Chapter 3A: Water Quality in the Everglades Protection Area

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SUMMARY

This chapter is intended to (1) provide an assessment of water quality within the Everglades Protection Area (EPA) during Water Year 2011 (WY2011) (May 1, 2010–April 30, 2011), (2) fulfill numerous reporting requirements of the Everglades Forever Act (EFA), (3) provide a preliminary assessment of total phosphorus (TP) criterion achievement, and (4) provide an annual update of the comprehensive overview of nitrogen and phosphorus levels throughout the EPA. The information provided in this chapter is an update to Chapter 3A of the *2011 South Florida Environmental Report* (SFER) – *Volume I.*

WATER QUALITY CRITERIA EXCURSION ANALYSIS

The analyses and summaries presented provide a synoptic view of water quality conditions in the EPA on a regional scale, including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge, also known as WCA-1), Water Conservation Areas 2 and 3 (WCA-2 and WCA-3, respectively), and Everglades National Park (ENP or Park). For parameters with water quality criteria, regional analyses were conducted based on the frequency of exceedances of the applicable criteria, similar to the methods employed in the 1999 Everglades Interim Report, 2000–2004 Everglades Consolidated Reports, and 2005–2011 SFERs. For WY2011, water quality parameters that did not meet existing standards were classified based on excursion frequencies that were statistically tested using the binomial hypothesis test. These categories are (1) concern – any parameter with a criterion exceedance frequency statistically greater than 10 percent, (2) potential concern – any parameter with an exceedance frequency statistically greater than 5 percent but less than 10 percent, and (3) minimal concern – any parameter with an exceedance frequency less than 5 percent but greater than zero.

With a few exceptions, water quality was in compliance with existing state water quality criteria during WY2011. Comparisons of WY2011 water quality data with applicable Class III water quality criteria revealed excursions for four parameters: dissolved oxygen (DO), alkalinity, pH, and specific conductance. Similar to previous periods, these excursions were localized to specific areas of the EPA, and all of these parameters exhibited excursions in WY2010. In WY2010 two exceedances of the un-ionized ammonia criterion were reported; however, in WY2011 no exceedances were observed.

For WY2011, a summary of the DO, alkalinity, pH, and specific conductance excursions, as well as the status of phosphorus and nitrogen within the EPA, is presented below.

- Due to excursions of the site-specific alternative criterion, DO was classified as a concern for the Refuge and WCA-2 interiors and as a minimal concern for the WCA-3 inflows.

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- Alkalinity and the pH criteria exceedances were observed in the Refuge; however, the Florida Department of Environmental Protection considers the low values to be representative of the natural range of variability. Therefore, they should not be considered violations of state water quality standards. Additionally, WCA-3 inflow data indicated a single pH measurement above the state criterion so this area was categorized as minimal concern.
- Specific conductance was categorized as a minimal concern for the Refuge, WCA-2, and WCA-3 inflows, as well as WCA-2 interior sites. The most specific conductance exceedances occurred at Refuge inflow station S362.
- Median sulfate (SO_4^{2-}) concentrations were highest in Refuge [58.1 milligrams per liter (mg/L)] and WCA-2 (45.1 mg/L) inflows. However, SO_4^{2-} concentrations in the Refuge interior have remained relatively low. WCA-2 interior sites exhibited a median SO_4^{2-} concentration of 19 mg/L.
- Nine pesticides, or pesticide breakdown products, including alpha endosulphan, ametryn, atrazine, atrazine desethyl, malathion, metolachlor, metribuzin, norflurazon, and simazine, were detected at levels above the Method Detection Limit. Only atrazine exceeded the toxicity guideline concentrations and no parameters exceeded state water quality standards.
- Total phosphorus (TP) concentrations were highest in Refuge inflows and lowest within the Park. Annual geometric mean inflow TP concentrations ranged from 42.0 micrograms per liter (µg/L) for the Refuge to 9.8 µg/L for the Park. Annual geometric mean TP concentrations at interior sites ranged from 8.5 µg/L in the Refuge to 4.1 µg/L in the Park. Annual geometric mean TP concentrations for individual interior marsh monitoring stations ranged from less than 3.0 µg/L in some unimpacted portions of the marsh to 32.8 µg/L at a Refuge site that is highly influenced by canal inputs. Of the interior marsh sites, 78.2 percent exhibited annual geometric mean TP concentrations of 10.0 µg/L or less, with 87.2 percent of the marsh sites having annual geometric mean TP concentrations of 15.0 µg/L or less.
- Orthophosphate (OP) concentrations at interior marsh sites ranged from 5.7 µg/L in the Refuge to 1.2 µg/L in the Park. The annual geometric mean OP concentration levels at interior sites were less than 2.0 µg/L for all areas.
- TP loads from surface sources to the EPA totaled approximately 29.9 metric tons (mt), with a flow-weighted mean concentration of 19 µg/L. Another 193 mt of TP are estimated to have entered the EPA through atmospheric deposition. The 29.9 mt TP load in the surface inflows to the EPA represent a decrease of approximately 65 percent compared to the previous year (85.0 mt in WY2010).
- The five year (WY2007–WY2011) TP criterion assessment results indicate that unimpacted portions of each WCA passed all four parts of the compliance test. In contrast, impacted portions of each water body failed one or more parts of the test. The impacted portions of the WCAs routinely exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively. In all cases, the annual network geometric mean TP concentrations for WY2011 in both the impacted and unimpacted areas were the lowest of the five-year assessment period.
- The highest average inflow total nitrogen (TN) concentrations were observed in the Refuge (2.25 mg/L) and the lowest concentrations were Park inflows (1.00 mg/L). The geometric mean TN concentrations for the Refuge and WCA-2 interior sites were slightly lower than the levels for the preceding reporting periods and the mean TN inflow concentrations for WCA-2 were slightly below those for other reporting periods. TN concentrations at interior marsh sites ranged from 1.02 mg/L in the Refuge to 1.73 mg/L in WCA-2.

PURPOSE

The primary purpose of this chapter is to provide an assessment of water quality within the Everglades Protection Area (EPA) during Water Year 2011 (WY2011) (May 1, 2010–April 30, 2011) and an update to the information provided in Chapter 3A of the *2011 South Florida Environmental Report* (SFER) – *Volume I.*

The chapter is intended to fulfill the requirement of the Everglades Forever Act (EFA), which requires the annual report to "identify water quality parameters, in addition to phosphorus, which exceed state water quality standards or are causing or contributing to adverse impacts in the Everglades Protection Area." In addition, this chapter provides an annual update of the comprehensive overview of nitrogen and phosphorus levels throughout the EPA along with a preliminary assessment of total phosphorus (TP) criterion achievement utilizing the protocol provided in the *2007 SFER – Volume I, Chapter 3C*.

