Chapter 5: STA Performance, Compliance and Optimization

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SUMMARY

Wetlands are a crucial component of the Everglades restoration program because of their ability to assimilate phosphorus (P) (**Figure 5-1**). Over 65,000 acres of freshwater wetlands (equating to about 45,000 acres of effective treatment area) have been constructed south of Lake Okeechobee in the Everglades area in order to remove excess phosphorus from surface waters entering the Everglades Protection Area (EPA) (**Figure 5-2**). As part of the ongoing efforts to restore the Everglades, the construction of six large wetlands was mandated through the Everglades Forever Act (EFA) [Chapter 373.4592, Florida Statutes (F.S.)] and the Everglades Settlement Agreement, which required the Everglades Construction Project (ECP) to build constructed wetlands, referred to as the ECP Stormwater Treatment Areas (STAs). Throughout the chapter, the ECP STAs will be referred to as STAs. The STAs (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6) are operated under EFA and National Pollution Discharge Elimination System (NPDES) permits.

The overall efforts to improve water quality in the Everglades watershed and throughout the South Florida ecosystem involve the cooperation of the South Florida Water Management District (District or SFWMD), the U.S. Army Corps of Engineers, the Florida Department of Environmental Protection, and other agencies and private landowners. This chapter serves as the reporting mechanism for their performance during Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008).

Varying in size and configuration, the STAs are shallow freshwater marshes divided into treatment cells by levees. Water flows through the system via water control structures, such as pump stations, gates, or culverts. The dominant plant communities in the treatment cells are broadly classified in the following general categories: (1) emergent aquatic vegetation (EAV), (2) submerged aquatic vegetation (SAV), and (3) floating aquatic vegetation (FAV).

Since 1994, the ECP STAs have retained over 1,000 metric tons of total phosphorus (TP) that would have otherwise entered into the EPA, reducing TP loads by 71 percent and phosphorus concentrations from an overall annual TP flow-weighted mean concentration of 158 parts per billion (ppb) to 43 ppb. For the second consecutive year, drought conditions impacted the region. Proactive operational measures to protect the vegetation in the STAs during drought conditions were initiated with positive results. Compared to WY2007 (May, 1, 2006–April 30, 2007), the STAs received less water and TP load in WY2008, and retained 80 percent of the TP load received.

STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6 are in compliance with the EFA and NPDES operating permits for WY2008. Further refinements were made in the use of near real-time data in comparing long-term performance estimates for operational decision making. In addition, three new recreational facilities opened to the public in STA-1E, STA-1W, and STA-3/4.

Figure 5-1. Stormwater Treatment Areas (STAs) attract wildlife and provide recreational activities in addition to removing excess phosphorus from surface waters entering into the Everglades Protection Area. This photo of STA-5 shows the diverse plant and bird species found in an STA marsh (photo by the SFWMD).

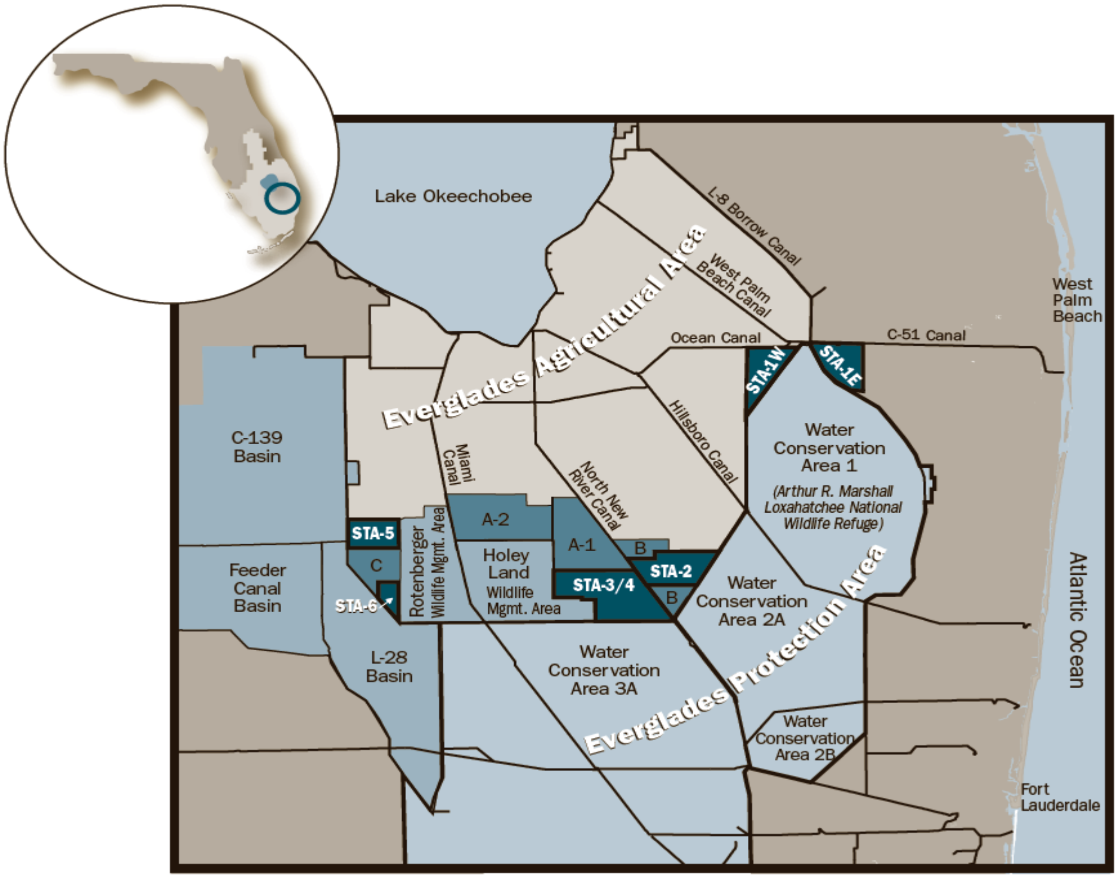


Figure 5-2. Location of the Everglades Construction Project (ECP) STAs (STA–1E, STA–1W, STA–2, STA–3/4, STA–5, and STA–6).

INTRODUCTION

This chapter serves as the reporting mechanism for the performance of the six Everglades Construction Project Stormwater Treatment Areas (ECP STAs) (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6) (**Figure 5-3** and Appendix 5-2 of this volume) that operate under the Everglades Forever Act (EFA) and National Pollutant Discharge Elimination System (NPDES) permits and Administrative Orders (AOs). The STAs vary in size and configuration, and began operation at different times over the 14 years of the ECP (**Table 5-1)**. A listing of the specific permit reporting requirements is in Appendix 5-1 of this volume. In addition to reporting on the permit-mandated requirements, various research and other issues pertaining to the STAs, such as the status of the various components identified in the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) (see Chapter 8 of this volume), are presented.

This chapter presents a general summary of STA performance during Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008), followed by the highlights of individual STA performance, construction, maintenance, research, and optimization efforts. A brief overview of the permit reporting mandates is provided, as well as STA performance in WY2008 for phosphorus (P) compliance, water quality parameters other than phosphorus, dissolved oxygen (DO), and mercury (Hg) This chapter also includes information about long-term STA performance for each STA as a whole and by individual flow-ways.

Additionally, research and monitoring results from the monitoring conducted in areas downstream of the STAs [Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), Water Conservation Area 2A (WCA-2A), and the Rotenberger Wildlife Management Area (RWMA)] are presented, which characterize the impact of hydropattern restoration activities on these areas. Summaries of STA research, the status of large-scale vegetation conversions, wildlife issues, recreational opportunities, and the impact of the drought on the STAs are also contained in this chapter (see *Drought Impacts on the STAs* section of this chapter).

New operating permits were issued for some of the STAs during WY2008, and the reporting requirements, such as Technology-Based Effluent Limitations (TBELs) for phosphorus and STA operational envelope information are also provided. This chapter concludes with an in-depth update of the status of the STA-1W rehabilitation efforts, performance of the Periphyton-based Stormwater Treatment Area Implementation Project in STA-3/4, an evaluation of STA soil data for each STA, and an update on other Long-Term Plan projects.

Further details about individual STA performance can be found in Appendix 5-2 of this volume, which contains period of record (POR) time-series graphs for inflow and outflow volume, total phosphorus (TP) load, TP flow-weighted mean concentration (FWMC), and hydraulic and phosphorus loading rates. Other appendices contain a timeline of major operational activities in the STAs from 2004 to present (Appendix 5-2 of this volume), black-necked stilt nest survey results (Appendix 5-11 of this volume), compliance monitoring for mercury in the STAs (Appendix 5-4 of this volume), information about herbicide application in the STAs (Appendix 5-10 of this volume), and the raw data for the water quality parameters other than phosphorus (Appendices 5-5 and 5-6 of this volume).

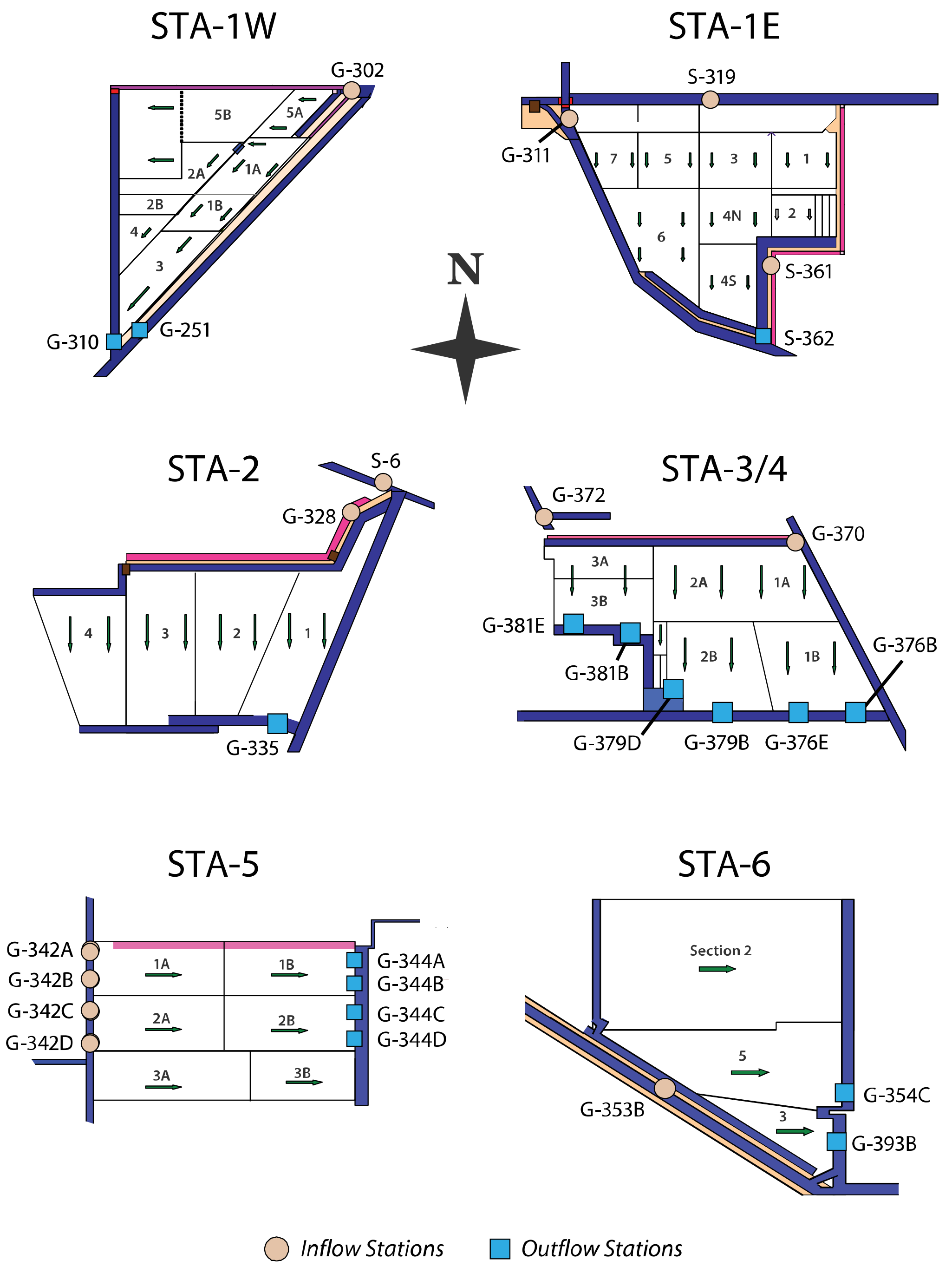


Figure 5-3. Schematics of the ECP STAs showing the treatment cell names and the permitted inflow and outflow stations.

Table 5-1. The acreage of the treatment cells within each ECP STA along with the estimated effective treatment area and the dominant vegetation community type, emergent aquatic vegetation (EAV) or submerged aquatic vegetation (SAV).

STA	Cell	Effective Treatment Area (acres)[a]	Dominant Vegetation Type
STA-1E	Cell 1	556	EAV
	Cell 2	552	SAV
	Cell 3	589	EAV
	Cell 4N	645	SAV
	Cell 4S	752	SAV
	Cell 5	571	EAV
	Cell 6	1,049	EAV
	Cell 7	418	EAV
STA-1W	Cell 1A	745	EAV
	Cell 1B	745	SAV
	Cell 2A	471	EAV
	Cell 2B	470	SAV
	Cell 3	1,026	SAV
	Cell 4	358	SAV
	Cell 5A	562	EAV
	Cell 5B	2,293	SAV
STA-2	Cell 1	1,798	EAV
	Cell 2	2,270	EAV
	Cell 3	2,270	SAV
	Cell 4	1,902	SAV
STA-3/4	Cell 1A	3,039	EAV
	Cell 1B	3,488	SAV
	Cell 2A	2,542	EAV
	Cell 2B	2,894	SAV
	Cell 3A	2,153	EAV
	Cell 3B	2,427	SAV
STA-5	Cell 1A	835	EAV
	Cell 1B	1,220	SAV
	Cell 2A	835	EAV
	Cell 2B	1,220	SAV
	Cell 3A	1,065	EAV
	Cell 3B	920	SAV
STA-6	Cell 3	245	EAV
	Cell 5	625	EAV
	Section 2	1,387	SAV
TOTAL		44,937	

[a] This effective treatment area estimate is based on the assumption that all treatment cells are operational and will change under certain operational situations. Details about how the effective treatment area for each water year is calculated are in Appendix 5-7 of this volume.

WATER YEAR 2008 HIGHLIGHTS

- STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6 are in compliance with the EFA and NPDES operating permits for WY2008. New operating permits were issued in 2007 for STA-1E/STA-1W (combined), STA-2, STA-5, and STA-6.
- Since 1994, the ECP STAs have retained over 1,000 metric tons (mt) of TP that would have otherwise entered the EPA, reducing TP loads by 71 percent and phosphorus concentrations from an overall annual TP FWMC of 158 ppb to 43 ppb (**Figure 5-4**, **Table 5-2**, and Appendix 5-2 of this volume).
- During WY2008, the six ECP STAs received a total of 775,040 acre-feet (ac-ft) of water, equating to an average hydraulic loading rate of 2.04 centimeters per day (cm/day). The TP load received was 123.2 mt, equating to an average phosphorus loading rate of 0.95 grams per square meter per year ($g/m^2/yr$). An estimated 80 percent load reduction was achieved, with the STAs retaining 98.1 mt of TP and reducing inflow TP FWMC from 129 ppb to 26 ppb (**Table 5-2** and **Figure 5-5**). Lake Okeechobee releases and diversions are listed in **Table 5-3**.
- For the second year, drought conditions impacted the region, and in WY2008, the STA Drought Contingency Plan was implemented with positive results. By setting higher water stage target levels, many of the treatment cells maintained a minimum water level, resulting in (1) less phosphorus flux observed after rehydration, (2) less impact on vegetation, and (3) fewer migratory birds nesting in the STAs compared to WY2007, thereby reducing the potential for operational conflicts.
- Further refinements were made in the use of near real-time data in comparing long-term performance estimates for operational decision making. The STA performance tool that is generated weekly was enhanced to include information to evaluate STA performance as it relates to the permit compliance limits.
- STA operations were affected again in WY2008 due to issues pertaining to migratory birds. The STAs were operated under the draft 2007 Avian Protection Plan (APP), which is currently under review by the U.S. Fish and Wildlife Service (USFWS). Surveys were conducted during the nesting season to monitor for the presence of nests and eggs; information collected helped guide STA operations for water quality treatment while avoiding impacts to nests (see *Wildlife and Avian Protection* section of this chapter).
- STA-1W rehabilitation efforts were successful, and an update of the performance results can be found in the *STA-1W Rehabilitation* section of this chapter.
- The vegetation conversion from EAV to SAV in STA-3/4, Cell 1B continues with preliminary positive results (see *Vegetation Conversion Status Updates* section of this chapter).
- Although the new STA expansion cells in STA-2, STA-5, and STA-6 became flow-capable in December 2006, not enough water was available during WY2008 to allow for flow-through conditions. STA-2, Cell 4 and STA-6, Section 2 passed start-up criteria for TP and Hg as of the end of WY2008, but STA-5 Southern Flow-way (Cells 3A and 3B) had not passed start-up due to the lack of water available to hydrate the treatment cells.

- Under the applied research program, activities focused on optimizing and sustaining STA performance in WY2008 (see *STA-related Research and Activities* section of this chapter). Multiple studies within the STAs as well as in mesocosms were conducted. Studies examining the response of cattail (*Typha domingensis*) to extreme water conditions were initiated this water year and are planned to continue in WY2009.
- Three new recreational facilities opened to the public in STA-1E, STA-1W, and STA-3/4. Some of the STAs also offered hunting and bird watching programs (see *Recreational Facilities and Activities* section of this chapter).

Table 5-2. STA Performance for Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008) and period of record (POR) 1994–2008.

	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6	All STAs ***WY2008***
Average Effective Treatment Area (acres)[1]	4,024	5,289	6,712	16,543	4,110	870	37,548
Inflow							
Total Inflow Volume (ac-ft)	138,694	116,291	204,381	295,080	13,919	6,676	775,040
Total Inflow TP Load (mt)	18.952	26.574	26.850	48.104	1.968	0.772	123.221
Flow-weighted Mean Inflow TP (ppb)	111	185	106	132	115	94	129
Hydraulic Loading Rate (HLR) (cm/d)	2.88	1.84	2.54	1.49	0.28	0.64	2.04
TP Loading Rate (PLR) ($g/m^2/yr$)	1.16	1.24	0.99	0.72	0.12	0.22	0.95
Outflow							
Total Outflow Volume (ac-ft)	125,391	117,002	227,003	296,162	7,075	2,458	775,091
Total Outflow TP Load (mt)	3.1	7.6	6.1	7.4	0.8	0.1	25.1
Flow-weighted Mean Outflow TP (ppb)	20	53	22	20	96	38	26
Hydraulic Residence Time (d)	23	14	18	21	12	5	
TP Retained (mt)	15.8	19.0	20.8	40.7	1.1	0.7	98.1
TP Removal Rate (g/m2/yr)	0.97	0.89	0.76	0.61	0.07	0.56	0.65
Load Reduction (%)	83%	71%	77%	85%	58%	85%	80%
Period of Record Performance							
Start date	Sep-04	Oct-93	Jun-99	Oct-03	Oct-99	Oct-97	***1994 - 2008***
Inflow Volume (ac-ft)	318,544	2,668,189	1,940,844	2,075,025	950,121	445,569	8,398,291
TP Retained to Date (mt)	40.308	357.480	200.927	262.833	160.199	36.132	1,057.877
TP Outflow to Date (ppb)	78	55	21	19	106	21	43
Permit Mandated Reporting for WY2008 for the permits: **Everglades Forever Act (EFA), National Pollutant Discharge Elimination System (NPDES), Administrative Order (AO)**							
Operational Permit Phase	**Stabilization**	**Stabilization**	**Stabilization**	**Post Stablization[3]**	**Stabilization**	**Stabilization**	
In compliance with Permits?	Yes	Yes	Yes	Yes	Yes	Yes	
Within Operational Envelope?	Yes	Yes	Yes	Yes	Yes	Yes	
Was EFA TBEL Achieved?	Yes	No[2]	Yes	Yes[3]	No[2,4]	No[2,4]	
Was NPDES/AO TBEL Achieved?	Yes	Yes	Yes	Yes	No[2,4]	No[2,4]	
Was Dissolved Oxgyen (DO SSAC) achieved? [5]	Yes	No	Yes	Yes	Yes	No	
Were there any Water Quality (other than Phosphorus) excursions? [5]	None	None	None	None	TN	TN, Alk	
Permit Limits							
Operational Envelope:							
Avg. Inflow volume (ac-ft)	*160,121*	*164,155*	*276,650*	*576,021*	*135,000*	*48,793*	
Max. Inflow volume (ac-ft)	*233,411*	*321,529*	*432,241*	*977,270*	*209,265*	*94,234*	
Avg. Inflow TP load (mt)	*26.855*	*35.294*	*34.882*	*64.821*	*33.300*	*5.148*	
Max. Inflow TP load (mt)	*39.244*	*70.596*	*57.318*	*117.668*	*63.929*	*10.714*	
Outflow EFA and NPDES/AO Limits:							
Outflow EFA TBEL TP (ppb) Limit	*27*	*29*	*23*	*76*	*81*	*30*	
Outflow NPDES/AO TBEL TP (ppb) Limit	*68*	*76*	*23*	*76*	*81*	*30*	

1: Average effective treatment areas reflect treatment cells temporarily off-line for plant rehabilitation or LTP enhancements. Refer to Appendix 5-7 for details on how the effective treatment areas were estimated.

2: Because the STA is in the stabilization phase of the permit, excursions to the TBEL limit are allowed. Details found in "ECP STA Performance" section of this chapter.

3: STA-3/4 is operated under permits issued in 2004 and is considered to be in the post-stabilization phase and the TBEL limit is set at 76 ppb as defined in those permits.

4: The phosphorus and hydraulic loadings received by the STA were below the historic range of values used to develop the TBELs.

5: See "Dissolved Oxygen", "STA Performance Water Year Synopsis" and "Water Quality" sections of this chapter for details.

Notes:

Flow-proportional autosamplers samples are used to calculate TP loads and concentrations, if available.
Period of record calculations Include start-up data.
TN = Total Nitrogen (mg/L), Alk = alkalinity (mg/L $CaCo_3$)

Table 5-3. Information fulfilling the permit-related reporting requirement for the amount of water diverted around the STAs and received by the STAs from Lake Okeechobee as regulatory inflows in WY2008.

Permit-Mandated Reporting for WY2008								
	STA Diversion				**Inflows from Lake Okeechobee**			
STA	**Structure**	**Volume (ac-ft)**	**TP Load (mt)**	**FWMC TP (ppb)**	**Structure**	**Volume (ac-ft)**	**TP Load (mt)**	**FWMC TP (ppb)**
STA-1E	G-300	0	0		G-311	17	0.003	
					S-319	0	0	
Total		0	0			17	0.003	157
STA-1W	G-301	0	0		G-302	181	0.05	
Total		0	0			181	0.05	210
STA-2	G-338	0	0		S-6	478	0.03	
	G-339	3*	0					
Total		3*	0			478	0.03	54
STA-3/4	G-371	211*	0.01*		G-370	160	0.01	
	G-373	5,775*	0.34*		G-372	236	0.02	
Total		5,986*	0.35*	48*		396	0.03	54
STA-5	N/A				N/A			
Total				N/A				N/A
STA-6	G-407	0	0		N/A			
		0	0					

* During WY2008, all the water that flowed through G-339, G-371, and G-373 was for water supply releases and not due to limited capacity conditions in the STAs.
N/A – Not applicable

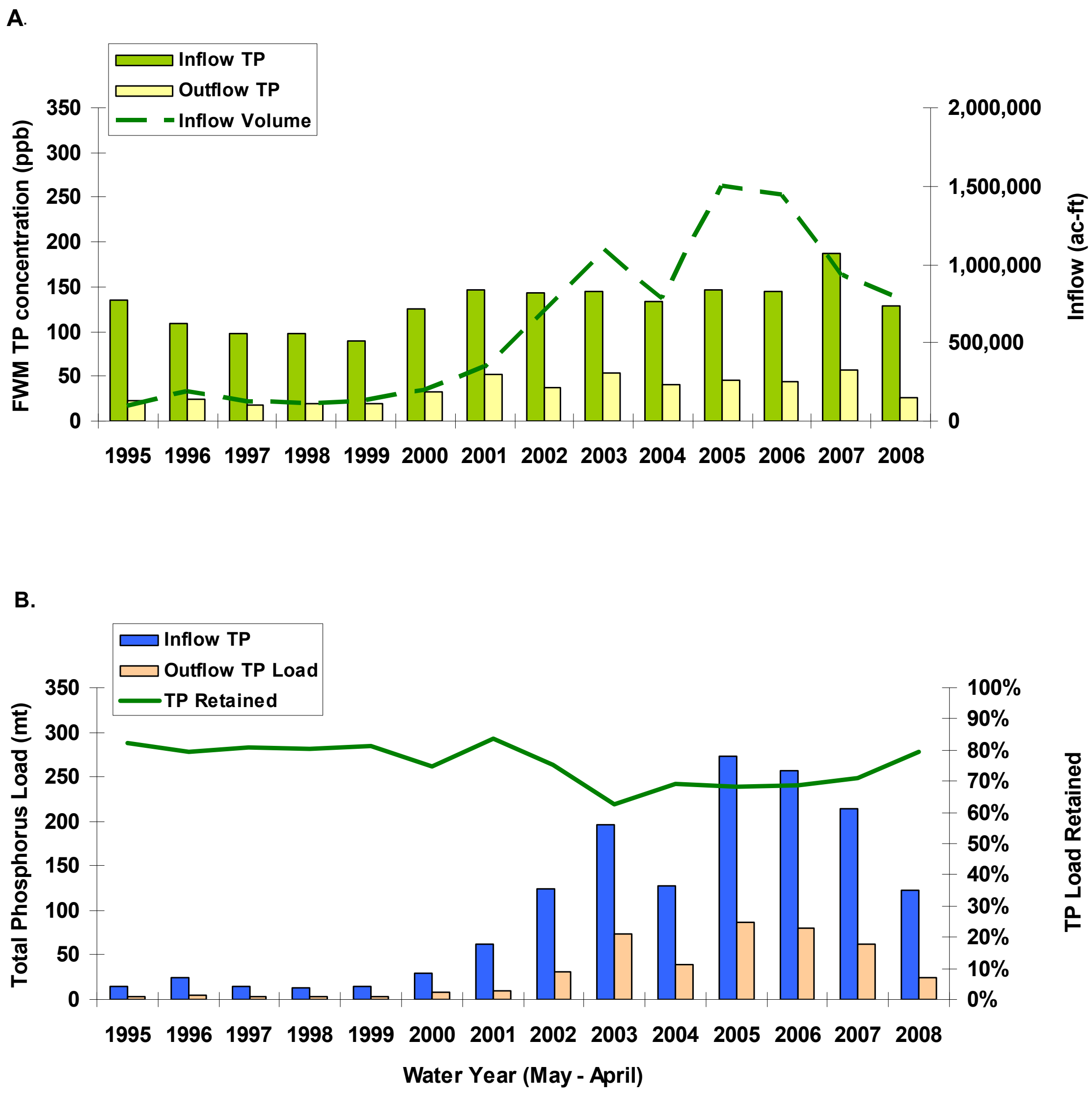


Figure 5-4. Overall annual inflow and outflow total phosphorus (TP) flow-weighted mean concentration (FWMC) and inflow volume (panel A). Overall annual inflow and outflow TP loads and percent TP load retained by all the STAs (panel B). The amount of effective treatment area in the STAs varies as more treatment cells are built or as existing treatment cells undergo temporary restrictions during maintenance activities.

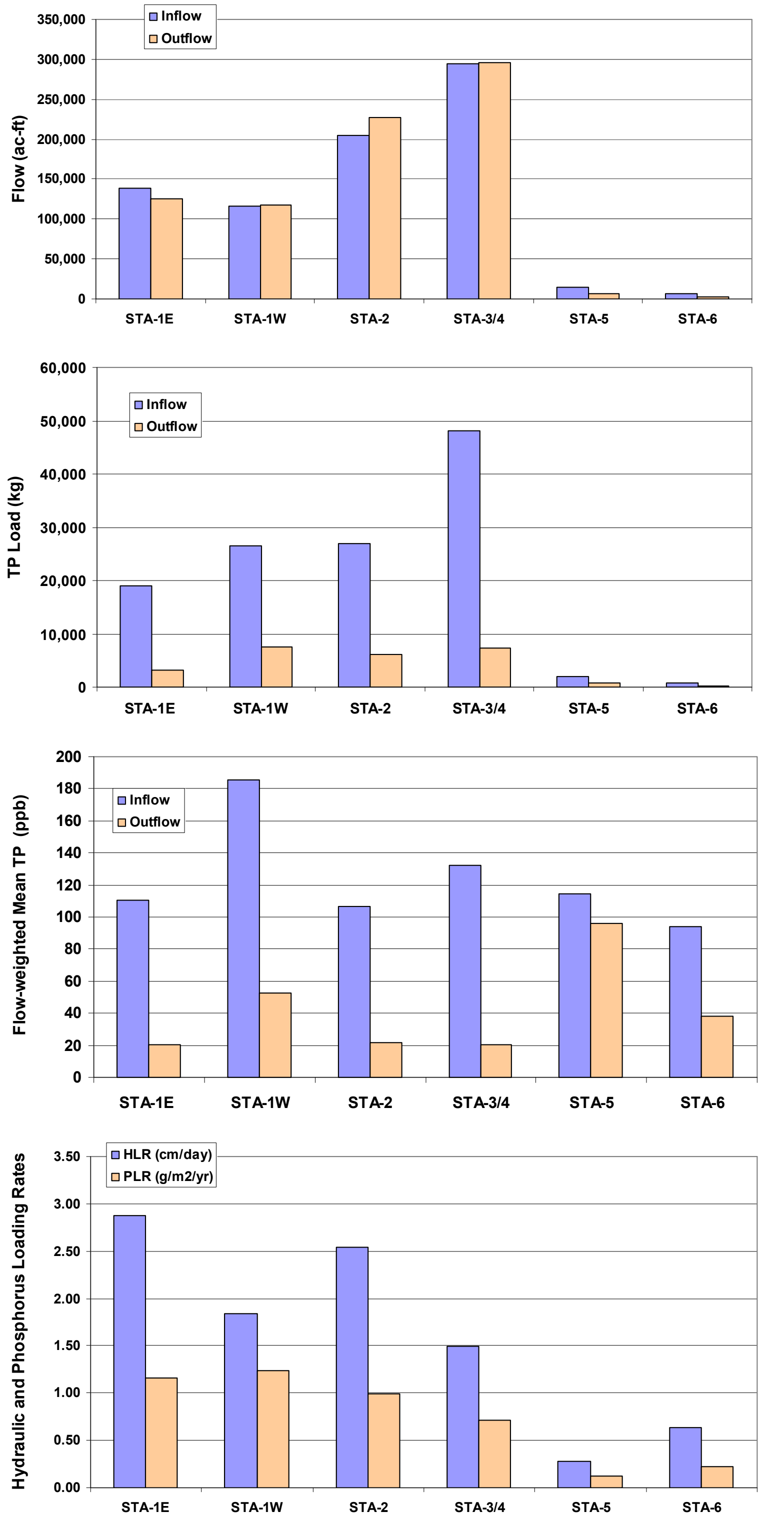


Figure 5-5. Hydraulic and phosphorus loading rates and outflow TP FWMC for the ECP STAs for WY2008.

INDIVIDUAL STA HIGHLIGHTS

STA-1E

- Cells 3, 4N, 4S, 5, 6, and 7 were online for the entire water year. Cells 1 and 2 came online in late May 2007, following the completed construction of the U.S. Army Corps of Engineers (USACE) Periphyton-based Stormwater Treatment Area (PSTA) Demonstration Project in February 2007.
- In anticipation of drought conditions, in September 2007 the between-storm target stages in the SAV cells (Cells 3, 5, and 7) increased by 6 inches (in.) to maintain water levels and protect the vegetation from dryout conditions.
- S-375 was taken offline in March 2008 due to structural failure of the culverts; the structure will remain offline during WY2009 for repairs.

STA-1W

- The Northern Flow-way (Cell 5) was operational during the entire water year (restricted operations in May and June 2007 for SAV reestablishment). The Eastern Flow-way (Cells 1 and 3) and Western Flow-way (Cells 2 and 4) were offline part of the water year to allow for plant reestablishment following completion of Long-Term Plan Enhancement projects and rehabilitation efforts in WY2007.
- In anticipation of drought conditions, in September 2007 the between-storm target stages in the SAV cells (Cells 1B, 2B, 3, 4, and 5B) increased by 6 in. to maintain water levels and protect the vegetation from dryout-out conditions.
- Rehabilitation efforts in Cells 1, 3, and 4 were completed, and as a result, positive results were observed, such as the establishment of desired plant communities and a decrease in outflow TP concentration (see *STA-1W Rehabilitation* section of this chapter).
- In WY2008, work to improve the STA-1 inflow basin levee and the 5.1-mile Florida Power & Light mid-levee in STA-1W began and was completed in November 2008.

STA-2

- Cells 1, 2, and 3 were operational during WY2008. The newly constructed test cell, Cell 4, was offline until December 2007 to allow for plant establishment, and then was online for the remainder of the water year.
- In anticipation of drought conditions, in September 2007 the between-storm target stages in the SAV cells increased by 6 in. to maintain water levels and protect the vegetation from dryout-out conditions.
- Cell 4 passed the water quality start-up criteria test for TP and mercury in September 2007.
- Construction to improve the L-6 levee adjacent to the STA-2 discharge canal started in WY2008 and was completed in November 2008.

STA-3/4

- During WY2008, all three flow-ways (Eastern, Central, and Western) were operational.
- In anticipation of drought conditions, in September 2007 the between-storm target stages in the SAV cells (Cells 1B, 2B and 3B) increased by 6 in. to maintain water levels and protect the vegetation from dryout-out conditions.

STA-5

- The Northern and Central flow-ways were operational in WY2008. The Southern Flow-way did not pass the start-up phase during WY2008 due to lack of water for hydration.
- In WY2008, STA-5 received only a fraction of anticipated flows and loads: 10 percent of the long-term average annual flow and 6 percent of the long-term average annual TP load. The long-term average annual flows and loads are based on the simulated data used to derive the TBEL limits.
- The inflow canal upstream of G-342 A-D was dredged and improvements were made to the internal distribution canals in Cells 1A and 2A in WY2008. Construction started March 13, 2008, in Cell 1A. The dewatering water for this part of the project was sent to Cell 2A. The G-343 structures were closed to prevent backflow to Cell 1A, which was closed except in case of an emergency. Construction then started in Cell 2A in late April 2008. The dewatering water for this part of the project was sent to Cell 3A. The G-343 structures were closed to prevent backflow to Cell 2A.
- In anticipation of drought conditions, the between-storm target stage in the SAV cells increased by 6 in. Cell 1B received water delivered through the G-507 pump [0.2 mt of TP; 191 kilograms (kg)], (4,014 ac-ft) annual TP FWMC 39 ppb], and Cell 1B received water via the internal G-345 culvert.

STA-6

- Cells 3 and 5 were operational the entire water year. Section 2 passed the water quality start-up criteria test for TP and mercury in August 2007. Although start-up compliance was documented, the South Florida Water Management District (SFWMD or District) did not initiate discharges from STA-6 Section 2 during WY2008 due to severe regional drought conditions.
- Telemetry at the new water control structures at STA-6 was completed in fall 2008.
- STA-6 received only 14 percent of the simulated long-term average annual flow and 15 percent of the long-term average annual TP load in WY2008. The long-term average annual flows and loads are based on the simulated data used to derive the TBEL limits.

STA PERFORMANCE

PERMIT STATUS AND REPORTING MANDATES

Permit Phases and Phosphorus Loading Requirements

In calendar year 2007 (CY2007), new operating permits [EFA, NPDES, and AOs) were issued for all the ECP STAs, except for STA-3/4, requiring TBELs for phosphorus as well as comparisons of actual TP loads to the operational envelopes (**Table 5-4**). STA-3/4 is still operating under permits issued in CY2004. The new STA-3/4 permit is currently being developed, and in the interim, the existing permit was extended to allow time to complete processing of the new permit. The Technical Support Documents for the TBELs, located on the District's web site at www.sfwmd.gov, under *What We Do*, *Watershed Management section (STA Management, Long-Term Plan, Documents* tab), explains the derivation of the TBEL limits and identifies factors that may impact flows and loads associated with the treatment system. The operational envelope criterion was added to account for the variable inflows the STAs receive. The original conceptual design of the STAs was based on a first-order phosphorus removal model. Because this design approach obscured the temporal/seasonal characteristics of the inflows, there was little reference against which actual inflows and resulting STA performance could be assessed. By contrast, the design of the STA enhancements and projections of performance were based on a dynamic model utilizing a 31-year set of simulated daily flows and phosphorus loads, also referred to as the Operational Envelope. This design approach captures the variability of inflows and provides a reference against which actual inflows can be compared to the predicted inflows. Weekly summaries comparing the actual inflows to the Operational Envelopes are used to assist in operational decision making to try to ensure that the STAs are not subject to overload of either flow or nutrients.

The permits recognize that the natural systems undergo maturity changes and the STAs are categorized into phases, depending on the developmental and performance phase of the system. The permits describe three phases with regard to application of the TBEL: Start-up Phase, Stabilization Phase, and Routine Operations Phase. The TBEL does not apply until the STA is in the Routine Operations Phase. STAs 1E, 1W, 2, 5, and 6 are in the Stabilization Phase of Operations, and this phase ends when the STA achieves the annual TP limits as defined in the TBEL. Because STA-3/4 is operating under permits issued in CY2004, it is considered to be in the Post-stabilization Phase and the TBEL identified in that permit applies. As defined in the EFA permit issued in CY2007, during the Stabilization Phase, the treatment vegetation will be maturing and the STA performance will generally be improving toward achieving the TBEL. It is anticipated that the treatment vegetation may require one to three years after flow-through operations begin for the treatment cells to achieve optimal performance. During the stabilization phase, the TBEL shall apply, and it is also acknowledged that exceedances of the TBEL may occur. An STA or flow-way may enter the Stabilization Phase after one of four antecedent conditions, (1) once flow-through operations begin following the initial start-up of a new treatment cell, (2) when a treatment cell is taken offline for implementation of Long-Term Plan enhancements that may have adverse impacts on STA performance, (3) when a treatment cell is taken offline for recovery activities associated with a major event that compromises the structural integrity or performance of the STA, or (4) when planned/unplanned maintenance activities would cause adverse impacts to the STA's treatment capabilities.

Table 5-4. Current permit status table and reporting criterion used to assess the STA phosphorus removal performance for the Everglades Forever Act (EFA) and National Pollutant Discharge Elimination System (NPDES) permits, and Administrative Orders (AOs). The AO, which has been issued in conjunction with each of the STA permits, establishes a schedule for achieving compliance with the permit effluent limit.

STA-1E Permit Phase: Eastern Flow-way Restricted Operations; Central and Western flow-ways in Extended Stabilization Phase	
EFA permit issued 11/16/07 is in effect.	The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements.
NPDES permit issued 8/30/05 is in effect. AO issued 8/30/08 is in effect.	These permits have the annual limit of 68 ppb and three-year target of 50 ppb, in lieu of the newer TBEL.
STA-1W Permit Phase: All Treatment Cells in Extended Stabilization Phase	
EFA permit issued 11/16/07 is in effect.	The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements.
NPDES permit issued 5/11/99 is in effect. AO issued 5/11/99 is in effect.	The NPDES and AO permits have the annual limit of 76 ppb and three-year target of 50 ppb, in lieu of the newer TBEL, for the STA when it is in the Post-stabilization Phase.
STA-2 Permit Phase: Cells 1–4 in Stabilization Phase	
EFA permit issued 9/4/07 is in effect. NPDES permit issued 9/4/07 is in effect. AO issued 9/4/07 is in effect.	The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements.
STA-3/4 Permit Phase: Post-Stabilization Phase (according to 2004 Issued Permit)	
EFA permit issued 1/9/04 is in effect. NPDES permit issued 1/9/04 is in effect. AO issued 1/9/04 is in effect.	These permits have the annual limit of 76 ppb and three-year target of 50 ppb, in lieu of the newer TBEL, for the STA when it is in the Post-stabilization Phase.
STA-5 Permit Phase: North and Central Flow-way in Stabilization Phase, Southern Flow-way in Start-up Phase	
EFA permit issued 9/4/07 is in effect. NPDES permit issued 9/4/07 is in effect. AO issued 9/4/07 is in effect.	The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements.
STA-6 Permit Phase: Section 1 and 2 in Stabilization Phase	
EFA permit issued 9/4/07 is in effect. NPDES permit issued 9/4/07 is in effect. AO issued 9/4/07 is in effect.	The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements.

For STA-1E, until the Eastern Flow-way has been converted to full flow-through operations after completion of the PSTA Demonstration Project, the Central and Western flow-ways may receive flows and phosphorus loads in excess of their design. As a result, STA-1E will remain in the Stabilization Phase.

For STA-1W, when the TBEL is achieved, it will then enter the Routine Operations – Interim Performance Period. As part of the phased implementation of the Everglades restoration program, numerous regional water management projects are under way that will influence the flows and phosphorus loads entering STA-1W and, therefore, its performance, over the life of the five-year permits (2007–2012) and beyond. During this Routine Operations – Interim Performance Period, flows to STA-1W will likely be higher than anticipated in the Everglades Agricultural Area (EAA) Regional Feasibility Study for the WY2006–WY2009 period, and could result in less than optimal STA performance. STA-1W is expected to receive flows and loads higher than those anticipated while the EAA Regional Feasibility Study is being conducted because the canal conveyance improvements needed in the EAA to redistribute runoff will not be completed until later than originally anticipated. Until these canal improvements are completed, STA-1W will receive higher than anticipated inflows, and as a result, performance will be less than optimal. The Interim Performance Period will begin when the three flow-ways have completed the Stabilization Phase. The Interim Performance Period will end when the regional projects identified in the permits are completed.

STA-2 is in the Stabilization Phase of operation. For STA-3/4, because the operational permits are older for this STA (issued January 9, 2004), the stabilization period ended when the 12-month TP FWMC at the outflow stations was less than (<) or equal to (=) 50 ppb. Until the new permits are issued with the TBEL as the effluent limit, STA-3/4 is considered to be in Post-stabilization/Normal Flow-Through Operations. When the new permits are issued, STA-3/4 will be in the Stabilization Phase of operation.

STA-5 (Flow-ways 1 and 2) are in the Stabilization Phase of operation and shall remain until the annual TBEL limit is achieved. STA-6 Sections 1 and 2 are in the Stabilization phase of operation and shall remain until the annual TBEL limit is achieved.

The STA flow volumes are based on daily average surface water flow, and the TP loads are calculated using weekly flow or time-proportional auto-sampler data. If auto-sampler data are not available, then TP data from grab samples collected during flow events are used instead. The TP loads in surface water inflow and outflow were calculated using a Microsoft Excel VBA application that accessed the District’s hydrometeorologic database DBHYDRO (Reardon and Germain, 2005). Both positive and negative (i.e., reverse) flows at water control structures were used in these calculations.

WATER YEAR 2008 PERFORMANCE

Phosphorus Loading

Approximately 99.4 mt of TP were removed in the STAs that otherwise would have entered the Everglades, bringing the total removal to over 1,050 mt since 1994 (**Figure 5-4** and Appendix 5-2 of this volume). Total phosphorus load reduction averaged 80 percent for all the STAs during WY2008. Due to drought conditions and lower inflow phosphorus concentrations, the inflow TP loads decreased by approximately 90 mt from last year (124 mt in WY2008 compared to 214 mt in WY2007). In WY2008, all the STAs received TP loads below the simulated long-term average annual used to derive the TBEL limits (**Table 5-2**). The loads were exceptionally low for STA-5 and STA-6 (6 and 15 percent of the simulated long-term average annual, respectively). The annual STA TP mass removal rates (also referred to as the effective settling rate) for WY2008 increased for all the STAs, except for STA-5 and STA-6 (Appendix 5-2 of this volume). Low TP mass removal rates for STA-5 and STA-6 [0 and 2 meters per year (m/yr), respectively] were influenced by the decreased amount of flow-through due to drought conditions.

As the region experienced the second consecutive year of drought conditions, inflows to the ECP STAs during WY2008 remained below the long-term average design conditions (**Table 5-2).** The long-term average annual flows and loads are based on the simulated data used to derive the TBEL limits. Overall, the TP FWMCs entering the STAs were much lower this water year (129 ppb compared to 187 ppb in WY2007) (**Figures 5-4** and **5-5**, and Appendix 5-2 of this volume). The combination of below-average inflows, reduced inflow concentrations, and implementation of performance enhancement projects — such as the addition of divide levees, improved water control structures, and vegetation conversions within the STAs — resulted in improved outflow TP concentrations compared to WY2007.

