 2009 and vegetation changes.

In STA-6, the outflow TP FWM concentration was 25 ppb, which is much lower than values achieved in WY2010 and WY2009. This excellent performance was achieved despite this STA receiving additional flows due to STA-5 restrictions and from Compartment C construction-related dewatering, and with Section 2 being offline for construction. Previous years' investigations about this STA indicated that the frequent cycles of extended dryout (as a result of drought or lack of flows during the dry season) and subsequent reflooding has resulted in high outflow TP concentration.

Inflow TP concentration and PLR have a significant influence on outflow TP concentration at both the STA and treatment cell levels. There is a highly linear and significant positive relationship between inflow and outflow TP concentrations at both STA and treatment cell levels, and this relationship is more dramatic in EAV cells. The relationship between PLR and outflow TP is non-linear with an inflection point at around 1.0 $g/m^2/yr$. Keeping PLR at less than 1.0 $g/m^2/yr$ can help achieve approximately 20 ppb or lower in SAV cells, and maintaining a loading rate of 2.5 $g/m^2/yr$ in EAV cells can help achieve P concentrations of 60 ppb or below in the front-end cell of a sequentially designed EAV-SAV flow-way. At very low loading rates (e.g., 0.5 $g/m^2/yr$ or lower), factors other than PLR are influencing the outflow TP concentration. Future evaluations will aim at understanding what those other controlling factors are, which are critical in finding ways to further lower outflow TP concentrations.

Results of the water quality transect studies reveal different treatment patterns for the different flow-ways and under different flow scenarios. Flow-ways differ in terms of topography, shape, vegetation composition, and bottom substrate (i.e., soil and floc), which could be influencing the patterns observed. In a properly performing STA, most of the soluble reactive P is readily removed from the water column, and the residual P is comprised of DOP and PP. In most cases, as presented in this chapter, and under low to moderate flow events, the bulk of TP reduction occurs before the first half of the flow-way. More data is needed that represents various flow conditions before any meaningful conclusion can be made.

Results of WY2011 soil monitoring for both STA-1W and STA-3/4 reveal little change from the previous sampling event (approximately three years ago). Most of the changes are reflected in the floc layer and primarily on the organic matter content (AFDW) and TP concentrations. Generally, TP is higher in the floc layer than in the 0-10 cm soil layer. In STA-1W, Cells 2B and 4, which underwent soil disking and removal, respectively, the difference between the floc layer and soil organic matter and TP contents is not as distinct as the undisturbed or less disturbed areas. This indicates that since the floc material sampled in WY2011 is relatively recent accrual, organic carbon and TP have not accumulated to the level found in other less disturbed or undisturbed areas, including those that have been operational for the same period. For both STA-1W and STA-3/4, the highest soil TP concentrations were found in the EAV cells, which are in the front end of the treatment flow-way. The contribution of stored P in floc and soil layers has been studied widely and published in several publications, but they have been less explored in the STAs. Since these wetlands are subject to periodic dryout, the role of stored P in overall P cycling and its contribution in the outflow TP values need to be studied further. This examination requires not just basic soil chemical analysis, but a study of the processes (e.g., P flux with repeated cycles of dryout and reflooding, isotherm reactions to determine the equilibrium P concentration of the accreted layer, and diffusion studies to determine the amount of P released from the soil layer under no flow and flow condition). Results from these studies can then be analyzed with those from other studies such as the water quality transect studies, soil chemical analysis results, and water quality to be able to quantify the role of soil in overall STA performance, and perhaps make proper recommendations to further improve outflow concentrations. It has been demonstrated in STA-1W that removal or disking of enriched soil with high amounts of reactive P and easily resuspended particulates can improve a cell's performance. Although this practice is costly, when the opportunity exists, such as during dryout, some type of soil management may help a cell improve or recover. In new areas, such as cells in Compartments B and C with high levels of labile and moderately labile P, disking of soil to bury the highly enriched layer may accelerate achievement of desired performance.

In both STA-1W and STA-3/4 also, the surface soil layer is organic, with greater than 70 percent AFDW, while in the floc layer, the type of recent or current vegetation defines the AFDW level. In areas that have been recently converted to SAV (e.g., STA-1W Cells 1B and 3), the sediment still reflects the contribution of previous accretion with organic matter content of 59 and 70 percent, respectively. In cells where the dominant vegetation has been SAV at least for the past three years, the organic matter content is less than 50 percent, indicating accretion of more mineral material. This information is important because the stability of P in mineral and organic soils could differ, depending on other biogeochemical and hydrological factors. A study on stability of accreted layer for selected STA cells and its role in internal P cycling will be completed in WY2012 and results will be reported in the future.