More specifically, this chapter and its associated appendices use water quality data collected during WY2011 to achieve the following objectives:

1. Summarize areas and times where water quality criteria are not being met, and indicate trends in excursions over space and time.
2. Discuss factors contributing to excursions from water quality criteria, and provide an evaluation of natural background conditions where existing standards may not be appropriate.
3. Summarize sulfate (SO_4^{2-}) concentrations in the EPA, and indicate spatial and temporal trends.
4. Present an updated review of pesticide and priority pollutant data made available during WY2011.
5. Present a preliminary TP criterion achievement assessment for different areas within the EPA for the most recent five-year period (i.e., WY2007–WY2011).
6. Summarize phosphorus and nitrogen concentrations measured in surface waters within different portions of the EPA.
7. Summarize the flow and phosphorus loads entering different portions of the EPA during WY2011, and describe spatial and temporal trends observed.
8. Describe and discuss factors contributing to any spatial and temporal trends observed.

METHODS

A regional synoptic approach similar to that used for water quality evaluations in previous SFERs was applied to phosphorus and nitrogen data for WY2011 to provide an overview of water quality status within the EPA. Consolidating regional water quality data provides for analysis over time but limits spatial analyses within each region. However, spatial analyses can be made between regions because the majority of inflow and pollutants enter the northern third of the EPA, and the net water flow is from north to south.

AREA OF INTEREST

The EPA is a complex system of marsh areas, canals, levees, and inflow and outflow water control structures that covers almost 2.5 million acres (1 acre = 0.405 hectare). In addition to rainfall inputs, surface water inflows regulated by water control structures from agricultural tributaries, such as the Everglades Agricultural Area (EAA) and the C-139 basin, feed the EPA from the northern and western boundaries. The EPA also receives surface water inflows originating from Lake Okeechobee to the north and from predominantly urbanized areas to the east. The timing and distribution of the surface inflows from the tributaries to the EPA are based on a complex set of operational decisions that account for natural and environmental system requirements, water supply for urbanized and natural areas, aquifer recharge, and flood control. The major features of the EPA and surrounding area are illustrated in **Figure 1-1** of this volume.

WATER QUALITY SAMPLING STATIONS

To efficiently assess the annual water quality standard violations and the long-term trends, a network of water quality sampling sites has been identified (**Figures 3A-1** through **3A-4**). These sites are part of the South Florida Water Management District's (SFWMD or District) existing long-term monitoring projects and are monitored for different purposes. These stations were carefully selected to be representative of either the EPA boundary conditions (i.e., inflow or outflow) or ambient marsh conditions (interior). Furthermore, an effort has been made to utilize a consistent group of stations among previous annual consolidated reports to ensure consistent and comparable results. Every attempt is made to maintain the same sampling frequency for the network of monitoring sites to ensure a consistent number of samples across years and the data available for each year undergo the same careful quality assurance/quality control (QA/QC) screening to assure accuracy.

Water quality sampling stations located throughout the Water Conservation Areas (WCAs) and Everglades National Park (ENP or Park) were categorized as inflow, interior, or outflow sites within each region based on their location and function (**Figures 3A-1** through **3A-4**). This organization of monitoring sites allows a more detailed analysis of the water quality status in each region of the EPA and assists in the evaluation of potential causes for observed excursions from Class III water quality criteria.

Several interior structures convey water between different regions in the EPA and therefore are designated as both inflow and outflow stations based on this categorization system. For example, the S-10 structures act as both outflow stations for the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge, also known as WCA-1) and inflow sites to Water Conservation Area 2 (WCA-2) (**Figures 3A-1** and **3A-2**). The interior sites of each region consist of marsh and canal stations as well as structures that convey water within the area.

In addition to inflow, outflow, and interior sites, the Refuge has an additional site category (Rim Canal sites) to account for the fact that much of the water entering the Refuge interior is conveyed in Rim canals that border the east and west levees of the Refuge (**Figure 3A-1**). Waters discharged to the L-7 Rim Canal will either overflow into the Refuge interior when canal stages exceed the levee height or will bypass the marsh and be discharged to Water Conservation Area 2A (WCA-2A) through the S-10 structures. The extent (distance) to which Rim Canal overflows penetrate the marsh depends on the relative stages of the L-7 Rim Canal and the Refuge interior.

The current District monitoring programs were described by Germain (1998). Sampling frequency varies by site depending on site classification, parameter group, and hydrologic conditions (e.g., water depth and flow). Water control structures (inflows and outflows) were typically sampled biweekly when flowing; otherwise, sampling was performed monthly. Generally, interior monitoring stations were sampled monthly for most parameters reported in this chapter. Pesticide monitoring is conducted across the entire District at 15 sites on a biannual basis. An overview of the water quality monitoring projects, including project descriptions and objectives with limited site-specific information, is available on the District's website at www.sfwmd.gov/environmentalmonitoring.