Discharge TP concentrations for STA-1E, STA-2, and STA-3/4 were at or below 22 ppb, with the outflow from STA-1E showing a reduction in TP FWMC of about 50 ppb from the previous year (71 ppb in WY2007 compared to 20 ppb in WY2008). The outflow TP FWMC for STA-1W also markedly decreased from 119 ppb to 53 ppb. STA-1W underwent Long-Term Plan Enhancements construction, vegetation reestablishment, and rehabilitation efforts in WY2006 and WY2007, and an evaluation of the success of these activities is provided in the *STA-1W Rehabilitation* section of this chapter. STA-5 and STA-6 received only a small fraction of expected inflows (11 and 14 percent of the long-term average derived TBEL, respectively) and dried out for the second consecutive year. Although additional treatment cells in STA-5 and STA-6 have been flow-capable since December 2006, drought conditions have prevented full utilization. STA-5 had the highest outflow TP concentration (96 ppb), although that represents a 50 percent improvement over WY2007. As a result of the dry conditions in the STA-6 treatment cells, the annual outflow TP concentration during WY2008 was 38 ppb, considerably higher than the POR average of 20 ppb.

STA-1E received runoff from a larger watershed due to completion of the basin diversion project that redirected flows from Wellington Acme Basin B into the C-51W canal instead of into Water Conservation Area 1 (WCA-1) (see Chapter 4 of this volume for additional details about the diversion project). This eliminated direct discharge of untreated runoff to WCA-1 and contributed to a slight increase in STA-1E inflow volume compared to WY2007. The Eastern Flow-way of STA-1E remained off-line during WY2008 as the USACE continued construction and start-up of the PSTA Demonstration Project.

Permit Compliance for Phosphorus

In late 2007, new permits containing TBELs went into effect for STA-1E, STA-1W, STA-2, STA-5, and STA-6; the methodology used to calculate the TBEL limits is presented in the Technical Support Documents for these STAs, respectively. STA-3/4 is currently operating under the 2004 EFA and NPDES permits, which requires reaching an annual limit of 76 ppb and a three-year target of 50 ppb, in lieu of the newer TBEL. In WY2008, STA-3/4 achieved compliance of the current operating permit as well as the TBEL criterion, even though the TBEL criterion was not yet required for this STA. For the STAs requiring the TBEL comparison, STA-1E and STA-2 achieved their respective TBEL limits for TP; however STA-1W, STA-5, and STA-6 did not achieve the TBEL limit (**Table 5-2**). These STAs are considered to be in the Stabilization Phase, and the 2007 operating permits recognize that the TBEL may not be met during this phase.

STA-1W, STA-5, and STA-6 have undergone Long-Term Plan Enhancements construction and/or restoration activities over the past few water years. STA-1W underwent Long-Term Plan Enhancements construction, vegetation conversions, and rehabilitation. Sections of the treatment cells were drained for levee construction and water control structure installation, areas of phosphorus-enriched accrued sediments were removed, and vegetation management to establish desired vegetation was performed (see *STA-1W Rehabilitation* section of this chapter for additional details). During the vegetation establishment period from June 30, 2007–July 3, 2007, there were three days of inadvertent discharge from Cell 3 due to a computer error, resulting in an outflow TP FWMC of 870 ppb at G-251. STA-5 also underwent Long-Term Plan Enhancements construction, which included vegetation conversion in Cell 2B, dredging of the inflow supply canal (L-3), and improvements to the internal distribution canals in Cells 1A and 2A. Long-Term Plan Enhancements construction also occurred in STA-6, where the inflow structures were modified. Additionally, both STA-5 and STA-6 experienced dryout-out conditions due to the drought; the inflows and outflows were drastically reduced over the water year (**Table 5-2)**. Inflows into STA-5 in WY2008 were 11 and 14 percent of the long-term average derived TBEL, respectively. The monthly Discharge Monitoring Reports required by the NPDES permits have also included descriptions about the STA-1W restoration activities, and STA-5 and STA-6 drought-related operations. Although STA-1W, STA-5, and STA-6 did not achieve their respective TBELs for WY2008 for the reasons provided, recent data suggest that the performance of these STAs is improving in achieving their TBELs for WY2009.

In WY2008, all the STAs received flows and TP loads within the Operational Envelope (**Table 5-2**). The diversion calculations and the amount of Lake Okeechobee regulatory releases received over the water year are shown in **Table 5-3**.

Permit Compliance Requirements for Water Quality Parameters Other than Phosphorus

Water quality parameters with Florida Class III standards are identified in **Table 5-5**. Compliance with the EFA permit is determined based on the following three-part assessment:

1. If the annual average outflow concentration does not cause or contribute to violations of applicable Class III water quality standards, then the STA shall be deemed in compliance.
2. If the annual average concentration at the outflow causes or contributes to violations of applicable Class III water quality standards, but does not exceed or is equal to the annual average concentration at the inflow stations, then the STA shall be deemed in compliance.
3. If the annual average concentration at the outflow causes or contributes to violations of applicable Class III water quality standards and also exceeds the annual average concentration at the inflow station, then the STA shall be deemed out of compliance.

The determination as to whether or not an STA is contributing to a violation for a specific parameter is a comparison of the average annual inflow concentration to the average annual outflow concentration relative to the three-part assessment. The District has performed all sampling and analysis in compliance with Chapter 62-160, Florida Administrative Code (F.A.C.), and the District's Laboratory Quality Manual (SFWMD, 2008a) and Field Sampling Quality Manual (SFWMD, 2008b). Certification statements as to the procedures used in collection and analysis are provided in Appendix 5-3 of this volume. The Annual Permit Compliance Monitoring Report for Mercury in the STAs is located in Appendix 5-4 of this volume. Each STA has different permit reporting requirements for annual water quality constituents. The required parameters are shown in **Table 5-6**.

For WY2008, the ECP STAs are in compliance with all requirements of the EFA and the NPDES operating permits.

Table 5-5. Water quality parameters with Florida Class III criteria specified in Section 62-302.530, Florida Administrative Code. Because the STAs are freshwater systems, background concentration for conductivity is assumed to be less than 1,275 µmhos/cm, and background concentration for turbidity is considered to be less than 29 nephelometric turbidity units (NTUs).

Parameter	Units	Class III Criteria
Dissolved Oxygen[a]	mg/L	Greater than (>) or equal to (=) 5.0 mg/L
Conductivity	µmhos/cm	Not > 50 percent of background or > 1,275 µmhos/cm, whichever is greater
pH	Standard units	Not less than (<) 6.0 or > 8.5
Turbidity	NTU	< or = 29 NTU above background conditions
Unionized Ammonia	mg/L	< or = 0.02 mg/L
Alkalinity	mg $CaCO_3$/L	Not < 20 mg/L

[a] Permits for all STAs, except STA-3/4, require compliance with the Site-Specific Alternative Criteria (SSAC) for dissolved oxygen (Weaver, 2004).

Table 5-6. Summary of annual FWMC for parameters other than TP for the STA permitted inflow and outflow locations during WY2008. (Note: Excursions occurred when FWMC at outflows were greater than those at inflows. (**Bold** and *italicized* values identify excursions; dashed lines indicate that the parameter was not required by permit to be measured.)

Stormwater Treatment Area	Data Classification	Flow-Weighted Mean Concentrations							
		Alkalinity (mg $CaCO_3$/L)	Chloride (mg/L)	Sulfate (mg/L)	Un-ionzied Ammonia (mg NH_3/L)	Nitrate+Nitrite (mg N/L)	Total Dissolved Nitrogen[2] (mg/L)	Total Nitrogen (mg/L)	Total Dissolved Phosphorus (mg/L)
STA-1E	Inflow	207	----	26.8	----	0.105	----	1.32	----
	Outflow	135	----	24.6	----	0.022	----	1.03	----
	Excursions	No	----	No	----	No	----	No	----
STA-1W	Inflow	283	----	-NA-	----	0.898	----	4.31	----
	Outflow	221	----	63.4	----	0.138	----	2.30	----
	Excursions	No	----	-NA-	----	No	----	No	----
STA-2	Inflow	314	----	57.5	----	0.914	----	3.74	----
	Outflow	257	----	44.9	----	0.061	----	1.97	----
	Excursions	No	----	No	----	No	----	No	----
STA-3/4[1]	Inflow	307	108	60.0	0.003	1.281	3.45	3.67	0.03
	Outflow	229	105	47.2	0.001	0.481	2.34	2.40	0.01
	Excursions	No	No	No	No	No	No	No	No
STA-5	Inflow	----	----	13.8	----	0.076	----	***1.56***	----
	Outflow	----	----	6.6	----	0.013	----	***1.93***	----
	Excursions	----	----	No	----	No	----	***Yes***	----
STA-6	Inflow	***196***	----	10.1	----	0.030	----	***1.33***	----
	Outflow	***197***	----	7.0	----	0.007	----	***1.68***	----
	Excursions	***Yes***	----	No	----	No	----	***Yes***	----

Note: NA indicates that a FWMC could not be calculated because no samples were collected or samples were collected when the structure was not flowing.

[1] Because STA-3/4 is operated under the EFA and NPDES permits issued in 2004, different required parameters are reported compared to the other STAs (see **Table 5-4**).

[2] For the nitrogen species, based on previous data, most of the total nitrogen (TKN+NOX) was composed of total dissolved nitrogen (TDKN+NOX). Therefore, ammonia was removed from the permits for the other STAs after no exceedances were observed for ammonia.

Water Year 2008 Performance for Water Quality Parameters Other Than Phosphorus

Water quality parameters with Florida Class III standards are provided in **Table 5-5**. Compliance with EFA permits is determined based on the three-part assessment presented in the *Water Quality Permit Requirements* section of this chapter. The description of background for the turbidity and specific conductance criteria is described as follows: For conductivity, the value "shall not be increased more than 50 percent above background or to 1,275, whichever is greater". Because the standards are for fresh water, background conductivities are typically lower than 1,275 microsiemens per centimeter (µS/cm). For turbidity, the measured value shall be "< 29 above natural background conditions." Under Chapter 62-303, F.A.C., natural background is defined as "shall mean the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered water body may be based upon a similar unaltered water body or on historical pre-alteration data." Since the Florida Department of Environmental Protection (FDEP) has not compiled any information on what it considers natural background, the District determines that any measured value that is greater than 29 nephelometric turbidity units (NTUs) is considered to exceed the turbidity criterion. For the other water quality parameters that do not have Class III standard, excursions will be noted when the outflow FWMCs are higher than the inflow. An STA may have excursions and still be considered to be in compliance with the permit.

Monitoring data collected during WY2008 for permitted water quality parameters at the six STAs (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6) inflows and outflows are presented in Appendix 5-5 of this volume. A consolidated summary of annual FWMC at inflows and outflows of the STAs, including excursion analysis, is presented in **Table 5-6**. In addition, the annual permit compliance monitoring report for mercury in the STAs is included as Appendix 5-4 of this volume.

Pursuant to EFA permits for each of the STAs (except STA-3/4), dissolved oxygen compliance shall be evaluated annually using a statistical analysis to compare DO levels within facility as set forth in the Everglades Marsh Dissolved Oxygen Site Specific Alternative Criteria (DO SSAC). See the *Dissolved Oxygen* section of this chapter for more details regarding compliance with the DO SSAC.

Based on water quality data (excluding TP and DO) collected during WY2008 at inflows and outflows to the STAs, only STA-5 and STA-6 exhibited excursions. These excursions were observed for alkalinity (STA-6) and total nitrogen (TN) (STA-5 and STA-6) (**Table 5-6**). An excursion is characterized when the annual outflow FWMC for an STA is greater than its annual inflow FWMC. Because the annual FWMC for alkalinity measured at both inflows and outflows of STA-6 are above the threshold criteria of 20 milligrams per liter (mg/L) (**Table 5-5**), the STA is deemed in compliance. In the water quality assessment methodology, no numeric criterion exists for TN under Section 62-302.530, F.A.C.; therefore, both STA-5 and STA-6 are deemed to be in compliance with respect to this parameter as per the three-part assessment presented in the EFA permits. As a result of this assessment, in WY2008 all STAs met permit requirements with regard to water quality and are, therefore, deemed to be in full compliance.

As part of the performance evaluation specified by permit for each STA, a statistical comparison of inflow and outflow FWMC is required to be reported at a significance level (α) of 0.05. The test (i.e., Student's t-test) specified in the permits to statistically compare the parameter concentrations may not be the most appropriate based on distribution assumptions of the data. If the datasets to be compared are not significantly different from a normal distribution, then the Student's t-test can be applied. However, when data deviate significantly from normality, the comparisons using the Student's t-test are not appropriate and can result in incorrect significance. For the purpose of this report, distribution of the datasets was determined using the Shapiro-Wilkes test of normality at $\alpha = 0.05$. Data exhibiting probability values (p-values) greater than 0.05 did not deviate significantly from a normal distribution and could be tested using the Student's t-test. However, datasets with significant deviations from normality were tested using the Mann-Whitney test ($p\text{-value} < 0.05$), a non-parametric equivalent of the Student's t-test.

Table 5-7 provides a summary of these statistical comparisons for parameter FWMC at STA inflows and outflows during WY2008. Of the 33 evaluations performed, 21 comparisons exhibited statistically higher concentrations at the inflows than outflows. Only TN measured at STA-5 exhibited statistically higher concentrations at the outflows compared to the inflows.

Table 5-7. Statistical comparison of FWMC at inflows and outflows of STAs that discharge to the Everglades Protection Area (EPA) during WY2008. Highlighted probability values (p-values) indicate a statistically significant difference between inflows and outflows for a parameter.

Parameter Name	Variable	Storm Water Treatment Areas					
		STA-1E	**STA-1W**	**STA-2**	**STA-3/4**	**STA-5**	**STA-6**
Specific Conductivity	P-Value[a]	***<0.001***	0.879	***<0.001***	***<0.001***	***0.034***	0.094
	Structure[b]	***Inflow***	Inflow	***Inflow***	***Inflow***	***Inflow***	Inflow
	Statistical Test[c]	***Mann-Whitney***	Mann-Whitney	***Mann-Whitney***	***Mann-Whitney***	***Mann-Whitney***	Mann-Whitney
Turbidity	P-Value[a]	NA	NA	***<0.001***	***<0.001***	0.515	***<0.001***
	Structure[b]	NA	NA	***Inflow***	***Inflow***	Outflow	***Inflow***
	Statistical Test[c]	NA	NA	***Mann-Whitney***	***Mann-Whitney***	Mann-Whitney	***Mann-Whitney***
Dissolved Chloride	P-Value[a]	NA	NA	NA	0.843	NA	NA
	Structure[b]	NA	NA	NA	Outflow	NA	NA
	Statistical Test[c]	NA	NA	NA	Mann-Whitney	NA	NA
Alkalinity	P-Value[a]	***<0.001***	0.169	***0.007***	***<0.001***	NA	0.636
	Structure[b]	***Inflow***	Inflow	***Inflow***	***Inflow***	NA	Outflow
	Statistical Test[c]	***Mann-Whitney***	T-test	***Mann-Whitney***	***Mann-Whitney***	NA	Mann-Whitney
Sulfate	P-Value[a]	0.620	NA	0.425	***0.001***	***0.030***	***0.003***
	Structure[b]	Inflow	NA	Outflow	***Inflow***	***Inflow***	***Inflow***
	Statistical Test[c]	Mann-Whitney	NA	Mann-Whitney	***Mann-Whitney***	***Mann-Whitney***	***Mann-Whitney***
Total Dissolved Phosphorus	P-Value[a]	NA	NA	NA	***<0.001***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***Mann-Whitney***	NA	NA
Unionized Ammonia	P-Value[a]	NA	NA	NA	***0.019***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***Mann-Whitney***	NA	NA
Nitrate + Nitrite	P-Value[a]	NA	0.261	***<0.001***	***<0.001***	0.661	NA
	Structure[b]	NA	Inflow	***Inflow***	***Inflow***	Outflow	NA
	Statistical Test[c]	NA	Mann-Whitney	***Mann-Whitney***	***Mann-Whitney***	Mann-Whitney	NA
Total Dissolved Nitrogen	P-Value[a]	NA	NA	NA	***<0.001***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***Mann-Whitney***	NA	NA
Total Nitrogen	P-Value[a]	***<0.001***	0.845	***<0.001***	***<0.001***	***0.014***	NA
	Structure[b]	***Inflow***	Inflow	***Inflow***	***Inflow***	***Outflow***	NA
	Statistical Test[c]	***Mann-Whitney***	Mann-Whitney	***Mann-Whitney***	***Mann-Whitney***	***Mann-Whitney***	NA

Notes: NA - indicates that data was not collected or there were insufficient data to perform the statistical analyses. Sulfate samples from STA-1W inflow station (G-302) were collected during periods of no flow to the STA, therefore FWMC could not be caluclated and comparisons between inflows and outflows could not be made.

[a] Probability level (p-value) computed using appropriate comparison test. A significance level (α) of 0.05 was used. When p-value was less than 0.05, the parameter concentrations were significantly different between the inflow and outflow. Significant p-values are identified by shading and are presented in the table as italicized and bolded values.

[b] STA structure(s) exhibiting higher parameter concentrations during the water year.

[c] Statistical test used to compare inflow and outflow water quality data. Choice of test was based on distributional assumptions. If the distribution of the data did not significantly deviate from normality, the Student t-test was used. When the distribution of the data did deviate significantly from normality, the Mann-Whitney test (non-parametric equivalent) was used.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations below 5.0 mg/L occur commonly throughout the EPA, including interior marsh sites minimally impacted by nutrient enrichment or cattail invasion. Frequent DO levels below 5.0 mg/L are typical in macrophyte-dominated wetlands where marsh processes of photosynthesis and respiration result in wide diel cycle swings in DO levels. Since low DO concentrations often measured in the EPA represent natural variability in this type of ecosystem, the FDEP, pursuant to Section 62-302.800(1), F.A.C., has promulgated a Site Specific Alternative Criterion (SSAC) for DO in the Everglades. This SSAC addresses the wide-ranging natural daily (diel) fluctuations that influence natural background DO levels. The SSAC limit is calculated using an equation derived from diel dissolved oxygen concentrations measured at a variety of interior marsh stations in the Everglades. The equation is a sinusoidal function that varies based on water temperature and time of day. Chapter 3A of the 2008 *South Florida Environmental Report* (SFER) – Volume I contains a summary explanation of the SSAC, its development, and its application in assessing DO excursions. The specific methods for determining compliance are set forth in the DO SSAC (Weaver, 2004), which was adopted by Secretarial Order on January 26, 2004, and approved by the U.S. Environmental Protection Agency (USEPA) as a revision to the state of Florida's water quality standards on June 16, 2004.

Previous reports (Jorge et al, 2002; Goforth et al., 2003, 2004; 2005; Pietro et al., 2006, 2007) provided monitoring results, comparisons, and evaluations with regard to diel DO for the STAs. These reports were used to assess the impact of STA discharges on the downstream Everglades ecological system or downstream water quality with respect to DO and pursuant the STA-1E, STA-1W, STA-2, STA-3/4, and STA-5 EFA permits and associated AOs. This effort also provided data to the FDEP for development of the DO SSAC.

For the purpose of the 2008 SFER – Volume I, Chapter 5 report, DO levels measured at outflow stations from five STAs (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5) were assessed using the developed SSAC rather than the diel DO evaluation as performed in previous reports. This change in last year's report was agreed to by the FDEP and the District. Since the STA-6 permit did not have diel requirements, no SSAC comparison was performed for this STA for WY2007.

The SSAC is presently included in EFA permits and associated AOs for five STAs (STA-1E, STA-1W, STA-2, STA-5, and STA-6) as a permit compliance criterion. The SSAC is also expected to be included in future STA permits for STA-3/4. The NPDES Permit issued on January 9, 2004, for this STA stipulates that it shall be revised in the event the state of Florida establishes a SSAC for dissolved oxygen in the EPA. As a result, permit compliance for DO at this STA shall be determined using the DO SSAC.

Permits issued for the six STAs require the District to provide the FDEP with an annual report consisting of an analysis demonstrating that DO levels in STA discharges do not adversely change the downstream Everglades ecology or the downstream water quality. Since the SSAC has been adopted by the FDEP and formally approved by the USEPA, assessment of possible downstream impacts by the outflows from STAs during WY2008 were performed by applying the SSAC limit with respect to DO at the outflow stations. A map showing the permitted outflow points for each STA is provided in **Figure 5-3**.

Biweekly DO concentrations measured at STA discharge stations during WY2008 were used to summarize annual DO levels (Appendix 5-6 of this volume). A summary of these annual DO levels for permitted outflows at each STA and calculated SSAC DO limits is provided in

Table 5-8. By comparing the measured mean annual DO for an outflow station with the calculated mean annual SSAC limit, a determination can be made if the station complies with the permitted limit. When mean annual DO concentrations measured at the effluent compliance points (outflow stations) are greater than the calculated mean annual lower limit utilizing the SSAC equation, then the outflow values are above the SSAC limit or comply with the permitted limit. During WY2008, one outflow station at STA-1W (G-251) and two outflow stations at STA-6 (G-354C and G-393B) had mean annual DO levels that were lower than the SSAC limit (**Table 5-8**).

Some of the treatment cells in STA-1W were offline for Long-Term Plan Enhancements construction and rehabilitation during WY2008 (for more information regarding enhancement and rehabilitation activities in STA-1W, see *STA-1W Rehabilitation* section of this chapter). Additionally, discharge at G-310 during WY2008 was 290-fold higher than at G-251 as flow was diverted from G-251 to G-310. Both of these factors, as well as drought conditions during part of WY2008, probably contributed to the low DO levels (annual mean of 1.84 mg/L) observed at outflow station G-251.

While both outflow stations at STA-6 exhibited lower mean annual DO levels compared to their corresponding mean annual SSAC limits, greater deviation from the SSAC limit was observed for G-393B (2.33 mg/L) than G-354C (< 0.5 mg/L) (**Table 5-8**). Limited flow-through at STA-6 and dryout conditions resulting from a drought during WY2008 probably resulted in lower DO levels recorded at the two outflow structures. For more information regarding operation of STA-6 see the *Individual STA Highlights* section of this chapter.

In addition to determining STA performance to the SSAC for WY2008, a comparison of STA performance with the SSAC for the past two years was performed. **Figure 5-6** presents the mean annual residual DO levels for STA outflow for WY2007 and WY2008. When mean annual DO levels are greater than the SSAC, the mean annual residuals are positive. Most of the outflow stations exhibit higher residuals in WY2008 compared to WY2007. Two outflow stations at STA-5 (G-344A and G-344B) shifted from negative residuals in WY2007 to positive residuals in WY2008 (**Figure 5-6**) indicating an improvement in DO levels. Three outflow stations (G-251 at STA-1W, and G-354C and G-393B at STA-6) exhibited negative mean annual residuals for both water years. These results suggest that no improvement in DO levels was observed for these stations.

Table 5-8. For WY2008, annual dissolved oxygen (DO) concentrations measured at STA outflow stations and calculated Site-Specific Alternative Criteria (SSAC) DO limits.

STA	Outlfow Station	No. of Samples	Mean[a]	Standard Deviation	Minimum	Maximum	Mean Annual SSAC Limit[b]	SSAC Limit Classification[c]
STA-1E	S-362	51	6.15	2.01	1.14	11.50	3.96	Above
STA-1W	G-251	50	1.84	1.87	0.30	10.80	3.08	Below
	G-310	51	4.66	2.21	0.38	11.50	2.77	Above
STA-2	G-335	50	4.27	1.28	1.71	7.47	2.87	Above
STA-3/4	G-376B	51	3.42	1.72	0.44	7.71	2.88	Above
	G-376E	51	3.56	1.64	0.71	7.22	3.05	Above
	G-379B	51	4.39	1.92	1.24	9.05	3.27	Above
	G-379D	51	4.76	1.84	0.45	9.41	3.53	Above
	G-381B	51	5.50	2.07	0.03	11.10	3.67	Above
	G-381E	51	5.19	1.72	0.34	10.00	3.85	Above
STA-5	G-344A	51	4.20	1.99	0.32	8.49	3.31	Above
	G-344B	50	4.99	2.10	0.92	9.72	3.41	Above
	G-344C	51	4.91	2.40	0.81	9.77	3.52	Above
	G-344D	51	5.24	2.53	0.85	10.60	3.66	Above
STA-6	G-354C	31	3.28	1.89	0.76	7.42	3.69	Below
	G-393B	32	1.51	1.24	0.17	5.18	3.84	Below

Note:

[a] Arithmetic mean

[b] SSAC limit derived using the equation derived by Weaver (2004) which calculates the limit using water temperature and time of day data recorded at each monitoring location during each monitoring event.

[c] SSAC limit indicates whether the mean annual DO level measured at an outflow station was above or below the SSAC limit. To be above the SSAC limit, mean annual DO must be equal to or greater than the mean annual SSAC limit.

STA-1E and STA-1W EFA Permit No. 0279499-001-EM; STA-2 EFA Permit No. 0126704-005-EM; STA-3/4 EFA Permit No. 0192895 and NPDES Permit No. FL0300195; STA-5 EFA Permit No. 0131842-006-GL; and STA-6 EFA Permit No. 0236905-001 (PATS No. 262918309)

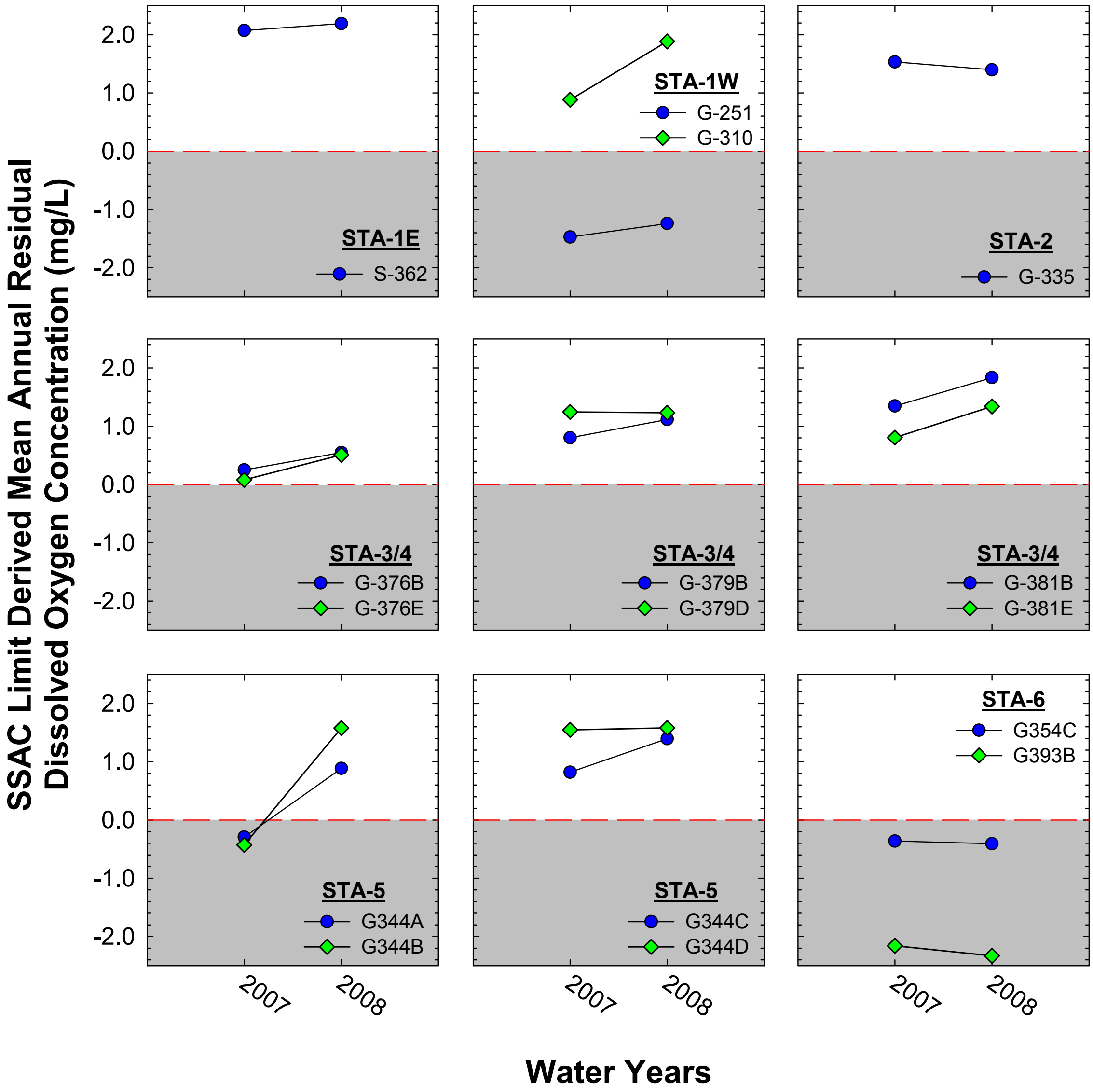


Figure 5-6. The mean annual residual DO plots at STA outflow stations for WY2007 and WY2008. Mean annual residuals were computed as the difference between the mean annual DO and mean annual SSAC. Negative residuals (gray area below the red dashed line) indicate that an outflow station was below the SSAC limit, while positive residuals (white area above the red dashed line) indicate that an outflow station was above the SSAC limit.

Mercury

For WY2008, there were no violations of the Florida Class III numerical water quality standard of 12 nanograms (ng) of total mercury per liter (THg/L) during the reporting year at any of the STAs. Average annual outflow loads for total mercury (THg) and methylmercury (MeHg) at all STAs were lower than inflow, except for STA-2. The smallest difference in THg and MeHg loading was for STA-1E. For collection year 2007, mercury concentrations in mosquitofish (*Gambusia holbrooki*) and sunfish (*Lepomis* spp.) from all STAs showed an overall 25 percent increase since 2006, and largemouth bass (*Micropterus salmoides*) showed minimal change. The largest decrease in mercury burden for all fish species since 2006 was within STA-1E (45 percent decrease) and the largest overall increase was within STA-1W (70 percent increase). With the above increases, however, there was no exceedance of any action criterion listed in the mercury monitoring protocol (SFWMD, 2006). Based on the USFWS and USEPA predator protection criteria, fish-eating wildlife foraging within all STAs appears to be at an overall moderate risk to mercury exposure. Despite the increase in mercury concentration for all fish species within STA-1W, fish-eating wildlife foraging within this STA is still of lowest concern. Of greatest concern is fish-eating wildlife foraging within STA-6. STA mercury performance criteria are evaluated on an annual basis. If respective action levels are exceeded, corrective measures are taken in accordance with the FDEP-approved monitoring plans. Additional information about the mercury monitoring and research for the STAs is located in Appendix 5-4 of this volume, and data for mercury and sulfur monitoring in South Florida can be found in the 2009 SFER – Volume I, Chapter 3B and Appendix 3B-1.

LONG-TERM STA PERFORMANCE

Overall STA Performance

The construction of the STAs occurred over time and the start dates of operation are listed in **Table 5-2**. Over the POR since 1994, the ECP STAs combined have received over 8.3 million ac-ft of inflow volume, equating to a TP load of 1,490 mt with an average TP FWMC of 158 ppb. The STAs retained between 63 to 84 percent of the TP loads (averaging 71 percent), reducing the overall outflow TP FWMC to 43 ppb (**Table 5-2**). The TP removal efficiency in WY2008 increased 9 percent compared to last year.

Because the STAs are operated for flood control, constant annual or steady monthly inflow volumes were not always received as depicted in the time-series plots found in Appendix 5-2 of this volume. The methodology used to estimate flow volume and TP loads as well as the amount of effective treatment areas is found in Appendix 5-7 of this volume. The chronology of events experienced by the STAs since 2000 (Appendix 5-2 of this volume) show that various events, such as Long-Term Plan Enhancements construction, periods of vegetation establishment, or rehabilitation activities, have occurred. The amount of hydraulic and phosphorus loading to the STAs is dependent upon conditions within the contributing basins, which are influenced by rainfall, land use, etc. The largest contributor to the STAs is the EAA, and the main source of irrigation water for the EAA is Lake Okeechobee. The loading rates also take into account the changes in effective treatment area (Appendix 5-7 of this volume). Loading rates into the STAs also show much variability, with some STAs receiving a wider range of annual loadings (**Figure 5-4**). STA-6 consistently had the highest hydraulic loading rates (HLRs) and showed the most variability in annual rates compared to the other STAs. The phosphorus loading rates (PLRs) were most variable for STA-5 and STA-1W. STA-1W received high loadings in WY2003 and experienced a decline in vegetation coverage and an increase in outflow concentrations, with the highest outflow concentration (119 ppb) in WY2007. Application of the results of the soil TP concentrations and amount of organic content guided the restoration work in STA-1W, which included sediment removal and planting rice to encourage desired SAV establishment (see *STA-1W Rehabilitation* section of this chapter). Rehabilitation efforts have been ongoing in STA-1W, and increased coverage of desired vegetation coverage and decreases in outflow TP were seen in WY2008, during which outflow TP FWMC decreased from 119 ppb in WY2007 to 53 ppb in WY2008. The drought conditions may also have contributed to the decrease in outflow TP FWMC.

Over 14 years of operation, the STAs have experienced a wide range of climatic events, such as major storms or droughts, with some of these events impacting the STAs for consecutive years. Hurricanes or topical storms impacted the STAs during WY2005–2006, and the region experienced drought conditions in WY2001, WY2007, and WY2008. Further investigation into the variability of HLR and PLR and the velocity at which the water flows through the system is currently under way. As observed by the extent of plant damage, plant communities show a response to high loading events (Pietro et al., 2007, 2008), which are expected to have an affect on future reactions to changes in loadings, thus affecting the outflow TP concentrations. The impact of these climatic and high-flow events on the hydraulic and phosphorus loading rates and the resulting outflow TP FWMC (**Figures 5-7**, **5-8,** and **5-9**) show no clear trends associated with hydraulic or phosphorus loading rates or large climatic events. Each of the STAs were affected in different ways, indicating that these wetlands are complex systems, and performance trends are not solely based on climatic events or on the hydraulic and nutrient loadings. The long-term HLR and PLR are just two of many factors that influence the phosphorus removal performance of an STA; others include vegetation type, soil type, antecedent land use, phosphorus loading history, inflow concentrations, hurricanes, droughts and other disturbances. STA-6 showed the highest HLRs, although little effect is observed on the outflow TP concentrations.

In addition to TP, several other water quality parameters are routinely monitored at STA inflows and outflows stations. The STAs process these constituents with varying levels of efficiency. To illustrate this point, **Figure 5-10** shows the annual inflow and outflow mass for some of these parameters over the operational history of each STA. The relative efficiency of mass removal can be inferred by comparing slopes of the constituent inflow-outflow regressions; i.e., the smaller the slope, the more mass removed on a proportionate basis and the greater the mass removal efficiency. The range of values for annual inflow mass for all constituents varied considerably among the STAs due to differences in inflow constituent concentrations and/or water loads. The STA removed almost no chloride, a conservative element in freshwater ecosystems (Cl; slope ~ 1), and relatively little calcium (Ca) and sulfate (SO_4) (slopes = 0.94 and 0.89, respectively). Conversely, the STAs were much more efficient at sequestering inorganic phosphorus and nitrogen (N) [soluble reactive P (SRP) and dissolved inorganic N; slopes = 0.34 and 0.17, respectively]. Compared to inorganic P and N, the STAs were less efficient at removing dissolved organic P and almost completely ineffective at treating dissolved organic N (slopes = 0.59 and 0.95, respectively). Finally, the STAs were better at removing TP than TN (slopes = 0.30 and 0.62, respectively). These findings are consistent with an analysis of treatment performance in the Everglades Nutrient Removal Project (ENRP), the precursor to STA-1W that operated from 1994–1999 (Gu et al., 2006). Water and TP budgets for the treatment cells/flow-ways of each STA are presented in the *Analysis and Interpretation* section of this chapter.

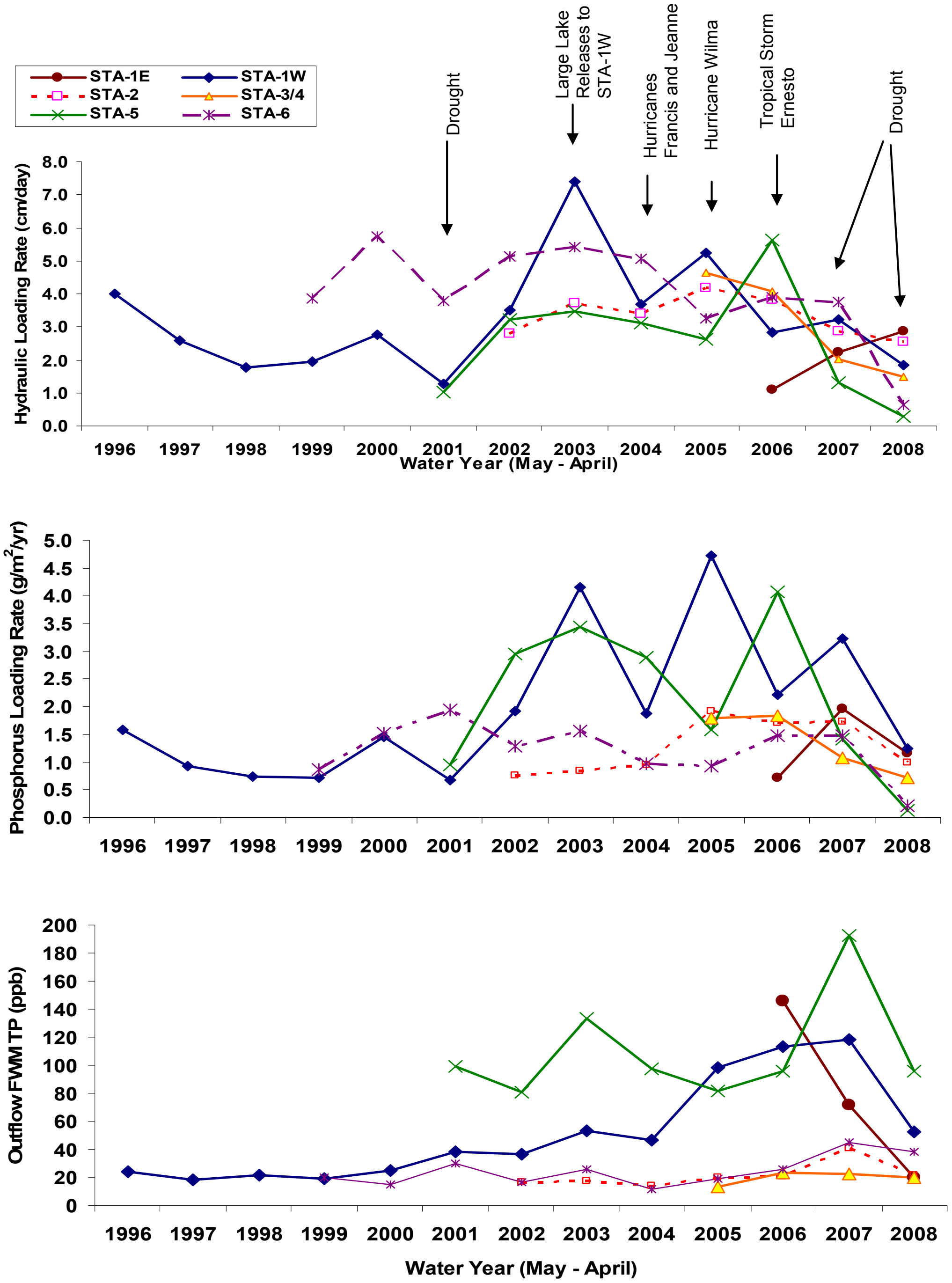
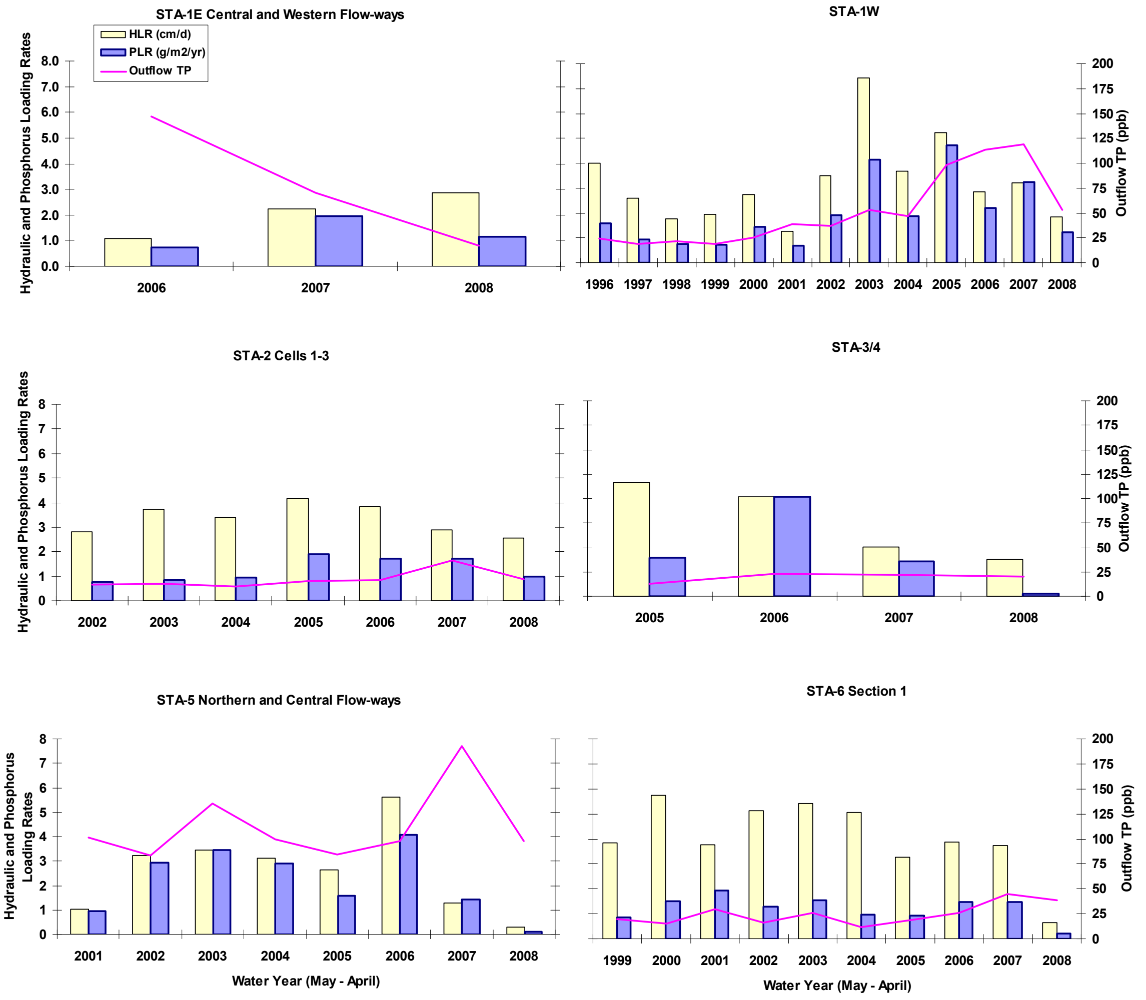


Figure 5-7. Time series showing annual hydraulic loading rates, TP loading rates, and outflow TP FWMC over the POR for each STA. The occurrence of tropical storms, droughts, and unusually high inflow events is shown.


STA-1E Central and Western Flow-ways

STA-1W

STA-2 Cells 1-3

STA-3/4

STA-5 Northern and Central Flow-ways

STA-6 Section 1

Figure 5-8. POR hydraulic and TP loading rates (HLR, PLR) and outflow TP FWMC for the STAs. [Note that the dates in this figure reflect flow-through operations and do not necessarily coincide with the start-up dates shown in **Table 5-2**.] Major climatic and operational events have occurred over the periods of operation as follows: regional drought conditions were experienced in water years 2001, 2007, and 2008; large Lake Okeechobee releases were treated in STA-1W in WY2003; Hurricanes Francis and Jeanne occurred in WY2005; Hurricane Wilma occurred in WY2006; and Tropical Storm Ernesto occurred in WY2007.