Based on initial analysis of soil accretion rates, the average soil and P accretion rates are highest in STA-3/4 (1.7±0.8 cm/yr and 3.3±2.0 $g/m^2/yr$) compared to STA-1W and STA-2 with a soil accretion rate at approximately 1 cm/yr and P accretion rate of approximately 2 $g/m^2/yr$. Lower soil accretion in STA-1W and STA-2 when compared to STA-3/4 is likely a result of the dryout experienced in STA-1W and STA-2, particularly the EAV cells during the recent drought. Dry condition accelerates soil oxidation and consequently, soil loss and compaction.

Aside from the effects of runoff, the difference in P retention rates may be attributed to P mining from subsurface soil as deeply-rooted cattail uptakes nutrients from deeper soil layers and deposits it on the surface via litter fall and decay. Based on the consistently low outflow concentrations from STA-3/4, it is apparent that the higher rate of P accretion is not a concern at this time, but must be analyzed further to determine if these observed differences are significant, and to determine the stability of the accreted P.

Vegetation information gathered to date show that there is no cell with a monotype of vegetation. In other words, EAV exists in SAV-targeted cells and SAV exists in EAV-targeted cells. The extent of coverage changes seasonally, and users of this information should realize that the coverage on the day of aerial imagery acquisition or SAV ground survey may not reflect the condition for the entire year. The results presented in this chapter were from images acquired in May 2010, towards the end of the dry season, which could have biased the results. Based on the data, EAV coverage ranged from 5 to 34 percent in established SAV-targeted cells, and much higher in cells that are still undergoing conversion or have been dried for construction purposes or lack of flow. In EAV-targeted cells, as much as 46 percent of the area has SAV and open water with no vegetation. There are also smaller areas that are colonized with floating aquatic vegetation, although those are actively controlled. The reported area coverages are gross estimates that allow the authors to do a rough temporal analysis despite the large uncertainties. The information is useful in assessing status of conversions, tracking vegetation history over years of operation, and in documenting impacts of extreme weather conditions. Since these data do not indicate the health of vegetation, additional surveys, or more in-depth scientific studies are sometimes needed for cells that may be having performance issues.

In WY2012 and beyond, the District scientists and engineers will continue to analyze the data further to better understand the mechanisms and factors affecting STA performance, continue to work with the operations group to help ensure optimal and adaptive management of the STAs, and continue researching ways to further improve STA performance.

RECREATIONAL OPPORTUNITIES AND ACTIVITIES

Various public recreation opportunities continue to be available in the STAs. Trailheads, boardwalk, and viewing platforms provide excellent opportunities for wildlife viewing. Fishing is also allowed in the external canals of the STAs. STA-1E, STA-1W, and STA-3/4 are open to the public and have information kiosks. Two public access sites at STA-3/4 include several miles of trails for hiking, biking, and wildlife viewing. STA-3/4 also has a boat ramp that leads to 27 miles of canals for fishing. Facilities at STA-1E and STA-1W are available for hiking, biking, and fishing in the waters outside the STA. STA-1E allows catch and release fishing in the internal cells of the STA. A boardwalk and viewing area at STA-1W provide added opportunities for birdwatchers and nature viewing. In STA-5, a wheelchair-accessible boardwalk/bird blind to enhance recreational opportunities was built 100 yards into the STA. Additional public access, including a boardwalk, will be constructed as part of the Compartment C project.

HUNTING

The WY2011 STA hunting program, primarily for alligators and waterfowl, was coordinated with the Florida Fish and Wildlife Conservation Commission (FWC). Hunting was limited to weekend days to minimize impacts on STA management activities. The use of motorized boats is not allowed during hunts in the STAs.

In WY2011, there were 300, 200, and 50 alligator hunt permits issued for STA-1W, STA-3/4 and STA-5, respectively, with each permit allowing two alligators to be harvested. A total of 221, 126, and 76 alligators were harvested from STA-1W, STA-3/4, and STA-5, respectively.

STA-1W, STA-3/4, and STA-5 were opened for waterfowl hunting in WY2011. Hunting was permitted on one weekend day per STA during the 2010–2011 waterfowl hunting season, for one to two hunt days (including one hunt for youths) from mid-November to the first week of February. With bag limits set by the FWC, a total of 7,346 hunters bagged 25,474 waterfowl.

BIRD-WATCHING PROGRAM

The STAs offer substantial bird watching opportunities. Organized bird-watching tours are conducted by the Hendry-Glades Audubon Society at STA-5. Because of diversity and abundance of species, birding tours in the STAs have been extremely popular with local and visiting birders. In 2010, approximately 900 bird enthusiasts participated in STA-5 birding tours and bird counts. In December 2010, Audubon partnered with the District to document 105 bird species and nearly 99,000 individual birds in STA-5 during the 111th North American Christmas bird count.