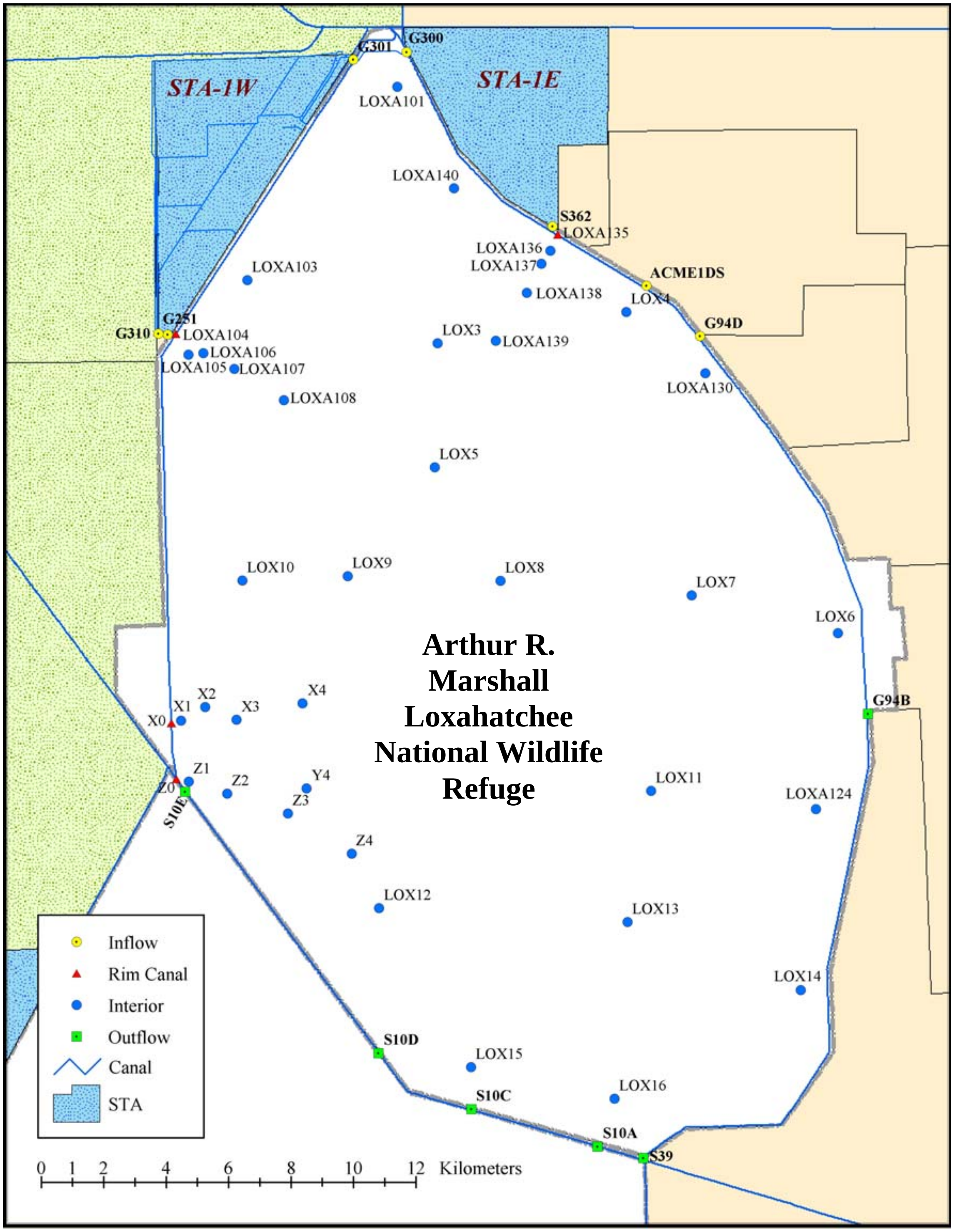

Figure 3A-1. Location and classification of water quality monitoring stations in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge).

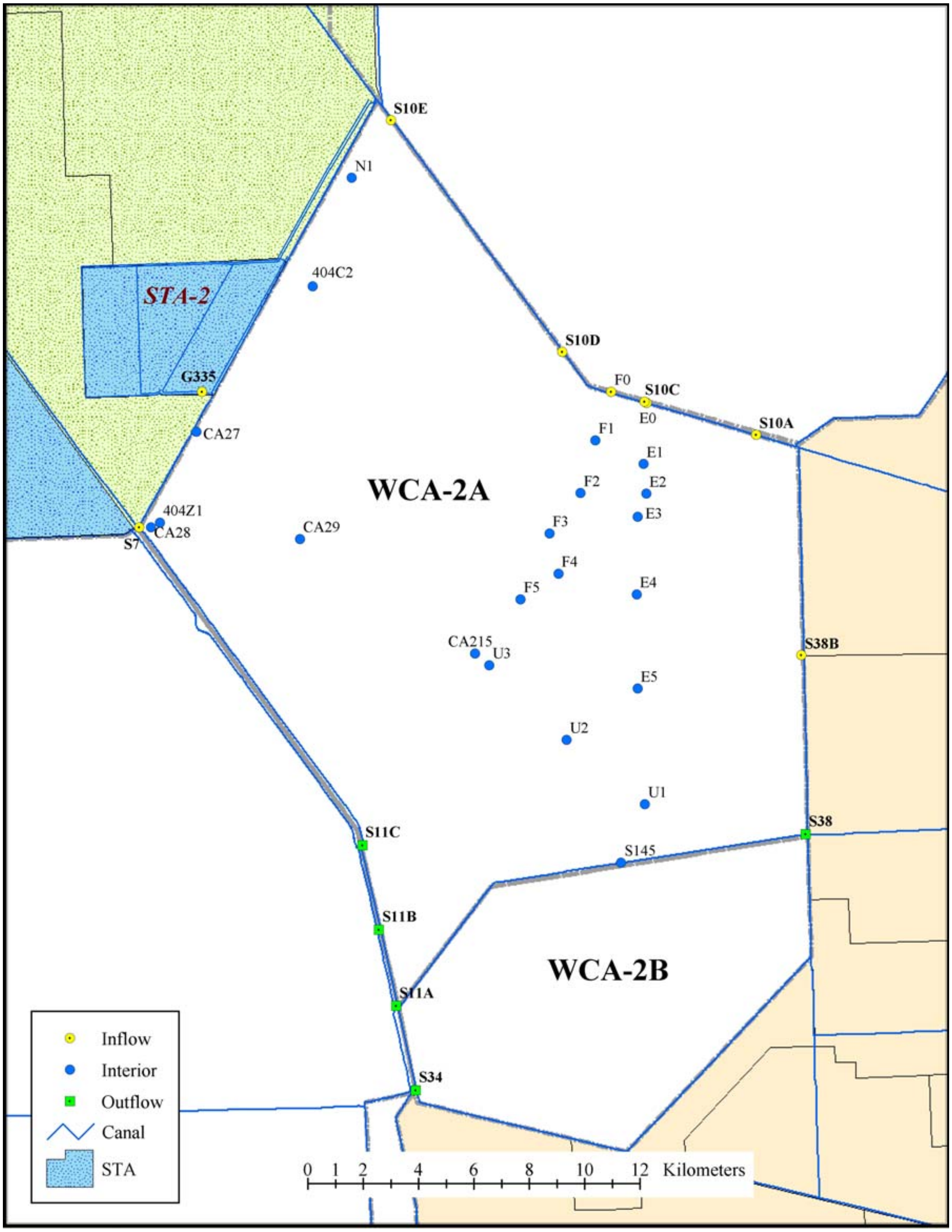

Figure 3A-2. Location and classification of water quality monitoring stations in Water Conservation Area 2 (WCA-2).