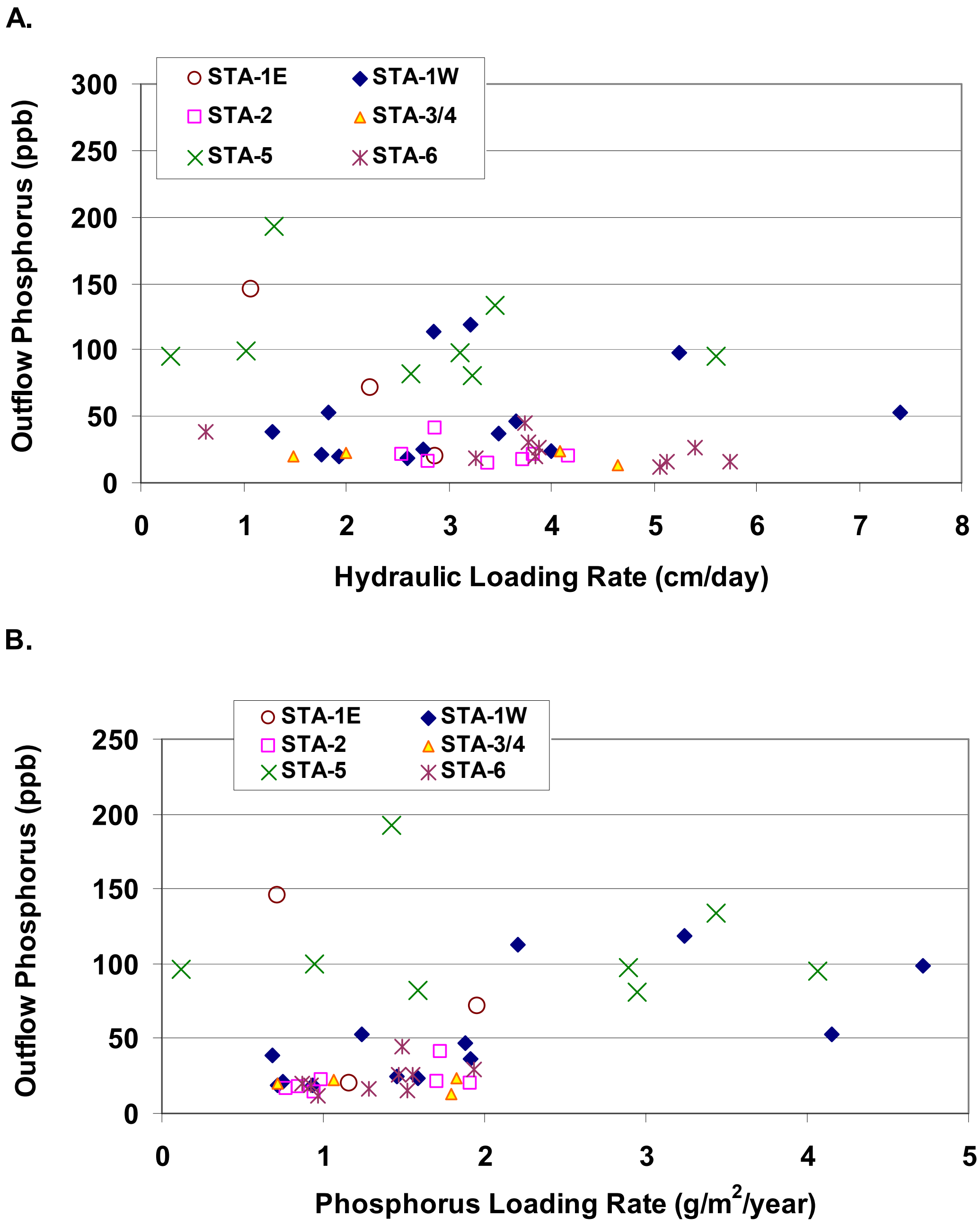


Figure 5-9. STA outflow TP FWMC (panel A) compared to the HLR (panel B). [Note that the TP loading rate (PLR) by water year is for the STAs when in flow-through mode and does not include partial water year start-up loadings.]

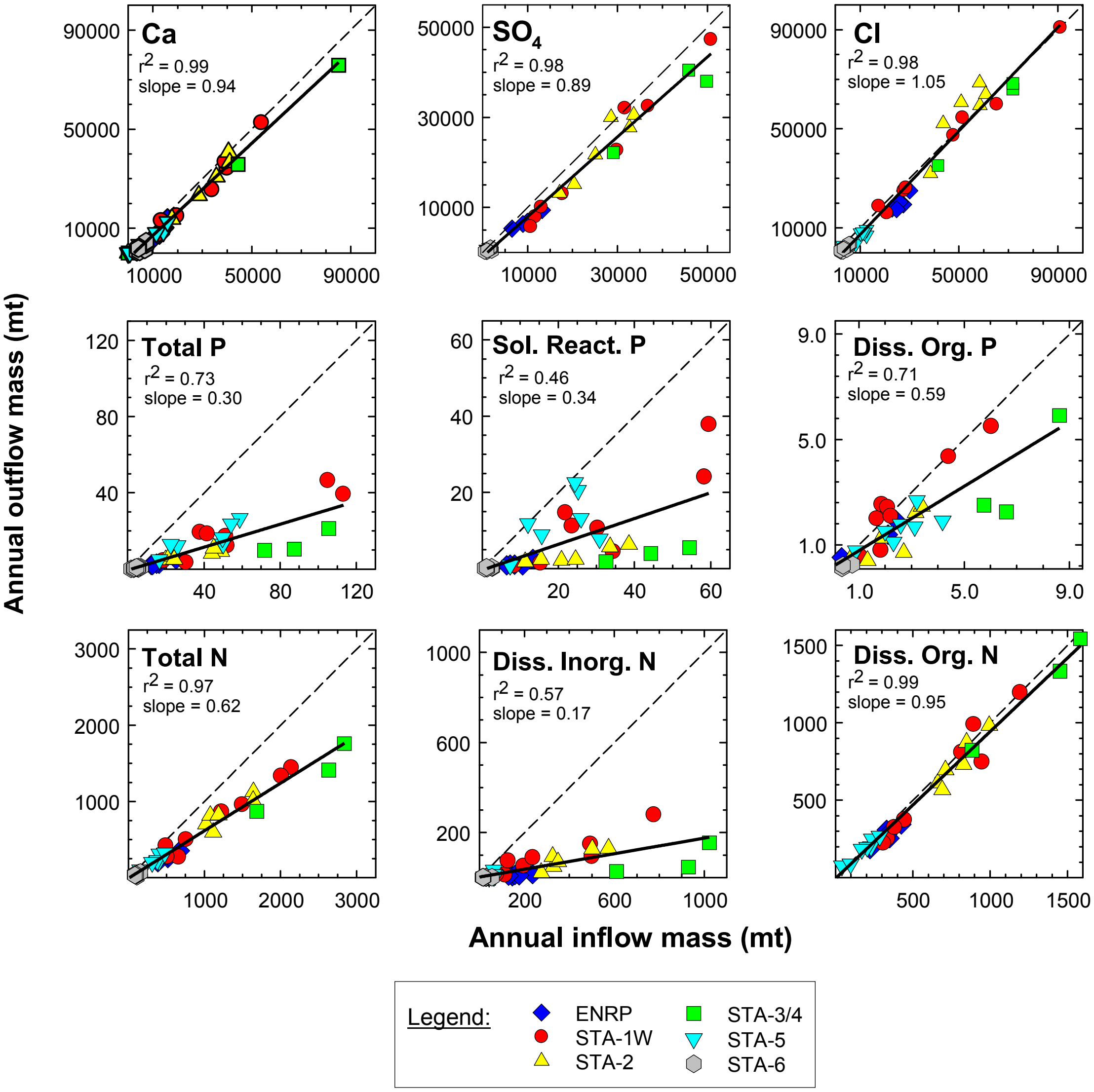


Figure 5-10. Annual inflow and outflow mass [in metric tons (mt)] for several water quality constituents monitored in the STAs from WY1994–WY2007 (data from Chimney, 2007). Data points that fall below the diagonal line indicate net mass removal.

Analysis and Interpretation

This section is a report on the Process Development and Engineering component of the Long-Term Plan that requires monitoring of the physical/chemical environment and TP sequestration in the STAs. A requirement that follows from this objective is to develop water and TP mass balance budgets for individual STA treatment cells or flow-ways and, ultimately, to understand the mechanisms that control STA performance.[1]. The District conducts the field sampling and laboratory analyses associated with this effort under the ECP Operations Monitoring Project.

Annual (water year) and POR water budgets were developed for all operational cells/flow-ways: STA-1E (Cells 3, 4N, 4S, 5, 6, and 7); STA-1W [Cells 1, 2, 3, 4, and 5A + 5B (5 Flow-way)]; STA-2 (Cells 1, 2, and 3); STA-3/4 (Cells 1A, 1B, 2A, 2B, and 3); STA-5 (North and South flow-ways); and STA-6 (Cells 3 and 5) (Appendix 5-8, Table 1 of this volume). Surface flow was calculated using a hydraulic equation developed for each water control structure. Rainfall was measured at rain gauges located within or near each STA. Evapotranspiration (ET) was estimated from first-order models with coefficients specific to different wetland vegetation communities. Groundwater outflow was estimated as seepage through the perimeter levees, and is based on head differences between the STA and outside water levels, levee length, and a first-order seepage coefficient [cubic feet per second per mile per feet (cfs/mi/ft)] optimized for each STA. All water budget components were calculated on a daily basis and aggregated over longer periods. Water budgets were developed using the best available data at the time of this report, which may reflect revisions to data reported in previous SFERs. Future SFERs likewise may contain revisions to the data provided in this report.

Total phosphorus concentrations were monitored at the inflow and outflow of each cell/flow-way as either flow- or time-proportioned auto-sampler composite samples plus separate grab samples on a weekly basis. Annual and POR TP mass balance budgets (TP budgets) were developed for each cell/flow-way (Appendix 5-8, Table 2 of this volume). The TP loads in surface water inflow and outflow were calculated using a Microsoft Excel VBA application that accessed DBHYDRO (Reardon and Germain, 2005). Both positive and negative (i.e., reverse) flows at water control structures were used in these calculations. The TP load in precipitation was based on annual rainfall volume multiplied by the median rainfall TP concentration (4 ppb) monitored at STA-1W (Site ENR308) from January 2000 through May 2008. The TP load in groundwater outflow was based on the annual groundwater outflow volume (where available) multiplied by the annual geometric mean of the annual inflow and outflow TP FWMC for each cell/flow-way. Residuals to the TP budgets were regarded as mass retained within the cell/flow-way. TP removal coefficients were calculated using a first-order model following Kadlec and Knight (1996):

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[1] While not a Long-Term Plan requirement, soluble reactive P, total dissolved reactive P, ammonium-nitrogen, nitrite+nitrate-nitrogen, chloride, calcium, and alkalinity were monitored in weekly grab samples collected at the inflow and outflow to each cell/flow-way. Analysis of cell/flow-way treatment performance and mass balance budgets for these constituents are presented in the 2006 SFER – Volume I, Chapters 4, and the 2007 and 2008 SFER – Volume I, Chapter 5, respectively.

$$k = \ln\left(\frac{C_{in}}{C_{out}}\right) \times \left(\frac{(Q_{in} + Q_{out})/2}{A}\right) \times (12/\Delta t)$$

Equation 5.1

where k is the TP removal coefficient [month/year (m/yr)], C_{in} is the inflow TP FWMC (ppb), C_{out} is the outflow TP FWMC (ppb), Q_{in} is the inflow water load (m^3), Q_{out} is the outflow water load (m^3), A is the cell/flow-way surface area [square meter (m^2)], and Δt is number of months. Because k values were used only to assess the relative treatment performance of cells/flow-ways and not for design, **Equation 5.1** was judged to be sufficient for the District's needs.

All water budgets were dominated by surface flow (Appendix 5-8, Table 1 of this volume). Groundwater and precipitation in the STAs usually made up less than 15 percent of the total inflow water volume, while surface outflow comprised at least 80 percent of total outflow. Exceptions occurred in the South Flow-way of STA-5 and STA-6, Cells 3 and 5, where seepage losses and ET made up 32 to 40 percent of POR outflow. Reduced flow or missing data in STA-1W, Cells 2, 4, and 5 from WY2006–WY2008 resulted from restoration activities in these cells. Reduced flows in other WY2008 water budgets were attributed to the continued regional drought; i.e., the STAs treated much less water compared to previous years. Some of the STAs have large water budget errors that are associated with relatively small volumes of water due to rehabilitation efforts and/or the drought unmonitored pumping between cells. Additional analyses and discussion of water budgets were presented in the 2008 SFER – Volume I, Chapter 5.

Given the importance of surface flow in the water budgets, it was expected that TP budgets also would be dominated by surface water. Precipitation made up less than 1 percent of the POR inflow TP load to all cells/flow-ways; the remaining 99+ percent of the TP load was contributed by surface water (Appendix 5-8, Table 2 of this volume). Likewise, POR outflow TP loads were dominated by surface water, although groundwater contributions ranged from 12 to 47 percent in STA-2, Cell 3, both flow-ways in STA-5, and both cells in STA-6. Some, but not all, of the cells/flow-ways managed for SAV have consistently produced annual and POR outflow TP FWMC at or below 25 ppb (STA-1E, Cell 4S, STA-2, Cell 3, and STA-3/4, Cells 2B and 3) (Appendix 5-8, Table 3 of this volume). However, some non-SAV cells also had similar or better treatment performance (i.e., all annual and POR values for STA-1E, Cell 1 and STA-3/4, Cell 1B; POR values for both cells in STA-6). [The cell with the best treatment performance, STA-2, Cell 1 (POR outflow TP FWMC = 11 ppb), was built on a portion of relic Everglades marsh that had never been farmed.] With the exception of STA-6, all the other STAs were built on former farmland. The treatment performance of STA-1W, Cell 4 and Cell 5 improved markedly during WY2008 (outflow TP FWMC = 26 and 31 ppb, respectively) suggesting that recent rehabilitation efforts are succeeding. POR treatment performance was inversely correlated with areal TP loading and positively correlated with k values, although there was considerable scatter in the data for both relationships (**Figure 5-11**). Additional analyses and discussion of TP budgets and cell/flow-way treatment performance were presented in the 2008 SFER – Volume I, Chapter 5.

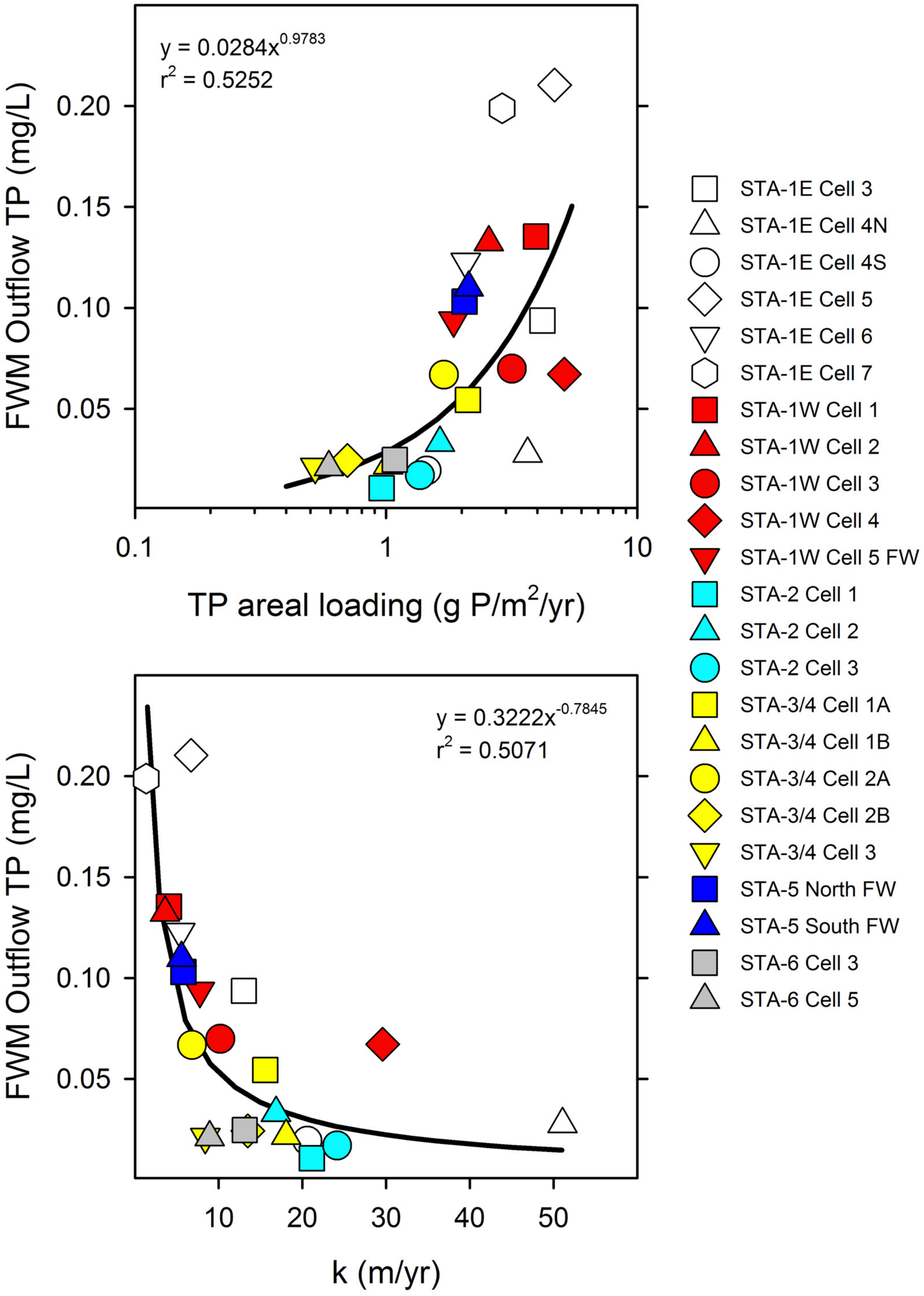

Figure 5-11. Relationship of POR outflow TP FWMC with TP areal loading rates and k values in operational STA treatment cells and flow-ways.

HYDROPATTERN RESTORATION AND STA DISCHARGE MONITORING ON THE DOWNSTREAM AREAS

This section presents the monitoring and research results from the monitoring conducted in the areas downstream of the STAs (Refuge, WCA-2A, and the RWMA. Part of the EFA Permit requirements for STA-1W, STA-1E, STA-2, and STA-5 is the characterization of the effects of STA discharges on adjacent marsh areas. This characterization is based on monthly samples collected for specific conductance (conductivity) and TP. Water quality monitoring stations in the marsh areas have been chosen along a transect from the discharge points and have been categorized as either being “impacted” or “unimpacted” based on sediment phosphorus levels. Those transect stations in areas where sediment phosphorus levels are greater than 500 milligrams per kilogram (mg/kg) are identified as impacted. Monitoring data for each transect are provided in Appendix 5-9 of this volume. A summary of conductivity and TP collected for these transects is provided in **Table 5-9** and **Table 5-10**, respectively. Summary data in these tables are grouped by STA. In addition, these water quality data are graphically presented as notched box-and-whisker plots under each individual section along with the results of the monitoring conducted as part of the hydropattern restoration monitoring.

Table 5-9. Summary statistics for conductivity [in microseimens per centimeter (µS/cm)] measurements collected during WY2008 at transect stations from STA outflows.

STA Transects	Station Information		Distance from Canal (km)	Number of Samples	Mean	Standard Deviation	Minimum	Percentiles			Maximum
	Name	Category[1]						25th	50th (Median)	75th	
STA-1W	LOXA104	Rim Canal	0.0	4	591.8	175.2	447	463	544	721	833
	LOXA104.5	Impacted	0.4	4	421.8	156.7	245	299	418	545	606
	LOXA105	Impacted	0.8	4	322.5	128.4	195	219	309	427	477
	LOXA106	Impacted	1.1	4	196.3	44.0	150	162	193	231	250
	LOXA107	Impacted	2.2	4	161.5	32.3	128	136	159	188	200
	LOXA107U	Unimpacted	3.4	4	135.8	29.1	113	115	127	157	176
	LOXA108	Unimpacted	4.1	4	129.5	23.9	110	111	124	148	161
STA-1E	LOXA135	Rim Canal	0.0	4	629.0	70.5	569	570	620	689	708
	LOXA136	Impacted	0.6	4	259.3	88.7	159	185	268	334	343
	LOXA137	Impacted	1.1	4	185.0	65.0	107	132	196	239	242
	LOXA138	Unimpacted	2.1	4	137.3	39.9	88	106	141	169	179
	LOXA139	Unimpacted	4.0	4	103.3	19.7	78	91	105	116	126
STA-2 Transect 1	2AN.25	Impacted	0.2	7	1,131.0	126.2	967	1,012	1,204	1,224	1,274
	2AN1	Impacted	0.9	7	1,097.7	146.1	825	1,028	1,162	1,213	1,220
	2AN2	Impacted	1.9	6	1,003.8	246.5	579	879	1,053	1,226	1,233
	2AN4	Impacted	3.7	7	966.0	244.0	566	778	1,001	1,165	1,214
	2AC4	Unimpacted	6.8	5	917.0	261.6	556	753	866	1,165	1,187
STA-2 Transect 2	2AFS.25	Impacted	0.4	8	1,088.1	266.5	503	1,030	1,147	1,236	1,378
	FS1	Impacted	1.0	7	1,066.0	272.4	477	1,041	1,194	1,220	1,255
	FS3	Impacted	3.1	9	1,094.0	271.1	501	1,022	1,102	1,235	1,487
	CA29	Unimpacted	5.6	22	1,009.0	220.3	578	853	979	1,140	1,591
STA-5	ROTC1	Impacted	0.2	4	733.9	93.6	657	658	714	810	850
	ROTC2	Impacted	2.3	2	765.5	181.7	637	637	766	894	894
	ROTC3	Impacted	4.2	1	547.0	-NA-	547	-NA-	-NA-	-NA-	547

Table 5-10. Summary statistics for TP (in ppb) measurements collected during WY2008 at transect stations from STA outflows.

STA Transects	Station Information		Distance from Canal (km)	Number of Samples	Mean	Standard Deviation	Minimum	Percentiles			Maximum
	Name	Category[1]						25th	50th (Median)	75th	
STA-1W	LOXA104	Rim Canal	0.0	5	36.6	9.7	24	32	36	41	51
	LOXA104.5	Impacted	0.4	5	23.8	3.1	19	22	24	26	27
	LOXA105	Impacted	0.8	11	16.4	11.0	9	11	12	17	47
	LOXA106	Impacted	1.1	4	8.8	0.5	8	9	9	9	9
	LOXA107	Impacted	2.2	4	7.0	0.8	6	7	7	8	8
	LOXA107U	Unimpacted	3.4	4	6.8	0.5	6	7	7	7	7
	LOXA108	Unimpacted	4.1	10	8.0	1.9	5	7	8	10	10
STA-1E	LOXA135	Rim Canal	0.0	5	23.4	11.1	11	16	22	29	41
	LOXA136	Impacted	0.6	5	15.0	5.0	10	12	15	17	23
	LOXA137	Impacted	1.1	13	9.8	3.3	6	7	10	12	17
	LOXA138	Unimpacted	2.1	5	7.4	1.1	6	7	7	8	9
	LOXA139	Unimpacted	4.0	5	7.6	1.5	6	7	7	9	10
STA-2 (Transect 1)	2AN.25	Impacted	0.2	7	23.1	6.0	18	20	21	24	36
	2AN1	Impacted	0.9	7	19.1	4.7	13	15	19	23	25
	2AN2	Impacted	1.9	6	14.7	4.6	8	11	15	19	20
	2AN4	Impacted	3.7	7	8.1	2.8	5	6	7	11	12
	2AC4	Unimpacted	6.8	5	6.8	1.6	5	6	6	8	9
STA-2 (Transect 2)	2AFS.25	Impacted	0.4	8	20.3	6.4	15	15	18	25	32
	FS1	Impacted	1.0	7	18.7	9.3	11	13	15	24	36
	FS3	Impacted	3.1	9	8.8	2.0	6	7	9	10	12
	CA29	Unimpacted	5.6	22	6.6	2.0	5	5	6	8	12
STA-5	ROTC1	Impacted	0.2	5	56.4	27.8	35	37	52	66	104
	ROTC2	Impacted	2.3	3	30.3	22.5	14	16	21	47	56
	ROTC3	Impacted	4.2	1	32.0	-NA-	32	-NA-	-NA-	-NA-	32

[1] Categories of “impacted” and “unimpacted” refer to station identification based on sediment phosphorus concentrations. Impacted stations have sediment phosphorus levels greater than 500 mg/kg.

Arthur R. Marshall Loxahatchee National Wildlife Refuge

Discharges from STA-1W and STA-1E are released into the rim canal surrounding the Arthur R. Marshall Loxahatchee National Wildlife Refuge. These discharges enter the rim canal from the northwestern (STA-1W) and northeastern (STA-1E) quadrats of the Refuge. Marsh transects downstream from both discharges extend approximately 4 km into the Refuge (**Figure 5-12**). Impacted stations extend approximately 2 km (downstream of STA-1W) and 1 km (downstream of STA-1E) into the marsh (**Tables 5-9** and **5-10**). A total of 12 stations are monitored in the Refuge, with seven stations along the western transect and five stations along the eastern transect. A station from each transect is monitored in the rim canal.

Transects in the Refuge exhibited a substantial decrease in both conductivity and TP concentrations within 1 km from the rim canal (**Figure 5-13**). TP concentrations measured in the western transect (downstream of STA-1W outflows) decreased by approximately 25 micrograms per liter (µg/L) (or ppb), and conductivity decreased by approximately 350 µS/cm within 1 km from the rim canal station. The eastern transect (downstream of the STA-1E outflow) exhibited a decrease of approximately 420 µS/cm in conductivity and 12 ppb in TP within the first kilometer from the rim canal (**Tables 5-9** and **5-10**). Stations on both transects located at a distance greater than 1 km from the rim canal had median TP concentrations ranging from 7–10 ppb (**Table 5-10**). Median conductivity values for these stations ranged from 105–196 µS/cm (**Table 5-10**). All conductivity levels measured at Refuge transect stations were below the Class III criterion of 1275 µS/cm. A Kruskal-Wallis test was performed on TP and conductivity levels for both transects to determine if concentrations along each transect were statistically different. Both parameters exhibited a statistically significant decrease in both TP concentrations and conductivity levels ($p < 0.01$) across each transect.

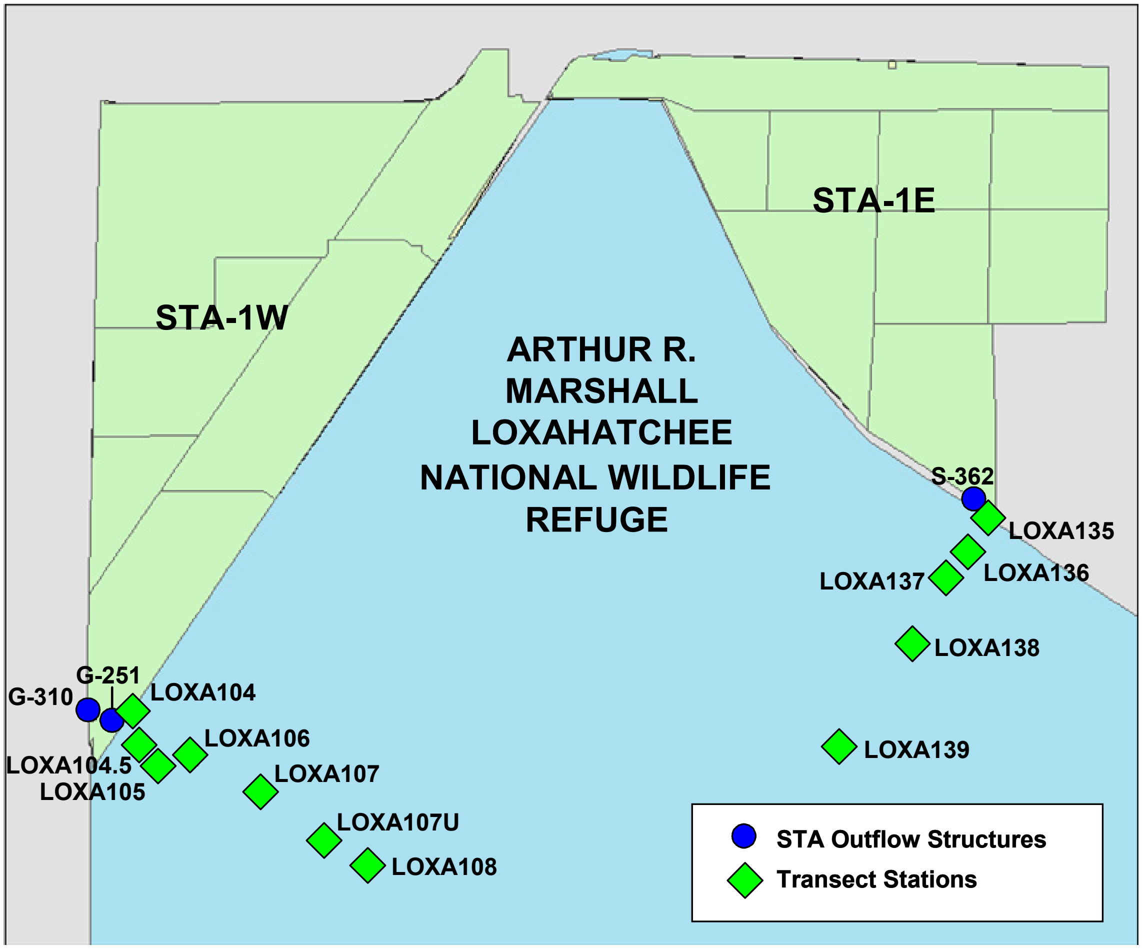

Figure 5-12. Locations of marsh transect stations in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) and outflow structures from STA-1W and STA-1E.

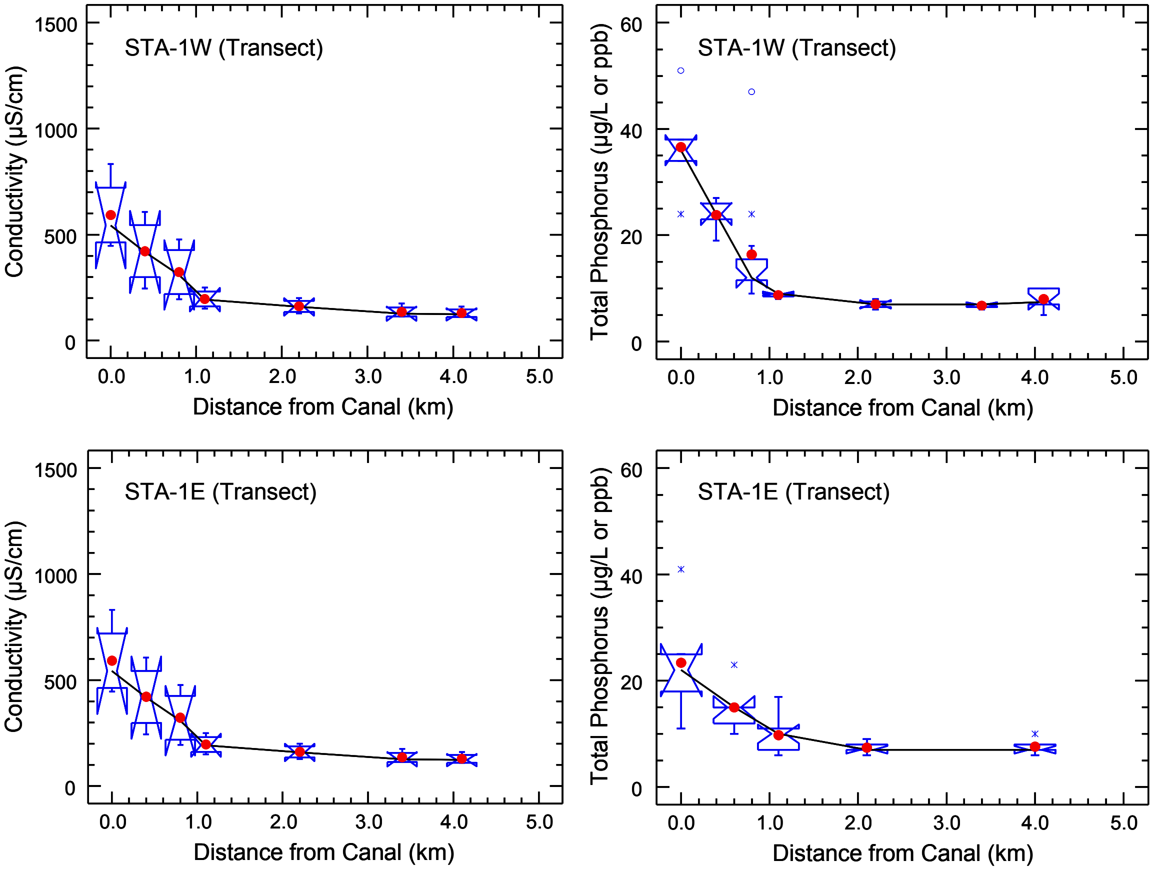

Figure 5-13. Notched box-and-whisker plots of conductivity and TP levels measured at transect stations during WY2008 for STA-1W and STA-1E that enter the Refuge. The notch on a box plot represents the 95 percent confidence interval (C.I.) about the median, which is represented by the narrowest part of the notch. The top and bottom of the box represent the 75th and 25th percentiles, respectively. The whiskers represent the highest and lowest data values that are within two standard deviations (S.D.) of the median. Values above and below the whiskers are greater than two S.D. from the median (*) and outliers are denoted by open circles (°). Notches that do not overlap indicate that the data represented by the boxes being compared are significantly different at the 95 percent C.I.

Northwestern Water Conservation Area 2A

This section presents the research conducted to evaluate the hydropattern restoration efforts in the northwestern WCA-2A as well as the monitoring conducted to evaluate the possible impacts that STA-2 discharges may have on the marsh.

WCA-2A Hydropattern Restoration Monitoring Objectives

In accordance with the EFA, the USACE Section 404, and the NPDES permits, the SFWMD has been operating and monitoring water discharges from STA-2 into the northwestern region of WCA-2A. The main objective of releasing the STA discharge is to restore the hydropattern and ecological functionality of the marshes downstream of STA-2. These permits require the SFWMD to implement a monitoring and assessment program to evaluate ecological changes associated with STA-2 discharges within the northwestern region of WCA-2A by performing field monitoring, research, mapping, and reporting activities. Specifically, the 2007 STA-2 EFA permit requires a monitoring program to determine the effects of the hydropattern restoration discharges from STA-2 and to ensure that the discharges do not adversely affect previously unimpacted downstream portions of WCA-2A. The permit requires annual reports about the previously unimpacted marsh downstream of STA-2, including documentation of:

1. Beneficial environmental effects, including changes in water quality, soil, vegetative conditions, inundation, and timing of discharges

2. Adverse environmental effects, including imbalances in natural populations of flora or fauna, changes in periphyton communities, increased phosphorus accumulation rates in soil, expansion of cattail or other undesirable or exotic vegetation, or other undesirable consequences of hydropattern restoration

WCA-2A Hydropattern Restoration Monitoring Sites

STA-2 primarily discharges into WCA-2A through six culverts (the G-336A–F structures) (**Figure 5-14**). Additional STA-2 effluent is discharged via the G-336G structure into a discharge canal south of STA-2. Approximately 1 km northeast of the S-7 pump station, the levee separating this discharge canal from WCA-2A is degraded, which allows discharge passing through the G-336G to passively enter WCA-2A. Sampling stations were established in 1998 to capture environmental changes in WCA-2A downstream of STA-2. In 2005, a new transect (FS-transect) was established to monitor this additional STA-2 discharge.

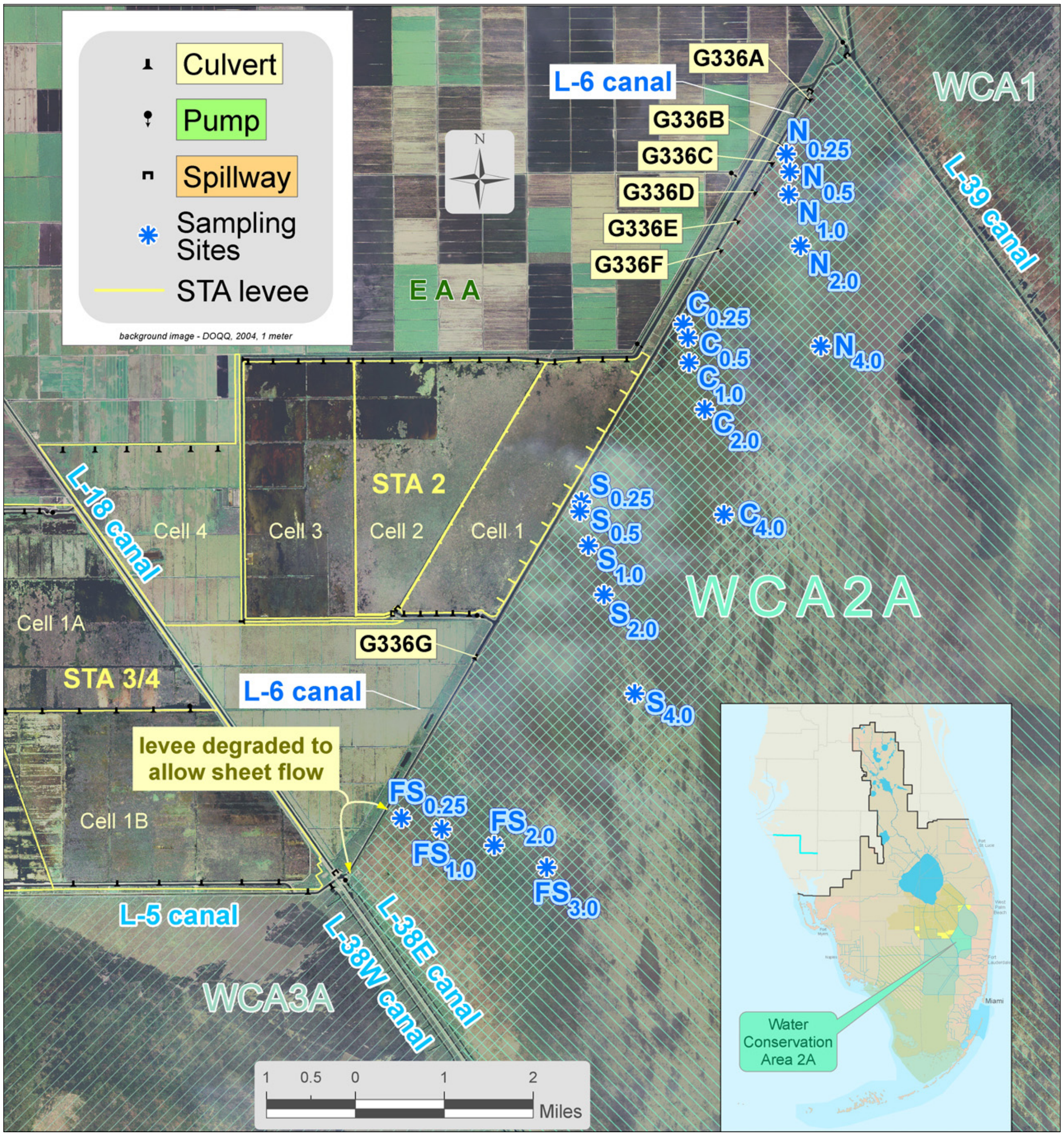

Figure 5-14. The STA-2 G-336A-G discharge culverts and the hydropattern restoration sampling stations located within the northwestern section of WCA-2A.

WCA-2A Hydropattern Restoration Evaluation

Hydropattern improvements resulting from STA-2 discharges were presented in Pietro et. al, 2008 and in the Hydropattern Restoration in Water Conservation Area 2A report (Garrett and Ivanoff, 2008). To monitor water levels within northwestern WCA-2A, water depth recorders were set up at eight stations between 2004 and 2006. The accuracy of these depth recorder measurements has been estimated during 2006 and 2007 by comparing them with periodic field measurements (**Table 5-11**). Water depths in the field were obtained using a meter stick (during field visits) and were compared to the depths of the water depth recorders for the same dates. Discrepancies between the measured depths and the recorded depths ranged from 3.6 cm to 9.0 cm and could have been caused by (1) microtopographic variations, which can vary by several centimeters (even within a foot or less of the recorder), and (2) the water levels in the porewater wells that are used by the water depth recorders may take some time to catch up to surrounding water depths, especially when water depths are rising or falling rapidly. Water depths at the six northern stations during 2007 are presented in **Figure 5-15**. Inundated periods among these six stations ranged from 172 days at $S_{1.0}$ to 267 days at $N_{0.25}$. Mean water depth ranged from 7 cm at $S_{1.0}$ to 37 cm at $N_{0.25}$. Depth recorders were also placed at $FS_{0.25}$ and $FS_{3.0}$, but are not displayed in **Figure 5-15** because they receive STA-2 discharge from an additional discharge point (G-336G). The $FS_{0.25}$ depth recorder was damaged in 2006 during a high water event and was not replaced until mid-2007, so the inundation period could not be estimated. $FS_{3.0}$ displayed an inundation period of 283 days with a mean depth of 25 cm during 2007.

Table 5-11. Water depth measurements from deployed depth recorders during calendar year 2007 (CY2007). Measurements were recorded every 30 minutes, and a mean depth was calculated for the year. The mean difference was from comparing water depth measurements taken during field visits.

Station	Est. Days Inundated	Mean Water Depth (cm)	Water Depth Range (cm)	Mean Difference (cm) from Field-Measured Water Depth
$N_{0.25}$	265	37	0 - 111	3.8
$N_{4.0}$	259	18	0 - 65	9.0
$C_{0.25}$	263	31	0 - 84	5.7
$C_{1.0}$	259	25	0 - 73	6.2
$C_{4.0}$	263	15	0 - 47	6.1
$S_{1.0}$	172	7	0 - 56	3.6
$FS_{0.25}$*	196*	48*	17 - 105*	6.7
$FS_{3.0}$	287	25	0 - 86	7.7

* Data from $FS_{0.25}$ were only available during part of 2007 (March 16–December 31).

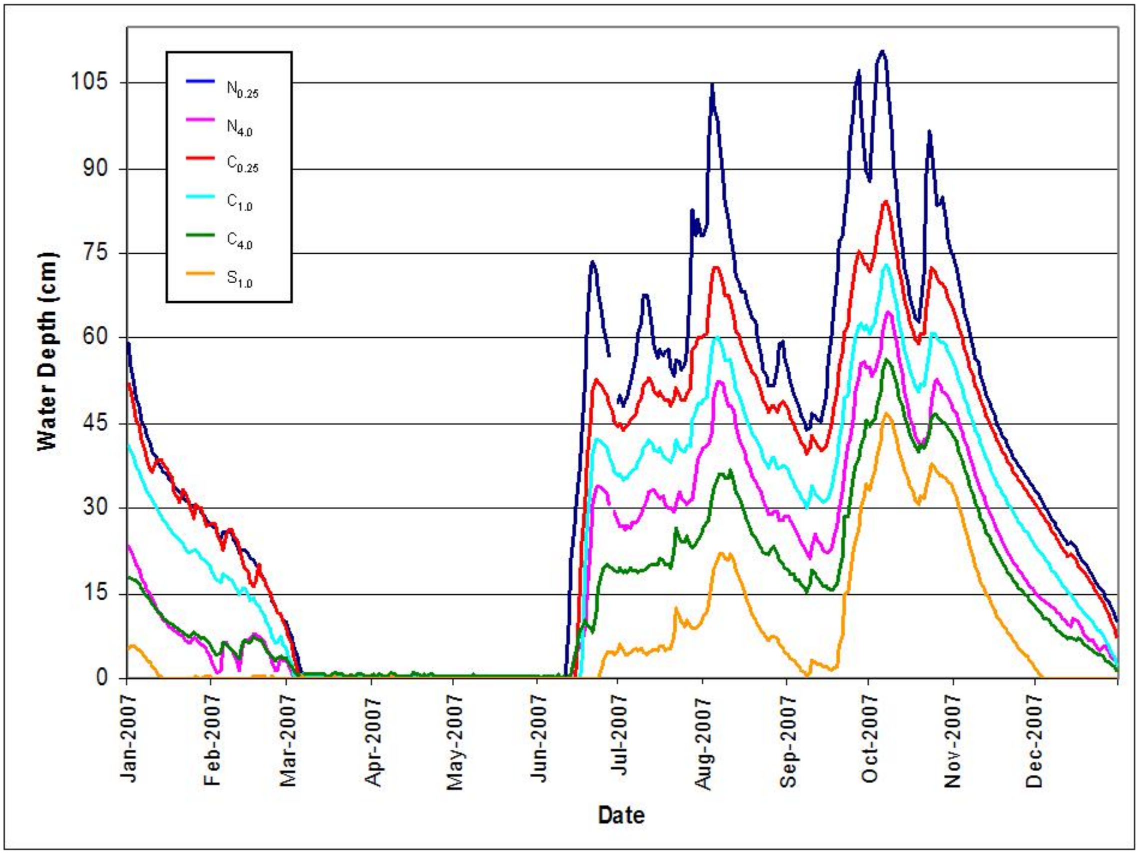

Figure 5-15. Daily mean water depths obtained from deployed depth recorders at six stations in the northwestern region of WCA-2A during CY2007.

WCA-2A Hydropattern Restoration Monitoring Surface Water Quality Results

Surface water samples were collected on a monthly basis at 16 sites within the northwestern portion of WCA-2A when sufficient water ($\geq$ 10 cm) was available. Mean surface water TP, total Kjeldahl nitrogen (TKN), SO_4 concentrations, and mean conductivity measurements were calculated for each station (**Table 5-12**). These parameters were selected based on the 2008 WCA-2A Report (Garrett and Ivanoff, 2008) and the STA-2 permit requirement that those factors that may affect flora and fauna in the area be monitored and reported. Nitrogen and phosphorus are essential nutrients, and because of concerns about elevated sulfate levels in the WCA-2A and surrounding areas, sulfate is also reported. Specific conductivity is specified in the permit.