IMPLEMENTATION OF THE LONG-TERM PLAN FOR ACHIEVING WATER QUALITY GOALS IN THE EVERGLADES PROTECTION AREA

Pursuant to the Everglades Forever Act [EFA; Section 373.4592(13), Florida Statutes], this section presents the annual update on implementation of the Long-Term Plan for Achieving Water Quality Goals in the EPA (Long-Term Plan) (Burns and McDonnell, 2003) and subsequent amendments. Achieving Everglades water quality standards by implementing the Long-Term Plan is one of the strategic priorities of the District and is required by state and federal law. For this reporting period, a cross-walk of Long-Term Plan-related reporting is presented in Appendix 5-5 of this volume. Additional supporting information on Long-Term Plan reporting is available in the *2005–2011 SFERs – Volume I, Chapter 8*.

The Long-Term Plan is a comprehensive set of water quality improvement measures designed to ensure that all waters entering the EPA achieve compliance with water quality standards. These measures include STA expansions, enhancements to existing STAs, expanded Best Management Practices (BMPs), and integration with Comprehensive Everglades Restoration Plan (CERP) projects. In addition, the Long-Term Plan continues a strong science-based and adaptive implementation philosophy to allow continuous improvement until the long-term water quality goals in the EPA are achieved. The District has adaptively revised the Long-Term Plan to improve performance, and these revisions were vetted with stakeholders and approved by the Florida Department of Environmental Protection (FDEP) in previous years; to date, nine plan revisions have been authorized (see *2005–2009 SFERs – Volume I, Chapter 8*). Similar to the past two years, no revisions were made to the Long-Term Plan during this reporting period.

In 1994, the Florida legislature enacted the EFA which required the District to submit a plan to the FDEP by December 31, 2003, for achieving compliance with the TP criterion and other state water quality standards in the EPA and to include the estimated costs, funding mechanisms and implementation schedules associated with the plan. Subsequently, in 2008, in *Miccosukee Tribe v. U.S. Environmental Protection Agency*, the court determined that portions of the 2003 amendments to the EFA and Florida's Everglades TP rule constituted improper changes in water quality standards and were invalid under the Clean Water Act. In general, the court invalidated provisions allowing the discharge of TP concentrations above the TP criterion even if the District was implementing the requirements of the Long-Term Plan (note that the District was not a party to that case). Although the Long-Term Plan may no longer be used as part of an EFA moderating provision, it is a District planning document and its implementation continues to be mandated under state law, until the EFA is amended directing otherwise.

STATUS OF LONG-TERM PLAN PROJECTS AND ACTIVITIES

The Long-Term Plan encompasses 48 individual projects and processes, each having a schedule, scope, and cost estimate. Since the Long-Term Plan overlaps with other agency Everglades restoration efforts, updates for Long-Term Plan projects and processes appear in other chapters of this volume (see Appendix 5-5 of this volume). The Long-Term Plan projects that address the non-Everglades Construction Project (non-ECP) basins and source controls are discussed in Chapter 4 of this volume; the Long-Term Plan projects relating to the Everglades Construction Project (ECP) STAs and Compartments B and C STA expansion projects are discussed in this chapter. **Figure 5-35** identifies the locations of the ECP and non-ECP basins addressed in the Long-Term Plan. Financial reporting related to the implementation of the Long-Term Plan is summarized in Appendix 5-5 of this volume.

The long-term Everglades water quality goal is to achieve and maintain water quality standards in the EPA, including compliance with the TP criterion established in Rule 62-302.540, Florida Administrative Code (also see Chapter 3A of this volume). Substantial progress toward reducing TP levels discharged into the EPA has been made by the State of Florida and other stakeholders. As of April 30, 2011, the EAA BMPs and ECP STAs have collectively removed 3,820 metric tons[4] (mt) of TP that otherwise would have entered the Everglades. The STAs account for approximately 1,470 mt of TP since 2004 and BMPs are responsible for removing about 2,350 mt. As described in Chapter 3A, the effectiveness of the BMP and STA TP removal efforts is demonstrated by the decreased TP loading to the Water Conservation Areas (WCAs) in recent periods compared to the baseline period, despite increased flows to the EPA. Impacted portions of the WCAs are not consistently meeting the TP criterion; therefore, additional measures may be necessary to achieve the Everglades water quality goal.