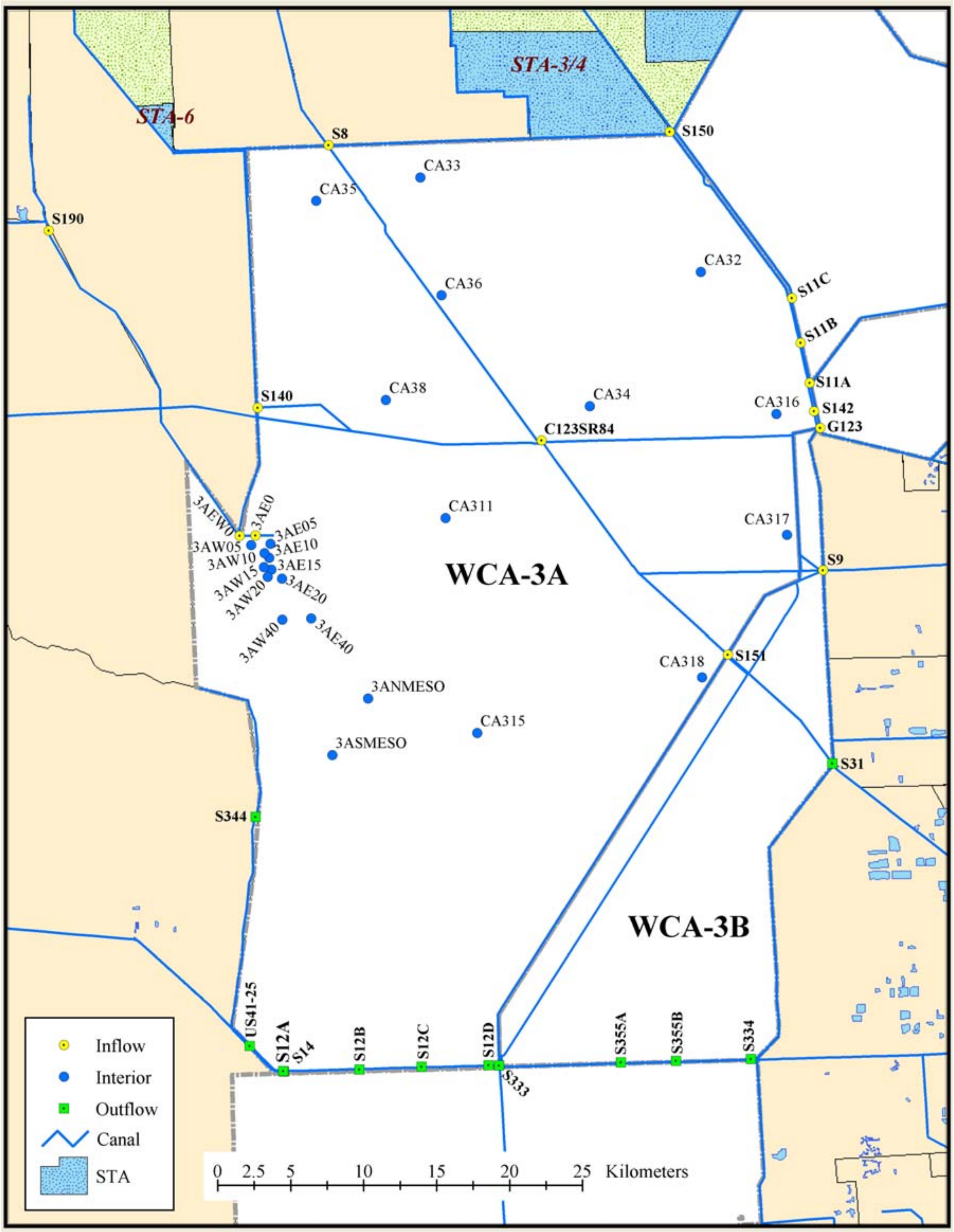

Figure 3A-3. Location and classification of water quality monitoring stations in Water Conservation Area 3 (WCA-3).

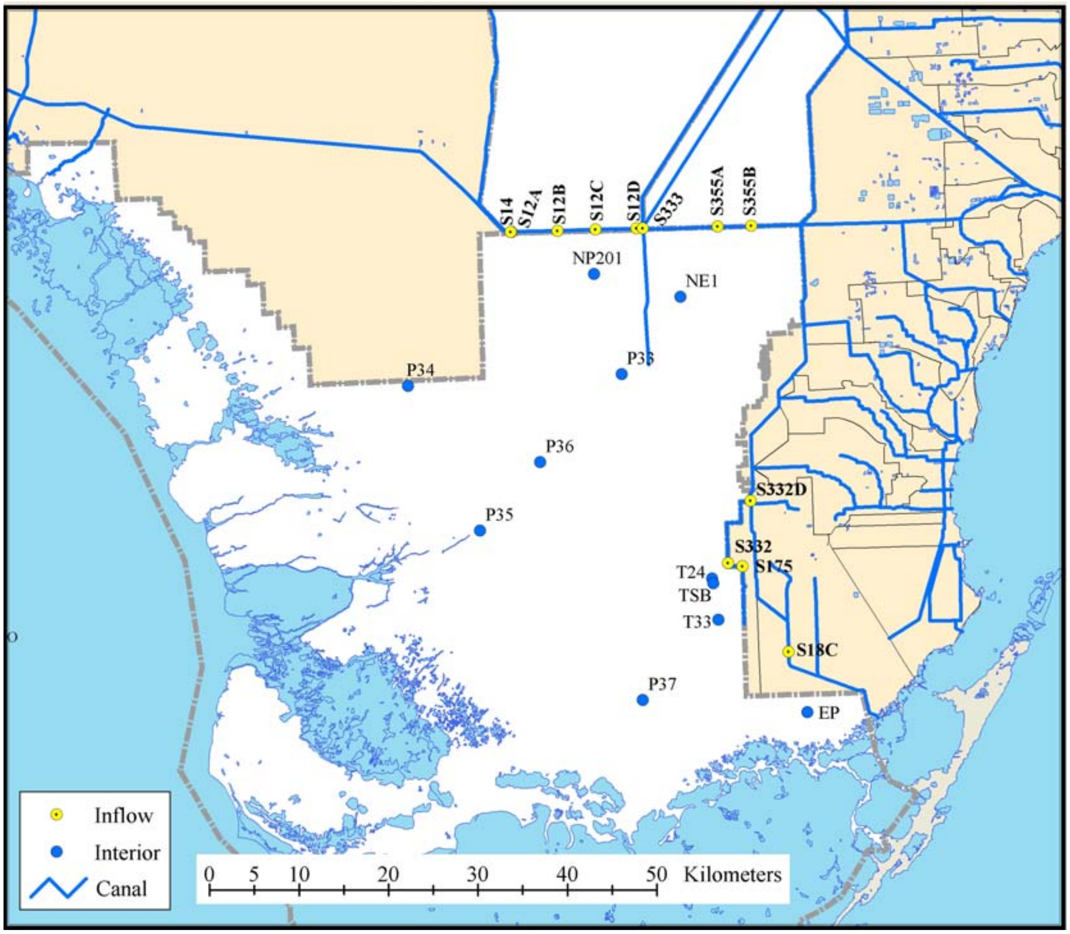

Figure 3A-4. Location and classification of water quality monitoring stations in Everglades National Park (ENP or Park).

ANALYSIS PERIODS

As previously noted, the primary focus of this chapter is to summarize the status of water quality within the EPA during WY2011 and to describe trends or changes in water quality conditions over time. To accomplish this objective, comparisons are made across discrete multiple periods that correspond to major restoration activities occurring within the EPA. The four periods are (1) the historical WY1979–WY1993 period (Baseline), which corresponds to the time frame prior to implementation of the EAA Best Management Practices (BMPs) Program and the Everglades Construction Project (ECP) [i.e., the Stormwater Treatment Areas (STAs)], (2) the intermediate WY1994–WY2004 period (Phase I), (3) the Phase II BMP/STA implementation period after WY2004 (i.e., WY2005–WY2010), and (4) WY2011.

Phase I represents the period in which implementation of the EAA BMP Program was increasing, and all the initial STAs were constructed and became operational. The Phase II BMP/STA implementation period corresponds to when the performance of the BMPs and STAs were being optimized and enhanced. Additionally, during this period various restoration projects were being implemented under the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) and Comprehensive Everglades Restoration Plan (CERP). Because optimization, enhancement, and other restoration activities are expected to continue for years, the Phase II period will continue to expand in future SFERs to incorporate additional years of sampling. In addition, data for the current water year (in this case, WY2011) will be used to make comparisons with the historic periods and will be analyzed independently as the fourth period. Individual station assessments and certain mandated reporting (e.g., TP criterion achievement) were based on the previous five water years (WY2007–WY2011) rather than on the single year used for regional analysis (e.g., WY2011). Reporting periods are specified in each section of this chapter.

WATER QUALITY DATA SOURCES

The majority of the water quality data evaluated in this chapter were retrieved from the District's DBHYDRO database. Additionally, water quality data from the nutrient gradient sampling stations monitored by the District were obtained from the District's Water Resources Division database.