During 2007, obvious surface water P gradients existed along the N-, C-, and FS-transects, while the S-transect displayed near background level concentrations along the entire transect. TP concentrations were highest at $N_{0.25}$ and $C_{0.25}$ at 30 ppb and 34 ppb, respectively, while $S_{1.0}$ and $S_{2.0}$ had the lowest mean TP concentration of 7 ppb. Mean TP concentrations increased along the N-transect and at $C_{0.25}$ and $C_{1.0}$ when compared to prior mean surface water concentrations listed within the Hydropattern Restoration in Water Conservation Area 2A report (Garrett and Ivanoff, 2008). However, TP concentrations at $C_{2.0}$, $C_{4.0}$, and the entire S-transect decreased compared to prior concentrations at these stations. The $FS_{1.0}$ and $FS_{2.0}$ stations displayed slight increases from prior mean concentrations during 2007, while the $FS_{0.25}$ and $FS_{3.0}$ exhibited declines in mean surface water TP.

TKN concentrations were similar among all stations, with a high mean concentration of 2.56 mg/L at $FS_{3.0}$ and a low mean concentration of 1.91 mg/L at $N_{2.0}$.

SO_4 concentrations were highest at $FS_{3.0}$ with a mean concentration of 63 mg/L, while $S_{2.0}$ displayed the lowest mean SO_4 concentration of 38 mg/L. SO_4 concentrations at nearly all stations were lower than mean concentrations measured from 2001–2006 and are listed in the Garrett and Ivanoff report. The exceptions were $S_{4.0}$ and $FS_{3.0}$, which both experienced increases in mean SO_4, likely due to concentration spikes during periods when dried soils were rewetted.

Conductivity levels were similar among all stations. Most stations exhibited a slight decline in conductivity when compared to mean levels measured since 2001 (or 2005 in case of the FS-transect). The only stations that displayed increases in mean conductivity were the $FS_{2.0}$ and $FS_{3.0}$.

Soil Chemistry. Soil samples are collected every other year at 19 monitoring sites in northwestern WCA-2A. Samples were last collected in March 2008. Cores were originally split into 0-2 and 2-10 cm layers for analysis, but results are presented as 0-10 cm soil layers. Samples were first corrected for bulk density in order to combine the results of both soil layers. Mean TP results from the 2008 collection periods are included for each site (**Table 5-13)**. During 2008, there were no notable changes from prior soil P concentrations reported in Hydropattern Restoration in Water Conservation Area 2A (Garrett and Ivanoff, 2008).

Table 5-12. Mean surface water TP, TKN, SO_4 concentrations and specific conductivity measurements with standard deviations measured when water was collected during CY2007 as part of the hydropattern restoration monitoring.

Station	Mean TP (ppb)	Mean TKN (mg/L)	Mean SO4 (mg/L)	Mean Conductivity (µS/cm)	Samples Collected in 2007
$N_{0.25}$*	30 ± 11	2.30 ± 0.16	52 ± 8	1168 ± 107	7
$N_{1.0}$*	23 ± 7	2.24 ± 0.17	51 ± 5	1146 ± 90	7
$N_{2.0}$	15 ± 6	1.91 ± 0.22	49 ± 14	1092 ± 170	4
$N_{4.0}$	9 ± 3	1.95 ± 0.32	45 ± 14	1058 ± 203	6
$C_{0.25}$	34 ± 19	2.25 ± 0.13	52 ± 9	1147 ± 95	8
$C_{1.0}$*	14 ± 7	2.09 ± 0.16	46 ± 11	1093 ± 119	7
$C_{2.0}$	12 ± 4	2.16 ± 0.28	44 ± 11	1097 ± 145	7
$C_{4.0}$	8 ± 2	1.99 ± 0.34	51 ± 14	1070 ± 178	3
$S_{0.25}$	9 ± 2	2.04 ± 0.10	48 ± 8	1102 ± 110	5
$S_{1.0}$	7 ± 2	2.01 ± 0.15	51 ± 10	1020 ± 111	3
$S_{2.0}$	7 ± 1	2.18 ± 0.29	38 ± 15	969 ± 167	6
$S_{4.0}$*	8 ± 3	2.36 ± 0.53	53 ± 39	1040 ± 144	7
$FS_{0.25}$*	23 ± 7	2.27 ± 0.13	48 ± 14	1148 ± 94	6
$FS_{1.0}$*	22 ± 9	2.29 ± 0.13	45 ± 16	1137 ± 81	6
$FS_{2.0}$	15 ± 7	2.47 ± 0.50	56 ± 35	1158 ± 105	7
$FS_{3.0}$*	9 ± 3	2.56 ± 0.62	63 ± 58	1191 ± 171	8

* Permit-mandated stations

Table 5-13. Mean soil TP concentrations with standard deviations measured in March 2008. Each value is the mean of three soil cores collected to a depth of 10 cm. Soil TP concentrations above 500 mg/kg are generally considered impacted.

Station	Mean Soil TP (mg/kg)
$N_{0.25}$*	835 ± 32
$N_{0.5}$	705 ± 25
$N_{1.0}$*	713 ± 63
$N_{2.0}$	675 ± 170
$N_{4.0}$*	518 ± 58
$C_{0.25}$	595 ± 50
$C_{0.5}$	527 ± 24
$C_{1.0}$*	458 ± 31
$C_{2.0}$	504 ± 52
$C_{4.0}$	476 ± 37
$S_{0.25}$	480 ± 51
$S_{0.5}$	539 ± 32
$S_{1.0}$	443 ± 26
$S_{2.0}$	515 ± 28
$S_{4.0}$*	421 ± 38
$FS_{0.25}$*	1134 ± 95
$FS_{1.0}$*	892 ± 150
$FS_{2.0}$	742 ± 113
$FS_{3.0}$*	500 ± 8

* Permit-mandated stations

WCA-2A Monitoring to Characterize Impact of STA-2 Discharges (Total Phosphorus And Conductivity)

In addition to the research conducted along the transects described above, TP and conductivity is monitored at two transects in WCA-2A to characterize the effects of STA-2 discharges on the marsh. These transects are located in the western portion of the WCA with one transect located in the northern portion and the other in the southern portion of WCA-2A (**Figure 5-16**). The northern transect comprises five monitoring stations extending approximately 7 km. The southern transect extends approximately 6 km into WCA-2A and contains four monitoring stations.

Conductivity and TP levels changed more gradually at the two transects located in WCA-2A. Median TP concentrations were ≤ 10 ppb at a distance of more than 3 km from the canal (**Figure 5-17**). Conductivity levels along both transects were not statistically different (p-value ~ 0.30 based on the Kruskal-Wallis test). A decrease in median conductivity levels of approximately 200 µS/cm occurred between 3 and 6 km from the canal (**Figure 5-19**). No conductivity measured along the northern transect exceeded the Class III criterion of 1,275 µS/cm. However, conductivities measured along the southern transect during WY2008 had five excursions from the Class III criterion. The station located closest to the canal (2AFS.25) had only one conductivity measurement (or 12.5 percent of measurements) that exceeded the Class III criterion. The other four exceedances occurred at stations more than 3 km from the canal (e.g., FS3 and CA29). The highest conductivity (1,591 µS/cm) measured along the southern transect in WY2008 occurred at the unimpacted station CA29 (**Table 5-9**). This high conductivity level may have resulted from drought conditions.

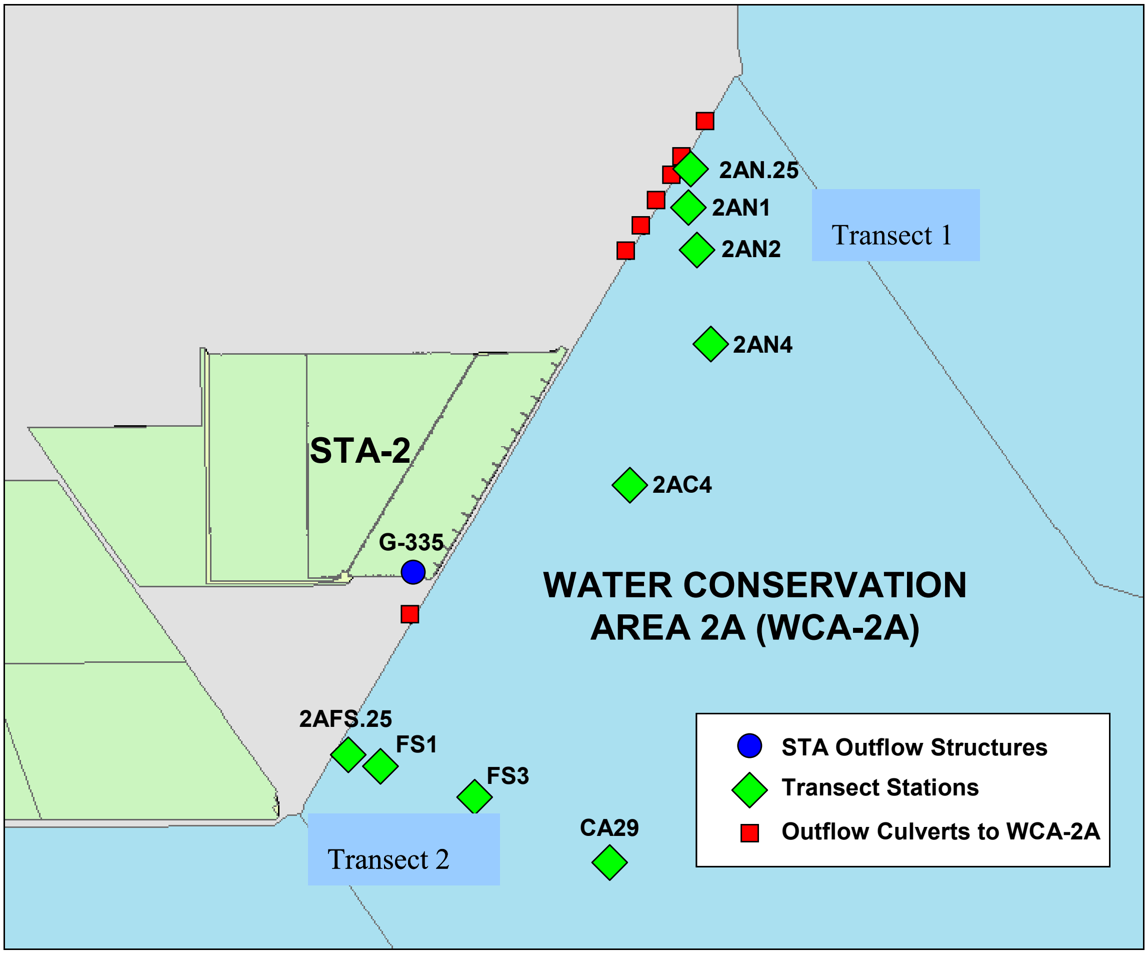

Figure 5-16. Locations of marsh transect stations in WCA-2A, the outflow structure from STA-2, and outflow culverts to the marsh.

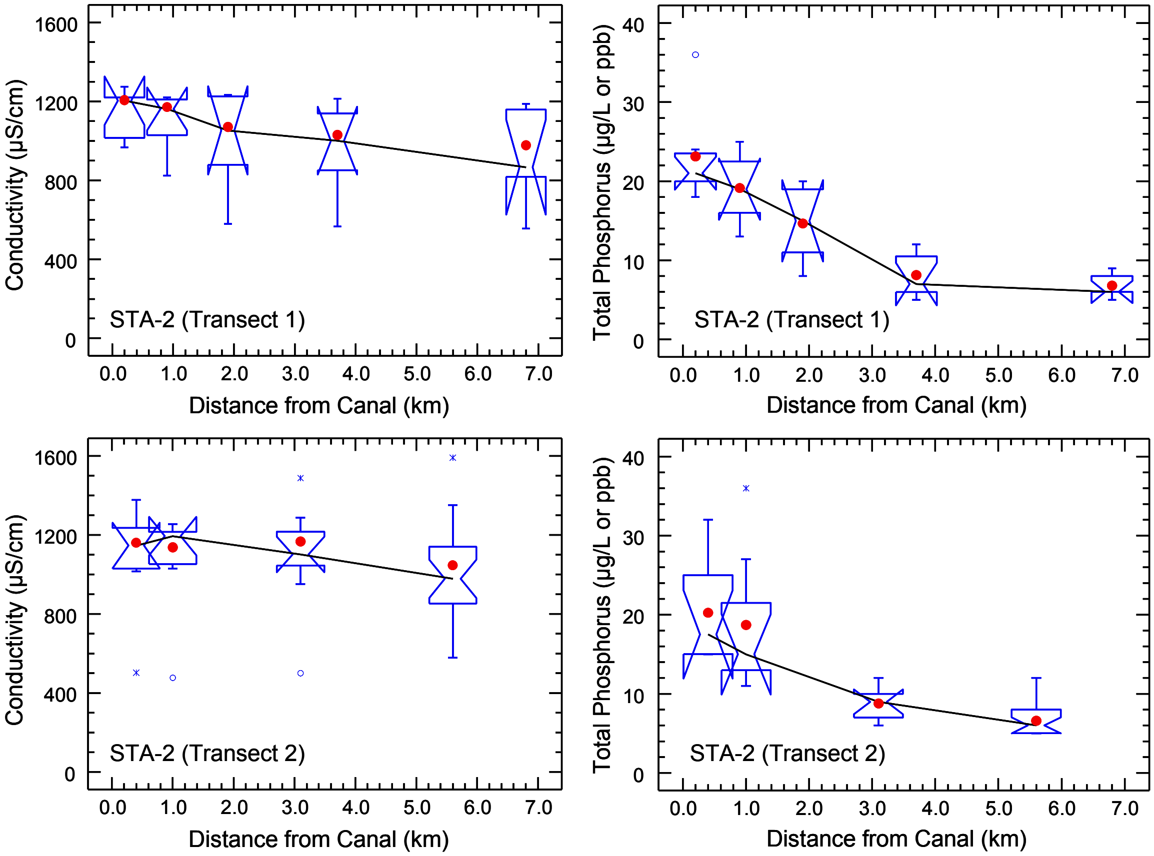

Figure 5-17. Notched box-and-whisker plots of conductivity and TP levels measured at transect stations during WY2008 for STA-2 discharges that enter into WCA-2A.

Rotenberger Wildlife Management Area

This section presents the research conducted to evaluate the hydropattern restoration efforts in the RWMA as well as the monitoring conducted to evaluate the possible impacts that STA-5 discharges may have on the marsh.

Hydropattern Restoration Monitoring Objectives and Monitoring Sites

The Rotenberger Hydropattern Restoration Project is a component of the larger ECP. The goal of this project is to slow, alter, and eventually reverse ecosystem degradation within the RWMA (**Figure 5-18**), primarily by restoring the area's natural hydropattern. This degradation is predominantly caused by overly dry conditions that have resulted from repeated peat fires, soil oxidation and compaction, nutrient release from surface soils, and conversion of obligate wetland vegetative communities to upland-type communities. Natural hydropatterns for the RWMA were estimated using a 31-year run of the Natural Systems Model (NSM), with the following revisions: (1) when the average NSM depth drops below ground, the base is set to ground level, and (2) to obtain the interim operational schedule, a 0.25-foot offset was added to the target stage to minimize the potential for excessive dryout during the dry season.

The interim operational schedule was officially adopted in 2006. Anticipated benefits include preserving the remaining wetlands, encouraging the growth of additional, desirable wetland vegetation species, and initiating the process of peat formation. Project features include a 240 cubic feet per second (cfs) electric pump station (G-410) to withdraw treated water from the STA-5 discharge canal for release into the RWMA. This pump station distributes water through a 3.5-mile-long spreader canal located parallel to the RWMA's western perimeter levee. Discharges out of the RWMA go into the Miami Canal (L-28 canal) through four gated culverts (G-402A through G-402D) along the eastern boundary of the RWMA. There is a quarter-mile-long collection canal upstream of each outlet structure. There is currently no vegetation goal for the RWMA. Stage targets are set to limit the time period of drying that soils experience and to reduce the possibility of peat fires. The District is currently working with an interagency group to potentially redefine operations so the desired hydrologic conditions can be achieved and maintained to minimize subsidence rates, minimize impacts to vegetation, and meet other performance goals for this area.

In January 2004, the District issued a modification to the Rotenberger Operations Plan. This plan increased the operation schedule to 0.25 foot above the NSM target. The EFA permit issued on September 2007 for STA-5 defined the current Rotenberger Hydropattern Restoration Project and the associated monitoring needed to measure the progress of the restoration. Additionally, it established the RC1, RC2, and RC3 stations as permit compliance locations within the RWMA. The sites were selected based on predicted flow patterns using flow estimates before STA-5 became operational. These flow estimates suggested that water would flow across the RWMA, especially when the G-402C structure gate was open; therefore, the RC1, RC2, and RC3 were selected as the best transect of stations for permit monitoring. The RC4, RA1, RA2, RA3, and RA4 are also sampled when water levels allow. The G-402C structure is also monitored when this gate is open. Both the RA and RC transects run from the G-410 structure to the G-402A and G-402C outflow structures, respectively. The additional sites are not included in the permit, but provide the District good coverage for evaluating water quality conditions in the RWMA.

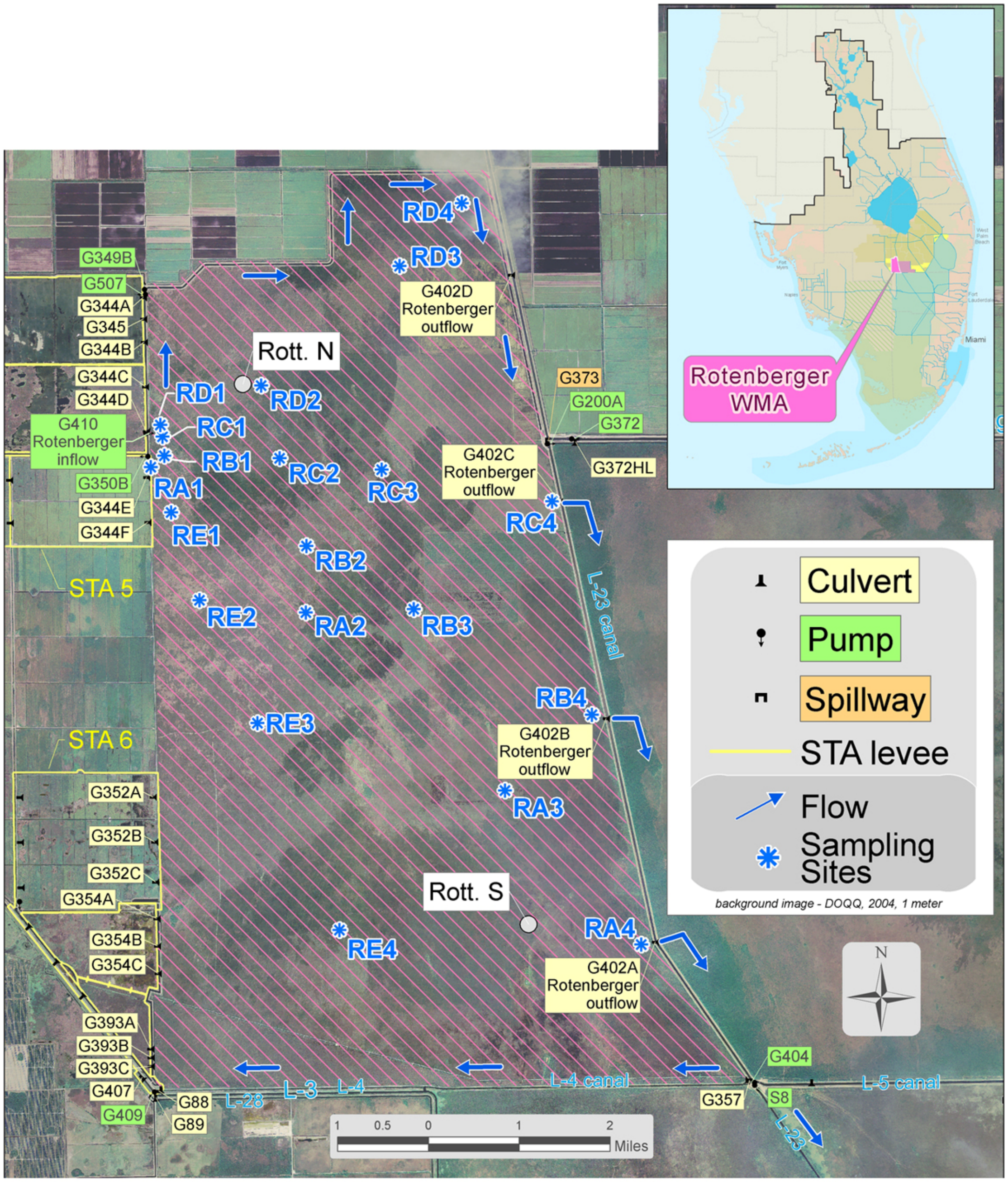

Figure 5-18. Schematic of water flow, sampling stations, and stage gauges (Rott.N and Rott.S) within the Rotenberger Wildlife Management Area (RWMA) to evaluate hydropattern restoration.

Hydrologic and Total Phosphorus Loads

In WY2008, approximately 11,646 ac-ft of STA treated water was delivered to the RWMA through the G-410 structure. Although the RWMA received some inflows, there was no water discharged to the Miami Canal through the G-402 outflow structures (**Figures 5-19** and **5-20**). The inflow TP FWMC was 51 ppb, yielding a TP inflow load of about 0.74 mt. Of the total inflow volume delivered to the RWMA in WY2008, 5,804 ac-ft of water came from STA-3/4 in March 2008. This inflow had a TP FWMC of 29 ppb, and was 0.2 mt of the TP inflow load.

Hydropattern Restoration Evaluation

The monthly target stages for the RWMA were determined by adding 0.25 foot to the NSM. As noted in the 2008 SFER – Volume I, Chapter 5, the hydropattern restoration goal was generally achieved for CY2005, although it fell short by approximately 0.4 ft at the end of the year. Rainfall during 2006 and 2007 was well below average, and as a result, the stage dropped over 1 ft below NSM targets for most of 2006 (**Figure 5-21**). By March 2007, the water level across the RWMA (as measured by the Rott.N and Rott.S stage gauges) receded below the bottom of the stilling wells. Therefore, the mean stage appeared to hold steady at approximately 10.90 ft, but was likely lower. The stage remained at this level through May 2007 and began to increase in early June 2007, but still remained well below the NSM target stage. The stage gauges malfunctioned in mid-October 2007, and data were unavailable until repairs were completed in March 2008. Due to above-average rainfall in March 2008, the District had treated water available from STA-3/4 that could not be discharged elsewhere. This water was directed into the RWMA and the mean stage in the RWMA was allowed to exceed the operation schedule for a brief period that lasted less than a month. This high water level was allowed to ensure that the tract would remain wet during the peak of the dry season, thus reducing the potential for peat fires.

With drought conditions continuing throughout 2007 and well into 2008, the threat of peat fires remained a concern. No peat fires have occurred during this period; however, a notable shift in the dominant vegetation occurred within much of the northern portion of the tract. Dogfennel (*Eupatorium capillifolium*), an upland plant species, spread across much of this region from November 2007–March 2008. Dogfennel, which can grow up to 10 ft, can dominate much of the upper vegetative canopy and shade shorter plant species. A similar dogfennel invasion occurred within the RWMA during analogous drought conditions in 2000. There are concerns that a fast-growing and quick-spreading plant species like dogfennel may exacerbate impacts of dry conditions within the marsh due to high rates of water uptake and transpiration. This hypothesis will be tested in the future if the proper conditions take place again.

In 2008, working closely with the FDEP and Florida Fish and Wildlife Commission (FWC), the SFWMD began updating the current operation schedule to potentially extend the hydroperiod in the RWMA during both normal and drought years. One of the suggested strategies is to adjust the current operation of the outflow structures, i.e., G-402 A-D.

It should be noted that the RWMA hydrographs reported in previous SFERs have displayed an incorrect mean target stage for the month of May. Although the target stage was reported to approach 12.0 ft National Geodetic Vertical Datum (NGVD) in May, the target stage is actually held at 12.30 ft NGVD 29 from April 17–June 8 according to the Operations Plan. This correction is shown in this report, and it is planned that data will be presented using a daily average instead of a monthly average in future SFERs.

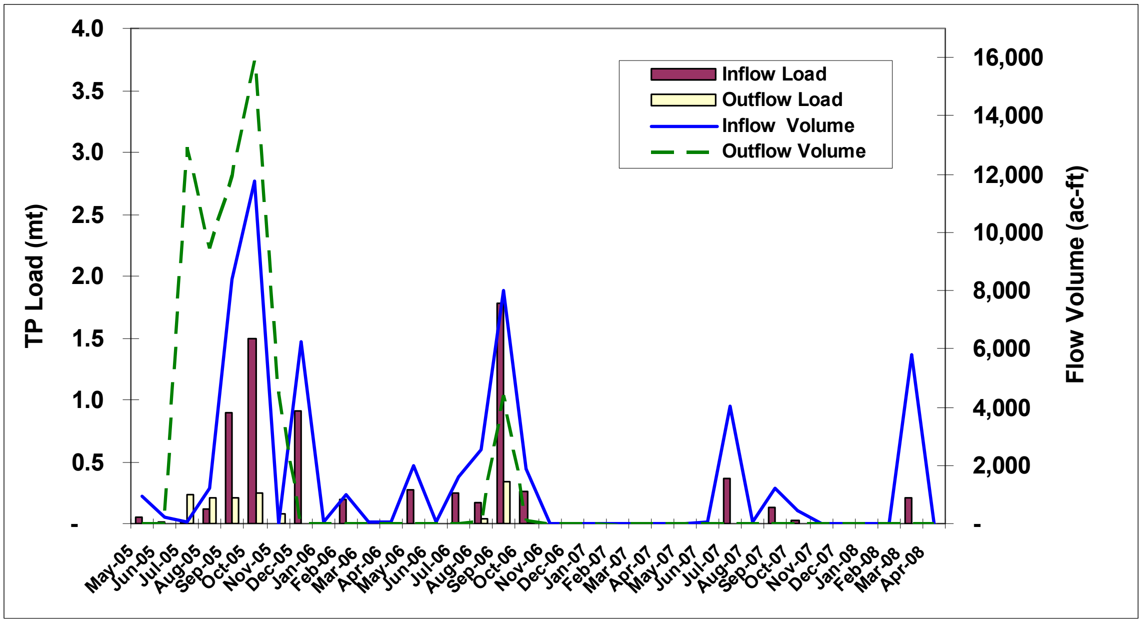

Figure 5-19. Summary of monthly flow and TP load for the RWMA during WY2006–2008.

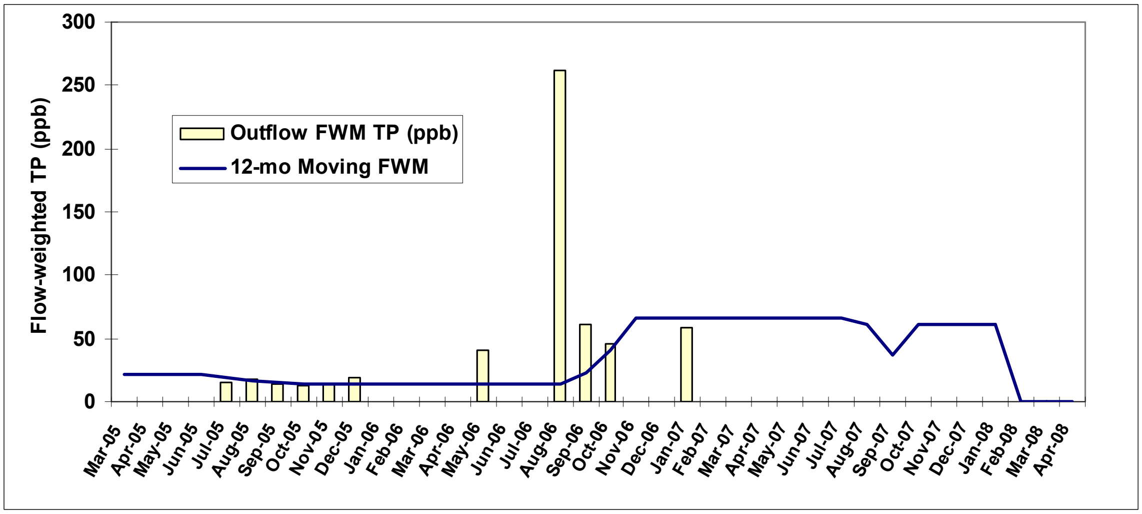

Figure 5-20. Comparison of monthly to 12-month moving average TP concentrations for the RWMA outflow during WY2006–WY2008.

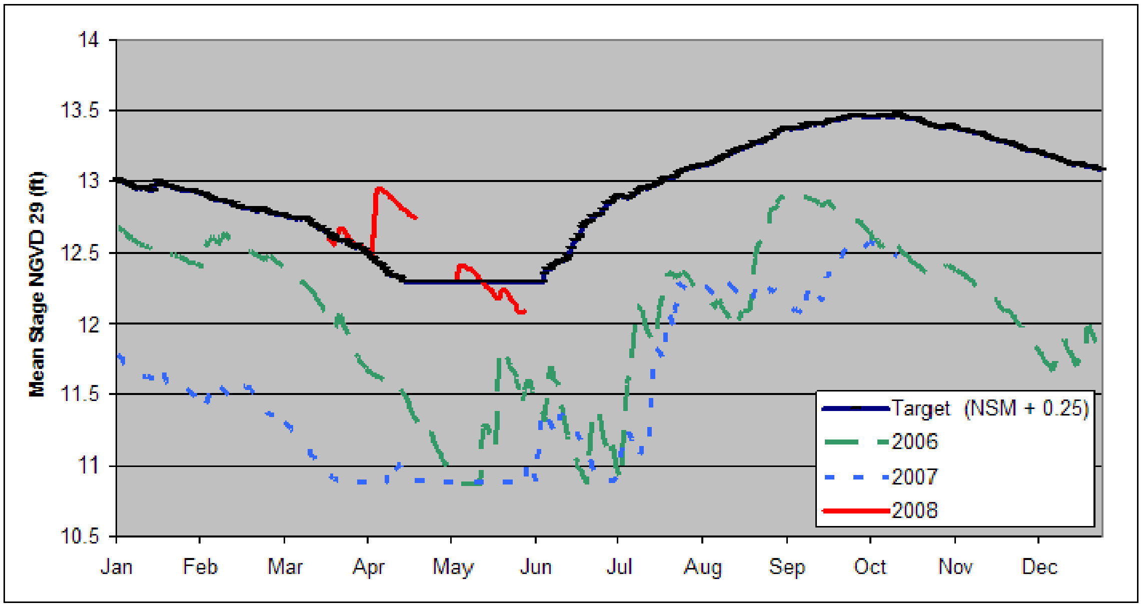

Figure 5-21. Mean daily target stages and mean daily stage readings (Rott.N and Rott.S) from January 2006–June 2008. Target stages were based on Natural System Model (NSM) for the RWMA, including a 0.25-foot offset.

Surface Water Quality. Surface water quality samples are collected monthly at eight sites within the RWMA when sufficient water ($\geq$ 10 cm) is available. Drought conditions in 2007 allowed for a very limited number ($n = 7$) of water collections or conductivity measurements ($n = 4$) within the RWMA. Mean surface water TP concentrations and conductivity measurements were calculated for each station (**Table 5-14**).

Table 5-14. Mean surface water TP concentrations (ppb) and conductivity ± S.D. collected during CY2007 in the RWMA along transects established to evaluate hydropattern restoration. N/A designates stations that did not have sufficient water depths ($\geq$ 10 cm) during any of the sampling periods.

Station	TP (ppb)	Samples Collected in 2007	Conductivity (µS/cm)	Samples Collected in 2007
RA1	0.073 ± 0.035		655	1
RA2	N/A	0	N/A	0
RA3	N/A	0	N/A	0
RA4	0.024	1	274	1
RC1*	0.070 ± 0.030	3	714 ± 78	2
RC2*	0.056	1	N/A	0
RC3*	N/A	0	N/A	0
RC4	N/A	0	N/A	0

* STA-5 permit-mandated stations

Soil Chemistry. Soil samples are collected every other year at 20 monitoring sites in the RWMA. Samples were collected in March 2005 and again in March 2007. Cores were originally split into 0-2 and 2-10 cm layers for analysis, but results are presented as 0-10 cm soil layers. Samples were first corrected for bulk density in order to combine the results of both soil layers. No samples were collected along the RE transect in 2005. Mean TP results from both collection periods are displayed in **Table 5-15**. The 2007 results were influenced by a large-scale fire that occurred in May 2006, which included several peat fires in northern sections of the RWMA (Pietro et. al., 2008). The 2007 soil collections performed at the RC2, RC3, and RC4 stations were taken from both surface-burned and peat-burned soils. TP concentration comparisons were made between these two burn types. Surface-burned soils experienced notable increases in soil TP concentrations compared to pre-fire soils. However, peat-burned soils exhibited significantly greater increases ($p < 0.0001$) in TP concentrations when compared to surface-burned soils. Peat-burned soils displayed two- to four-fold increases in soil TP than were measured in pre-fire soils.

The resulting soil subsidence due to peat fires can extend hydroperiods significantly. This, combined with the elevated soil TP concentrations, increases the possibility that species, such as cattail and willow (*Salix caroliniana*), can establish undesirable monocultures when the soil is inundated for long periods (> 11 months/year) of time (Newman et al., 1998; Smith and Newman, 2001). Some stations near the G-410, which experienced severe peat burns, have already experienced changes in vegetative communities from sawgrass (*Cladium jamaicense*) to cattail/willow mixes (**Figure 5-22**).

Table 5-15. Mean soil TP concentrations (mg/kg) ± S.E. from 2005 and 2007 collections in the RWMA. Each value is the mean of results from three soil cores collected to a depth of 10 cm.

Station	2005 Mean $TP_{0\text{-}10}$ (mg/kg)	2007 Mean $TP_{0\text{-}10}$ (mg/kg)	2007 Mean Peat Burn $TP_{0\text{-}10}$ (mg/kg)
RA1	375 ± 22	483 ± 76	-
RA2	378 ± 80	372 ± 106	-
RA3	452 ± 44	605 ± 114	-
RA4	735 ± 115	664 ± 102	-
RB1	495 ± 55	633 ± 142	-
RB2	468 ± 122	818 ± 72	-
RB3	372 ± 23	534 ± 65	-
RB4	563 ± 33	816 ± 29	-
RC1*	467 ± 25	2847 ± 388	-
RC2*	510 ± 37	669 ± 77[†]	1366 ± 295[††]
RC3*	334 ± 13	634 ± 98[†]	1400 ± 256[††]
RC4	639 ± 16	712 ± 76[†]	1718 ± 371[††]
RD1	447 ± 28	1858 ± 475	-
RD2	500 ± 85	792 ± 50	-
RD3	561 ± 65	889 ± 80	-
RD4	802 ± 257	1573 ± 209	-
RE1	-	666 ± 75	-
RE2	-	687 ± 120	-
RE3	-	1671 ± 451	-
RE4	-	447 ± 82	-

* STA-5 permit-mandated stations
[†] Surface-burned soils only
[††] Peat-burned soils only

RC1 Station - Nov 2004
Primarily Sawgrass

RC1 Station - Nov 2006
Primarily Cattail

RC1 Station - Apr 2008
Primarily Cattail with Some Willow

RD1 Station - Nov 2004
Primarily Sawgrass and Willow with some Cattail

RD1 Station - Nov 2006
Primarily Cattail and Willow

RD1 Station - Apr 2008
Primarily Willow with Some Cattail

Figure 5-22. Two examples of vegetative community change that have occurred in the RWMA between November 2004 and April 2008. The RC1 and RD1 stations are located near the G-410 pump station (photos by the SFWMD, 2004–2008).

Monitoring to Characterize Impact of STA-5 Discharges (Total Phosphorus and Conductivity)

In addition to the research conducted along the transects described above, TP and conductivity is monitored at one transect in the RWMA to characterize the effects of STA-5 discharges on the marsh. The RWMA transect comprises three monitoring stations that extend approximately 4 km downstream of pump station G-410 (**Figure 5-23**). All stations along this transect are identified as impacted (**Table 5-14** and **Table 5-15**).

Drought conditions existed during WY2008 that affected the number of samples collected at each monitoring stations (**Tables 5-9** and **5-10**). In addition, some of the transect stations are sampled for TP as part of the TP rule compliance (specifically in the Refuge and WCA-2A). Because water quality data were retrieved by station name from DBHYDRO, the number of samples for TP may not be consistent with the monitoring frequency specified in the permits.

All conductivity levels along the RWMA transect were below the 1,275 µS/cm for Class III waters (**Table 5-9**). While conductivity levels did not change substantially along the RWMA transect, median TP concentrations decreased by at least 20 ppb over a distance of 4 km from the canal (**Table 5-10** and **Figure 5-24**).

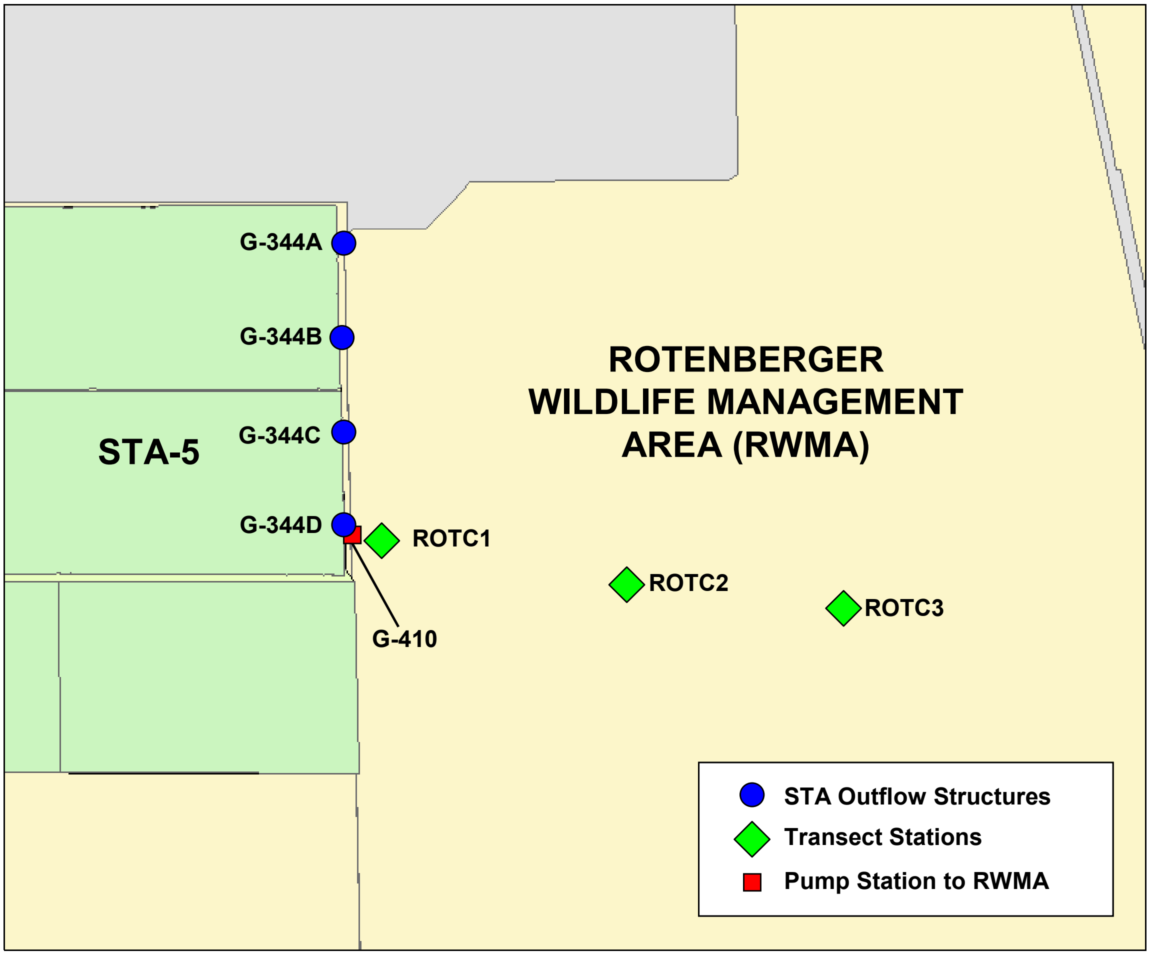

Figure 5-23. Locations of marsh transect stations in the RWMA monitored for conductivity and TP to evaluate the impact of STA-5 discharges on the marsh. The outflow structures from STA-5 and RWMA inflow pump station are also shown.

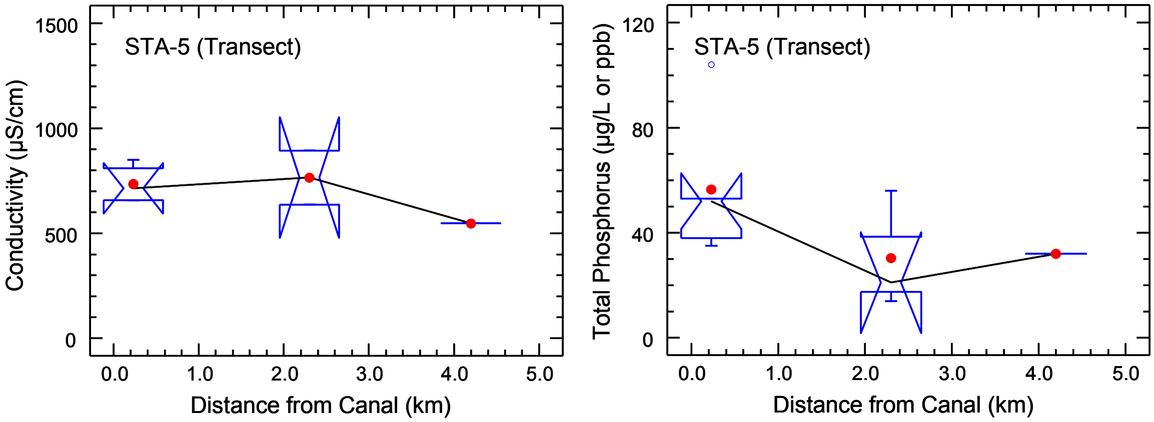

Figure 5-24. Notched box-and-whisker plots of conductivity and TP levels measured at transect stations during WY2008 for STA-5 that enters the RWMA.

STA-RELATED RESEARCH AND ACTIVITIES

The following sections summarize the research projects initiated or ongoing in WY2008 that have been designed to strengthen understanding about the mechanisms that control STA performance. These include vegetation surveys, soil sampling, monitoring of newly rehabilitated STA cells, assessment of floc soil biogeochemistry, and several large-scale experiments that examined biomass effects on SAV establishment and the influences of hydrologic extremes on cattail growth and survival to help identify stress indicators.

RESEARCH AND OPTIMIZATION STUDIES

The STA Research Program aims to understand the mechanisms that control the performance of STAs. This comprehensive program incorporates field research studies with an emphasis on evaluating the data collected over the years (**Table 5-16**). The information gained through the various research components is intended to be used for more effective management of the STAs and for achieving optimum performance and long-term sustainability. In addition to this performance-driven research program, the SFWMD has partnered with the EAA Environmental Protection District (EAA EPD) through DB Environmental, Inc., to conduct research and monitoring studies that can help in facilitating start-up and recovery of STAs and in improving STA performance and sustainability.

In order to predict vegetation decline and mortality, and perhaps allow sufficient time to counteract or lessen the impacts, it is important to understand the key metrics and stress indicators. Two studies were initiated this year that focused on the response of cattail, the dominant emergent plant found in the STAs, to water stress conditions (high water as well as water deficient conditions).

Table 5-16. District research projects conducted or initiated in the ECP STAs in WY2008.

Project	Description
Vegetation surveys	As described in Part 5 of Long-Term Plan and subsequent FDEP-approved revisions
Soil sampling	As described in Part 5 of Long-Term Plan and subsequent FDEP-approved revisions
Monitoring for newly rehabilitated STA-1W cells	Water quality, vegetation, and soil monitoring to determine effectiveness of rehabilitation and also to monitor cell performance
Data analysis	In-depth analysis of all data collected for entire POR for each STA
Drought study on cattail	Study effects of drought on cattail, identify stress indicators, and recovery pattern
Flooding depth and duration study on cattail	Study effects of extended period of flooding on cattail, identify stress indicators, and recovery pattern
Biomass effects on SAV establishment	Study effects of un-decomposed biomass on SAV establishment; determine SAV establishment patterns in rehabilitated or new cells with or without inoculation
Floc soil biogeochemistry	In-depth examination of the floc material from SAV cells, including mineralogical testing; laboratory simulation studies to determine potential factors inhibiting SAV growth

Physiological Response of Cattail to Drought Conditions

Wetlands may experience periods of dry conditions that could negatively affect the growth and survivability of the vegetation. Cattail is the major type of emergent plant found in the STAs, and it is the goal of this research project to examine the response of this obligate wetland plant to drought conditions that may be experienced in the STA treatment cells. This experiment examines the response of the cattail using a series of physiological measurements coupled with survivability responses to identify measurements that could be used to evaluate the response of cattail to drought conditions in the STA treatment cells.