Data summaries and findings related to the individual performance of the BMPs and STAs are presented in Chapter 4 and earlier sections of this chapter, respectively. A list of the basins addressed in the Long-Term Plan is presented in Appendix 5-5. The status of water quality conditions within the EPA is presented in Chapter 3A of this volume. While it is not possible to measure specific responses of the EPA to individual Long-Term Plan projects, there is a measurable reduction in the TP levels in discharges from the ECP basins when compared to the historical period prior to implementation of the EAA BMPs and ECP STAs.

Overall, the District continues to make significant investments in support of the Long-Term Plan projects and processes. Stakeholder communication has been a hallmark of Long-Term Plan implementation, and stakeholder collaboration continued over the past year at quarterly stakeholder meetings. On February 24, 2011, the eighth annual public meeting was held at the District headquarters in West Palm Beach, FL. Further details on the Long-Term Plan are available on the District's website at www.sfwmd.gov/sta, under the *Long-Term Plan for Achieving Water Quality Goals* link.

[4] The inception-to-date numbers for the Stormwater Treatment Areas include start-up flows and loads.

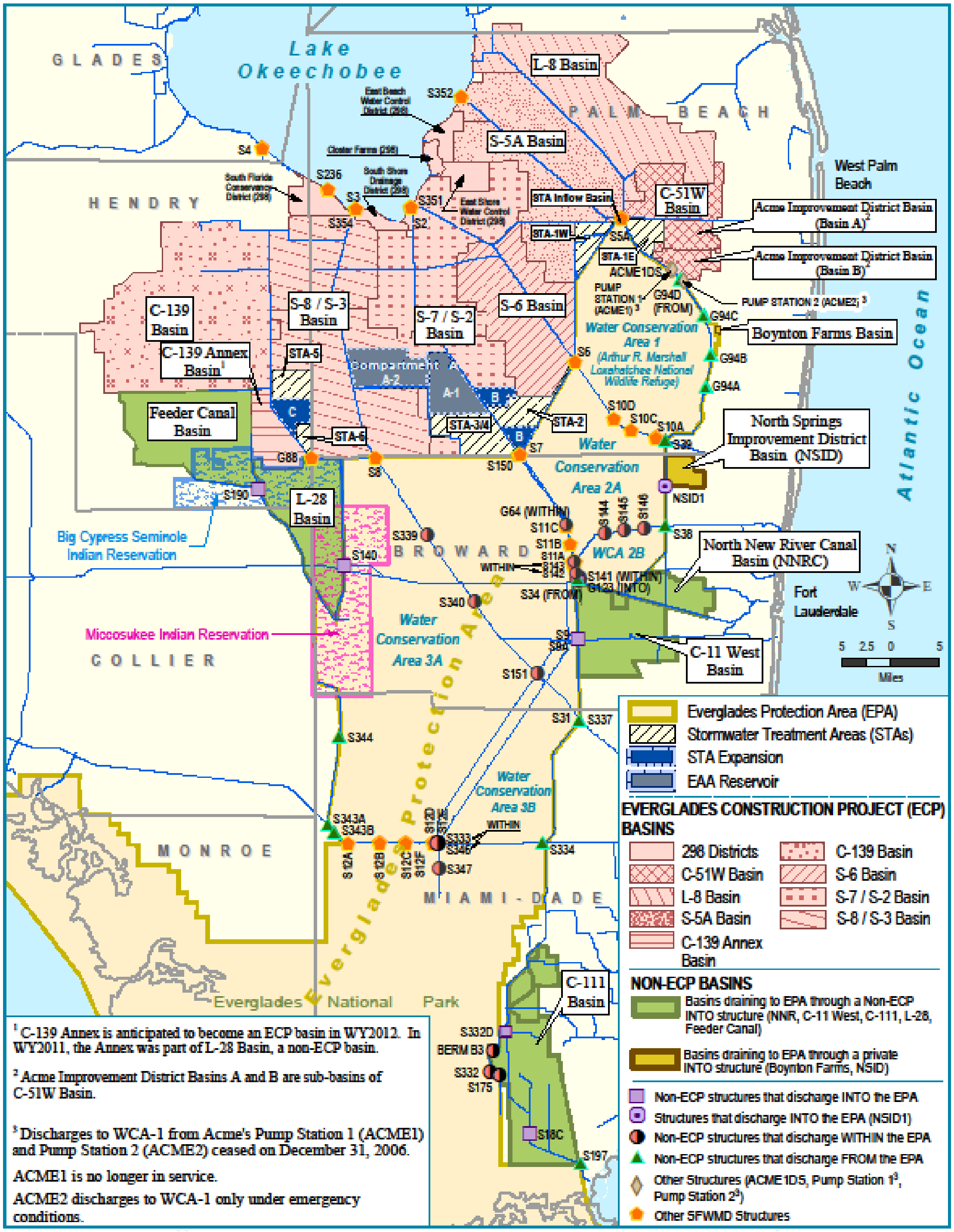


Figure 5-35. Overview of the EPA and tributary basins.