DATA SCREENING AND HANDLING

Water quality data were screened based on laboratory qualifier codes, consistent with the Florida Department of Environmental Protection's (FDEP) Quality Assurance Rule [Chapter 62-160, Florida Administrative Code (F.A.C.)]. Any datum associated with a fatal qualifier (e.g., H, J, K, N, O, V, Q, Y, or ?) indicating a potential data quality problem was removed from the analysis (SFWMD, 2008). Values that exceeded possible physical or chemical measurement constraints (e.g., if resulting pH is greater than 14), had temperatures well outside seasonal norms (e.g., 6° Celsius in July), or represented data transcription errors were excluded. Multiple samples collected at the same location on the same day were considered as one sample, with the arithmetic mean used to represent the sampling period.

Additional considerations in the handling of water quality data are the accuracy and sensitivity of the laboratory method used. For purposes of summary statistics presented in this chapter, data reported as less than the Method Detection Limit (MDL) were assigned a value of one-half the MDL unless otherwise noted. All data presented in this chapter, including historical results, were handled consistently with regard to screening and MDL replacement.

WATER QUALITY DATA PARAMETERS

The District monitors approximately 109 water quality parameters within the EPA (Bechtel et al., 1999, 2000). Given this chapter's focus on water quality criteria, the evaluation was primarily limited to parameters with Class III criteria pursuant to the FDEP's Surface Water Quality Standards Rule (Chapter 62-302, F.A.C.). The parameters evaluated in this chapter include 62 pesticides and the following water quality constituents:

- Alkalinity
- Dissolved oxygen (in situ)
- Specific conductance (in situ)
- pH (in situ)
- Total selenium*
- Total thallium*
- Total zinc*
- Turbidity
- Un-ionized ammonia
- Sulfate
- Total nitrogen (total Kjeldahl nitrogen + nitrate/nitrite)
- Total cadmium*
- Total iron
- Total lead*
- Total nickel*
- Total silver*
- Total antimony*
- Total arsenic*
- Total beryllium*
- Total copper*
- Total phosphorus
- Orthophosphate

Parameters marked with an astericks were not measured in WY2011. However, these have been analyzed and reported in previous SFERs and, if measured in the future, will be analyzed and reported in future SFERs.

WATER QUALITY CRITERIA EXCURSION ANALYSIS

The FDEP and the District have developed and documented an excursion analysis protocol for use in the annual SFER (Weaver and Payne, 2005). The primary objective of the protocol is to provide a synoptic view of water quality criteria compliance on a regional scale [i.e., the Refuge, WCA-2, Water Conservation Area 3 (WCA-3), and the Park]. This protocol was developed to balance consistency with previous versions of the report, other State of Florida ambient water quality evaluation methodologies [e.g., Impaired Waters 303(d) designations], and the United States Environmental Protection Agency (USEPA) exceedance frequency recommendations, as well as provide a concise summary for decision makers and the public. This methodology ensures results will be compatible with information from other sources provided to water managers.

A multi-tiered categorical system was used in this chapter to rank the severity of excursions from state water quality criteria (see **Table 3A-1** in the *Water Quality Criteria Excursion Analysis* section). Categories were assigned based on sample excursion frequencies evaluated using a statistically valid assessment methodology (i.e., binomial hypothesis test) that accounted for uncertainty in monitoring data. The basis for selecting the binomial approach is presented in Weaver and Payne (2004, 2005). Parameters without excursions were categorized as "no concern" and are not discussed further in this chapter. Based on the results of the binomial test using a 90 percent confidence level, parameters with an exceedance rate between 0 and 5 percent are classified as minimal concerns, those with exceedance rates between 5 and 10 percent are classified as potential concerns, and parameters with exceedance rates of more than 10 percent are classified as concerns.

Because exceedances of the pesticide criteria can result in more immediate and severe effects to aquatic organisms and human health, a 10 percent excursion frequency was not used in the assessment of pesticides as recommended by the USEPA (USEPA, 1997, 2002). Pesticides were evaluated under the assumption that the Class III criteria values represent instantaneous maximum concentrations for which any exceedance constitutes a non-attainment of designated use. Pesticides were categorized based on whether the parameter was detected at concentrations above the MDL (potential concern) or at concentrations exceeding Class III criteria or chronic toxicity values (concerns). Pesticides classified as concerns have a high likelihood of resulting in an impairment of the designated use of the water body. Classification of a pesticide as a potential concern signifies that the constituent is known to be present within the basin at concentrations reasonably known to be below levels that can result in adverse biologic effects but may result in a problem at some future date or in interaction with other compounds. The no concern category was used to designate pesticides that were not detected at sites within a given area.

The data sources as well as the data handling and evaluation methods employed in this chapter are identical to those used in previous SFERs. Greater detail concerning the methods used can be found in Weaver and Payne (2004, 2005) and Payne et al. (2011).

PHOSPHORUS CRITERION ACHIEVEMENT ASSESSMENT

A preliminary evaluation to determine achievement of the TP criterion was performed in accordance with the protocol provided in Chapter 3C of the 2007 SFER – Volume I, and the four-part test specified in the FDEP's Water Quality Standards for Phosphorus within the Everglades Protection Area (Chapter 62-302.540, F.A.C.). The available data from the 58 sites comprising the TP criterion monitoring network for the most recent five-year period (i.e., WY2007–WY2011) were utilized in the evaluation. The location of the TP criterion network monitoring sites established pursuant to the TP criterion rule used for the TP criterion assessment along with their classification as "impacted" or "unimpacted" are provided in **Figure 3A-5**. Details concerning the selection of sites in the TP criterion monitoring networks and their classification can be found in Payne et al. (2007).