This field study is being conducted in outdoor greenhouse enclosures located at the south research site at STA-1W (**Figure 5-25**). The hypothesis being tested is that extreme drought conditions have a negative impact on the survivability and health of cattail and the plant response is affected by the intensity and duration of the water stress conditions. This experiment uses replicated pots placed in a randomized block design with two treatments (water depth and time the depth is maintained) and three treatment water levels (1 in. above soil surface, 12 in. below surface, and 18 in. below soil surface) for two durations (two months and four months). Over 280 plants were planted in May 2007. In July 2008, the study began the water deficient phase of the experiment.

Figure 5-25. Greenhouse enclosures located at the STA-1W research site allow scientists to study the response of cattail (*Typha domingensis*) to water deficiency. Photo depicts cattail two weeks after being planted in large pots (photo by the SFWMD).

Cattail plants were harvested from STA-1W, Cell 1B and two plants were planted per pot. The pots were constructed of heavy-duty trash cans (22.5 x 22.75 in.) that were modified to include drainage holes at the bottom and a central well for water delivery. The plants were allowed to establish in the pots for six weeks before the water deficient conditions began. Each treatment and depth duration consists of 21 replicates with 21 control pots inside the greenhouses and 11 control pots located outside the greenhouse enclosures. Five blocks (greenhouse pavilions) are being used in this study. There are three water conditions — control (always saturated), stage 12 in. below surface, and stage 18 in. below surface, — and two time durations (two- and four-months of water deficient conditions). The source water is collected from the canal water quality sampling station located upstream of STA-1W outflow station G-251.

This study consists of four phases: (1) Phase 1: all pots are set at control water levels (saturated soil); (2) Phase 2: for two months controls remain at saturated water stages while 51 pots are set at each water deficit stage (-12 in./-18 in.); Phase 3 (after two months' treatment duration): controls remain at saturated soil, six pots of each treatment are destructively sampled for physiology and biomass, and 14 pots are set back to saturated water conditions for two months and then evaluated for survivability; Phase 4: the same procedures as identified for Phase 3, after water deficit durations of four months. The study will be conducted for eight months once the drought conditions are reached in the pots.

Assessment of plant stress will be evaluated using the following parameters: plant survival, visual effects on aerenchyma tissue using light microscopy, osmotic potential, plant biomass by tissue type (leaves, roots, rhizomes), length of tallest live leaf, shoot-base culm width, rate of plant growth. The following physiological and biochemical parameters will also be evaluated: soil percent moisture on a weekly basis; photosynthesis, transpiration, and fluorescence on a biweekly basis, and light response curve will be conducted at zero, two, four, six, and eight months. At each destructive harvest point, metabolic indicators of plant stress will be measured.

Growth, Photosynthesis and Nutrient Uptake of Cattail During and Following Deepwater Stress

During the wet season in South Florida, cattail plants within the STAs often encounter extensive flooding stress. To minimize deepwater impacts to STA vegetation and treatment performance, depth-duration thresholds for cattail between storm events have been proposed [i.e., avoid keeping the water stage too deep for extended periods of time by limiting depth to maximum of 137 cm (4.0 ft) for three consecutive days (Pietro et al., 2007)]. The objective of this study is to assess the response of cattail to deep water in order to provide scientific support for STA vegetation management strategies during and between storm events.

This study is being conducted at the south research site at STA-1W in large, aboveground tanks. The experiment is a single factor design, with one treatment (water depth) and three treatment levels [1.25 ft (control), 3 ft, and 4.5 ft above the soil surface], and three replicates within each treatment, for a total of nine experimental units (tanks). Each tank has six pots/plants for a total of 54 (9 x 6 in.) pots/plants used for the study. The study consists of two study phases, (1) a four-week deepwater stress study, and (2) a four-week recovery study.

Photosynthesis and fluorescence are measured weekly. Plant tissues will be sampled for biomass, tissue total phosphorus and nitrogen concentrations, and leaf elongation rates. The second study phase was completed in fall 2008 and the results are planned for inclusion in the next SFER.

THE SFWMD AND EAA EPD JOINTLY FUNDED STA RESEARCH

Investigations on improving the sustainability and performance of the STAs are being performed by a research contractor, DB Environmental, Inc. (DBE). This ongoing effort is funded by the SFWMD, with additional financial support provided by the EAA EPD. Research findings from four of the studies is presented below.

Studies Focused on Improving Sustainability of STAs

STA-2 Internal Water Quality Assessments

Internal water quality measurements are being performed in the three original flow-ways (Cells 1–3) in order to characterize water column phosphorus removal profiles as a function of vegetation type, flow, phosphorus loading, and season. Monitoring within Cell 3 has been performed since 2003, and monitoring in Cells 1 and 2 was initiated in 2007. Findings to date demonstrate that these internal profiles are useful for identifying regions of less than optimal performance, and also help define minimum achievable outflow TP concentrations for the wetlands. STA-2 was selected for this study because of the diversity of vegetation types (two EAV and one SAV-dominated flow path), and because it had an “appropriate” (modest) loading history at the time the study was initiated. The project end date has yet to be determined, and depends on the utility of findings.

Purpose. The three flow paths of STA-2 have been operational since 1999 and over time have exhibited widely varying P removal performance. Cells 1 and 2 are dominated by EAV (primarily cattail with some sawgrass, and because they were never farmed, are considered historical wetlands. By contrast, 77 percent of Cell 3 was previously farmed and currently is dominated by SAV.

As part of an ongoing investigation, internal water quality sampling is being performed in these three wetlands to characterize spatial P gradients. These data are proving to be instrumental in helping define well-performing and under-performing regions of the extremely long (~ 4.5 km) flow paths. Additionally, these data enable to the quantification of how much of the wetland footprint is being utilized for treatment, as a function of flow and TP loading rates. This information also facilitates the evaluation of effects of vegetation and/or soil perturbations (e.g., drydown) on treatment performance. **Figure 5-26** identifies the locations of internal sampling transects (labeled A–I from north to south), for which a combination of grab and spatial composite field sampling methods are being utilized.

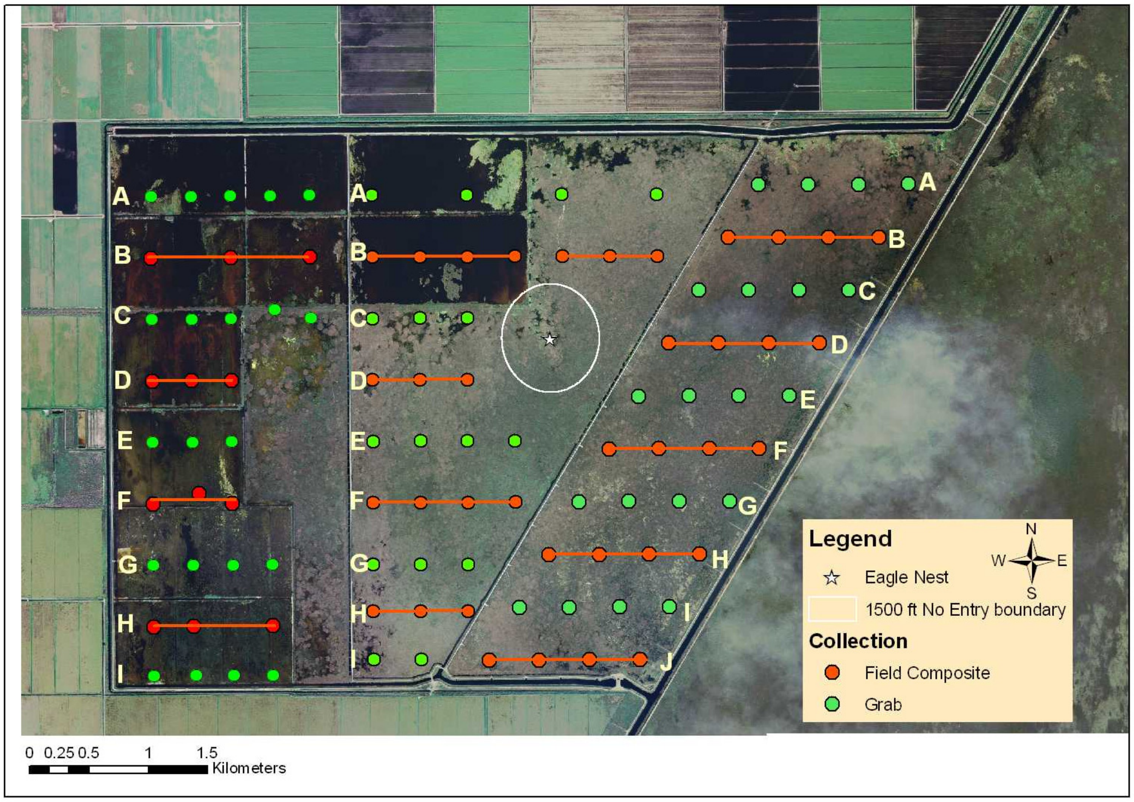

Figure 5-26. Location of internal water quality sampling stations within STA-2 Cells 1, 2, and 3. Transects are identified alphabetically along the north-to-south flow path. Grab samples (in green) are analyzed individually, while the samples collected along the orange transects are composited in the field prior to analyses.

Findings. During a sampling event performed in fall 2007, P concentration profiles differed dramatically among the three STA-2 treatment cells (**Figure 5-27**). At the time of sampling, Cell 1 had an inflow TP concentration of 92 ppb. The P concentration increased at transect A, declined until transect D, and then continued to gradually decrease with distance from the inflow, providing an outflow TP concentration of 9 ppb. For the two-week period prior to the collection event, the average inflow volume to Cell 1 was 402 cfs, with a maximum daily inflow of 491 cfs.

The inflow TP concentration to Cell 2 on October 2, 2007, was 130 ppb. With distance from the inflow, water column TP concentrations decreased to 77 ppb at transect B, increased to 100 ppb at transects C and D, and then gradually decreased to 22 ppb at transect I, before exiting the cell at 37 ppb (**Figure 5-27**). For the two-week period prior to the collection event, average inflow volume to Cell 2 was 610 cfs, with a maximum daily inflow of 1,228 cfs.

On October 3, 2007, the inflow TP concentration to Cell 3 was 187 ppb (**Figure 5-27**). With distance from the inflow, the TP concentrations decreased to 14 ppb at transect B, and then fluctuated between 16 and 10 ppb before exiting the cell at 11 ppb. For the two-week period prior to the collection event, average inflow volume to Cell 3 was 531 cfs, with a maximum daily inflow of 1,006 cfs.

Each of the STA-2 wetlands exhibited spatial variations in P speciation with distance from the inflow. Soluble reactive P levels were reduced to analytical detection limits in the well-performing Cells 1 and 3. Particulate P (PP) and dissolved organic P (DOP) were the dominant P species present in the outflows from the wetland cells. Additional internal monitoring events for STA-2 are planned in order to characterize spatial P concentration profiles within the cells under varying flow regimes.

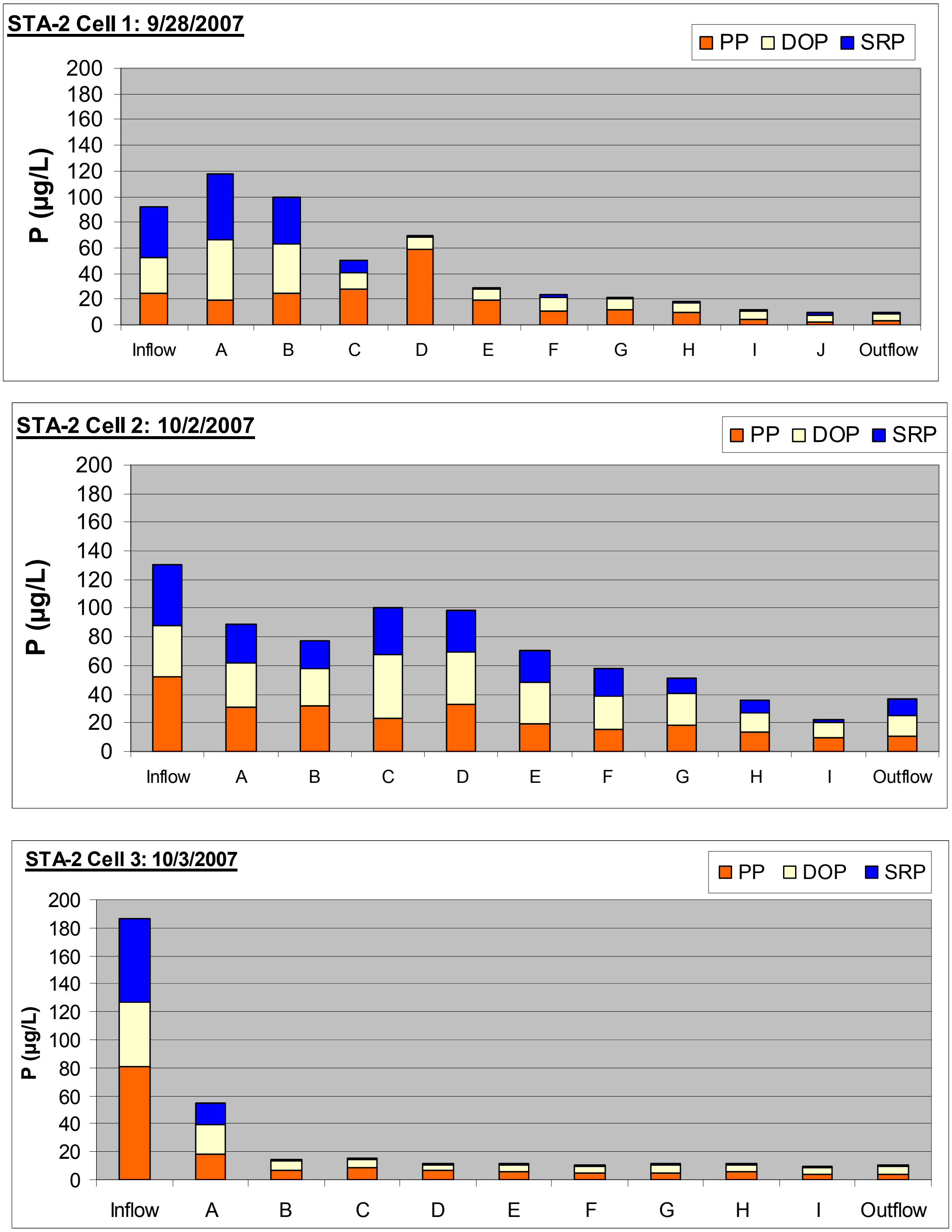

Figure 5-27. Phosphorus concentration profiles along the inflow-outflow gradient for the three wetlands in STA-2 during fall 2007. PP = particulate P; DOP = dissolved organic P; SRP = soluble reactive P.

STA-2 Internal Phosphorus Storage and Stability Gradients

Soils are being sampled and characterized to assess spatial (inflow to outflow) differences and temporal changes in soil phosphorus accrual and chemistry. Findings to date indicate that the SAV-dominated Cell 3 inflow soils are enriched with TP, exhibit greater soil to water column P flux, and contain higher porewater SRP concentrations than outflow region soils. Characterization of soils in the emergent vegetation-dominated Cells 1 and 2 is being performed during the 2008 wet season. The project end date has yet to be determined and depends on the utility of findings.

Purpose. Sediments represent the ultimate storage reservoir for phosphorus within the STAs. Because internal loading (release) of sediment P can influence wetland treatment efficiency, it is important to quantify the stability of P that accrues in STA sediments. Assessments of sediment P stability along the length of the flow path will provide a better understanding of factors such as wetland treatment longevity and the minimum achievable outflow TP concentrations. The three cells of STA-2 are excellent candidates for sediment stability characterization; the cells have been subjected to widely different P loadings, contain a range of vegetation community types, and historically have exhibited different levels of P removal performance.

The first internal sediment sampling effort was performed in Cell 3; additional sediment sampling in Cells 2 and 1 was performed in 2008 and will continue in 2009. In Cell 3, porewater and water column P concentrations were measured along five transects to spatially characterize P enrichment (**Figure 5-28**). Laboratory soil-water incubations also were performed as part of the spatial survey.

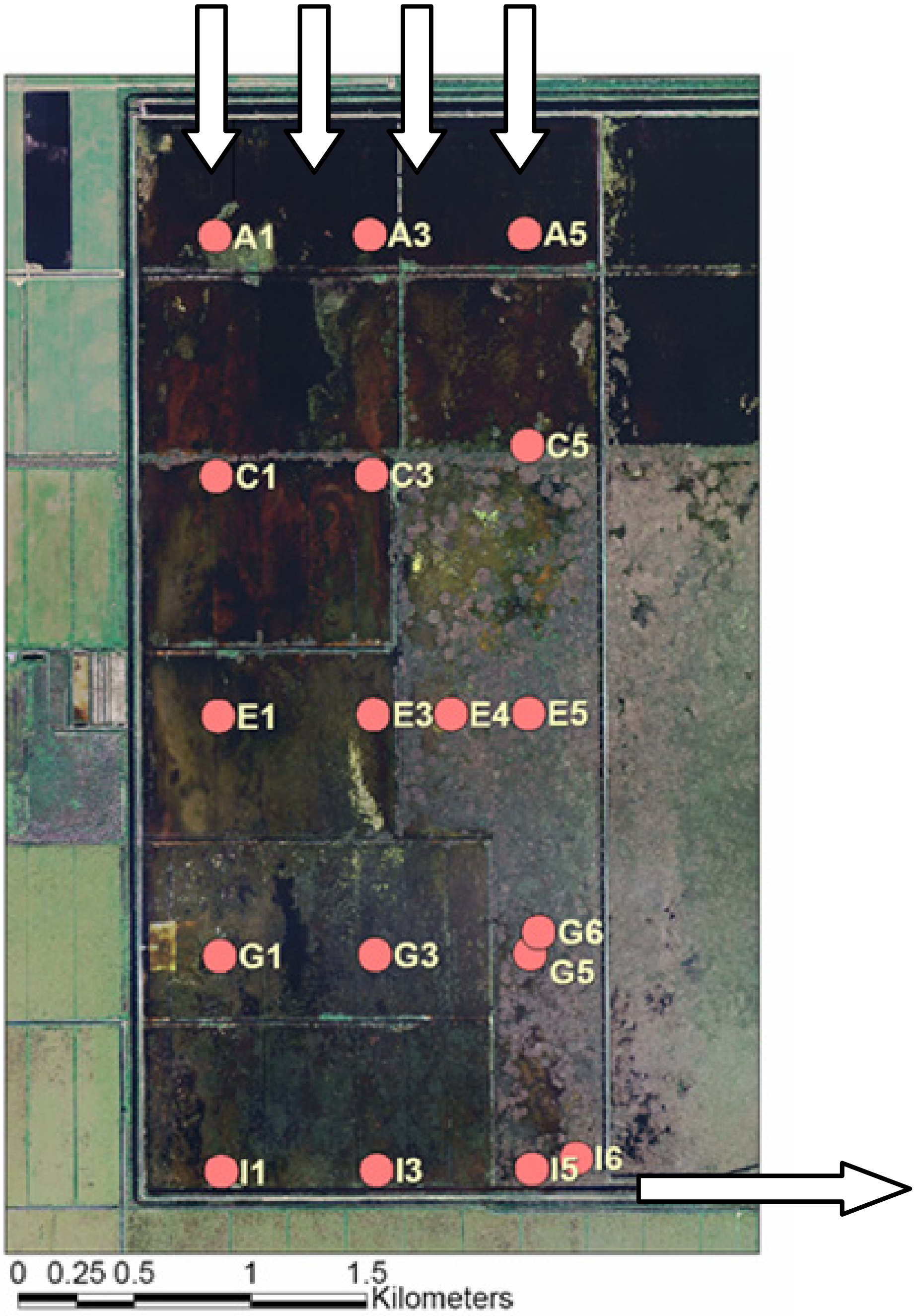

Figure 5-28. STA-2 Cell 3 aerial photo showing sediment sampling locations along five transects perpendicular to flow.

Findings. In STA-2, Cell 3, inflow (transect A) soil TP concentrations were higher than outflow (transect I) for all three soil depths (**Figure 5-29**). In addition, with the exception of the outflow transect (I), soil TP decreased with depth.

Porewater SRP decreased with distance from the inflow levee in SAV areas, but increased with soil depth (**Figure 5-30**). The higher porewater SRP concentrations at depth, relative to the surficial soils, may indicate that SRP-enrichment is related to in situ mineralization of soil organic matter. If STA inflow waters were the source of P, higher concentrations would be expected within the surface layer than at depth. Another reasonable explanation for the higher porewater SRP concentrations at depth is that some mechanism is operating preferentially to reduce surface layer porewater SRP levels. Uptake by macrophyte roots, diffusive flux to the overlying water, and/or sorption onto soil particle surfaces are possible mechanisms for the lower observed porewater SRP concentrations in surficial soils.

Based on 14-day anoxic incubations of surficial (0–4 cm) soils with low-P floodwater, results showed that P transfer from soil to water also decreased with distance from the inflow, and increased with soil TP (**Figure 5-31**). Change in concentration was greatest for soils collected near the STA 2, Cell 3 inflow (transect A), and was near zero for the outflow-region soils (transect I).

Spatial analyses of the sediment data collected from STA-2, Cell 3 were also initiated. The spatial patterns in P deposition within the cell, and the depth and TP content of accrued sediments, are depicted in **Figure 5-32**.

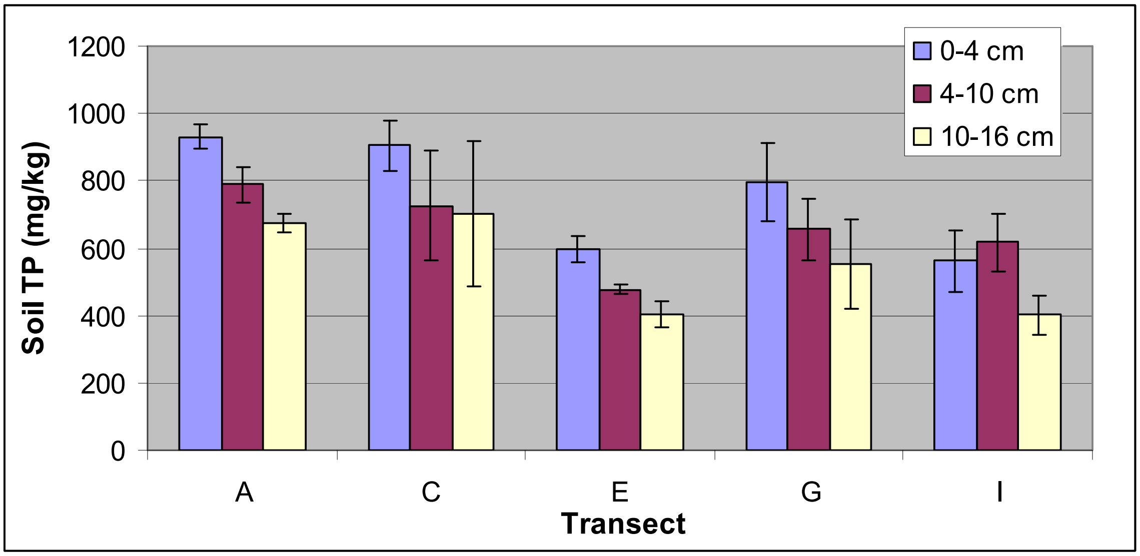

Figure 29. Soil TP concentrations in three soil layers, collected along transects from inflow region (A) to outflow region (I) of STA-2 Cell 3. Error bars indicate ± 1 S.E. around the mean of values from three or four stations per transect.

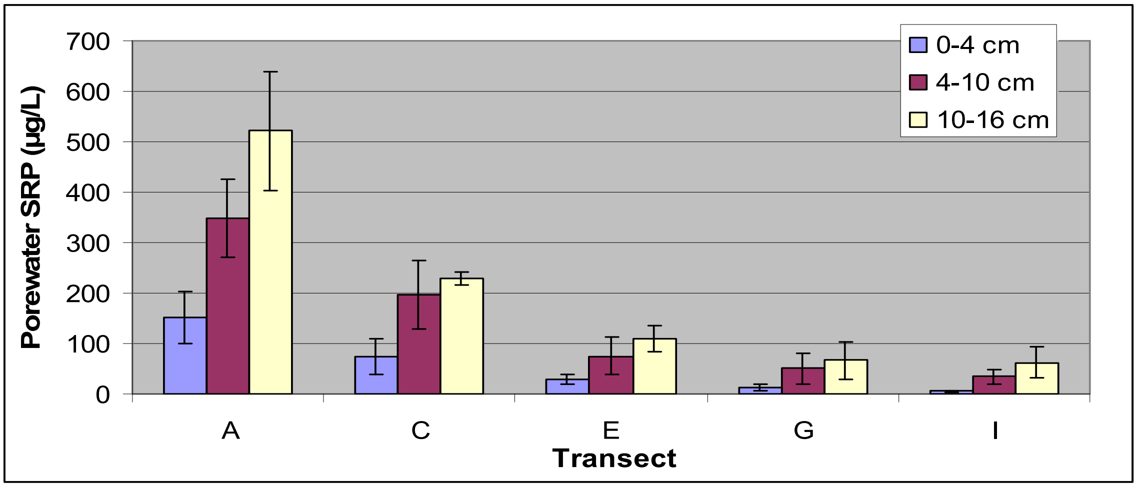

Figure 30. Porewater SRP concentrations in three soil layers, collected along transects from inflow region (A) to outflow region (I) of STA-2 Cell 3. Error bars indicate ± 1 S.E. around the mean of values from three or four stations per transect.

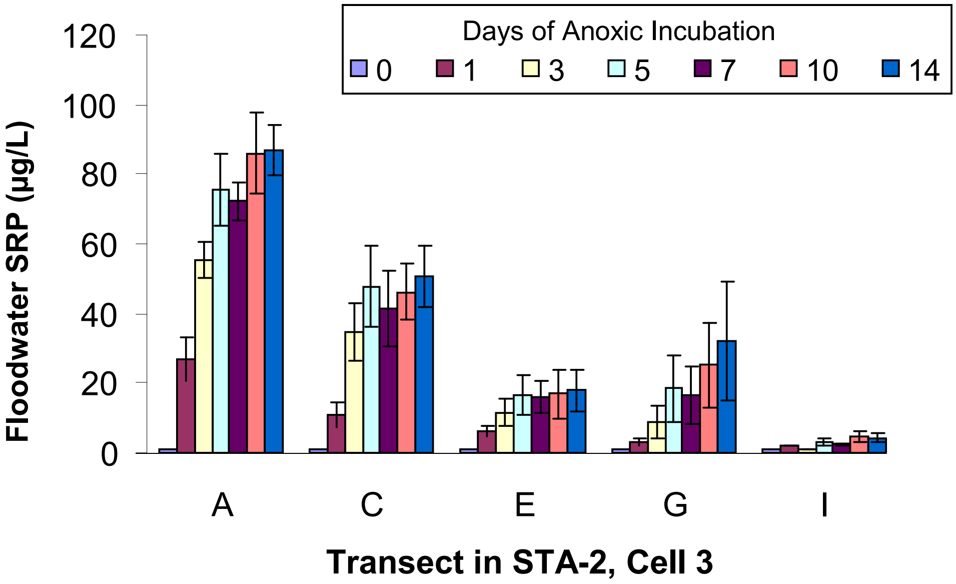

Figure 31. Water column SRP concentrations observed during the 14-day laboratory incubations of sediment collected along transects from inflow region (A) to outflow region (I) of STA-2, Cell 3. Error bars indicate ± 1 S.E. around the mean of values from three or four stations per transect.

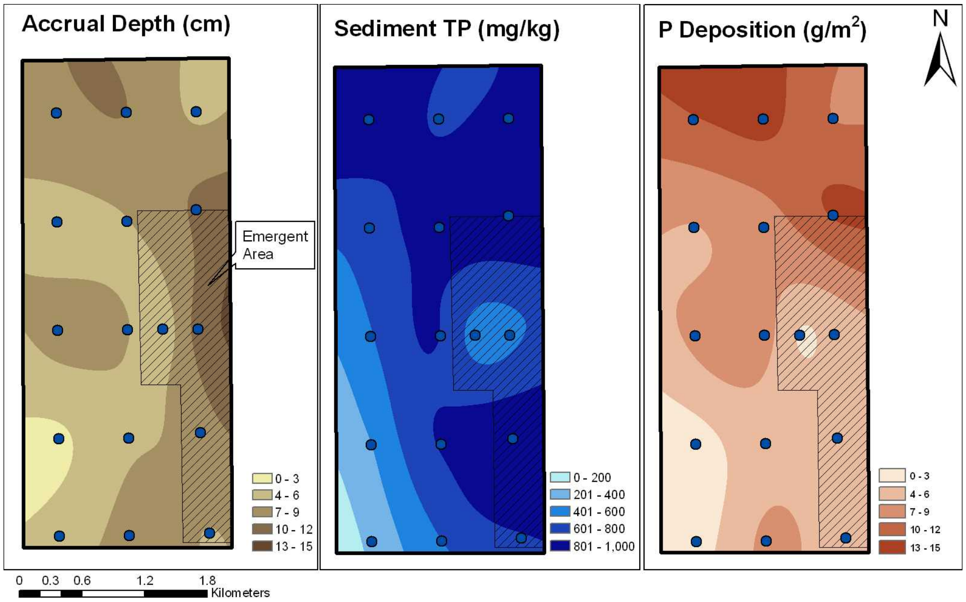

Figure 5-32. Spatial patterns in sediment accrual depth, TP content and P deposition in STA-2, Cell 3.

Submerged Aquatic Vegetation Surveys in STA-2 and STA-3/4

Vegetation surveys have been conducted in STA-2, Cell 3 since 2003 to characterize spatial and temporal changes in SAV speciation and cover. Vegetation surveys performed in 2007 demonstrated that the SAV community has recovered since the die-off that resulted from Hurricane Wilma in 2005. Vegetation surveys performed in STA-3/4, Cell 2B since 2007 have demonstrated widespread coverage of four native SAV species, with southern naiad (*Najas guadalupensis*) the dominant species. The project end date has yet to be determined and depends on the utility of findings.

Purpose. Results from previous studies suggest that the P removal performance of STA flow paths is closely related to vegetation health. SAV in STA treatment cells can be subject to a number of disturbances, including herbivory, hurricane winds, and excessive loadings of nutrient or particle-laden waters. Because SAV communities can be detected only periodically with aerial or satellite photography (i.e., when the plants "top out" in the water column), efficient survey methods are needed to assess temporal changes in distribution of the various SAV species. This project focuses on the conduct of vegetation surveys in all STA cells dominated by SAV. The results of two recent SAV surveys in STA-3/4, Cell 2B are provided below.

At each of 124 observation sites in the wetland, a visual assessment of both SAV speciation and vegetation cover was performed from an airboat. Five semi-quantitative cover categories were established and surface interpolation of data among the stations was performed using the spline/tension method in ESRI's ArcView 9.2.

Findings**.** **Figure 5-33** depicts the results of the first and second vegetation surveys in STA-3/4, Cell 2B conducted during July and November 2007, respectively. On both dates, southern naiad provided the most coverage (> 90 percent of stations) and overall greatest density of the SAV species within the cell. A decrease in pondweed (*Potamogeton illioensis*) coverage was observed from July (60 percent) to November (33 percent). The coverage of muskgrass (*Chara* spp.) in November was similar to that of July. On both dates, coontail (*Ceratophyllum demersum*) and hydrilla (*Hydrilla verticellata*) were observed at only a few stations throughout the cell.

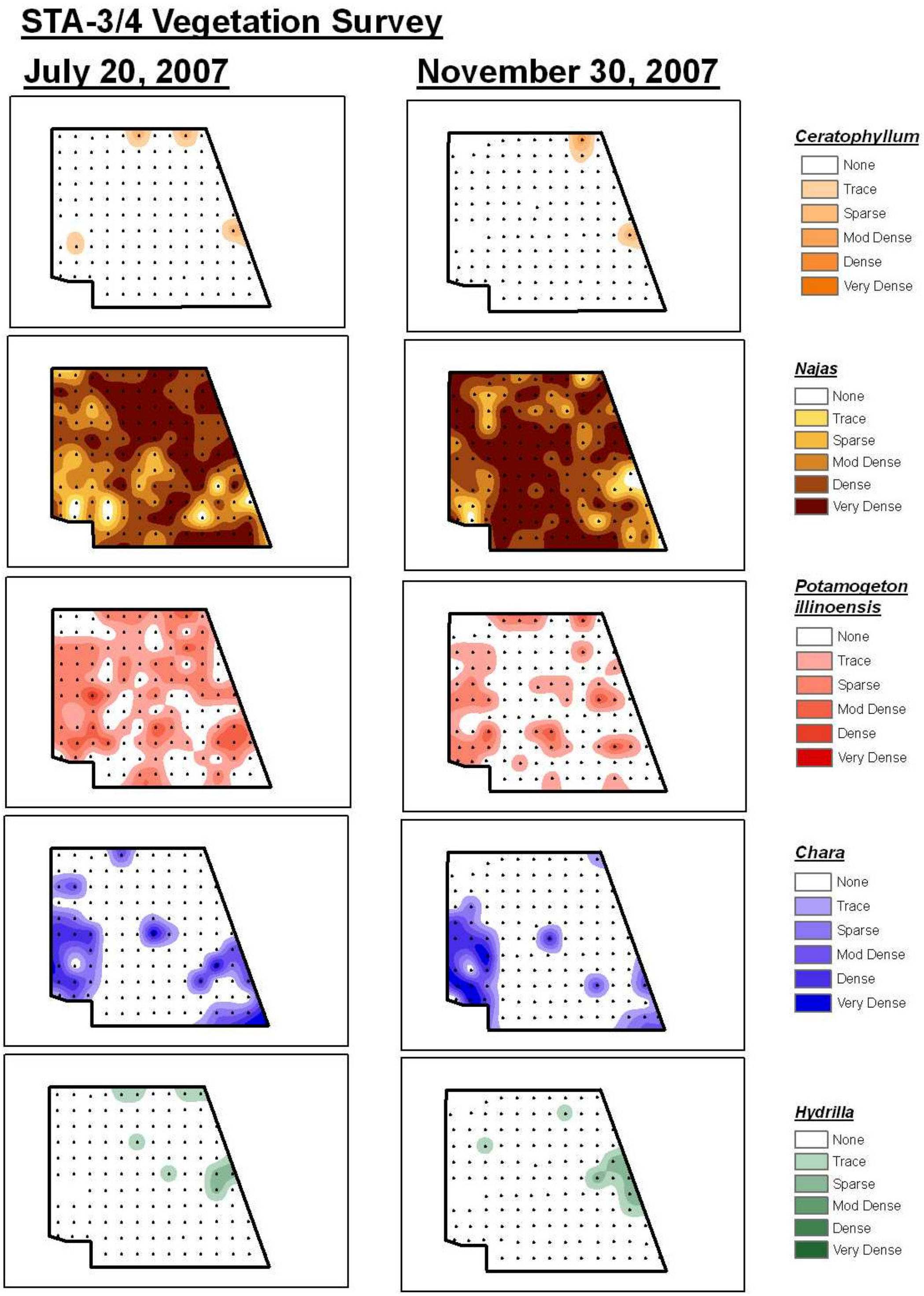

Figure 5-33. Spatial coverage of SAV [coontail, southern naiad (*Naja* sp.), pondweed, muskgrass, and hydrilla] in STA-3/4, Cell 2B during July and November 2007. The black points represent observations sites.

Sawgrass Mesocosm Assessment. During 2007–2008, scientists continued monitoring two mesocosm experiments related to the sustainability of STA communities. The Sawgrass Mesocosm Assessment is evaluating the P removal performance of sawgrass cultured in mesocosms. In natural stands, sawgrass has been able to achieve outflow concentrations of 10 ppb and has proven to be resistant to hurricane winds. To date, the mean outflow TP concentrations from sawgrass experimental systems have averaged 17 ppb. Immediate plans are to keep the mesocosms running for one more year to see if the sawgrass plants fill in at a greater density, and whether or not this increased coverage provides additional treatment benefits. When the experiment is terminated, accrued soils in the sawgrass and PSTA mesocosms with respect to P content will be characterized, and the stability of P in the deposited sediments may be evaluated. This project started in 2006 and is expected to end in 2010; however, it may be expanded to a field-scale study depending on initial findings but the appropriate platform has not yet been determined.

Effects of SAV Species on Soil Accrual Rate and Soil P Stability. In this second mesocosm experiment, scientists are comparing the soil accrual rate and soil phosphorus stability of muskgrass, pondweed, and southern naiad (three common SAV species). The mesocosms have been in operation since July 2006 and are providing outflow TP concentrations in the range of 12–16 ppb, with muskgrass exhibiting the best performance. In 2009, the accrued soils within the three vegetated systems will be collected and compared with respect to stability of their associated phosphorus. This project started in 2006 and is anticipated to end in 2009.

Impacts of Previously Enriched Soils on Outflow P Concentrations in a SAV Wetland. This mesocosm assessment was conducted to determine the effects of previously enriched soils on outflow P quality within SAV-dominated STA flow-ways. To date, the SAV communities cultured on native muck and Cell 4 outflow soils have provided lowest outflow TP concentrations, whereas SAV on Cell 4 inflow soils has provided only a slight reduction from inflow TP levels. At the beginning of the study, porewater SRP levels in Cell 4 inflow sediments were high, but have gradually declined, presumably due to the gradual flux of SRP from the sediments into the water column. This project started in 2005 and is scheduled for completion in 2009.

STA-1W Western Flow-way (Cells 2B and 4) Vegetation Surveys. During early 2007, the SFWMD rehabilitated the Western Flow-way of STA-1W because of its poor P removal performance, as well as its inability to support SAV communities. Hurricane damage in 2004 and an accumulation of unconsolidated sediments were thought to be responsible for the poor condition of SAV in this wetland. Scientists have performed three SAV surveys since the reflooding of the flow-way in mid-2007, and these have shown relatively rapid SAV colonization, primarily by muskgrass and southern naiad. The project end date has yet to be determined and depends on the utility of findings.

STA-1E Internal Water Quality Transects and Vegetation Surveys. During 2006–2008, several internal water quality and vegetation surveys were performed within the Western and Central flow-ways of STA-1E. These monitoring efforts have demonstrated gradually improved water column P removal, particularly in the front-end emergent vegetation-dominated cells. These surveys also show continued dominance by hydrilla in all three back-end SAV cells of STA-1E, with sporadic coverage by two native SAV species, southern naiad and coontail. The project end date has yet to be determined and depends on the utility of findings.

Characterizing Hydraulic Resistance of Emergent Macrophytes. Many of the emergent macrophyte-dominated STA cells currently contain dense vegetation stands, consisting of both live and dead plant material. Under high-flow events, it is thought that the hydraulic resistance created by this dense vegetation contributes to the high water depths observed in the front-end of many of the STA flow paths. For this project, scientists are deploying pressure transducers at various locations along the wetland flow path in STA-2, Cell 2. These instruments will facilitate water stage change measurements within the wetland as a function of flow regime. These data will help clarify the hydraulic resistance of STA-emergent communities, and also provide background information that may support selected management practice in the STAs. The project started in 2008; the end date has yet to be determined and depends on the utility of findings.

Studies Focused on STA Performance

Low-level Phosphorus Loading Rate Mesocosm Assessment. Several mesocosm assessments are being conducted to characterize and optimize STA phosphorus removal performance. The Low-Level Phosphorus Loading Rate Mesocosm Assessment has been in operation since spring 2004, with the objective of determining if substantial improvements in outflow quality can be achieved by operating STAs at extremely low loading rates. Each treatment consists of an optimized treatment train of two SAV tanks in series, followed by a calcareous periphyton system cultured on limerock. Under low load conditions, it has been noted that only marginal improvements in mean outflow TP concentrations [13 versus 11 micrograms per liter (μg/L)] by providing a twofold reduction in loading rates [from 0.51 to 0.26 grams per square meter per year (g/m^2/yr) of P]. This project started in 2003 and is slated to end in 2009.

Purpose. Using full-scale wetland performance data, DBE scientists described a close relationship between P loading rate and outflow TP concentrations for the STAs, and then subsequently proposed that 1.3 g/m^2/yr of P is a useful TP loading rate guideline for the STA flow paths. At or below this loading rate, performance can be quite good (outflow TP levels in 15–20 ppb range), whereas above this long-term loading rate, outflow quality appears to suffer. In the analysis, however, further reductions in load (below 1.3 g/m^2/yr of P) did not appear to lead to additional reductions in outflow TP concentrations. To better define loading effects on outflow quality, a mesocosm study was initiated to assess wetland treatment performance under low P loading conditions.

The loading rate experiment originally comprised six treatment trains separated into two replicates, identified as Low P, Moderate P, and High P Load systems. Each treatment train consisted of two sequential SAV mesocosms, followed by a third mesocosm containing calcareous periphyton (**Figure 5-34**). The SAV mesocosms contain a muck substrate, whereas the back-end periphyton mesocosms contain a limerock substrate. The different P loading rates are achieved by providing varying HLR to the respective treatment trains.

Findings. From May 2004 through January 2006, the P loading rates to the High, Moderate, and Low load systems averaged 1.79, 0.89, and 0.45 gP/m^2-yr, respectively. The inflow TP concentration to the mesocosms averaged 62 ppb, and the respective mean outflow concentrations were 13, 12, and 11 ppb (**Figure 5-35**). The High P Load systems were discontinued in January 2006, due to receiving prolonged loading rates higher than the targeted 1.3 g/m^2/yr of P.

The low and moderate load process trains, which have operated for more than three years (May 2004–December 2007), have reduced inflow TP levels from 53 ppb to 11 and 13 ppb, respectively (**Figure 5-35**). Outflow SRP concentrations were comparable between the two treatments (3 ppb), whereas mean outflow DOP and PP levels were each 1 ppb higher in the moderate load (0.55 g/m^2/yr of P) than in the low load (0.27 g/m^2/yr of P) treatment (**Figure 5-35**).

It is notable that despite extremely low P loadings and the incorporation of a final limerock substrate unit process (to encourage calcareous periphyton growth and to minimize internal P loading), neither the low nor the moderate loading treatments have attained a long-term TP outflow average of 10 ppb.

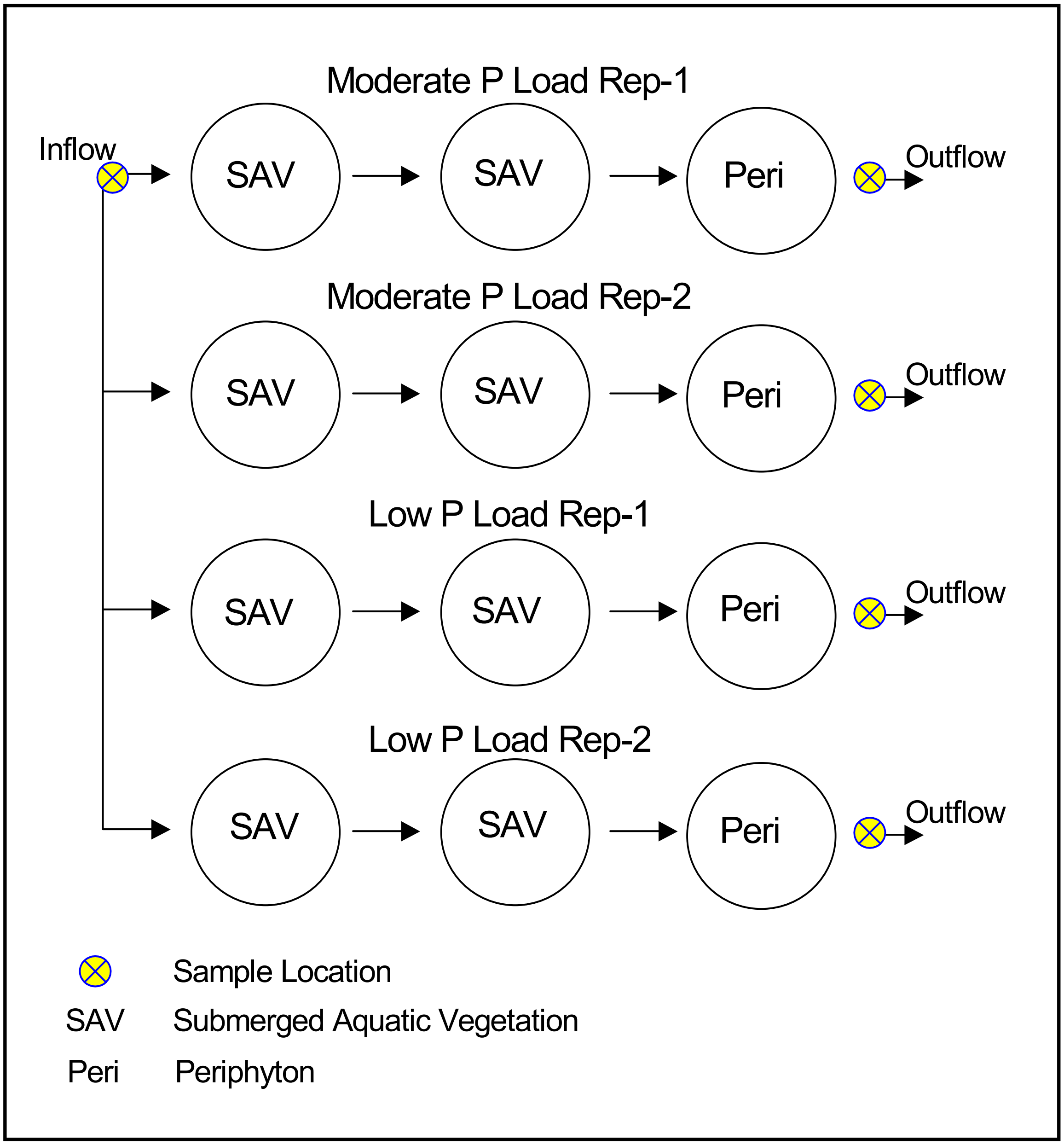

Figure 5-34. Schematic showing the experimental design of the Low-level Phosphorus Loading Rate Mesocosm Assessment.