LITERATURE CITED

Burns and McDonnell. 2003. Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area. Prepared for the South Florida Water Management District, West Palm Beach, FL.

Carleton, JN. 2002. Damköhler Number Distributions and Constituent Removal in Treatment Wetlands. *Ecological Engineering*, 19(4):233-248.

Chen, H., M. Zamorano, and D. Ivanoff. 2010. Effect of Flooding Depth on the Growth, Biomass, Photosynthesis, and Chlorophyll Fluorescence of *Typha Domingensis*. *Wetlands,* 30: 957-965.

Dierberg, F.E. and T.A. DeBusk. 2008. Particulate Phosphorus Transformations in South Florida Stormwater Treatment Areas Used for Everglades Protection. *Journal of Ecological Engineering*, 34(2):100-115.

Juston, J.M. and T.A. DeBusk. 2011. Evidence and Implications of the Background Phosphorus Concentration in Submerged Aquatic Vegetation Wetlands in Stormwater Treatment Areas Used for Everglades Restoration. *Water Resources Research,* 47, W01500, doi:10.1029/2010WR009294.

Kadlec, R.H. 1999. The Limits of Phosphorus Removal in Wetlands. *Wetlands Ecology and Management*, 7: 165–175.

Kadlec, R.H. 2006. Free Surface Wetlands for Phosphorus Removal: The Position of the Everglades Nutrient Removal Project. *Ecological Engineering*, 27:361-379.

Kadlec, R.H., and S.D. Wallace. 2009. *Treatment Wetlands*. Second Edition. Taylor and Francis Group, Boca Raton, FL.

Kadlec R.H., W. Bastiaens and D.T. Urban. 1993. Hydrological Design of Free Water Surface Treatment Wetlands. G.A. Moshiri, ed. Pp. 77-86. In: *Constructed Wetlands for Water Quality Improvement*, CRC Press: Boca Raton, FL.

Mitsch, W.J., and J.G. Gosselink. 1993. *Wetlands*. Van Nostrand Reinhold, New York, NY.

Morris, D.R., B. Glaz and S.H. Daroub. 2004. Organic Matter Oxidation Potential Determination in a Periodically Flooded Histosol Under Sugarcane. *Soil Science Society of America Journal*, 68:994-1001.

Pietro, K., G. Germain, R. Bearzotti and N. Iricanin. 2011. Chapter 5: Performance and Optimization of the Everglades Stormwater Treatment Areas. In: *2011 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Reddy, K.R., and W.H. Patrick. 1984. Nitrogen Transformations and Loss in Flooded Soils and Sediments. *CRC Critical Reviews in Environmental Control*, 13:273-309.

Reddy, K.R., and E.M. D'Angelo. 1994. Soil Processes Regulating Water Quality in Wetlands. W.J. Mitsch, ed. pp. 309-324. In: *Global Wetlands: Old World and New*. Elsevier Science, Amsterdam.

Richardson, C.J. 2008. Long-term Phosphorus Assimilative Capacity (PAC) in the Everglades. C.J. Richardson, ed. pp. 567−578. In: *The Everglades Experiments: Lessons for Ecosystem Restoration*, Springer, New York, NY.

Richardson, C.J., S.S. Qian, C.B. Craft and R.G. Qualls. 1997. Predictive Models for Phosphorus Retention in Wetlands. *Wetlands Ecology and Management*. 4: 159–175.

Scinto, L.J. and D. Johnson. 2010. Soil Characterization in Stormwater Treatment Area 3/4. Final Report submitted to the South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2008. Chapter 5: STA Performance, Compliance and Optimization. In: *2008 South Florida Environmental Report*, West Palm Beach, FL.

SFWMD. 2009. Chapter 5: STA Performance, Compliance and Optimization. In: *2009 South Florida Environmental Report*, West Palm Beach, FL.

Wetlands Biogeochemistry Laboratory. 2009. Comprehensive Analysis and Evaluation of Historical Data and Information for the Stormwater Treatment Areas (STAs). Report submitted to the South Florida Water Management District, West Palm Beach, FL.

Wetzel, R.G. 1999. Organic Phosphorus Mineralization in Soils and Sediments. K.R. Reddy, G.A. O'Connor and C.L. Schelske, eds. In: *Phosphorus Biogeochemistry in Subtropical Ecosystems*, CRC Press LLC, Boca Raton, FL.