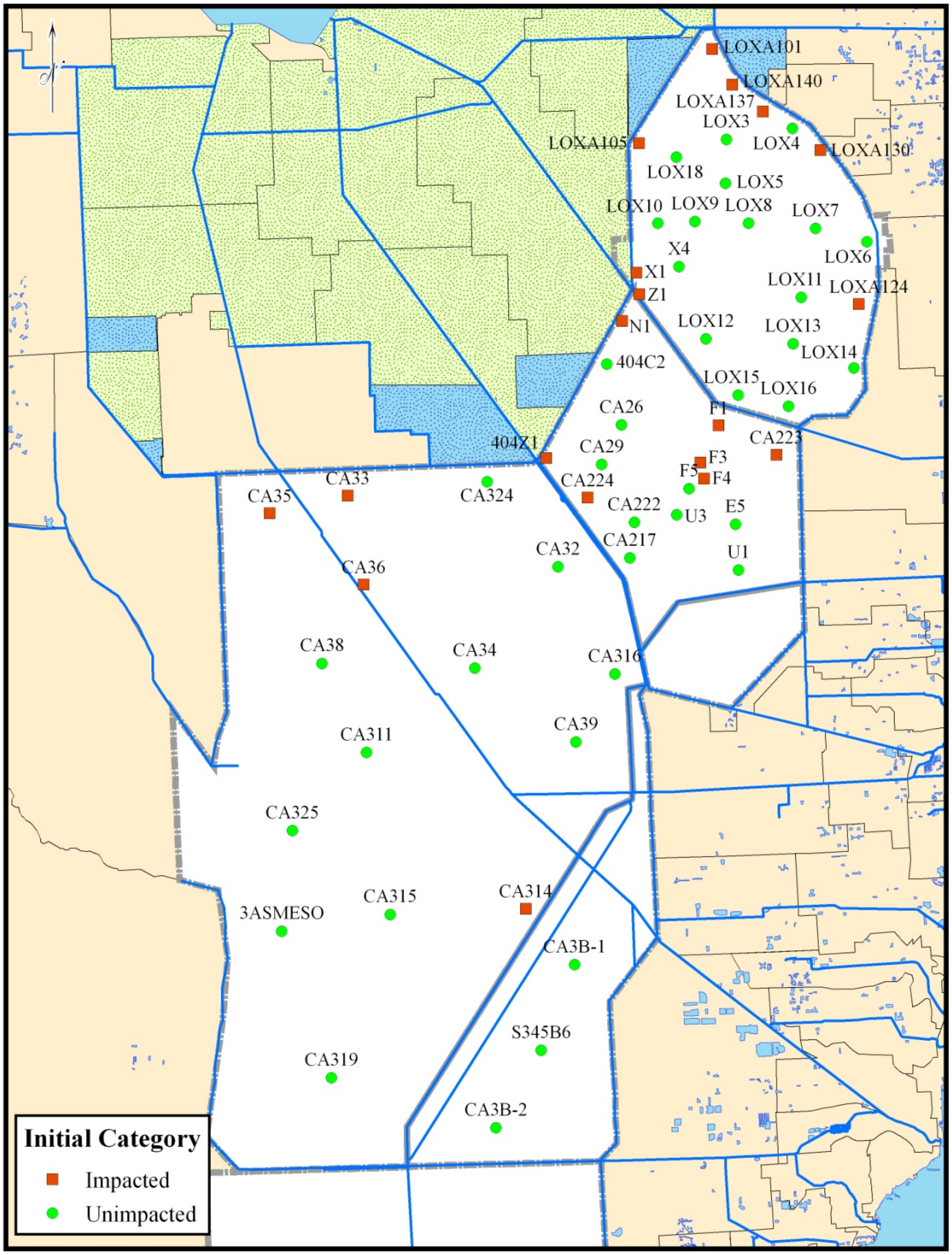

Figure 3A-5. Location of total phosphorus (TP) criterion assessment monitoring network sites used in the Water Year 2007–2011 (WY2007–WY2011) (May 1, 2006–April 30, 2011) evaluation.

Data collection from the complete TP criterion monitoring network was initiated in January 2007. Due to the relatively recent inception of network monitoring, not all sites have data available for the full five-year assessment period. In addition, data availability is further limited for certain portions of the EPA due to extremely dry conditions that have prevailed during a number of years since WY2007. Because the results of the TP criterion compliance assessment presented in this chapter could be affected by these data limitations, this evaluation should be considered preliminary and the results cautiously interpreted. It is expected that future assessments will improve as additional datasets are added. Data were screened according to the QA/QC procedures described in the protocol on the FDEP's website at www.dep.state.fl.us/water/wqssp/everglades/docs/DataQualityScreeningProtocol.pdf.

WATER YEAR 2011 WATER QUALITY RESULTS

WATER QUALITY CRITERIA EXCURSION ANALYSIS

WY2011 data for water quality parameters with Class III numeric criteria are summarized by region and monitoring station in Appendices 3A-1 and 3A-2 of this volume, respectively. Comparisons of WY2011 water quality data with applicable Class III water quality criteria resulted in excursions for four water quality parameters: dissolved oxygen (DO), alkalinity, pH, and specific conductance (**Table 3A-1**). Similar to previous periods, these excursions were generally localized to specific areas of the EPA. All of these parameters also exhibited excursions during WY2010. Additionally, two exceedances of the un-ionized ammonia criterion were reported for WY2010; however, no exceedances of this parameter were observed during WY2011.

Water quality parameters with exceedances of applicable criteria are discussed in greater detail below with the excursion frequencies summarized for the Baseline through current water year periods (WY1979–WY1993, WY1994–WY2004, WY2005–WY2010, and WY2011) to evaluate the presence of any temporal trends (**Table 3A-1**). Due to the link between SO_4^{2-} levels and mercury methylation, the temporal and spatial trends in SO_4^{2-} concentrations within the EPA are also summarized and discussed using a similar approach although no water quality criteria currently exist for SO_4^{2-} or methylmercury. During WY2011, the SO_4^{2-} concentrations for the interior stations of all areas were lower than the SO_4^{2-} levels reported for the previous monitoring periods.

Additionally, during WY2011, nine pesticides or pesticide breakdown products, including alpha endosulphan, ametryn, atrazine, atrazine desethyl, malathion, metolachlor, metribuzin, norflurazon, and simazine, were detected at levels above the MDL within the EPA. Similar to WY2010, only atrazine exceeded the toxicity guideline concentrations during WY2011 (see **Table 3A-3** in the *Pesticides* section). No other parameters exceeded state water quality criteria during WY2011.

Dissolved Oxygen

Dissolved oxygen conditions within the EPA were assessed against the Everglades DO site-specific alternative criterion (SSAC). Because a single-value criterion does not adequately account for the wide-ranging natural daily fluctuations observed in the Everglades marshes, the SSAC includes an algorithm that uses sample collection time and water temperature to model the observed natural sinusoidal diel cycle and seasonal variability. Greater detail concerning the Everglades DO can be found in Weaver (2004) and previous versions of this chapter (Payne et. al., 2011). The SSAC is assessed based on a comparison between the annual average measured DO concentration and the average of the corresponding DO limits. DO excursion results for WY2011 for individual stations are provided in Appendix 3A-3.

Table 3A-1. Excursions from Class III criteria in the Everglades Protection Area (EPA) for the Baseline period (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011.