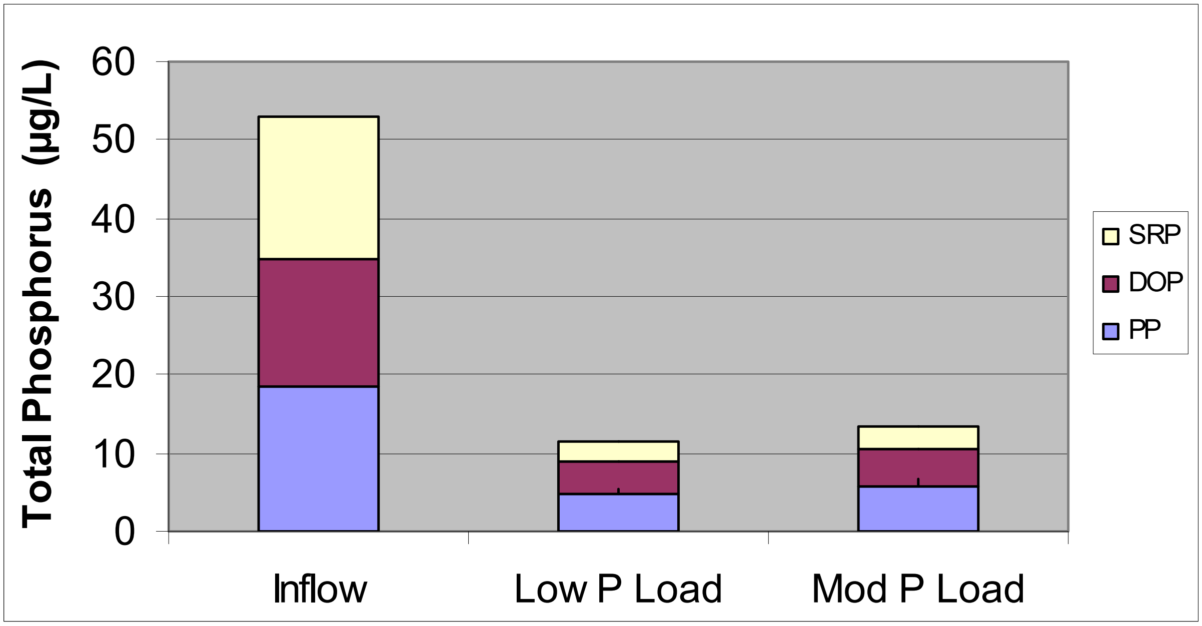

Figure 5-35. Average inflow and outflow P concentrations for the low and moderate load mesocosms from May 2004 through December 2007. Mean P loading rates for the low and moderate treatments during this period were 0.27 and 0.55 g/m^2/yr of P, respectively.

Effects of Water Column Calcium Concentrations on Phosphorus Removal by a Mesocosm-Scale STA Flow-way. In this study, scientists are evaluating whether the approximately twofold higher calcium levels found in EAA farm runoff, in comparison to Lake Okeechobee waters, can lead to lower outflow TP concentrations from a sequence of cattail, SAV, and calcareous periphyton mesocosms operated at a low P loading rate. To date, calcium levels appear to exert a slight influence on the minimum attainable outflow TP levels in the system, with low [~35 milligrams per liter (mg/L)] and high (70 mg/L) calcium systems achieving outflow TP concentrations of 20 and 16 ppb, respectively.

Torpedograss (Panicum repens) Mesocosm Assessment. The performance of torpedograss, a common emergent species in STA-3/4 and STA-1E, was compared to that of cattail and SAV species. Average outflow TP levels were 28, 30, and 15 ppb for torpedo grass, cattail, and SAV, respectively. Monitoring of this study has been terminated, and sediment characterization efforts are under way. This project started in 2004 and is expected to end in 2008.

Assessing the Ability of STA Outflows to Support Pristine Everglades Flora. The goal of this study is to determine whether pristine species (e.g., calcareous periphyton and bladderwort (*Utricularia* spp.) can thrive downstream of the STAs at water column P concentrations in excess of 10 ppb (the phosphorus criterion value for the EPA). Much of the P in waters discharged from well-performing STAs consists of particulate P and DOP (some of which is not readily bioavailable), and this appears to facilitate growth of the pristine species in STA outflows that do not quite achieve P levels as low as 10 ppb. The research scientists believe that while the best long-term FWM outflow TP from an entire STA is 20 ppb, selected flow paths have achieved outflow TP levels of 14–16 ppb. This project started in 2004; the end date has yet to be determined and depends on the utility of findings.

Internal Water Column Gradients in STA-5. The wetlands comprising STA-5 are among the poorest performing Everglades STAs. Reasons for their limited P removal effectiveness are unknown. For the present effort, scientists are performing monitoring along internal transects in the northern and central flow paths of STA-5 in order to assess spatial and temporal patterns in water column P levels. Similar efforts in STA-2 and STA-1W have facilitated the identification of problem areas, for example, regions where P is being released by sediments or unhealthy stands of vegetation. This project started 2007; the end date has yet to be determined and depends on the utility of findings.

Internal Sediment P Gradients (Surficial TP and Porewater P). In STA-5, scientists are performing internal sediment sampling (primarily of porewater constituents) along transects within the northern and central STA-5 flow paths. This effort should complement the findings from the internal water quality characterization, and lead to wetland operation and management approaches to enhance the P removal performance of this STA. This project started in 2007; the end date has yet to be determined and depends on the utility of findings.

Potential Water Quality Benefits of an FAV Front-End for STAs. FAV commonly occurs in the inflow regions of STA flow paths and is typically controlled with herbicides. However, because many FAV species exhibit explosive growth as well as rapid assimilation of nutrients, FAV communities may actually enhance STA front-end P removal effectiveness. A second potential benefit to FAV species is that they are unaffected by the deepwater conditions that can occur in front-end STA cells during high-flow conditions. For this project, test cells at STA-1W are being used to document the P removal effectiveness of FAV versus cattail, and sequential combinations of FAV-cattail, as front-end communities for STAs. This project started in 2007; the end date has yet to be determined and depends on the utility of findings.

VEGETATION MANAGEMENT RESEARCH

Vegetation management activities in the STAs involve operational and research efforts. In general, EAV is encouraged at the beginning of the treatment system where nutrient concentrations are higher, and SAV is encouraged farther down the flow-way in areas where phosphorus concentrations are expected to be lower. Specific Condition 13(b) of the EFA permit requires annual reporting of information on applying herbicides used to exclude and/or eliminate undesirable vegetation within the treatment cells. The acreage treated by STA and the herbicide applied is found in Appendix 5-10 of this volume. Vegetation management includes other management activities in addition to herbicide applications. Minimum target stages are maintained to avoid inundation by exotic species. Helicopter flights are conducted monthly to access the exotics. Close coordination with the STA Management and the Vegetation Management divisions ensures that the appropriate management steps are taken and the plants are treated accordingly.

Several studies have been initiated to facilitate SAV establishment and conversion efforts, and to investigate alternative vegetation management strategies for sustaining STA performance. Effects of dead and decomposing cattail litter on rates of natural (i.e., unassisted) colonization of SAV and periphyton are being evaluated in 10 experimental 480 m^2 (12 m x 40 m) plots that were established in a dense cattail stand within one of the emergent vegetation strips in STA-3/4, Cell 2B in spring 2007. Bimonthly random standing crop biomass sampling has indicated no natural colonization of SAV has occurred in the 12-month period following herbicide treatments of cattail in five plots, but significantly greater periphyton biomass was found in treated plots than untreated plots within five months after treatment. This suggests that periphyton may provide an interim P uptake pathway during SAV conversions.

To further investigate the potential for dead cattail to interfere with SAV establishment, a complementary study was initiated in the 800 acres of cattail in STA-3/4, Cell 1B that had been treated with glyphosate in November 2007 (i.e., Phase 2 of the incremental conversion of this cell). Glyphosate has been applied extensively to control nuisance weed species in aquatic environments (Barrett, 1985; Linz et al., 1999). It is readily absorbed and translocated after contact with targeted plant species (Sprankle et al., 1975) and rapidly dissipates through biodegradation, photolysis, and sediment adsorption (Bronstad and Friestad, 1985; Reinert and Rodgers, 1987; Goldsborough and Beck, 1989); therefore, no residual effects of glyphosate are expected after two months. In this study, survivorship and establishment of “transplanted” SAV will be compared in plots with dead cattail litter remaining and in plots where this litter has been removed. This study was initiated in January 2008 (i.e., two months after herbicide treatment of cattail) when southern naiad and muskgrass were inoculated in three paired (i.e., harvested and unharvested), randomly selected 36 m^2 plots, and will continue with repeated inoculations at four month intervals (i.e., as dead cattail litter decomposes) over a two-year period. Results of these two studies are expected to clarify the time frame required for SAV conversions and the associated need for SAV inoculations and/or measures to remove dead emergent plant biomass (e.g., through harvesting, tilling, fire, etc.). These and other associated planned studies may have implications for alternative vegetation management strategies, such as the potential value of rotation of EAV and SAV cover to maintain sustainability of STA cells.

Vegetation Conversion Status Updates

STA-3/4, Cell 1B Conversion

Per the revision to the Long-Term Plan, conversion of STA-3/4, Cell 1B from an EAV marsh to an SAV marsh is intended to occur incrementally while keeping the cell online. The ongoing conversion requires elimination of the cattail (*Typha domingensis* and *T. latifolia*) and willow that cover most of the cell, and subsequent establishment of one or more of the desirable SAV species (i.e., southern naiad, muskgrass, and/or pondweed) for STAs. Initial conversion measures were taken in November 2005 when an herbicide was applied aerially to 650 acres of cattail and willow in the southernmost portion of the cell. Although vegetative (plant fragments) and generative (seed) diaspores of SAV species in several open water areas farther north (upstream) in the cell could have provided for natural colonization of the treated area, subsequent monitoring indicated that very limited natural colonization of SAV occurred between December 2005 and July 2007. Thus, efforts to expedite establishment of SAV were taken on July 20, 2007, when SAV was mechanically harvested from established beds in Cell 3 of STA-2, gathered in a net, and transported via helicopter to 11 inoculation sites in the treated area in the south end of Cell 1B. As demonstrated in the startup of STA-3/4, Cell 2B, these inoculations are expected to serve as founder sites for the subsequent rapid establishment and spread of SAV.

Subsequent surveys indicate that beds of muskgrass are establishing throughout the southernmost section of the cell. The second phase of the incremental conversion was initiated on December 6, 2007, when an aerial herbicide treatment was applied to an additional 800 acres of cattail immediately north of the first treatment area. These two herbicide applications have cumulatively treated emergent vegetation cover on 41 percent of the effective treatment area of Cell 1B. Although establishment of SAV has been slow and presently covers only an estimated 15 percent of the cell (July 2008 survey), water quality data indicate that the incremental conversion strategy has been successful in maintaining performance. During 49 automated flow sampling events following the initial herbicide treatment of emergent vegetation (i.e., November 21, 2005–November 13, 2007), TP concentrations in cell outflows averaged 22 ppb, which was comparable to the mean pre-treatment concentrations of 19 ppb. Based on these performance data, the incremental conversion of Cell 1B will continue to proceed with an iterative adaptive implementation process.

STA-1W, Cell 3 Conversion

Efforts to facilitate conversion of Cell 3 to SAV were initiated in 2007 when dead cattail was removed by disking the northern third of the cell, and cattail within the central portion of the cell was roller chopped. A relatively small area [1.6 hectares (ha)] of remaining dead cattail was subsequently mechanically harvested in the southern portion of the cell in March 2008. These efforts were undertaken to reduce or eliminate the decomposing cattail litter that could potentially interfere with the colonization of SAV. Several locations within the northern portion of this cell were inoculated with SAV (via helicopter) in July 2007. Based on averaged May–June 2008 survey data, SAV covers 58 percent of the cell. Dominant species include muskgrass (43 percent), southern naiad (22 percent), coontail (18 percent), and hydrilla (13 percent). Most of the SAV cover occurs in the northern two-thirds of the cell (mean cover = 78 percent), which accounts for most of the effective treatment area for discharge from G-308.

STA SITE MANAGEMENT

The operation of the STAs involves extensive coordinated efforts by multidisciplinary teams and the use of innovative technologies and integrative diagnostic tools. The SFWMD's Operations and Maintenance Department currently performs STA site management functions. The primary function of STA site management is to coordinate among various departments, divisions, and external stakeholders to facilitate resolution of day-to-day STA management and operational issues. Site managers maintain an on-site presence at STAs to ensure the program's objectives are met.

Site managers routinely report observations of changing environmental and site conditions, maintenance concerns, or infrastructure problems to appropriate SFWMD staff. Significant additional coordination between the SFWMD's Construction Department and the site managers has been and will continue to be required during the build-out of the Long-Term Plan components. Additionally, site managers coordinate monthly vegetation management surveys to identify priorities and strategies to meet the overall vegetation goals of the STA program. Site managers also monitor daily stormwater operations and confirm that these operations are consistent with the established STA operation plans.

Research and optimization studies provide data used to guide operations. For example, guidance regarding water deliveries to the individual treatment flow-ways is based on information such as cumulative average annual inflow volumes and TP loads, treatment cell outflow TP concentrations, or the status of vegetation establishment within the treatment cells. During the recent drought, target water stages within the treatment cells were managed according to the STA 2007 Drought Contingency Plan*,* which includes raising the stages by another 6 inches and prioritization of SAV cells. Also during the drought, bird-nesting activities were closely monitored and scientists coordinated closely with the operations control room staff to prioritize water deliveries to the STA treatment cells without impact to existing nests. Vegetation management activities are coordinated with multidisciplinary teams, and meetings between STA management staff and operations staff occur weekly to discuss operations related to performance and sustainability issues.

WILDLIFE AND AVIAN PROTECTION

The draft Avian Protection Plan (APP) for Black-necked Stilts and Burrowing Owls Nesting in the Everglades Agricultural Area Stormwater Treatment Areas discussed in the 2008 SFER – Volume I, Chapter 5 is still under review by the USFWS and has not been finalized.[2] However, the SFWMD implemented the protective measures outlined in the APP during WY2008, and modified operation of those treatment cells where black-necked stilts (*Himantopus mexicanus*) nested. Results of this year's STA bird surveys are presented in this section.

During WY2008, the District also initiated a study to evaluate and quantify the environmental lift of the STAs on avifauna community. This study, which is being conducted jointly by Florida Atlantic University and the University of Florida (UF), Institute of Food and Agricultural Services under a contract with the District and EAA EPD, involves scientific evaluation of the bird population, their prey, and habitat among three different habitat categories: agricultural

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[2] The Avian Protection Plan for Black-necked Stilts and Burrowing Owls Nesting in the Everglades Agricultural Area Stormwater Treatment Area*s* was developed voluntarily by the SFWMD to help manage STA operations for water quality treatment while minimizing harmful impacts to migratory birds and nests.

cropland, natural marsh, and the STAs. Initial results indicate that the STAs cause significant lift. Detailed results will be reported in the next SFER.

Eagles, Burrowing Owls and Snail Kites

The bald eagles (*Athene cunicularia floridana*) found at STA-2 in previous years were not seen this year. The tree that housed the nest fell over between December 2007 and April 2008, and the nest was abandoned. No burrowing owl (*Athene cunicularia floridana*) nests or Everglades snail kites (*Rostrhamus sociabilis*) were noted in any of the ECP STAs. STA-3/4 was surveyed twice this year for snail kites and none were observed.

Black-necked Stilts

During WY2008, the SFWMD implemented the draft APP for the ECP STAs. This plan, in conjunction with proactive implementation, provided management guidelines that resulted in a 99 percent success rate regarding the 2008 black-necked stilt breeding season. In addition, survey and information-sharing methods were standardized and operational procedures related to levee and canal maintenance were modified and implemented to reduce impacts to ground-nesting birds within the STAs.

Scouting trips, beginning in late March/early April, determined the start of the black-necked stilt breeding season. As per the APP, black-necked stilts were the focus of the surveys as these birds are a sufficient and conservative indicator species for ground-nesting birds in the STAs. They are in high numbers throughout the region, so nest counts of this particular species are a good surrogate for other ground nesters. Additionally, black-necked stilts nest directly on the ground often close to the water’s edge. Nest sites are vulnerable to any increase in water level, more so than other ground-nesting species that select sites farther upslope or in standing vegetation. STA operating strategies that protect stilts also protect other ground-nesting species.

Internal black-necked stilt nest surveys of treatment cells were performed from the levee (called levee surveys) by contractor BEM Systems, Inc. and SFWMD personnel. Levee surveys represent a resourceful way to observe a large area to obtain useful information regarding the potential number of nests within a treatment cell. Internal ground surveys were not applicable during the 2008 breeding season due to existing environmental conditions and practicality of assessing 46,000 acres. Three different types of levee surveys were executed based on the type of information needed to make operational decisions. Those surveys are listed as follows:

- Monthly (Performed every 30 days from the start of the breeding season; all treatment cells surveyed; provides baseline nesting information and the basis for operational decisions throughout the season)
- Supplemental (performed when needed depending on water conditions; all treatment cells surveyed; only STA-1W and STA-1E received this type of survey in 2008)
- Spot (performed when needed depending on water conditions: survey done on specific nest locations previously recorded, and/or treatment cells of operational interest surveyed; nest numbers in cells not surveyed assumed to remain as previously observed)

Black-necked stilt survey information was obtained using binoculars [10 x 50 millimeter (mm)] and/or a spotting scope (20-60 x 80 mm). A hand-held global positioning system unit provided latitude and longitude of observer location on the levee where nests were detected inside of a treatment cell. Information including coordinates of observer, number and distance of nests, observations, and observer initials were recorded in the field using an Access database (Appendix 5-11 of this volume). Once the survey was completed, data were sent via email for analysis and report generation. Reports were standardized for all STAs and used to inform SFWMD staff regarding the location of black-necked stilt nests and the number of nests by flow-way and treatment cell (Appendix 5-11 of this volume). Information regarding stilt nest activity and the resulting activity restrictions within the STAs were distributed to involved parties via emails, signs, and the posting of reports to an internal web site.

Modification of Operational Procedures and Levee and Canal Maintenance

Adjustments to operational and mechanical procedures were developed in accordance with the APP to reduce impacts to ground-nesting birds within the STAs. Operational adjustments were typically implemented on a case-by-case basis and were derived from stilt nesting activity and available flow-alternatives. Mowing and grading schedules, as part of levee and canal maintenance, were adapted to occur annually before April or after July, which is outside of the stilt breeding season. The mowing schedule is based on the species observed nesting in the STAs and not other species (although there are several other species of ground nesters frequent the STAs, they have never been observed nesting there). The least tern (*Sterna antillarum*) was included because there were nests close to STA-3/4 found in the EAA reservoir.

There have only been two identified species of ground nesters — the black-necked stilt and the killdeer (*Charadruis vociferous*) — that nest on the levee roads and slopes in the STAs. While the mowing schedule within the STAs is modified based on the stilt's breeding season, it also incorporates the killdee's breeding season. Both species start nesting on levee roads between the months of April and May and have a similar gestation period of 20–30 days. The modified mowing schedule also typically works around the breeding season of other rock-using ground nesters, such as the state-threatened least tern (starts in mid-April, with gestation period from 20–22 days). Modifications to operations and maintenance within the STAs are found in **Table 5-17**.

Table 5-17. Modified operational and levee and canal maintenance activities implemented during the 2008 black-necked stilt breeding season.

STA	Type of Action	Date Implemented	Impact Reduction of Ground Nesters Description of Action
All	Operational	9/25/07 – held throughout the season when possible	Increased the water depth in SAV cells by 0.5 ft from the target stage of 1.25 ft in response to predicted drought impacts.
All	Operational	Throughout breeding season	Utilized flow-ways that were not impacted with black-necked stilt nests to reduce phosphorus in stormwater runoff.
All	Maintenance	3/2008	Modified mowing and grading schedule to reduce impacts to ground nesters and young on levee roads and embankments.
Operation Changes to Individual STAs			
2	Operational	5/1/08	Increased water depth to decreased exposed ground in the inflow canal at the beginning of breeding season.
1E	Operational	5/30/08	Redirected storm water from the C-51 to S5A-S to avoid impacts to black-necked stilt nests within downstream treatment cells.
1E	Operational	6/11/08	Coordinated with the U.S. Army Corps of Engineers to redirect storm water into the Periphyton-based Stormwater Treatment Area bypass area.

Status of the 2008 Black-Necked Stilt Breeding Season

The 2008 breeding season began the first week of May 2008 with the earliest nests observed in STA-2, Cell 4. Monthly surveys were implemented from May 13–21, and were again performed from June 19–24. Supplemental and spot surveys were performed when needed depending on water conditions. Most nests were inactive by the June monthly survey, with the exception of STA-3/4 and STA-5, where nesting finished on June 24, 2008, and July 3, 2008, respectively. Previous 2006 and 2007 nesting surveys for black-necked stilts also indicated that peak breeding season began in early May and extended into late June or early July. This suggests that the stilt nesting season remained relatively constant even though environmental conditions changed.

There were 179 black-necked stilt nests observed via levee surveys during the 2008 breeding season, with the highest number found in STA-5 (73 nests), followed by STA-1E (67 nests) (Appendix 5-11 of this volume). Two nests were flooded this year in the Eastern Distribution Cell of STA-1E to avoid impacting 65 additional nests that were located downstream of this cell. No other treatment cells containing nests were flooded, and if all active nests were assumed to be successful, the 2008 breeding season is assumed to have resulted in a 99 percent success rate in the STAs.

Plant and Animal Surveys

The plant, fish, and bird communities in the STAs have been surveyed with varying levels of intensity over the years. Plants were inventoried in all the STAs in conjunction with ground-truthing needed to compile vegetation coverage maps and other plant survey work. Information about fishes and birds, in contrast, was obtained on an ad hoc basis. Fishes were collected only in the ENRP, the predecessor to STA-1W (Chimney and Jordan, 2008), while birds were systematically observed only in STA-1W and STA-5 (Chimney and Gawlik, 2007). The plant, fish, and bird data are presented in this report to document the ecological lift that the STAs have provided to the region by creating high-quality wetland habitat on what previously had been farmland.

A total of 127 plant taxa representing 51 families were identified in the STAs (Appendix 5-12 of this volume). Thirty-three of these taxa are exotics. Taxa richness ranged from 27 taxa in STA-5 to 110 taxa in STA-1W. STA-1W had at least twice the number of taxa as any other STA, which was attributed to the diversity of plants collected during an intensive single-day sampling effort by a college botany class in the ENRP. The class sampled along the levees above the water line, a practice that has not been repeated in the other STAs where sampling was restricted to inundated areas. The status of 63 taxa (50 percent of total) is classified as obligate wetland species, while another 38 taxa (30 percent of total) were either facultative wetland or facultative species. Additional analysis of the STA plant diversity data is ongoing.

The ENRP supported 28 fish species in 16 families; five of these species were exotics (Chimney and Jordan, 2008). Average total density (76.9 fishes/m^2) and bio-mass (1.4 g dry weight/m^2) of fishes in the ENRP were elevated relative to nearby oligotrophic marshes. Numerically dominant fishes were small-bodied species belonging to the families *Cyprinodontidae*, *Fundulidae*, and *Poeciliidae*. Large-bodied species were most abundant in deepwater canals, whereas small-bodied fishes were most abundant in densely vegetated habitats. The ENRP fish assemblage was similar to that of the adjacent Refuge (Jaccard similarity coefficient = 0.700). Community similarity of the ENRP with other Florida wetlands was inversely proportional to their distance from the ENRP. Null model analyses suggested that the pattern of species co-occurrence among these wetlands was random and not structured by competition or other factors. Fish species richness was highly correlated with family richness and both varied as power functions of wetland surface area. The diversity of the fish assemblage in the ENRP was comparable to that of fish communities in other Florida wetlands.

A total of 139 bird species representing 39 families was observed in STA-1W and STA-5 (Chimney and Gawlik, 2007). Seventy-two species are classified as residents and are known to breed in South Florida. Wading birds (*Ciconiiformes*), shorebirds (*Charadriiformes*), gallinules and coots (*Gruiformes*), and ducks (*Anseriformes*) were often numerically abundant as were perching birds (*Passeriformes*) on occasion. Twenty-eight of the 35 frequently observed species belonged to these groups. Sixteen species are state and/or federally listed as endangered, threatened or a species of special concern, including six frequent species [osprey (*Pandion haliaetus*), roseate spoonbill (*Ajaja ajaja*), snowy egret (*Egretta thula*), tricolored heron (*Egretta tricolor*), white ibis (*Eudocimus albus*), and wood stork (*Mycteria americana*)] that breed in the region. These two STAs were used by many migratory species, often in great numbers, during the spring and fall [e.g., American white pelican (*Pelecanus erythrorhynchos*), black-bellied whistling duck (*Dendrocygna autumnalis*), blue-winged teal (*Anas discors*), lesser yellowlegs (*Tringa flavipes*), and black-necked stilt]. STA-1W and STA-5 shared 91 and 78 percent of its avifauna with the Refuge and the EAA, respectively. Differences in surface area accounted for slightly more than 50 percent of the variance in bird species richness among the STAs, Refuge, EAA, and a number of other treatment wetlands around the country. A census of the avifauna in each STA is currently under way as part of the environmental lift study discussed previously in the *Wildlife and Avian Protection* section of this chapter.

DROUGHT IMPACTS ON THE STAS

In September 2007, the District implemented a Drought Contingency Plan that included strategies and specific operating procedures to maintain minimum stages in the STAs in an effort to sustain vegetation and to ensure achievement of water quality targets. Drought target stages were developed mainly for SAV cells, increasing normal operating target stage levels by another 6 inches. STA cell priorities were determined weekly and communicated to the water control operators.

Prioritization and hydration strategies were based on several factors, including:

- Elevation differences between cells
- Current cell performance and vegetation conditions
- Permit requirement (when applicable; currently this does not apply)
- Volume of water that can be treated within the cell (effective treatment area)
- Potential impacts of exotic vegetation

At the time of this report, no immediate harmful impacts to the target vegetation within STAs 1E, 1W, 2 and 3/4 have been observed as a result of implementing drought target stages. Despite the drought contingency efforts, dry conditions and high ground elevations in parts of the emergent cells of STA-5 and STA-6 resulted in a notable establishment of facultative and upland species within these STAs. In STA cells that experienced drydown conditions, spikes in TP concentrations upon reflooding were expected, based on data from previous years. An evaluation of outflow TP concentrations observed prior to and after reflooding is currently ongoing.

The drought contingency strategy implementation has several positive outcomes, including:

- Minimized occurrence of post-drydown TP spikes
- Minimized colonization of facultative and obligate upland species in SAV cells (Upland species are undesirable in SAV cells because they interfere with SAV establishment, persist in the cell for long periods of time, and are very difficult to manage or remove)
- Fewer black-necked stilt nests (137 nests) were observed compared to the 2007 nesting season (407 nests) (The presence of migratory bird nesting inside the STA treatment cells restricts operation)
- Implemented drought target stages early in the dry season, which created more opportunities to chemically control exotic FAV and woody species, such as willow
- Low water levels also allowed cost-effective dewatering and dredging of the STA-5 inflow distribution canals

RECREATIONAL FACILITIES AND ACTIVITIES

This year, three public access sites opened in the STAs. All these sites include the use "green technology," which utilizes dry vault composting toilets instead of septic fields that have the potential to seep nutrients into the marsh. In addition, solar-powered fans are used in the bathrooms to circulate air, and the automated gates at the front entrances are controlled by solar power. Each site has a shade shelter with interpretive signs explaining the functions of the STA and animals one might see.

The recreational facility at STA-1E opened in May 2008. This facility provides access to the north side of STA-1E, and when water control structure modifications are complete, the hiking and biking trail will extend to the south end of the STA. The trail will then take visitors past the different types of vegetation cells in the STA. STA-1E has a six-month test program for catch and release bank fishing inside a limited area of the STA.

The STA-1W recreational facility opened in July 2008. This facility provides access to the north side of STA-1W for hiking and biking. STA-1W is on the Great Florida Birding Trail, and this site is designed to provide a vista of an SAV cell, which offers excellent bird watching opportunities. There is a canoe launch for access into the northern exterior canal, and fishing is allowed in the external canals.

The STA-3/4 recreational facility opened in January 2008 (**Figure 5-36**). This facility includes a motor boat ramp to the exterior canals of the STA and access to other canals in the area, with a total access of 27 miles of canals. A footbridge and a four-mile loop trail are also provided for hiking, biking and enjoying the wildlife. The trail goes past the different types of vegetation cells in the STA. Fishing, whether from the bank or a boat, is allowed in the waters outside the STA. Successful catch-and-release bass tournaments have been held at this site.

Figure 5-36. The recreational facility at STA-3/4 includes boat ramps and covered picnic areas and offers hiking and fishing opportunities (photo by the SFWMD).

Hunting

The STA hunting program is coordinated through the FWC, and hunts are closely coordinated with STA staff. Many precautions are in place that have become part of the FWC rules as the program has evolved. The high quality of the hunts and the limited opportunity through the permit process encourages high compliance with the additional rules. Unlike traditional alligator (*Alligator mississippiensis*) hunting, motorized boats are not allowed in the STAs; only canoes are used by the hunters.

Alligator hunting took place in STA-1W and STA-5 in 2007. Alligator hunts in the STAs are managed by the FWC, and the season runs from mid-August 2007 to the end of October 2007. The alligator hunt permit numbers are determined by FWC to be sustainable harvest quantities. There were 100 and 50 permits issued for STA-1W and STA-5, respectively, and each permit allowed two alligators to be harvested. There were 151 alligators harvested from STA-1W and 58 from STA-5.

The STAs contain areas of open water and SAV, which provide ideal habitat for waterfowl. The FWC also coordinates the waterfowl hunting program. STA-5 opened for duck hunting as an experiment in 2002, with 25 permits issued per hunt day. Because of its popularity and no apparent impact to the functioning of the treatment areas, the hunting program was expanded to include the other STAs. STA-1W, STA-2, STA-3/4, and STA-5 were open for hunting in the 2007–2008 season. The waterfowl season involves migratory birds, and the bag limits are closely coordinated by the FWC with the federal government. Hunting was permitted on one weekend day per STA during the 2007–2008 waterfowl hunting season, for a total of 11 hunt days (including one hunt for youths) from mid-November to the first week of February. A total of 1,054 hunters bagged 4,535 ducks from STA-1W, 489 hunters bagged 1,558 ducks from STA-2, 1,400 hunters bagged 3,705 ducks from STA-3/4, and 1,698 hunters bagged 7,484 ducks from STA-5.

Bird-watching Program

Two of the STAs (STA-1E and STA-5) were open for bird watching activities. Organized bird-watching tours were conducted by Hendry-Glades Audubon Society in STA-5 and by Pine Jog Environmental Education Center of Florida Atlantic University in STA-1E. These birding tours have been as popular as hunting, with participants totaling up to 105 people on a single tour. Fifteen birding tours with 353 bird-watchers were held at STA-1E during the period of September through April. There were 83 species of wetland and upland birds identified by the birders. Similarly, there were 20 birding tours at STA-5 during the period of September through May, and over 1,000 bird enthusiasts participated. The number of wetland and upland bird species identified in and around STA-5 was 159.

STA-1E, STA-1W, and STA-3/4 are now open to the public Friday through Monday. The guided bird-watching tour at STA-1E will be discontinued as birding enthusiasts can now access the area on their own. However, the guided bird-watching tour at STA-5 will continue to be conducted by volunteer members of Hendry-Glades Audubon Society.

STA-1W REHABILITATION

The performance of STA-1W began to decline in 2004, aggravated by severe weather conditions and construction activities related to Long-Term Plan Enhancements projects. The purpose of the 2006 and 2007 rehabilitation efforts was to enhance and optimize performance through revegetation and, in the case of Cells 1B and 4, through removal of accrued soil layers with high TP concentrations. The rehabilitation effort was due to a combination of factors; however, the following are considered to be the most likely causes:

- Stress imposed by nutrient and hydraulic overloading
- Impacts from three hurricanes during the 2004–2005 hurricane seasons
- Inorganic sediments accumulation and suspension
- High water column turbidity issues

The 2008 SFER – Volume I, Chapter 5 contains a full description of both the 2006 and 2007 rehabilitation activities conducted in STA-1W.

HISTORICAL VEGETATION COVER AND REHABILITATION ACTIVITIES

Northern Flow-way

STA-1W came online in 1999 with the completion of Northern Flow-way Cells 5A and 5B. From start-up, Cell 5A, the upstream cell of this flow-way, was intended to be an emergent cell, while Cell 5B, the downstream cell, was to be maintained as an SAV cell. From start-up and through the first several years of operation, maintaining Cell 5A as an emergent cell was problematic due to the non-uniform ground elevations, resulting in water depths in some areas that were non-conducive for emergent species.

In general, the SAV in Cell 5B struggled to become established during the first couple years of operation; however, in years 2002 through 2004, the SAV community had become well established. This community was primarily dominated by southern naiad and hydrilla. Unfortunately, impacts from three hurricanes in 2004 and 2005 significantly decreased the SAV cover and increased the turbidity in the water column, further leading to the overall decline in this cell's SAV cover.

Detailed information regarding the 2006 Cell 5B rehabilitation activities can be found in the 2007 and 2008 SFER – Volume I, Chapter 5 reports.

Eastern Flow-way

Historically, the Eastern Flow-way was a cattail-dominated system that had performed fairly well since it became operational in 1994. Vegetation started to decline as early as 2002, and vast areas of highly turbid open water were evident as early as 2004. Since then, Cell 3 has been the only cell in this flow-way containing any significant vegetation coverage, which provided the majority of the treatment in this flow-way through 2007.

The Long-Term Plan had recommended structural and vegetation conversion activities and, in 2006, these ongoing projects presented the opportunity to conduct major earthwork and rehabilitation activities in an effort to improve the flow-way's overall performance. According to the Long-Term Plan, Cell 1A was to be maintained as a cattail-dominated cell while Cell 1B was to be converted to an SAV cell. Coincident with the construction of the G-248 levee, Cell 1B was drained with temporary pumps, and approximately 180,000 cubic yards of phosphorus-enriched sediment were removed. Following the sediment removal, and immediately prior to rehydrating, rice was planted in Cell 1B as interim vegetation to help recruit SAV. Initial efforts to convert Cell 3 from an emergent cell to an SAV cell were also done during this time. Additional efforts in Cell 3 included inoculation with submerged aquatic species.

Western Flow-way

Historically, this flow-way was composed of two cells, Cell 2 and Cell 4. The upstream cell in this flow-way, Cell 2, was maintained as an emergent cell through 2005. Cell 4, the downstream cell in this flow-way, was maintained as an SAV cell. Both cells performed well until 2004, when the vegetation coverage in both cells started to wane. Overloading (hydraulic and TP) and the formation of floating cattail tussocks in Cell 2 were identified as key factors leading to this decline. Additionally, the high productivity rates of the SAV in Cell 4 led to the rapid build-up of inorganic sediments that "choked" the desired submerged vegetation. Finally, three hurricanes during 2004 and 2005 further damaged the vegetation and aggravated conditions in both cells.

In 2005, the Western Flow-way was drained for implementation of Long-Term Plan Enhancements, which included the construction of the G-249 levee in Cell 2 to separate it into two cells, Cell 2A and Cell 2B. The northernmost cell, Cell 2A, in this flow-way was designated as an emergent cell, while Cell 2B was designated an SAV cell. The southernmost cell in this flow-way, Cell 4, was drained in an effort to consolidate the accumulated sediments and make the environmental conditions within this cell more favorable for reestablishment of the desired SAV community. The cattail community in Cell 2A reestablished; however, the sediment consolidation effort and rice planting in Cell 4 were not successful, and conditions in Cell 2B were still not favorable for SAV establishment.

In fall 2006, Cell 4 was drained again in an effort to consolidate the accumulated sediments to make environmental conditions more favorable for reestablishing the desired SAV community. Rice was aerially planted in Cell 4 because the cell was not sufficiently dry to plant using terrestrial equipment. The cattail community in Cell 2A rebounded; however, the sediment consolidation effort and rice planting in Cell 4 were not successful, and conditions in Cell 2B were still not favorable for SAV establishment.

In 2007, the opportunity to perform some rehabilitation activities in Cells 2B and 4 arose with the onset of the severe regional drought and the dewatering of the Eastern Flow-way for the construction of the G-248 levee. Rehabilitation efforts included:

- The removal of 180,000 cubic yards of highly inorganic sediments in Cell 4. The removed sediments were hauled by truck and earthmoving equipment to areas within the STA project site, but generally outside the treatment footprint
- The elimination of remnant farm ditches and roads in Cells 2B and 4
- The planting of rice in an effort to expedite the recruitment and establishment of SAV species in Cells 1B, 2B, and 4

- The inoculation of SAV species in Cell 2B in which muskgrass, a macroalgal species, was the only SAV found in this cell historically

STA-1W POST-REHABILITATION MONITORING

A thorough monitoring effort was initiated for all three flow-ways following the completion of the 2006 and 2007 rehabilitation activities to evaluate the success of these activities. The main objective of the monitoring effort was to answer the following questions:

- Were the problematic sediments in Cell 4 (inorganic sediments) and Cell 1B (high TP sediments) successfully removed as the result of the scraping effort?
- Were the sediments stabilized by planting rice (Cells 2B and 4)?
- Did SAV coverage increase significantly throughout all the cells as a result of the rehabilitation activities?
- Did the TP outflow concentrations decrease as a result of the increased SAV coverage in all three flow-ways?

Information collected through the monitoring effort included internal water quality samples, water column turbidity, water quality data obtained at the inflow and outflow structures for each cells, vegetation cover, and historical and recent soil characterization data.

Water Quality

Water samples were collected monthly from four locations within the interior portions of Cells 5B, 1A, 1B, 2B, 3, and 4. Internal sampling occurred in conjunction with the vegetation sampling events, which are explained below. Water quality samples were analyzed for SRP, TP, total organic carbon (TOC), calcium (Ca), total iron (TFe), SO_4, turbidity, color, and sulfide. Field measurements included pH, conductivity, temperature, DO, and water depth. Information regarding the Cell 5B internal water quality sampling was reported in the 2008 SFER – Volume I, Chapter 5; no additional Cell 5B monitoring or evaluation has been conducted.

Additional information collected from the water quality stations at each of the structures in STA-1W was used to determine overall STA and cell-by-cell performance throughout the period. This information is particularly useful to determine long-term trends in TP reduction along the flow path of each flow-way and overall in the STA. Additionally, long-term information, such total suspended solids (TSS), was used to determine if there were significant water quality improvements in the water columns of the cells where rehabilitation activities had taken place. All TP and TSS values reported in this section are based on an annual arithmetic mean; flow measurements are not taken into consideration.

Overall, it appears that both the performance and the environmental conditions in STA-1W have improved as a result of the 2006 and 2007 rehabilitation efforts (**Tables 5-18 and 5-19**). The outflow TP concentrations, turbidity, and TSS have decreased steadily. It should be noted that reduced flows and recent drought conditions could have also affected this observed improvement in performance.

Northern Flow-way Water Quality

The post-rehabilitation monitoring effort for this flow-way was completed in July 2007, and the results from this effort were reported in the 2008 SFER – Volume I, Chapter 5.

Overall, the outflow concentrations for this flow-way have continued to show significant improvement compared to water years 2005 and 2006, with an average outflow TP concentration of 37 ppb (WY2008). Additionally, TSS values continued to remain very low throughout WY2008, indicating that the environmental conditions in this flow-way continue to remain favorable for the long-term survival of the desired SAV community in Cell 5B, which has continued to expand throughout the entire cell (**Table 5-18).**

Eastern Flow-way Water Quality

The monitoring effort for this flow-way was initiated in August 2007 and continued through April 2008, with a total of six sampling events occurring during this time frame. Signs of recovery are evident in all three cells comprising this flow-way.

Cell 3 vegetation conversion efforts continued in WY2008; however, overall the Eastern Flow-way did not show significant signs of improved annual average TP concentrations throughout the water year. There was, however, significant improvement in TP reduction in Cells 1A and 1B. Upon the reflooding of this flow-way, there was a significant spike in TP concentrations at the G-308 outflow structure, while TP concentrations in Cells 1A and 1B were significantly reduced (**Table 5-19**). This spike was generally caused by (1) the flux of phosphorus from the soils upon rehydration, and (2) the large amount of decomposing biomass in Cell 3 as a result of the vegetation conversion effort conducted in this cell. Data collected from the G-253 divide levee and the G-308 structure indicate that this spike in TP concentrations was contributed specifically by Cell 3. Data collected from the G-308 for WY2008 also reveals that this exporting of phosphorus occurred for the first three months following rehydration, after which TP levels declined significantly to levels below 50 ppb (**Figure 5-37**). Overall, TSS concentrations did not significantly improve in Cells 1A and 3; however, there was a significant improvement in Cell 1B in WY2008 compared to previous water years.

Table 5-18. Average annual arithmetic mean of TP and total suspended solid (TSS) concentrations for each flow-way in STA-1W.

Average Annual Total Phosphate Concentrations (mg/L) in STA-1W										
Flow-way	Location	2000	2001	2002	2003	2004	2005	2006	2007	2008
Northern	Inflow	0.151	0.129	0.114	0.149	0.133	0.212	0.203	0.145	0.114
	Mid Levee	0.297	0.062	0.129	0.172	0.131	0.254	0.199	0.174	0.125
	Outflow	0.437	0.099	0.068	0.082	0.045	0.190	0.224	0.049	0.038
Eastern	Inflow	0.194	0.158	0.112	0.139	0.099	0.158	0.205	0.185	0.131
	Cell 1A									0.036
	*Cell 1B	0.022	0.055	0.054	0.070	0.109	0.170	0.174	0.187	0.040
	Outflow	0.144	0.051	0.024	0.048	0.039	0.063	0.072	0.080	0.067
Western	Inflow	0.139	0.083	0.069	0.140	0.113	0.287	0.161	0.190	0.107
	Cell 2A								0.102	0.103
	**Cell 2B	0.100	0.092	0.058	0.121	0.106	0.183		0.113	0.045
	Outflow	0.024	0.021	0.024	0.048	0.048	0.108	0.097	0.114	0.027

Average Annual Total Suspended Solid Concentrations (mg/L) in STA-1W										
Flow-way	Location	2000	2001	2002	2003	2004	2005	2006	2007	2008
Northern	Inflow	33.17	15.72	11.30	17.87	11.26	28.68	17.85	10.42	8.85
	Mid Levee	31.15	6.22	6.45	10.04	6.90	37.00	45.47	9.90	13.39
	Outflow	14.50	6.86	1.89	0.39	-0.51	13.63	48.47	4.40	1.25
Eastern	Inflow	22.07	14.79	8.83	18.47	10.84	18.88	17.38	10.53	12.17
	Cell 1A									-1.32
	*Cell 1B	1.84	2.11	1.14	-1.58	-2.74	9.57	21.83	18.00	-1.29
	Outflow	9.10	6.90	0.78	-1.15	0.98	7.11	2.64	2.05	-0.55
Western	Inflow	14.12	10.74	6.30	22.11	10.47	42.00	39.36	18.94	8.45
	Cell 2A								21.35	14.35
	**Cell 2B	5.77	5.02	2.94	9.97	12.85	21.18		22.56	1.00
	Outflow	2.19	1.66	0.56	-1.47	-2.70	3.79	12.00	20.41	-1.55

* Prior to WY 2008 cells 1A and 1B were operated as Cell 1

** Prior to WY 2006 cells 2A and 2B were operated as Cell 2. All availabe data is shown.

Note: Negative values are below detection limit

Table 5-19. Average water quality data for the Eastern and Western flow-ways of STA-1W.

	Average Internal Total Phosphorus Concentrations (mg/L)					Average Internal Total Suspended Solid Concentrations (mg/L)					Average Internal Water Column Turbidity (ntu's)				
	Western Flow-way		Eastern Flow-way			Western Flow-way		Eastern Flow-way			Western Flow-way		Eastern Flow-way		
Date	Cell 2B	Cell 4	Cell 1A	Cell 1B	Cell 3	Cell 2B	Cell 4	Cell 1A	Cell 1B	Cell 3	Cell 2B	Cell 4	Cell 1A	Cell 1B	Cell 3
Sep-06	0.087	0.074				24.00	7.90				9.40	6.13			
Nov-06	0.084	0.082				23.33	22.75				24.95	27.88			
Jan-07	0.071	0.100				12.89	18.30								
Aug-07	0.047	0.045	0.232	0.029	0.383	14.50	24.75	56.33	4.33	33.50	3.65	3.75	6.17	1.27	7.68
Sep-07	0.050	0.032	0.036	0.020	0.189	3.25	3.50	3.50	3.00	9.50	2.05	1.30	1.30	0.90	5.20
Oct-07	0.024	0.019	0.066	0.020	0.048	3.00	3.00	3.25	3.00	6.50	1.85	1.03	2.78	1.06	3.50
Nov-07	0.019	0.019	0.091	0.023	0.085	3.00	3.00	4.00	3.00	13.00	1.03	1.00	1.58	1.00	2.48
Dec-07	0.030	0.022	0.049	0.036	0.104	4.25	3.25	4.50	4.60	9.50	2.73	1.35	2.40	2.02	2.80
Feb-08	0.040	0.031	0.045	0.029	0.074	7.75	5.75	5.00	11.20	4.75	2.40	1.58	2.20	2.44	2.50
Apr-08	0.018	0.017	0.036	0.024	0.034	3.25	5.50	4.50	8.60	3.50	1.28	1.30	1.98	3.40	2.78

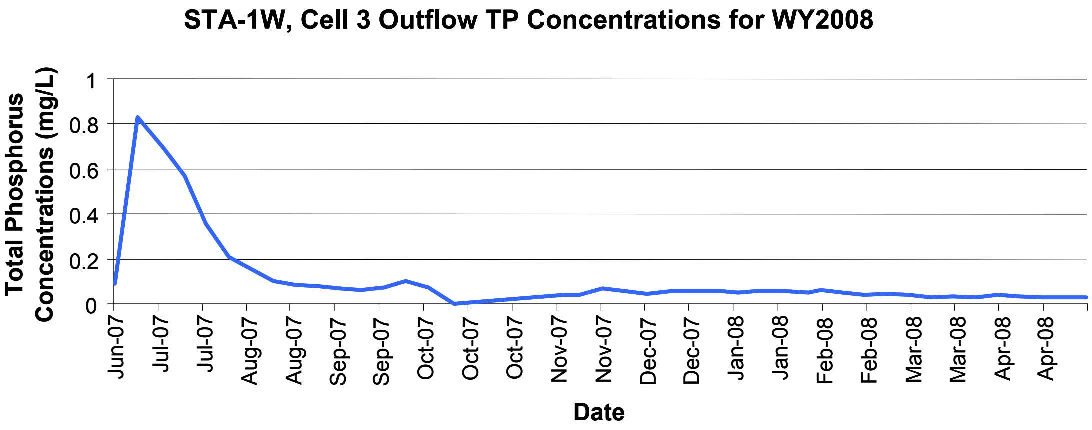


Figure 5-37. STA-1W Cell 3 weekly outflow TP concentrations for WY 2008

Internal water quality data generally shows the same trends as those observed from the data collected at the divide levees and outflow structure for this flow-way (**Table 5-19**). Cell 1B is the only cell where no export of phosphorus occurred following rehydration. There is no historical accounting for water column turbidity in this flow-way prior to WY2008; therefore, there is no way to compare pre-rehabilitation turbidity data to post-rehabilitation turbidity data. Overall, the turbidity in the water columns of all three cells has remained at levels sufficient to promote a healthy SAV community (**Table 5-19**), especially in Cell 1B where sediments were removed and rice was planted. The higher turbidity values in Cells 1A and 3 can be explained by the fact that there were large amounts of decomposing biomass in both cells throughout the period.

Western Flow-way Water Quality

Results from the internal and external water quality sampling indicated that the capability of this flow-way to remove phosphorus from the water column improved in WY2008 compared to previous years (**Tables 5-18 and 5-19**). It is very difficult determine how much of the overall decrease in outflow concentrations throughout this flow-way can be attributed to the increased vegetation cover and how much can be attributed to the decreased flows through this STA throughout the water year due to the regional drought conditions. Average TP outflow concentrations in 2008 for Cells 2B and 4 averaged around 41 ppb and 26 ppb, respectively. TP values as low as 14 ppb have observed at the G-309 outflow structure following the 2007 rehabilitation efforts. The last time outflows from this flow-way were below 20 ppb was in January 2002. Similar trends in TSS concentrations have been observed in Cells 2B and 4, with values significantly decreased in WY2008 compared to previous years. Internal water quality sampling results follow the same trends as those observed at the outflow structures in both cells. TP, TSS and water column turbidity values were significantly decreased in the year following the completion of the 2007 rehabilitation activities in this flow-way.

STA-1W Vegetation

Vegetation surveys were conducted to evaluate the extent of vegetation cover throughout the Eastern and Western flow-ways (excluding Cell 2A) and throughout Cell 5B of the Northern Flow-way. Surveys were conducted to evaluate the extent of either SAV or emergent species cover on a qualitative basis using a method devised to quickly assess cover over a large area. At each of the permanent monitoring locations in Cells 5B, 1A, 1B, 3, 2B, and 4 (**Figure 5-38**), vegetation coverage was determined as follows: No coverage (rating of 0), zero to 33 percent coverage (rating of 1), 33 to 66 percent coverage (rating of 2), and 66 to 100 percent coverage (rating of 3).

Surveying efforts in the Northern Flow-way were initiated in July 2006 and continued monthly through December 2006. Additional surveys in Cell 5B were conducted in May 2007 and May 2008. Vegetation surveys were conducted for the Eastern and Western flow-ways (excluding Cell 2A) following the same sampling regime as the surveys conducted in Cell 5B. Sampling efforts in the Eastern and Western flow-ways were initiated in August 2007 and continued monthly through December 2007 and again in April 2008.

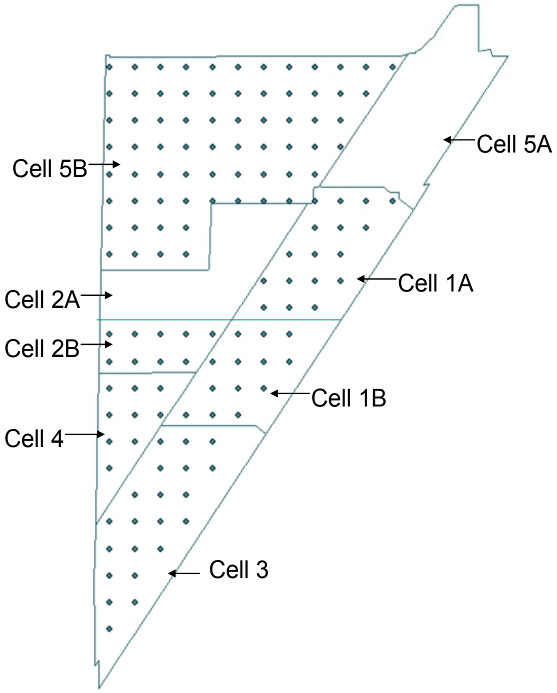


Figure 5-38. Permanent monitoring locations in STA-1W where all monitoring efforts were conducted for rehabilitation monitoring efforts.

Northern Flow-way Vegetation

SAV establishment in Cell 5B has continued to expand throughout the entire cell since the completion of the 2006 rehabilitation activities (**Figure 5-39**). As of May 2008, the dominant SAV species in this cell is southern naiad, which can be found in dense beds throughout this cell along with some hydrilla, coontail, and muskgrass.

Emergent species, primarily cattail, dominate small portions of this cell in areas with higher ground elevation and where water depths are too shallow to support SAV species. Additional areas maintained as emergent communities within Cell 5B include the four north-south vegetation strips, which were planted in 2006. Of the five species planted, fire flag (*Thalia geniculata*) and giant bulrush (*Scirpus validus*) best survived the fluctuating hydrological conditions within this cell. Emergent vegetation strips have been implemented in SAV cells, which help reduce the effects of high winds and wave action.

The Northern Flow-way of STA-1W continues to improve in overall vegetation cover, particularly in Cell 5A, where very little cattail was found prior to the rehabilitation effort. There continue to be areas in Cell 5A where cattail has been slow to establish due to the topographical variations and resulting higher water depths.

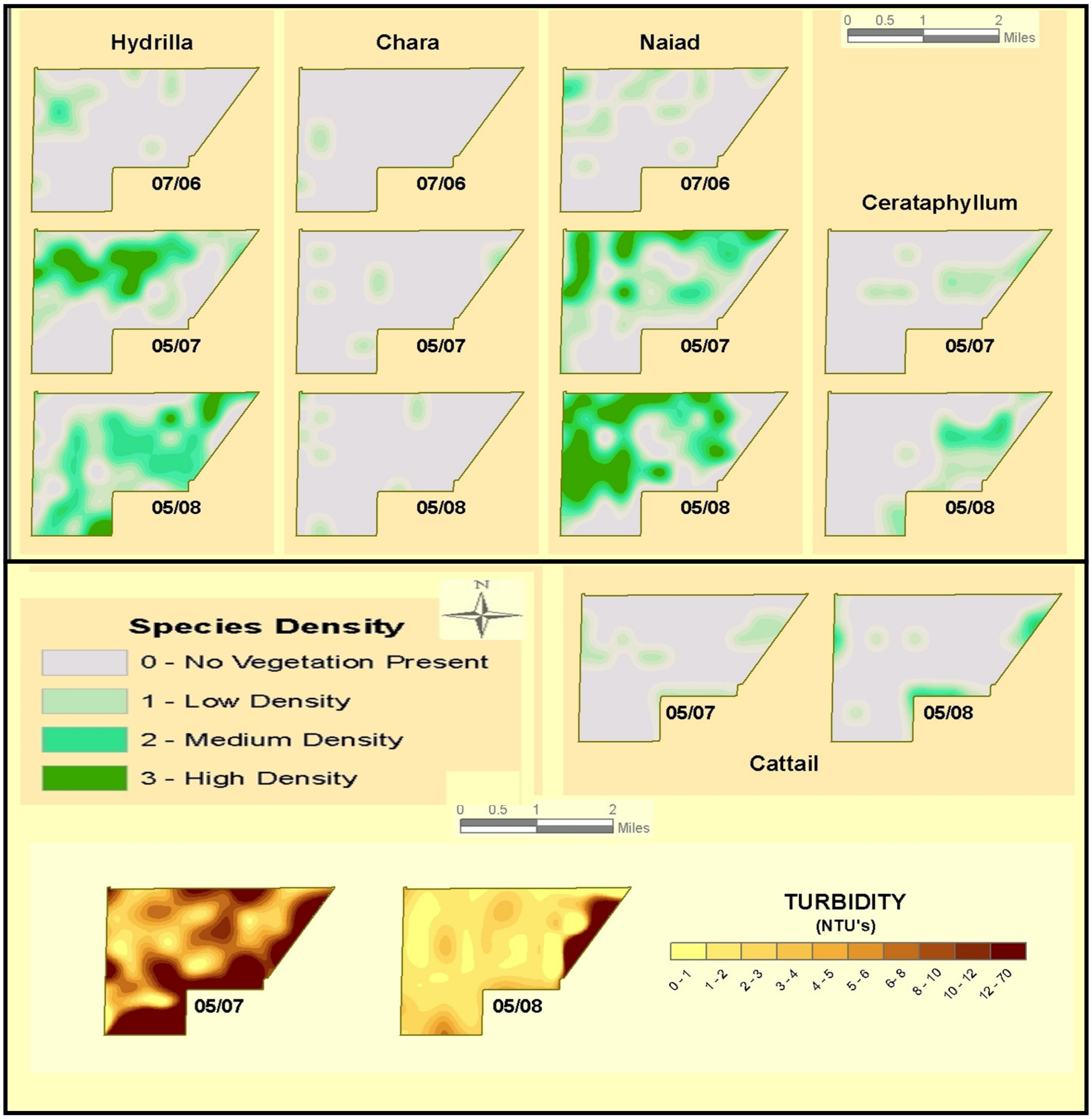


Figure 5-39. Vegetation and water column turbidity in the Northern Flow-way of STA-1W.

Eastern Flow-way Vegetation

SAV coverage has significantly increased following rehabilitation activities in this flow-way. Although muskgrass is the dominant submerged species throughout all three cells, there are copious amounts of southern naiad thriving throughout all three cells along with coontail and hydrilla (**Figure 5-39**).

Cattail growth in Cell 1A has been very slow to recover; however, expansion of this community continues and is expected to continue to expand through time. Although this cell is to be maintained as an emergent dominated cell, SAV is becoming established in conjunction with the cattail community, and it is believed that the combined communities are beneficial to the long-term performance of the cells. Cattail coverage in Cell 3 has decreased significantly as a result of the conversion efforts conducted during the 2007 rehabilitation activities. Large amounts of decomposing biomass remain in this cell as a result of the conversion effort. The "stomp and chomp" methodologies employed to initiate this conversion effort have expedited the decomposition process of this plant material, and conditions on the ground suggest that the conversion of the cell from an emergent community to an SAV community has been successful.

Western Flow-way Vegetation

Significant improvements in SAV coverage throughout Cells 2B and 4 were observed throughout the year following the completion of the 2007 rehabilitation activities (**Figure 5-39**). Southern naiad and muskgrass are the two dominant SAV species found throughout both cells. Dense communities of southern naiad can be found throughout Cell 4, while southern naiad is slow to establish in Cell 2B. Historically, Cell 4 was dominated by this species, while Cell 2B was a cattail-dominated system; therefore the SAV in Cell 4 reestablished itself naturally through the remaining seed bank and spore beds. No significant seed source was evident in Cell 2B; therefore, an inoculation effort was necessary, as discussed below.

STA-1W Submerged Aquatic Vegetation Inoculation. Preliminary vegetation surveys indicated that there was a sufficient amount of SAV (southern naiad, coontail, hydrilla, and muskgrass) growing in STA-1W, Cells 1B and 4; however, only muskgrass was found to be growing in Cells 2B and 3. Therefore, an inoculation effort was undertaken in late August 2007 in an attempt to colonize Cells 2B and 3 with SAV species, such as southern naiad and pondweed. Approximately 1,500 pounds (lbs) of SAV, primarily southern naiad and pondweed obtained from STA-2, Cell 3, were aerially dropped into nine locations in each of the cells (**Figure 5-40**), with a total of 13,500 lbs of SAV dropped into each of the two cells. In order to determine whether the inoculation effort was successful, a study was conducted to answer the following questions: (1) Did the inoculation methods result in SAV expansion, and (2) Which of the two species inoculated (southern naiad and pondweed) was successfully transplanted?

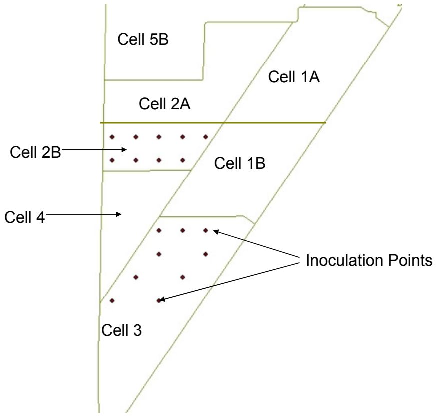


Figure 5-40. SAV inoculation points.

A line-intercept methodology was used to answer these questions, with a total of 13 sampling points at each inoculation location. Species presence/absence and percent cover were recorded at all the sampling points in October 2007 and March 2008. Results indicate that the inoculation effort was successful in both cells. The establishment of both species has been very slow, with most sites having sparse communities of the desired plants. However, there are numerous areas where thick patches of both southern naiad and pondweed are evident. As of May 2008, it appears that southern naiad is present at 54 to 74 percent of the sites in Cells 2B and 3, respectively. Pondweed has been much slower to establish in both cells, with a presence of 4 percent in Cell 2B and 13 percent in Cell 3 (**Figure 5-41**).

Although it is relatively early in the evaluation process, it appears that the overall inoculation efforts conducted in August of 2007 have been very successful (**Figures 5-41** and **5-42**). This is especially apparent given the fact that previous inoculation efforts in Cells 2B and 4 (pre-rehabilitation) were not successful. It appears that southern naiad is quick to establish and expand in coverage, while pondweed is slow to do either (**Figure 5-41**).

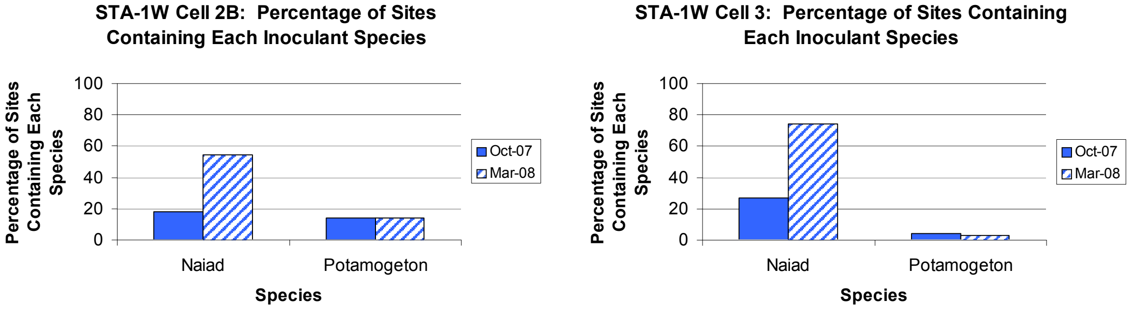
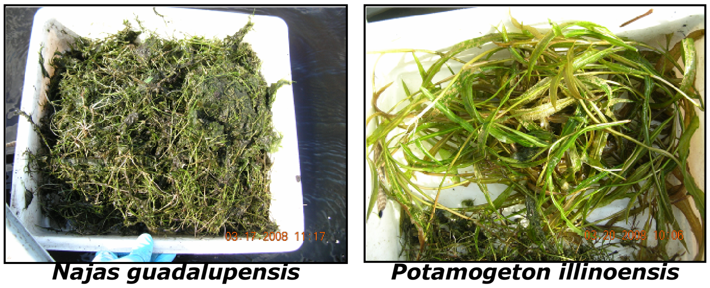


Figure 5-41. Results from vegetation surveys showing percentage of inoculated species present in Cells 2B and 3 of STA-1W.



Najas guadalupensis ***Potamogeton illinoensis***

Figure 5-42. Examples of both southern naiad (*Naiad guadalupensis)* and pondweed (*Potamogeton illinoiensis*) found in STA-1W Cells 2B and 3 (photos by the SFWMD).

STA-1W Soil Analysis

Soil samples were collected from Cells 1B, 2B, and 4 prior to draining the Eastern and Western flow-ways in early 2007 in order to characterize the upper soil layers and to determine if and how much material should be removed from each cell. Based on the nutrient concentration of the soil data, it was determined that the approximate upper 3 inches of sediments in Cells 1B and 4 had to be removed (**Figure 5-43**). In Cell 2B, data indicated that it was not necessary to remove soil in this cell, since it was primarily organic and the soil TPs was not of concern. Soil samples were tested after the rehabilitation efforts to determine if there were any significant differences in sediment composition.

The initial soil sampling efforts in the early days of the ENRP project characterized the soils in all three cells as having an organic content of 88 percent and higher. Throughout the10-year period of operating as the ENRP and STA-1W, it appears that the organic concentrations in all three cells decreased (**Figure 5-44**); however, the most significant changes occurred in Cell 4. The organic content of the soils in this cell decreased from having an organic content of 88 percent in 1996 to 44 percent and 43 percent organic content in 2003 and 2006, respectively. It was determined through topographic surveys that the upper 3 inches of the sediment layer in Cell 4 consisted of this highly inorganic sediment. These sediments were easily suspended into the water column, thereby increasing the turbidity in the water and decreasing the penetration of light into the water column. As a result, the photosynthetic capabilities of the desired submerged aquatic plants were restricted, and SAV coverage declined throughout Cell 4. Post-rehabilitation sampling in this cell indicated that the organic content in Cell 4 ranged from 70 to 87 percent, which is closer to the values obtained in the 1996 sampling efforts (**Figure 5-44**).

Background TP concentration for Everglades peat is around 400 mg/kg, which was found in STA-1W prior to start-up. Given the fact that STAs are designed to uptake phosphorus primarily through sediment accrual and burial, it is expected that sediment TP concentrations would increase as these treatment systems age. This is exactly what happened in STA-1W throughout the 10-year period, with average soil TP concentrations increasing from a range of 600 to over 1,000 mg/kg (**Figure 5-44**). The elevated soil TP levels were suspected to be a contributing factor in the decline in phosphorus removal in this flow-way. Scraping efforts in Cell 1B decreased the soil TP concentrations from 1,000 mg/kg (pre-rehabilitation) to an average concentration of 306 mg/kg (post-rehabilitation). The scraped material was hauled by truck and earthmoving equipment to areas within the STA project site, but generally outside the treatment footprint.

Post-rehabilitation soil sampling results indicate that both the high TP sediments in Cell 1B and the highly inorganic sediments in Cell 4 were successfully removed through the sediment removal efforts as part of the 2007 STA-1W Rehabilitation Project.

STA-1W Rehabilitation Summary

Overall, the rehabilitation efforts conducted in 2006 and 2007 have been very successful. SAV coverage increased significantly throughout Cells 5B, 2B, 4, and 1B (**Figures 5-45** and **5-46**). Water column turbidity values have improved considerably throughout all three flow-ways, and water quality has improved. Post-rehabilitation soil sampling indicates a significant decrease in soil TP in Cells 1B and 4 and an effective reduction in easily resuspended and enriched floc layer.

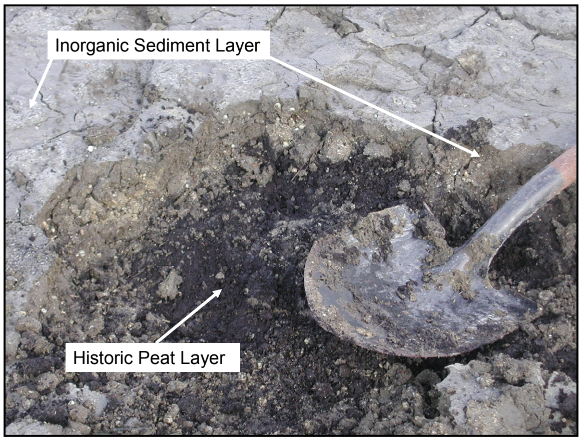


Figure 5-43. Accumulated inorganic sediment layer in STA-1W, Cell 4 prior to the 2007 rehabilitation effort (photo by the SFWMD).

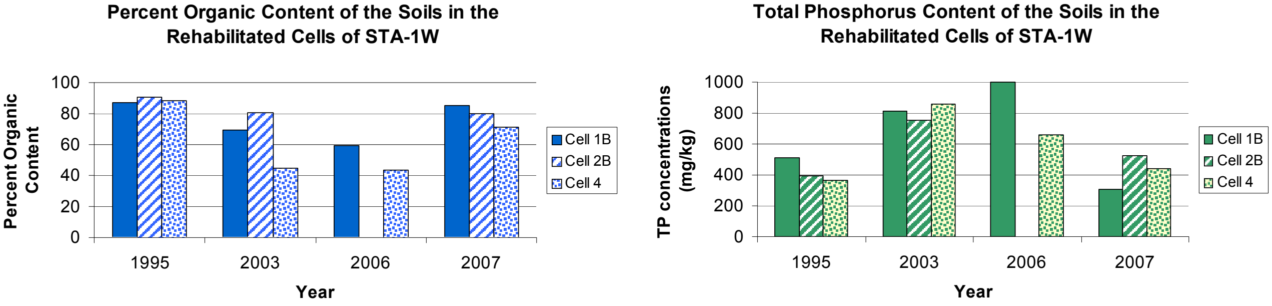


Figure 5-44. Sediment characterization results for STA-1W, Cells 1B, 2B, and 4.

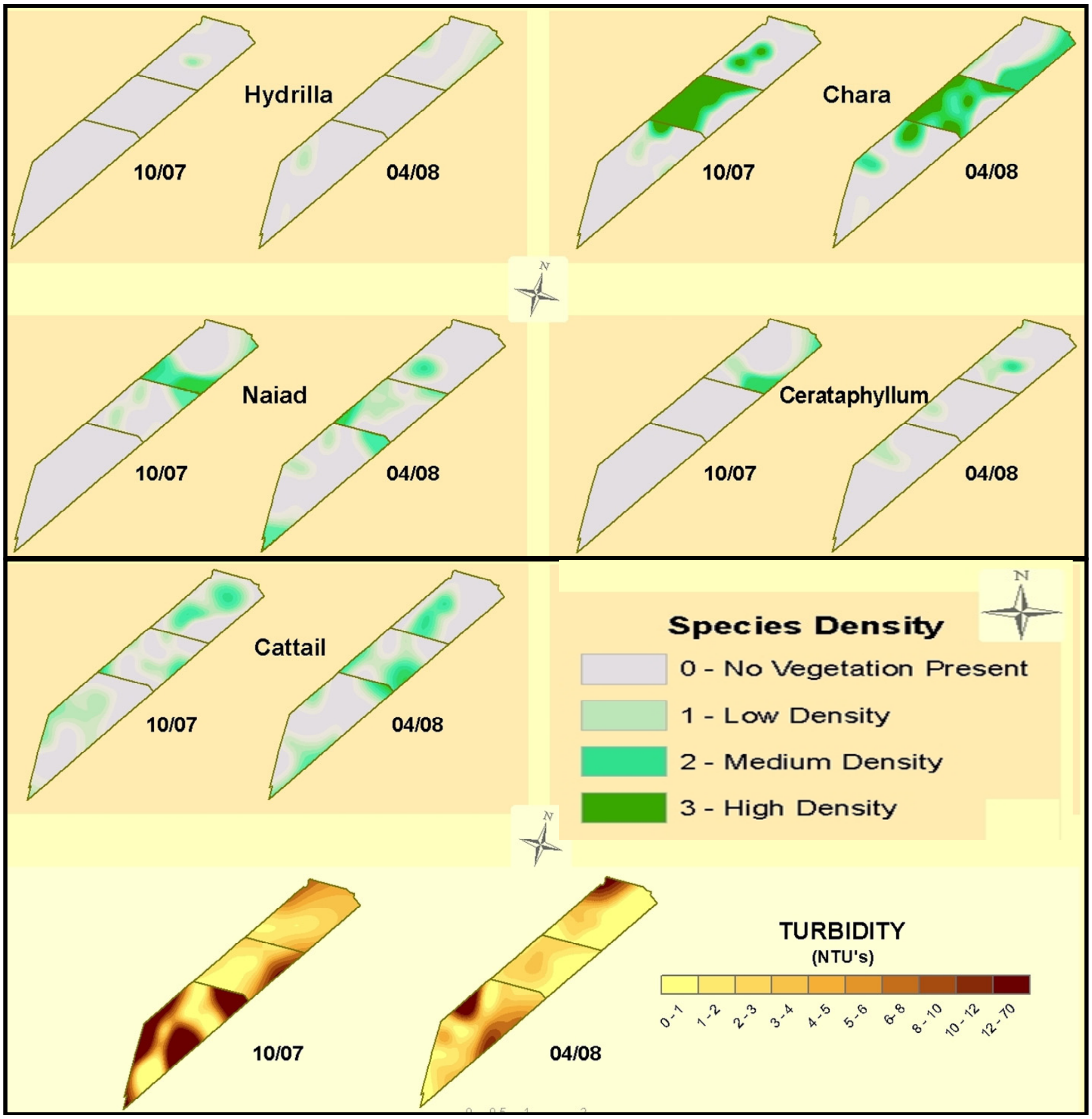


Figure 5-45. Vegetation and water column turbidity in the Eastern Flow-way of STA-1W.

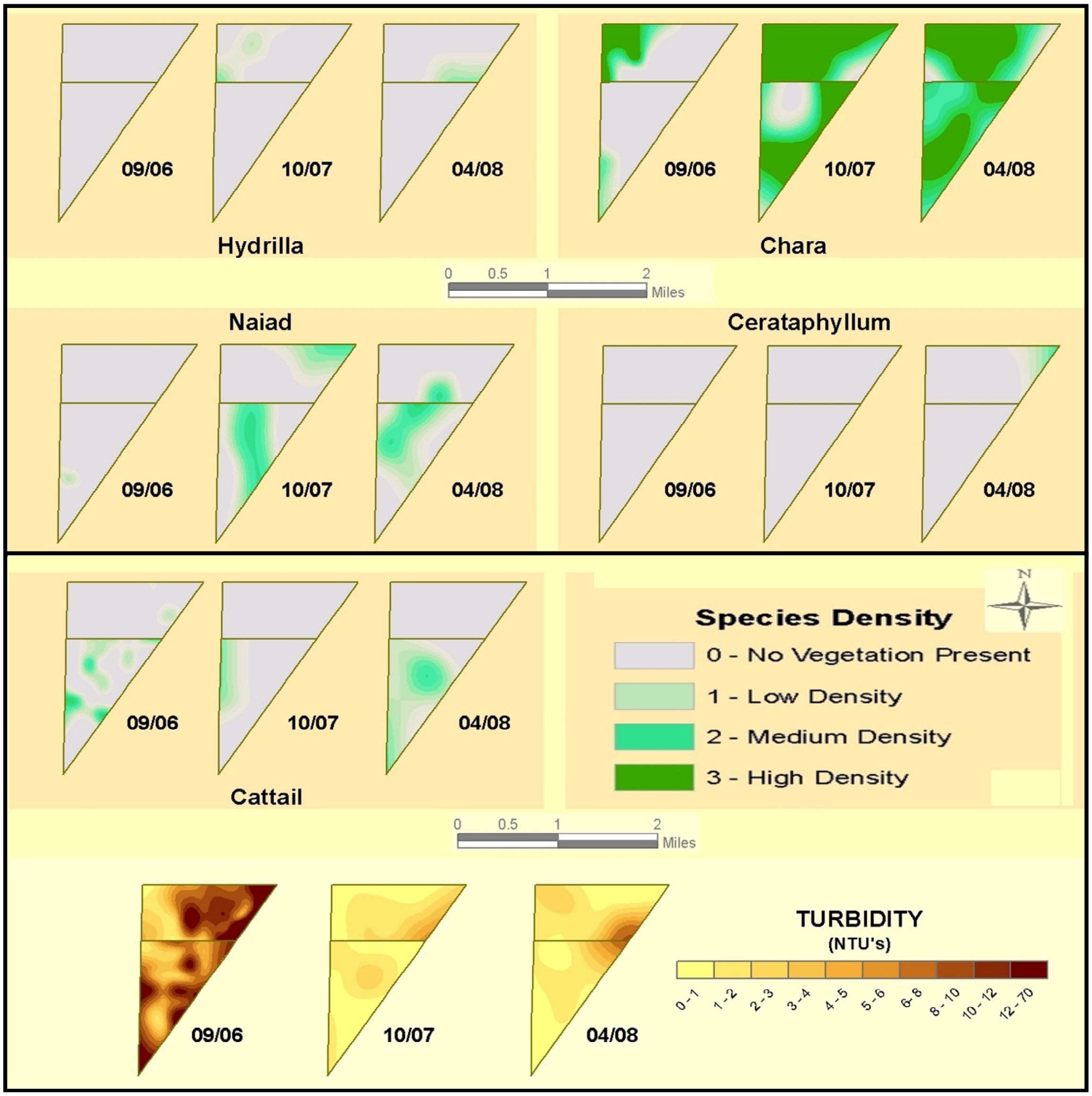


Figure 5-46. Vegetation and water column turbidity in the Western Flow-way of STA-1W.

PERIPHYTON-BASED STORMWATER TREATMENT AREA IMPLEMENTATION PROJECT

The PSTA Implementation Project comprises a 400-acre portion of STA-3/4, Cell 2B that was isolated by the construction of levees to form an upstream 200-acre cell (upper SAV Cell) and two adjacent downstream 100-acre cells (lower SAV and PSTA cells) (**Figure 5-47**). All cells have been managed to promote an SAV community and its associated periphyton through repeated herbicide applications to suppress emergent aquatic plants. The primary difference in the construction of the PSTA versus the SAV cells is that the peat substrate in the PSTA Cell was scraped down to caprock level and removed, while the soil in the upper and lower SAV cells was not disturbed. Consequently, the floor elevation of the PSTA Cell is approximately 1.8 ft (54 cm) lower than the adjacent SAV Cell. Peat was removed from the PSTA Cell because it provided a rooting medium for emergent plants and was a potential source of phosphorus that would flux back into the water column and reduce treatment efficiency. The two 100 cfs (≈ 244,658 m^3/d) pumps in the project's outflow pump station (G-388) are activated by a float switch and maintain the PSTA Cell at a depth of approximately 1.9 ± 0.25 foot (58 ± 8 cm). Surface inflow to the PSTA Cell through G-390A and B was adjusted to operate this cell at a nominal hydraulic retention time (HRT) (d) of approximately 5 d. The history of the PSTA Project, design considerations, project layout, and the project's Operating Plan are discussed in previous SFERs.

Water quality was monitored at all seven water control structures in the PSTA Project (**Figure 5-47**) during WY2008. Water temperature, dissolved oxygen, conductivity, and pH were measured in situ in conjunction with the collection of water samples. SRP, TP, and total dissolved P were monitored weekly; nitrite + nitrate-nitrogen, ammonium-nitrogen, TKN, Ca, chloride, and TSS were monitored monthly; and sodium, potassium, magnesium, sulfate, hardness, and alkalinity were monitored quarterly. Samples were collected at the upstream side of each structure. TP was collected with both grab and auto-sampler samples; all other parameters were collected only with grab samples.

The SAV community in the PSTA Project was surveyed on four dates during WY2008 (June 2007, October 2007, January 2008, and March 2008) using a geo-referenced grid of regularly spaced sampling stations in each cell: 104 sites in the upper SAV Cell and 48 sites in both the lower SAV and PSTA cells. The areal coverage of each SAV taxon at all sites was categorized as low (up to one-third coverage), medium (one-third to two-thirds coverage), or high (> two-thirds coverage). A new category of all SAV taxa was evaluated for the March 2008 survey.

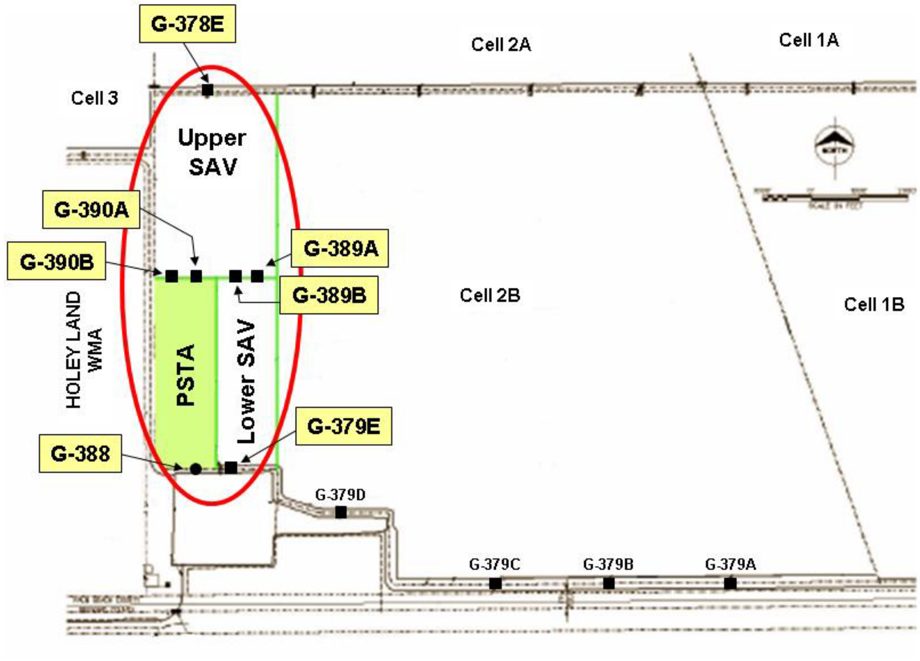


Figure 5-47. The Periphyton-based Stormwater Treatment Area (PSTA) Implementation Project showing the location of water control structures, the upper SAV Cell, the lower SAV Cell, and the PSTA Cell.

OPERATIONS AND PERFORMANCE

The drought that began in WY2007 throughout South Florida continued into WY2008 and again affected operation of the PSTA Implementation Project. During WY2007, the PSTA Cell inflow gates (G-390 and B) were not opened, so there was no surface water inflow to the cell. The outflow pump station for the PSTA Cell (G-388) was operated only for a period of 115 days, from June 17 through October 9, 2006 (the WY2007 operational period) and was stopped due to the lack of water in STA-3/4. The water discharged through G-388 was primarily groundwater seepage from the adjacent upper and lower SAV cells and a smaller contribution from rainfall. Operation of the PSTA Cell resumed nine months later on July 5, 2007, and continued through December 12, 2007 (the WY2008 operational period), a span of 161 days, when pumping at G-388 was again suspended due to the lack of water in STA-3/4 (**Figure 5-48**). The inflow gates at G-390 and B were operated during this time, so discharge from G-388 in WY2008 included surface water inflow, seepage, and rainfall. The discussion and analyses of data presented below are generally restricted to the WY2008 operational period unless noted otherwise.

Originally, the intent was to operate the PSTA and lower SAV cells in parallel; i.e., the cells would receive equal hydraulic loads to facilitate a comparison of the treatment efficiency of the PSTA versus SAV technologies. Unfortunately, this plan proved unworkable and the two cells were operated differently. The District attempted to establish a nominal HRT of 5 d in the PSTA Cell, while the timing and quantity of flow into the upper and lower SAV cells was dictated by the operation of the remainder of Cell 2B. Discharge from the PSTA Cell, for the most part, was continuous, while outflow from the lower SAV Cell at G-379E was sporadic (**Figure 5-48**). The PSTA Cell had a lower surface water hydraulic loading rate (HLR; 6.2 cm/d), a higher mean outflow rate [16.3 cfs (5,201 ac-ft)], and a shorter nominal HRT (5.9 d) than the lower SAV Cell [12.0 cm/d, 7.4 cfs (1,929 ac-ft) and 7.7 d, respectively] (**Table 5-20**). [3]

Periods of negative (i.e., reverse) flow at G-389A and B greatly complicated computing the water budget for the lower SAV Cell. The nominal HRT calculated for the PSTA Cell was close to the target value. Mean outflow from the PSTA Cell was 57 percent greater than surface water inflow via G-390 and B [10.4 cfs (3,326 ac-ft)]; the additional water volume at G-388 was attributed primarily to groundwater seepage from adjacent cells. Compared to the hydrologic characteristics for the lower SAV Cell, mean outflow from the PSTA Cell during the WY2008 operational period was within the range of mean flow at the Cell 2B outflow structures (G-379A to D; **Figure 5-47**) over the same period [14.2 to 18.0 cfs (4,522–5,738 ac-ft), respectively] and markedly higher than mean outflow at G-388 during the WY2007 operational period [9.5 cfs (2,162 ac-ft)] (**Table 5-20**).

The PSTA Implementation Project continued to support an abundant SAV community in all cells during WY2008 (**Figure 5-49**). Ten SAV taxa were observed on the four sampling dates: muskgrass, coontail, hydrilla, creeping primrose-willow, southern naiad, spiny naiad (*Najas marinas*), *Nitella tenuissima*, pondweed, bladderwort, and eelgrass (Appendix 5-13 of this volume) compared to 11 taxa noted in WY2007. The most frequently encountered taxa were muskgrass (as in previous years) and southern naiad. The distribution of hydrilla continued to be restricted primarily to the upper SAV Cell.

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[3] HRT was calculated based on outflow water volumes.

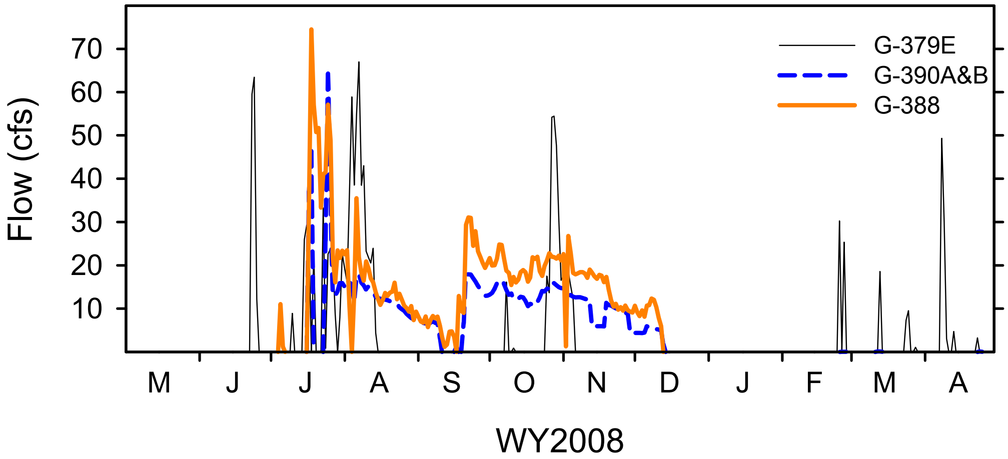

Figure 5-48. Daily surface flow-through water control structures G-379E (outflow from lower SAV Cell), G-390A and B (inflow to PSTA Cell), and G-388 (outflow from PSTA Cell) in the STA-3/4 PSTA Implementation Project during WY2008. 1 cfs ≈ 2,447 m^3/d or 1.98 ac-ft/d.

Table 5-20. Hydraulic characteristics and TP treatment performance of the PSTA and lower SAV cells during the WY2007 and WY2008 operational periods.

	WY2007[1]		WY2008[2]	
	PSTA	Lower SAV	PSTA	Lower SAV[3]
Surface-water hydraulic loading rate (cm/d)	0	--	6.2	12.0
Nominal hydraulic retention time (d)	10.1	--	5.9	7.7
Mean surface-water inflow rate (cfs)	0	--	10.4	21.4
Mean surface-water outflow rate (cfs)	9.5	--	16.3	7.4
Surface-water inflow volume (ac-ft)	0	--	3326	5548
Surface-water outflow volume (ac-ft)	2162	--	5201	1929
Inflow flow-weighted mean TP (ppb)[4]	--	--	28 (4)	30 (2)
Areal surface-water TP loading rate (g/m^2/yr)	0	--	0.630	1.291
Outflow flow-weighted mean TP (ppb)[4]	16 (3)	--	12 (2)	32 (6)
TP removal coefficient - k (m/yr)[5]	--	--	24.2	-2.7

Notes: 1 cm ≈ 0.39 in; 1 cfs ≈ 2,447 m^3/d or 1.98 ac-ft/d; 1 ac-ft ≈ 1,233.5 m^3; 1 ppb = 1 mg/L

[1] WY2007 operational period was June 17–October 9, 2006
[2] WY2008 operational period was July 5–December 12, 2007
[3] Calculations based only on months with net positive flow-through G389A and B
[4] Reported as mean value (standard error)
[5] $k = \ln(TP_{in}/TP_{out}) \times [((Vol_{in}+Vol_{out})/2)/Area] \times (365.25/d)$

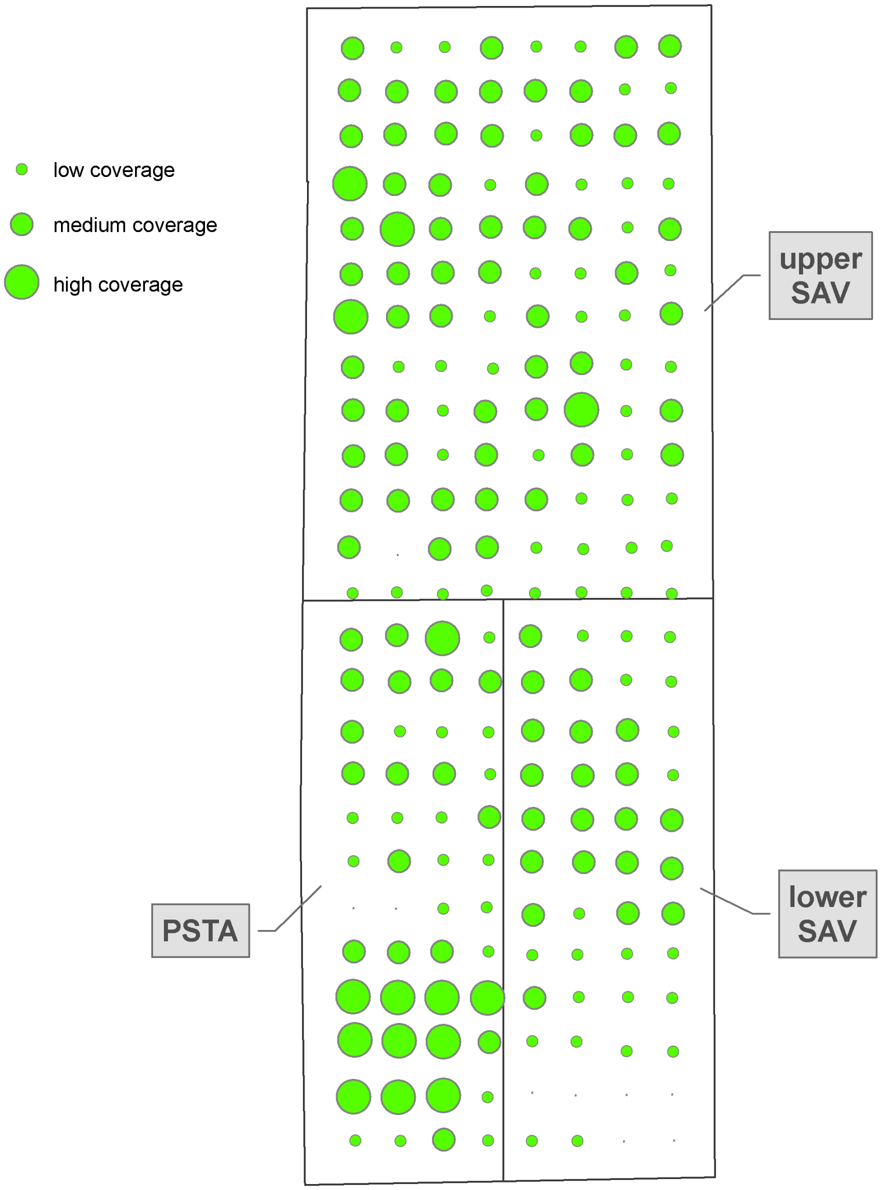

Figure 5-49. Distribution of all SAV in the upper SAV, lower SAV, and PSTA cells in March 2008. [Note: Each closed circle represents total areal coverage level of all SAV species at that site. Dots indicate sites without SAV. The depiction of cell boundaries is based on the project's Geographic Information Systems shapefile.]