Area	Class	Parameter	WY1979–WY1993		WY1994–WY2004		WY2005–WY2010		WY2011	
			Number of Excursions[1]	Percent Excursions[2]	Number of Excursions[1]	Percent Excursions[2]	Number of Excursions[1]	Percent Excursions[2]	Number of Excursions[1]	Percent Excursions[2]
Refuge	Inflow	Dissolved Oxygen	13 (61)	21.3 (C)	8 (68)	11.8 (PC)	5 (28)	17.9 (PC)	0 (3)	0.0 (MC[3])
		pH	9 (890)	1.0 (MC)	4 (1,782)	0.2 (MC)	4 (1027)	0.4 (MC)	0 (156)	0.0 (NC)
		Specific Conductance	355 (896)	39.6 (C)	258 (1,786)	14.4 (C)	89 (1026)	8.7 (MC)	9 (156)	5.8 (MC)
		Turbidity	28 (1,109)	2.5 (MC)	34 (1,034)	3.3 (MC)	1 (296)	0.3 (MC)	0 (0)	0.0 (NA)
		Un-ionized Ammonia	36 (867)	4.2 (MC)	2 (1255)	0.2 (MC)	3 (498)	0.6 (MC)	0 (78)	0.0 (NC)
	Rim	Specific Conductance	36 (118)	30.5 (C)	71 (634)	11.2 (PC)	4 (219)	1.8 (MC)	0 (24)	0.0 (NC)
		pH	0 (118)	0.0 (NC)	3 (629)	0.5 (MC)	1 (220)	0.5 (MC)	0 (24)	0.0 (NC)
	Interior	Alkalinity	91 (367)	24.8 (C[4])	477 (1,971)	24.2 (C[4])	312 (1,332)	23.4 (MC)	40 (101)	39.6 (MC[4])
		Dissolved Oxygen	0 (12)	0.0 (NC[3])	66 (210)	31.4 (C)	51 (194)	26.3 (C)	2 (25)	8.0 (C[3])
		pH	59 (238)	24.8 (C[5])	164 (2,204)	7.4 (PC[5])	66 (1,734)	3.8 (MC[5])	10 (209)	4.8 (MC[5])
		Un-ionized Ammonia	0 (177)	0.0 (NC)	3 (1,698)	0.2 (MC)	2 (1211)	0.2 (MC)	0 (86)	0.0 (NC)
	Outflow	Turbidity	7 (572)	1.2 (MC)	4 (708)	0.6 (MC)	3 (312)	1 (MC)	0 (36)	0.0 (NC)
WCA-2	Inflow	Dissolved Oxygen	21 (51)	41.2 (C)	22 (84)	26.2 (C)	2(44)	4.5 (MC)	0 (5)	0.0 (MC[3])
		Specific Conductance	161 (640)	25.2 (C)	152 (1233)	12.3 (C)	93 (935)	9.9 (MC)	3 (139)	2.2 (MC)
		Turbidity	9 (732)	1.2 (MC)	6 (721)	0.8 (MC)	3 (376)	0.8 (MC)	0 (43)	0.0 (NC)
		Un-ionized Ammonia	6 (616)	1.0 (MC)	62 (1012)	6.1 (PC)	38 (577)	6.6 (PC)	0 (81)	0.0 (NC)
		pH	2 (621)	0.3 (MC)	6 (1230)	0.5 (MC)	6 (932)	0.6 (MC)	0 (138)	0.0 (NC)
	Interior	Dissolved Oxygen	16 (52)	30.87 (C)	97 (211)	46.0 (C)	51 (120)	42.5 (C)	1 (10)	10 (C[3])
		pH	17 (869)	2.0 (MC)	4 (3,294)	0.1 (MC)	3 (1,386)	0.2 (MC)	0 (90)	0.0 (NC)
		Specific Conductance	86 (762)	11.3 (PC)	335 (3,344)	10.0 (PC)	136 (1,400)	9.7 (MC)	4 (88)	4.5 (MC)
		Un-ionized Ammonia	6 (777)	0.8 (MC)	6 (2,691)	0.2 (MC)	3 (1,083)	0.3 (MC)	0 (64)	0.0 (NC)

Table 3A-1. Continued.

Area	Class	Parameter	WY1979–WY1993		WY1994–WY2004		WY2005–WY2010		WY2011	
			Number of Excursions[1]	Percent Excursions[2]	Number of Excursions[1]	Percent Excursions[2]	Number of Excursions[1]	Percent Excursions[2]	Number of Excursions[1]	Percent Excursions[2]
WCA-3	Inflow	Dissolved Oxygen	51 (160)	31.9 (C)	42 (163)	25.8 (C)	8 (105)	7.6 (MC)	1 (16)	6.3 (MC[3])
		pH	19 (2,300)	0.8 (MC)	16 (2,814)	0.6 (MC)	39 (2,506)	1.6 (MC)	1 (394)	0.3 (MC)
		Specific Conductance	59 (2,354)	2.5 (MC)	7 (2803)	0.2 (MC)	1 (2,507)	0 (MC)	2 (394)	0.5 (MC)
		Turbidity	48 (2284)	2.1 (MC)	8 (1963)	0.4 (MC)	1 (1,305)	0.1 (MC)	0 (218)	0.0 (NC)
		Un-ionized Ammonia	3 (2,141)	0.1 (MC)	8 (2,125)	0.4 (MC)	1 (1,078)	0.1 (MC)	0 (102)	0.0 (NC)
	Interior	Dissolved Oxygen	1 (14)	7.1 (PC[3])	50 (140)	35.7 (C)	26 (116)	22.4 (C)	2 (11)	18.2 (MC[3])
		pH	0 (427)	0.0 (NC)	0 (2,102)	0.0 (NC)	3 (1,278)	0.2 (MC)	0 (100)	0.0 (NC)
	Outflow	Dissolved Oxygen	21 (91)	23.1 (C)	14 (95)	14.7 (C)	2 (67)	3.0 (MC)	0 (11)	0.0 (NC[3])
		pH	24 (1871)	1.3 (MC)	20 (2323)	0.9 (MC)	0 (1055)	0 (NC)	0 (265)	0.0 (NC)
		Specific Conductance	0 (1932)	0.0 (NC)	0 (2337)	0.0 (NC)	1 (1,307)	0.1 (MC)	0 (239)	0.0 (NC)
Park	Inflow	Dissolved Oxygen	20 (104)	19.2 (C)	14 (116)	12.1 (PC)	3 (64)	4.7 (MC)	0 (9)	0.0 (MC[3])
	Interior	Dissolved Oxygen	1 (62)	1.6 (MC)	2 (115)	1.7 (MC)	4 (69)	5.8 (MC)	1 (9)	11.1 (PC[3])
		Un-ionized Ammonia	17 (455)	3.7 (MC)	4 (1,019)	0.4 (MC)	1 (391)	0.3 (MC)	0 (55)	0.0 (MC)

[1]For the “Number of Excursions” columns, the number in front of the parentheses specifies the number of excursions, while the number inside the parentheses specifies the number of samples collected.

[2]Excursion categories of concern, potential concern, minimal concern, and no concern are denoted by “C,” “PC,” “MC,” and “NC”, respectively, and are provided within parentheses in the “Percent Excursions” columns.

[3]Insufficient sample size (< 28) to confidently characterize the excursion frequency; categorization for WY2010 is based on a five-year period of record.

[4]The low alkalinity levels in the Refuge are natural and therefore not considered by the FDEP to be violations of state water quality standards.

[5]Because pH excursions within the marsh interior are linked to natural background alkalinity conditions, the FDEP does not consider pH levels within the Refuge interior to be in violation of state water quality standards.

During WY2011, only seven sites (LOX16, LOXA130, F1, CA316, CA38, NE1, and G206) exceeded the DO SSAC. Two of the interior marsh stations that failed to achieve the SSAC during WY2011 are within phosphorus-impacted areas (e.g., F1 and LOXA130); that is, areas with long-term surface water TP above 10 micrograms per liter (µg/L) and sediment TP concentrations in excess of 500 milligrams per kilogram (mg/kg). Unlike most other parameters, DO is not a direct pollutant. Instead, it is a secondary response parameter that reflects changes in other pollutants or physical or hydrologic changes in the system. The FDEP recognizes that DO impairments in phosphorus-impacted areas are related to biological changes caused by phosphorus enrichment (Weaver, 2004). Phosphorus levels in excess of the numeric criterion produce a variety of system changes in the Everglades that ultimately depress the DO regime in the water column (Payne et al., 2000, 2001; Weaver, 2004). The District is implementing a comprehensive restoration program to lower TP levels within the phosphorus-impacted portions of the EPA. DO levels at the nutrient impacted sites are expected to continue to improve as phosphorus concentrations in surface water and sediment are reduced and biological communities recover. Four unimpacted sites (i.e., LOX16, CA316, CA38, and NE1) in areas with long-term surface water TP below 10 µg/L and sediment TP concentrations less than 500 mg/kg failed the DO SSAC in WY2011.