Summary statistics for all water quality parameters monitored throughout WY2008 and during the WY2008 operational period are presented in Appendix 5-14 of this volume. The areal TP loading rate due to surface water during the WY2008 operational period to the PSTA Cell was approximately one-half the rate for the lower SAV Cell (0.630 versus 1.291 g P/m^2/yr, respectively (**Table 5-20**). Treatment efficiency of the PSTA Cell, as measured by its outflow TP FWMC (12 ppb) and TP removal coefficient — k (24.2 m/yr) — was better than the corresponding values for the lower SAV Cell (33 ppb and -2.7 m/yr, respectively), although a direct comparison of treatment performance in these two cells is confounded by HLR and HRT differences between them. In contrast, the outflow TP FWMC from the SAV-dominated Cell 2B during the same period was 22 ppb. The outflow TP FWMC from the PSTA Cell during the 2007 operational period (when the cell treated only groundwater seepage and rain-water) was 16 ppb under a nominal HRT (10.1 d), almost twice that during the WY2008 operational period (**Table 5-20**).

The PSTA Implementation Project was referred to as a demonstration project in the Long-Term Plan; however, the project represents the implementation of this treatment technology in STA-3/4. The current intensive monitoring program is scheduled to continue for another year. Given the delays in project start-up and the abnormal operating conditions in WY2007 and WY2008 due to the severe regional drought, intensive monitoring may be continued for additional years. However, monitoring of the PSTA Project eventually will be scaled back to a level consistent with the monitoring program in the rest of STA-3/4. Consideration is being given to investigating TP removal in the PSTA Cell under increased surface water hydraulic loading.

EVALUATION OF STA SOIL DATA

The Long-Term Plan requires an inventory of phosphorus storage in soils within each STA cell. Soil samples are collected upon completion of construction of any new cells (baseline monitoring), and subsequent collection of soil cores is done every three years thereafter. Soil samples are collected at every 1,330 ft x 1,330 ft grid point station, whenever the area is accessible. The actual number of sampled locations per cell and per STA is indicated as "n" in Appendix 5-15 of this volume, Tables A-1 and A-2. Samples are collected using a 10-cm diameter aluminum soil corer. Flocculent material (floc) in the STAs usually consist of a decayed vascular and unconsolidated living and dead periphyton material. Its composition and accumulation are regulated by the type of vegetation source, microbial activities, and a number of biogeochemical factors, including hydrology and nutrient availability. When floc is present, which generally is the case in cells that have been continuously flooded for extended periods, it is sampled separately and the depth is recorded.

In areas that were accessible at the time of sampling, soil samples were collected at 0–10 cm depth. All floc and soil samples were sent to the laboratory for TP, TN, TOC, bulk density (BD), and ash-free dry weight (AFDW). AFDW, also known as loss-in-ignition, is an indicator of the organic matter content in the soil, and higher AFDW indicates higher organic matter content. Many areas, particularly in drier cells, were not sampled due to prevalent drought and/or inaccessibility. Further attempts to sample these areas are planned for late 2008 or early 2009. This section of the report presents and discusses results obtained from 2006–2008. It must also be noted that in STA-1W, physical removal or tilling in of some of the accrued layer was done as part of the rehabilitation process in early 2007.

A review of the entire STA soil monitoring program was under way in 2008 by UF Wetland Biogeochemistry Laboratory scientists under contract with the District. This effort is expected to streamline the soil sampling program so it can better assess phosphorus storage and stability in sediment, as well as other key parameters and processes affecting P uptake and release.

OVERVIEW BY STA

STA-1E

Other than one sampling location, no significant floc layers were observed in any STA-1E sampling locations. Floc analysis results are summarized in Appendix 5-15 of this volume, Table A-1. Results for samples collected at 0–10 cm depth are shown in Appendix 5-15 of this volume, Table A-2 and displayed in **Figure 5-50**.

Soil TP remains relatively low in most of the STA-1E cells compared to other STAs. Many of the sampling locations have TP concentrations less than 100 mg/kg. The mean for the entire STA is 124 ± 173 mg/kg, but as **Figure 5-50** indicates, there are pockets of higher level soil TP in Cell 5. Organic matter content in the soil seems to follow the same trend as soil TP, with more organic soils concentrating in the western portions of Cells 5, 6, and 7 (**Figure 5-50**). The mean AFDW for the entire STA is 11.1 ± 19.1 percent, indicating that the soil is predominantly mineral matter. Cells 6 and 7 have areas with greater than 60 percent AFDW; the mean percent AFDW in these two cells is 20.4 ± 24.7 and 40.2 ± 27 percent, respectively. BD is generally higher [1,031 ± 0.365 grams per cubic centimeter (g/cc)] compared to the other STAs, which is related to the high mineral content of the soil. Although TOC and TN in STA-1E soils are relatively low when compared to other STAs, the C:N ratio of 15:1 is comparable with what has been found in other STAs.

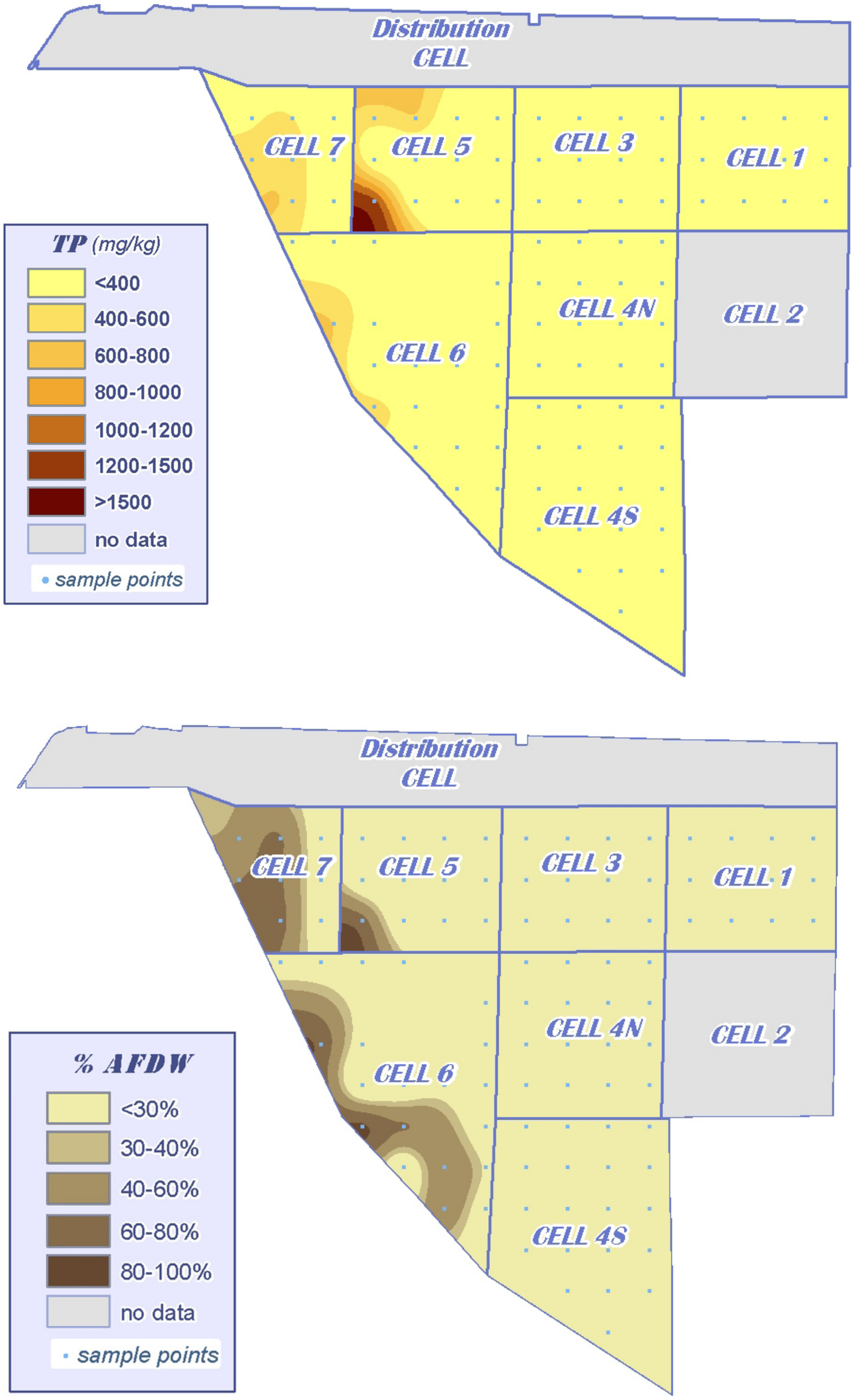

Figure 5-50. TP and organic matter (percent AFDW) in STA-1E at 0–10 cm depth.

STA-1W

STA-1W, Cell 4 has been an SAV cell since 1994. The demise of the formerly healthy SAV establishment in late 2004 resulted in deposition of a thick layer of highly inorganic material. That material had very low organic matter content and TP high levels. Upon scraping, the underlying peat material was exposed, which contained lower TP levels and higher organic matter content. Cells 4, 2B, and 1A were sampled before and after rehabilitation. There was no sediment removal in Cells 2B and1A, so data for those cells were included in the soil map, while post-rehabilitation data for Cell 4 was separated in the form of a pop-out map as shown in **Figure 5-51**. A limited amount of floc was collected from STA-1W, Cells 1 and 5B during this sampling period, primarily due to low water conditions (site inaccessibility and resulting settling of floc material) brought about by drought and dewatering activities in 2007. After rehabilitation and resumption of operation in the Eastern and Northern flow-ways, there was also lack of floc. Results from Cells 1 and 5B are presented in Appendix 5-15 of this volume, Table A-1. The mean floc depth is 3.2 ± 2.4 cm and soil TP is 1,237 ± 436 mg/kg. Mean organic matter content (percent AFDW) is 61 ± 6.13 percent. The estimated floc phosphorus storage in Cells 1 and 5 is 8 and
13 mt, respectively (Appendix 5-15 of this volume, Table A-3). As reported in the 2008 SFER – Volume I, Chapter 5, the 2007 STA-1W rehabilitation involved physical removal of floc and the upper accrued layer in Cells 1B and 4, and disking in of dried floc material in Cell 2B. The estimated mass of TP removed from Cells 1B and 4 was approximately 19 mt.

The soil composition in the 0–10 cm layer prior to rehabilitation indicates the presence of a moderate amount of TP (647 ± 366 mg/kg) and organic matter content of approximately 71 percent (Appendix 5-15 of this volume, Table A-2 and **Figure 5-51**). In Cell 4, however, AFDW is only 43.7 ± 23.0 percent, indicating a highly mineral soil condition. Scraping was done as part of rehabilitation of this cell, primarily to alleviate the highly turbid condition that was preventing reestablishment of SAV. Although turbidity was also a problem in Cell 2, percent AFDW was about 86 percent. Based on this and previous soil data, floc and a portion of the underlying soil in Cell 2B was simply disked into the sublayer. Both cells currently have successful SAV establishment after rehabilitation.

The C:N ratio is very consistent among cells in STA-1W (mean = 16:1) but the C:P ratio is highly variable, with cell means ranging from about 426 to 1,519:1. The highest C:P ratio was observed in Cell 1. The rehabilitation seems to have affected the C:P ratios in the upper 10-cm layer in both Cells 1B and 4, increasing from 426 and 461:1, respectively, to 802 and 1,549:1, respectively.

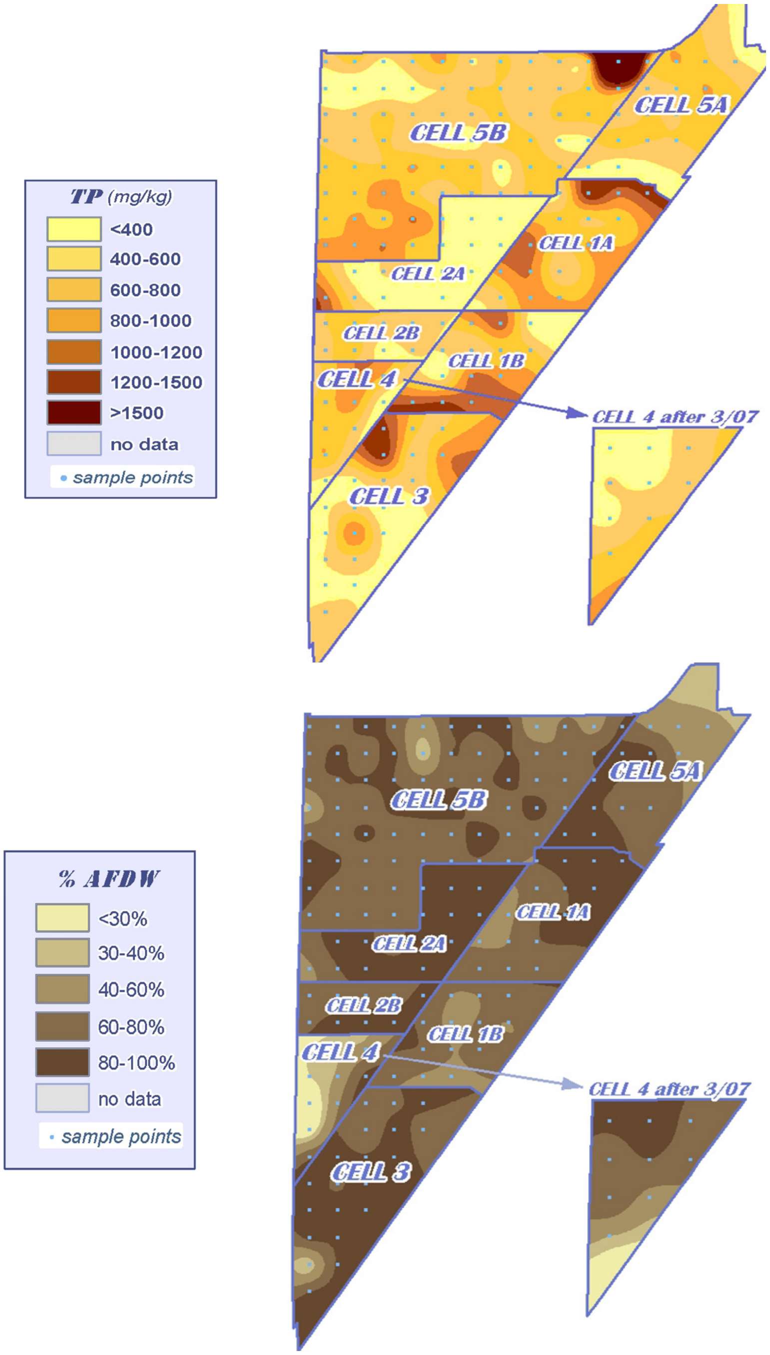

Figure 5-51. Soil TP and organic matter (percent AFDW) profile in STA-1W at 0–10 cm depth. Cells 4, 2B, and 1A were sampled before and after rehabilitation. There was no sediment removal in Cells 2B and 1A, so data for these cells were included in the soil map, while post-rehabilitation data for Cell 4 was separated in the form of a pop-out map.

STA-2

As the data indicates (**Figure 5-52** and Appendix 5-15 of this volume, Table A-2), several sampling locations in Cells 1 and 2 were not accessible during 2007–2008 sampling. For sites that were accessed, the mean floc depth was 7.1 ± 3.6 cm, with a mean TP concentration in STA-2 (Cells 1–3) of 852 ± 205 mg/kg. This translates to approximately 101 and 77 mt of P retained in the floc layer in Cells 1 and 2, respectively. Mean soil TP concentration is 540 ± 215 mg/kg, which is about 15 percent higher than found during baseline characterization (470 ± 249 mg/kg). Cell 4, which is a new cell, has a similar soil TP concentration at this depth (577 ± 212 mg/kg).

The percent AFDW is relatively low (29.8 ± 11.6 percent), indicating a highly mineral soil. Emergent cells (Cells 1 and 2) showed higher percent AFDW at about 40 percent. The underlying soils (0–10 cm) have much higher organic matter content, with a mean of 80.3 ± 9.04 percent AFDW. This is in the same range as the levels found in the baseline soil characterization (AFDW 85.5 ± 2.69 percent) performed in year 2000 (White and Reddy, 2000). In Cell 4, the AFDW is slightly less, 76.1 ± 12.6 percent, but still an indication of highly organic soil.

Soil (0–10 cm) BD was 0.25 ± 0.08 g/cc, which was very similar to levels found during baseline characterization (0.21 ± 0.07 g/cc). In the new cell, Cell 4, soil BD was found to be higher (0.30 ± 0.10 g/cc). In comparing TOC between this sampling period and sampling done in 2000, concentrations were similar in Cells 1–3 at 461 ± 31.4 mg/kg and 467 ± 16.9 mg/kg, respectively. This indicates that either the soil TOC consists of highly stable forms or that the input versus consumption is at about the same rate. Cell 4 soil TOC concentration at this depth was in the same range (412 ± 69.1 mg/kg). Similarly, soil TN in Cells 1–3 (27.7 ± 3.03 mg/kg) and in Cell 4 (27.3 ± 4.3 mg/kg) was also in the same range as found during baseline characterization (28.3 ± 2.78 mg/kg). The C:N and C:P ratios in STA-2 are 19:1 and 260:1, respectively, in the floc layer, and 16:1 and 820:1, respectively, in the soil layer.

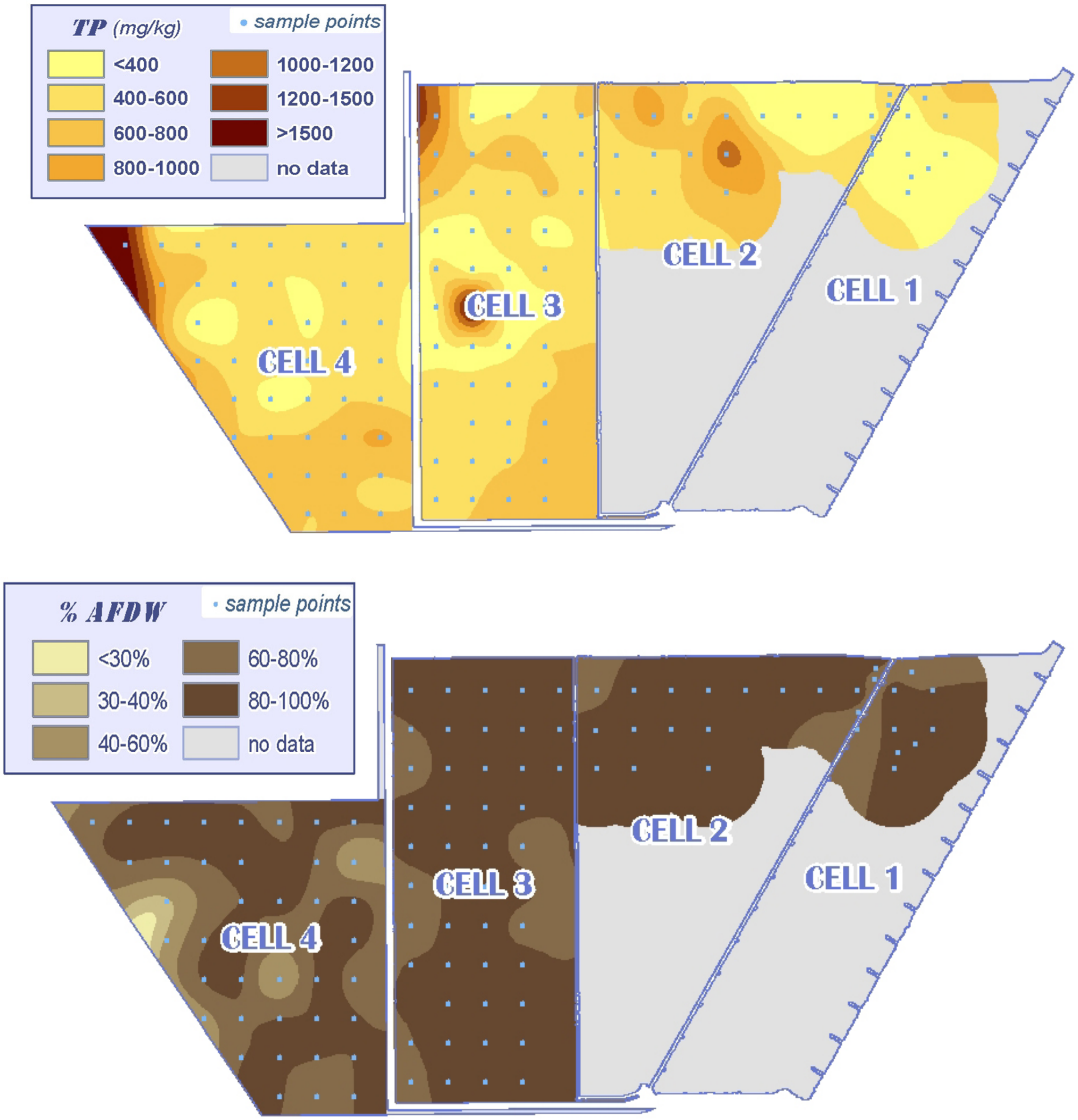

Figure 5-52. TP and organic matter content (percent AFDW) profiles in STA-2 at 0–10 cm depth.

STA-3/4

Very few of the sampling sites in STA-3/4 have floc; Cell 2B has the most locations with floc. The mean floc depth is 7.3 ± 3.8 cm, and the mean TP concentration is 1051 ± 170 mg/kg. Based on Cell 2A and 2B data presented in Appendix 5-15 of this volume, Table A-3, the floc sediment stored 183 mt of TP in these two cells alone. This estimate is unusually high considering that the TP retained in this STA, as per the 2008 SFER – Volume I, Chapter 5, was 222 mt. As mentioned earlier in this report, collection and delineation of the floc layer in the STAs has been a challenge and is a very subjective process. Mean soil TP at 0–10 cm depth is 615 ± 200 mg/kg, with fairly even distribution throughout the STA, except for occasional pockets of TP exceeding 1,000 mg/kg on the northern portion of Cells 1A and 2A (**Figure 5-53**).

The floc layer in STA-3/4 is an even mixture of organic and mineral matter, based on an average AFDW of 52.6 ± 8.49 percent. In terms of C:N and C:P ratios, STA 3/4 floc has ratios of 15:1 and 277:1, respectively. In contrast, the soil layer has 70.6 ± 14.1 percent AFDW. The mean C:N and C:P ratios are 15:1 and 621:1, respectively.

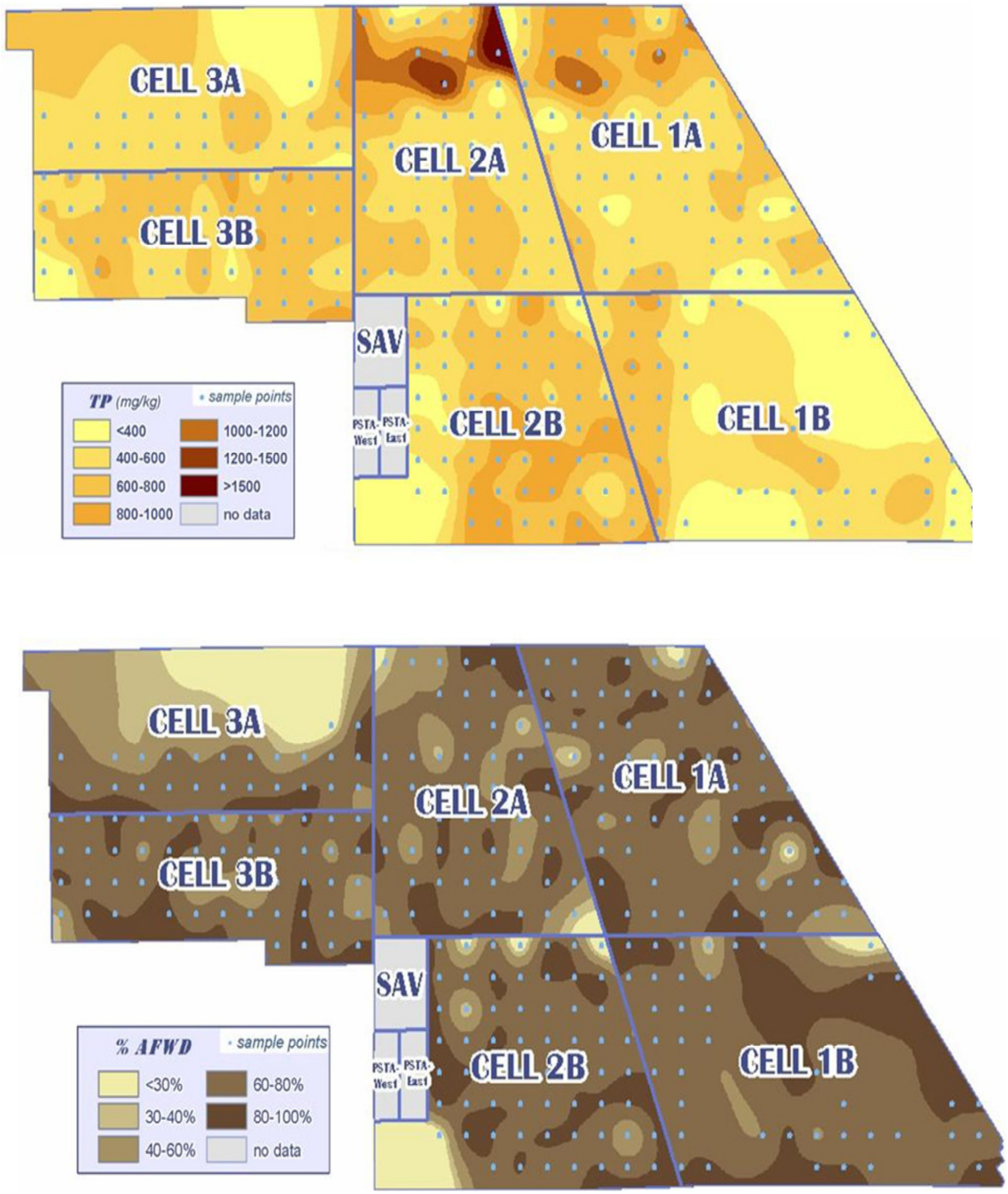

Figure 5-53. TP and organic matter (percent AFDW) profile in STA-3/4 at 0–10 cm depth.

STA-5

Floc was present at a limited number of sites within Cell 1B, primarily due to dry conditions brought about by drought conditions and construction activities. The mean floc depth in the Northern Flow-way is 5.4 ± 2.8 cm, and the TP content is 1,210 ± 483 mg/kg. It has a moderate amount of organic matter (66 percent AFDW).

Soil TP in the upper 10-cm layer of the Northern and Central flow-ways has increased from 462 ± 95.8 (baseline characterization in 2000) to 694 ± 512 mg/kg. The results are highly variable, with concentrations exceeding 1,500 mg/kg along the westernmost portion of Cells 1A and 2A, and along the middle sections of Cell 2B (**Figure 5-54**).

The upper 10-cm layer in the Northern and Central flow-ways has a mean AFDW of 57.2 ± 22.6 percent, suggesting an even mix of organic and mineral matter (Appendix 5-15 of this volume, Table A-1 and **Figure 5-54**). This value is lower than the values found during baseline characterization (71 ± 21.2 percent AFDW), possibly a result of oxidation as a consequence of alternating wet and dry conditions, along with high loading of mineral matter from agricultural runoff loaded into the STA. TOC levels, however, showed comparable results between the 2000 baseline result (391 ± 106 g/kg) and the 2007 sampling (318.4 ± 125.0 g/kg). BD and TN levels were also found to be comparable with baseline results.

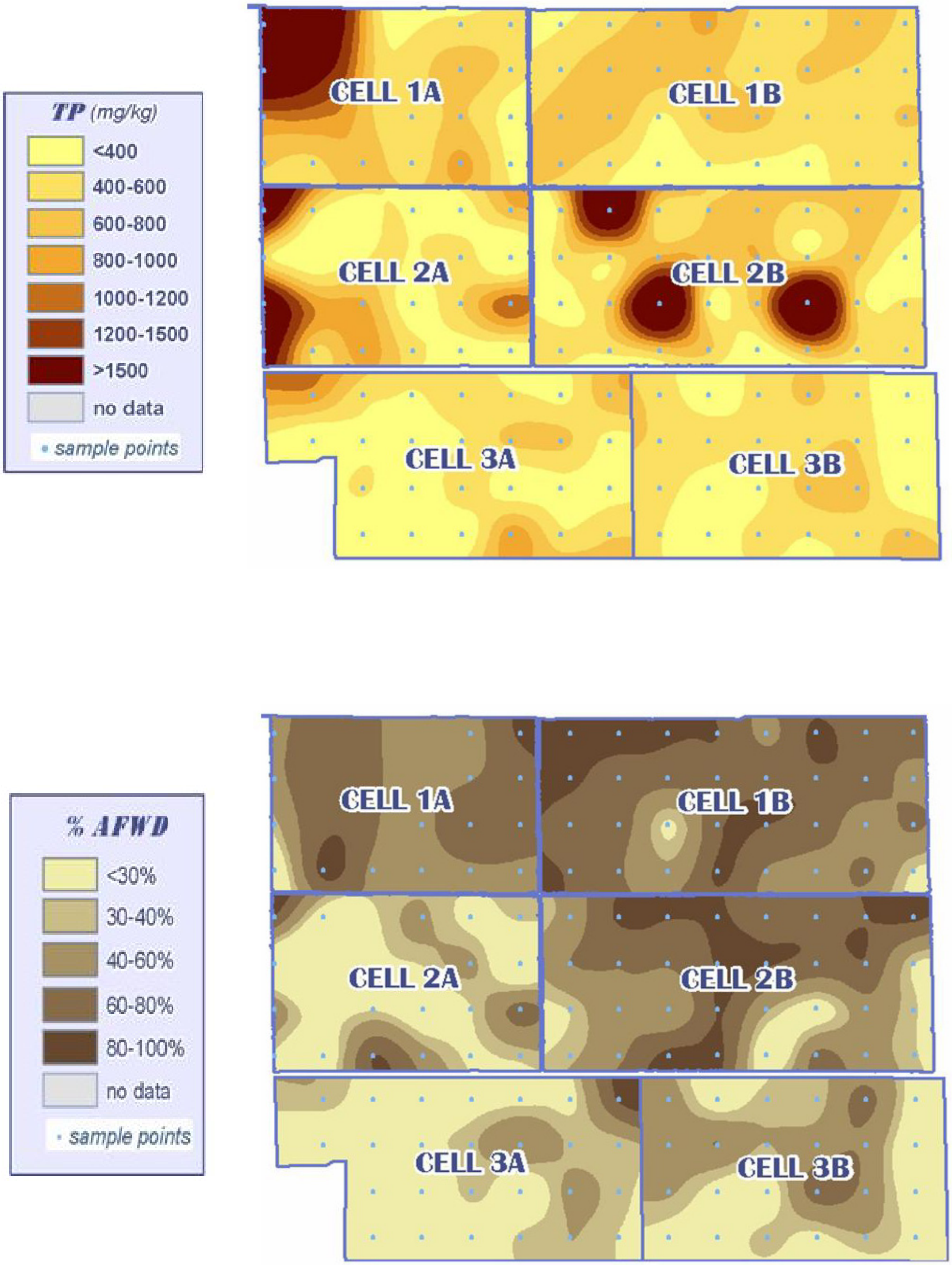

Figure 5-54. TP and organic matter (percent AFDW) profiles in STA-5 at 0–10 cm depth.

STA-6

Due primarily to dry conditions and thick stands of mixed vegetation, STA-6, Cells 3 and 5 were not sampled between 2006 and early 2008. A modified sampling plan is currently being evaluated to enable access to a reasonable amount of sampling sites. The following discussion pertains to the upper 10-cm layer in Section 2.

The TP content observed in this new cell (572 ± 202 mg/kg) is about twice as high as the baseline TP concentration in Cells 3 and 5 (236 ± 108 mg/kg). **Figure 5-55** indicates a highly variable distribution with lower concentrations around the middle of the cell. Organic matter content is low (31.2 ± 21.4 percent; **Figure 5-55**), but slightly higher than found in 2000 in STA-6, Cells 3 and 5 (21.7 ± 10.9 percent). TOC (177 ± 114 g/kg) and TN (13.4 ± 8.1 g/kg) results were also comparable to the baseline concentrations in the other two cells.

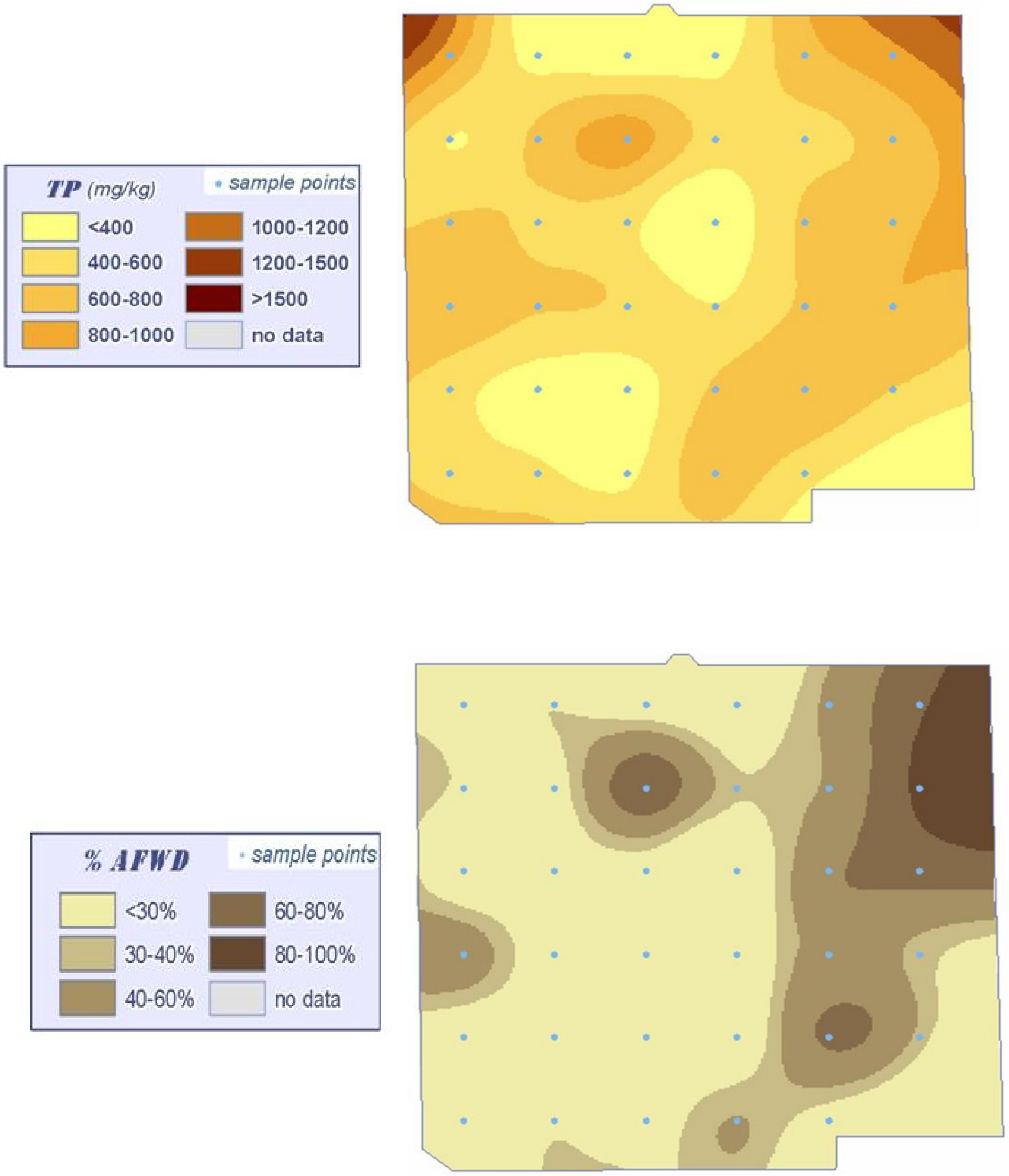

Figure 5-55. TP and organic matter (percent AFDW) profiles in STA-6, Section 2 at 0–10 cm depth.

FLOC SEDIMENT CHARACTERIZATION

These results were from a study initiated in 2007 to further characterize the biogeochemistry of the sediment and floc layer and their behavior relative to the growth and establishment of SAV in the STAs. Understanding the characteristic and behavior of floc material, as well as SAV response to the different environmental factors, could lead to long-term STA management strategies that would help ensure sustainability and optimal performance of the SAV cells. The study focused on STA-1W, Cell 4, which had excessive turbidity in 2006 after about 12 years of excellent performance. Excessive turbidity prevented reestablishment of SAV. Samples were collected prior to the cell being drained for rehabilitation (2007). This study is continuing through 2009, and more results are expected to be presented in the next SFER. A summary of some of the laboratory results leading to these findings for STA-1W, Cell 4 are in Appendix 5-15 of this volume, Tables B-1 to BA-5. Results show that coarse particles (size 1–0.25 mm) were the dominant fraction in floc and peat soils, followed by medium-sized particles (0.25–0.01mm and 0.01–0.01mm) that accounted for approximately 40–50 percent of the particle size distribution (Appendix 5-15 of this volume, Table B-3). However, the study indicates that abiotic turbidity in this cell was primarily due to poor aggregation of particles, with a high percentage of small size aggregates (< 0.053 mm) and lack of large size (> 1.00 mm) water-stable aggregates. The study also suggests that the following factors may have contributed to the poor sediment structure: (1) high Na^+/Ca^{2+} ratio; (2) the lack of quality colloids, such as layer silicates, with basic particles being dominant with sand and silt-sized calcite; and (3) low microbial and enzyme activity.

Generally, TN and TOC contents were higher, but pH and soil electrical conductivity were lower in peat layers than in floc layers (Appendix 5-15 of this volume, Table B-1). The amount and quality of organic matter in the sediments is an important factor for aggregate stability. The ratio of humic acid/fulvic acid (HA/FA) is frequently used to indicate organic matter quality of soil and sediment. Higher HA/FA ratio facilitates the formation of water-stable aggregates. Humic acids and FA contents were higher in the peat than in the floc layer. The contents of HA and FA, and HA/FA ratios tend to decrease from inflow to outflow direction in STA-1W (Appendix 5-15 of this volume, Table B-2).

Microbial activity (measured in terms of biomass) was investigated in this study as a potential cause for poor sediment aggregation in the highly inorganic floc layer. The results indicate much lower activities compared to upland soils and to areas with labile organic carbon sources. Microbial biomass P generally was low (mostly < 10 mg/kg) in floc and peat samples; however, it was higher in floc than in peat in the STA-1W (Appendix 5-15 of this volume, Table B-4). Microbial biomass C varied in the range of 306-914 mg/kg, while microbial biomass N was in the range of 39.9-324 mg/kg. Microbial biomass C/N was in the range of 1.8-23.2.

COMPREHENSIVE DATA ANALYSIS AND SOIL DATA VALIDATION

In 2008, the STA Management Division initiated an effort to comprehensively look at all historical STA data, with the objective of relating different causal variables with TP uptake performance and vegetation establishment. To prepare for this data analysis, all available soil data were compiled and validated. Over the years, soil data have been collected for various purposes and using different methodologies. The purpose of validation was to determine the quality and usability of the different datasets. Key results from this validation process and comprehensive data analysis are planned for inclusion in the next SFER.

STATUS OF OTHER LONG-TERM PLAN PROJECTS

COMPARTMENT B AND COMPARTMENT C BUILD-OUT STATUS

The Compartment B Build-out Project is located in Palm Beach County, west and south of the existing STA-2 (**Figure 5-2**). It will expand the size and enhance the performance of existing STAs created as part of the ECP. Compartment B Build-out, which involves STA construction in the remaining Compartment B areas, was in the design phase in Fiscal Year 2008 (FY2008) October 1, 2007–September 30, 2008), and is scheduled to start construction in FY2009. The project is expected to be flow-capable by the end of 2010.

The Compartment C Build-out Project, located in Hendry County between existing STA-5 and STA-6, will expand the size and enhance the performance of existing STAs created as part of the ECP Compartment C Build-out, which involves STA construction in the remaining Compartment C areas, was in the design phase in FY2008 and is scheduled to start construction in FY2009 (**Figure 5-2**). The project is expected to be flow-capable by the end of 2010.

EVERGLADES CONSTRUCTION PROJECT OPERATIONS MONITORING PROJECT

The objective of the ECP Operations Monitoring Project is to collect water quality samples and monitor flow at inflow and outflow locations of all treatment cells within the STAs that are not specified as compliance sampling locations by the STA operating permits. Flow is monitored on a continuous basis. Water quality samples analyzed for flow-proportional TP concentrations are collected weekly; all other water quality parameters are monitored biweekly. The TP data are routinely used to assess the performance of each treatment cell and contribute to the development of strategies for improving the efficiency of the TP load retained in the STAs as a whole.

Changes to the STA interior water quality sampling program are as follows:

- STA-1W, Cells 1A and 1B. Water quality sampling initiated at G-248B
- STA-1W, Cell 1B. Flow monitoring discontinued along the G-253 levee
- STA-1W, Cell 4. Water quality sampling at G-307 replaced G-256, which was removed
- STA-2, Cell 4 expansion. Water quality sampling initiated at G-337A and G-368
- STA-6, Section 2 expansion. Water quality sampling initiated at G-396A, B, and C, and G-352B

HYDROLOGIC AND HYDRAULIC ASSESSMENT AND INTERNAL MEASUREMENTS

No activities were scheduled or completed for this project in FY2008.

ACQUISITION OF SURVEY DATA

The Acquisition of Survey Data Project, as described in the 2003 Long-Term Plan, was completed in FY2005. As new STA facilities and structures are completed, or as new survey information is needed in support of optimization or rehabilitation efforts, acquisition of the survey data will be collected at that time.

ADDITIONAL FLOW AND WATER QUALITY MONITORING STATIONS

The Long-Term Plan contains the state of Florida's strategy for achieving compliance with the phosphorus criterion in the EPA. The following section contains status updates on several Long-Term Plan projects that focus on STA construction, operations, and monitoring. Updates on other Long-Term Plan projects, as well as the overall status of implementation of the Long-Term Plan, are presented in the 2009 SFER – Volume I, Chapter 8. The Additional Flow and Water Quality Monitoring Project, as described in the 2003 Long-Term Plan is complete. As new flow and water quality monitoring stations are needed (e.g., for facilities associated with the Compartment B and C STA expansion projects), they will be included in the design and construction contracts for the overall STA facilities.

Review and Correction of Flow Measurement Anomalies

The goal of this project is to address flow estimate uncertainties and to provide good quality flow data at all major flow stations in the STAs. Stream-gauging data are collected in the field for use in calibrating flow equations, and flow rating analysis is conducted to improve computed flows, detect and correct anomalous data, and estimate missing data.

Improved flow equations have been completed and implemented at 100 percent in STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6. Theoretical flow equations for flow computation have been implemented at 100 percent for structures in the STAs expansion project. Water balance analysis was conducted for STA-1E, STA-1W, STA-2, and six storm event water budget analyses have been completed for STA-3/4. Improved flow rating equations have been developed for G255, G259, G-300, G-301, G-302, G-303, G304E, G304E, G304J, G-308, G-309, G-311, G-328, G330A–E, G-332, G-334, G-335, G-371, G-372, G375, G-388, G-349C, G-600, S-155A, S363A–C, S366A–E, S369A~D, S370A–C, S375, S372A–E, S373A–B.

A stream-gauging plan was completed for STA-1W, STA-2, STA-5, and STA-6. About 20 additional streamflow measurements in the same were completed by the end of FY2008.

Update and Maintenance of Hydraulic Models

Efforts underway in FY2008 in support of STA hydraulic modeling include a study to optimize the stage monitoring network in the STAs. The results of this study are intended to avoid duplicative costs and minimize resource demands associated with multiple stage recorders when fewer recorders will suffice. Another effort underway in FY2008 that will improve STA hydraulic modeling results involves the development of nearly 100 new preferred datasets for flow monitoring stations located at interior STA sites. A preferred dataset is defined as the best available data, and consists of data that has undergone post-processing quality assurance. The production of preferred data is accomplished through a series of data and statistical analyses to assure that the data are of the highest quality possible, and is composed of the most appropriate combination of data available from any known data source in South Florida.

Operational Strategy

This project is complete. No activities were scheduled or completed for this project in FY2008.

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