Because compliance with the DO SSAC is based on the annual average of the instantaneous DO measurements for each site, sufficient annual average DO data is not available for a single year to confidently apply the binomial hypothesis test to the regional assessment units. Therefore, excursion categories for DO were assigned based on a five-year period of record (POR) (WY2007–WY2011). Similar to WY2010, DO for WY2011 was categorized as a concern for the Refuge and WCA-2 interior sites (**Table 3A-1**). An analysis of DO concentrations reported for the five-year POR period can be found in Appendix 3A-2, and the analysis of the WY2011 data is provided in Appendix 3A-3. Several areas categorized as levels of concern (e.g., potential concern, minimal concern, and concern) based on the five-year POR did not show any exceedances in WY2011, including inflows to the Refuge, WCA-2, and the Park, as well as the outflows from WCA-3.

No conclusions regarding differences (trends) in DO excursion rates between individual water years and the previous periods can be made given the large disparity in sample sizes among time periods.

Alkalinity and pH

Alkalinity is the measure of water's acid neutralization capacity and provides a measure of the water's buffering capacity. In most surface water bodies, the buffering capacity is primarily the result of the equilibrium between carbon dioxide (CO_2) and bicarbonate (HCO_3^-) and carbonate ions (CO_3^{2-}). The dissociation of calcium carbonate, magnesium carbonate, or other carbonate-containing compounds entering the surface water through weathering of carbonate-containing rocks and minerals (e.g., limestone and calcite) contributes to the water's buffering capacity. Therefore, in certain areas that are influenced by canal inflows primarily composed of mineral-rich agricultural runoff and groundwater (such as the Park, WCA-2, and WCA-3), alkalinity levels are relatively high (Weaver et al., 2007). Conversely, areas such as the Refuge interior, which receive hydrologic load primarily through rainfall, have very low alkalinities. Alkalinity protects against dramatic pH changes, which can be lethal to sensitive organisms. The current Class III water quality criterion specifies that alkalinity shall not be lowered below 20 milligrams of calcium carbonate per liter (mg $CaCO_3$/L).

Excursions from this water quality criterion have historically occurred in the Refuge interior (Bechtel et al., 1999, 2000; Weaver et al., 2001, 2002, 2003; Weaver and Payne, 2004, 2005, 2006; Weaver et al., 2007; Payne et al., 2010 and 2011). Similar to previous years, alkalinity was designated as a minimal concern for the Refuge interior for WY2011 due to an excursion rate of 39.6 percent (**Table 3A-1**). However, as discussed in previous SFERs (e.g., Weaver and Payne, 2004; Weaver et al., 2007), the Refuge interior is hydrologically dominated by rainfall, which is naturally low in alkalinity. As such, the FDEP considers the low alkalinity values to be representative of the natural range of variability within the Refuge; therefore, these should not be considered violations of state water quality standards. The excursion rate for alkalinity in the Refuge interior during WY2011 were slightly higher than for previous periods in which excursion rates of 24.8, 24.2, and 23.4 percent were reported for the Baseline, Phase I (WY1994–WY2004), and Phase II (WY2005–WY2010) periods, respectively. In WY2011, excursions occurred at numerous stations including the following sites, with the number of exceedances for each site provided in parentheses: LOX3 (1), LOX5 (1), LOX7 (8), LOX8 (10), LOX9 (4), LOX11 (7), LOX12 (1), LOX13 (6), LOX14 (1), and LOX16 (1).

The pH value is defined as the negative $\log_{(base10)}$ of the hydrogen (H^+) ion activity. Most organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0, although individual species have specific ideal ranges. In WY2011, pH was considered a minimal concern for the Refuge interior and WCA-3 inflow. For Refuge interior sites, pH levels occasionally fell slightly below the 6.0 minimum criteria at 8 of the 25 monitoring sites. The excursions were recorded for the following sites, with the number of excursions for each site provided in parentheses: LOX5 (1), LOX7 (1), LOX8 (3), LOX9 (1), LOX11 (1), LOX13 (1), LOX15 (1), LOX16 (1). Since pH excursions within the Refuge interior generally occur at sites well away from the influence of inflows and have been linked to natural low background alkalinity conditions, the FDEP does not consider these pH excursions within the Refuge interior a violation of state water quality standards.

In addition, WCA-3 inflow station S8, exhibited a single excursion in WY2011 due to a pH value slightly above the 8.5 unit maximum limit that was likely associated with increased photosynthetic activity during low flow periods.

Specific Conductance

Specific conductance (conductivity) is a measure of water's ability to conduct an electrical current and is an indirect measure of the total concentration of ionized substances (e.g., Ca^{2+}, Mg^{2+}, Na^+, Cl^-, HCO_3^-, and SO_4^{2-}) in the water. Conductivity will vary with the number and type of these ions in solution. The current state water quality criteria for Class III fresh waters, which allows for a 50 percent increase in the specific conductance or 1,275 micromhos per centimeter (µmhos/cm), whichever is greater, is meant to preserve natural background conditions and to protect aquatic organisms from stressful ion concentrations. Given that background conductivities are low within the EPA, excursions were calculated using the 1,275 µmhos/cm criterion (Weaver et al., 2001, 2002).

For WY2011, specific conductance was categorized as a minimal concern for the inflows to the Refuge, WCA-2, and WCA-3 as well as the interior sites in WCA-2 (**Table 3A-1**). Exceedances in the Refuge occurred at the S-362 inflow structure, which had nine specific conductance measurements above 1,275 µmhos/cm. In WCA-2, the G-335 and S-7 inflow sites and F1 and N1 interior sites showed exceedances during WY2011. In addition, WCA-3 inflow site S-150 exhibited two exceedances. Previous Everglades Consolidated Reports and SFERs have explained that the elevated conductivity levels at water control structures (e.g., G-335) and stations near canal inflows were probably linked to groundwater intrusion into canal surface waters (Weaver et al., 2001, 2002; Krest and Harvey, 2003). This groundwater intrusion can occur due to seepage into canals via pumping station operation (which can pull additional groundwater into surface water) and as a result of agricultural dewatering practices.

Specific conductance excursion frequency in WCA-2 inflows declined significantly from 25.2 and 12.3 percent for the Baseline (WY1979–WY1993) and Phase I (WY1994–WY2004) periods, respectively, to 9.9 percent during Phase II (WY2005–WY2010) and 2.2 percent in WY2011. Likewise, excursion rates in the Refuge inflows declined from 39.6 and 14.4 percent during the Baseline and Phase I periods, respectively, to 8.7 percent in Phase II (WY2005–WY2010) and 5.8 percent in WY 2011.

Overall, a steady long-term decrease in specific conductance within the Refuge and WCA-2 inflows has occurred since WY1979 (**Figure 3A-6**). In fact, median annual specific conductance levels in the Refuge inflows have decreased by 200 to 300 µmhos/cm over the POR. Similarly, specific conductance has decreased by approximately 100 µmhos/cm in WCA-2 inflows over the same period.

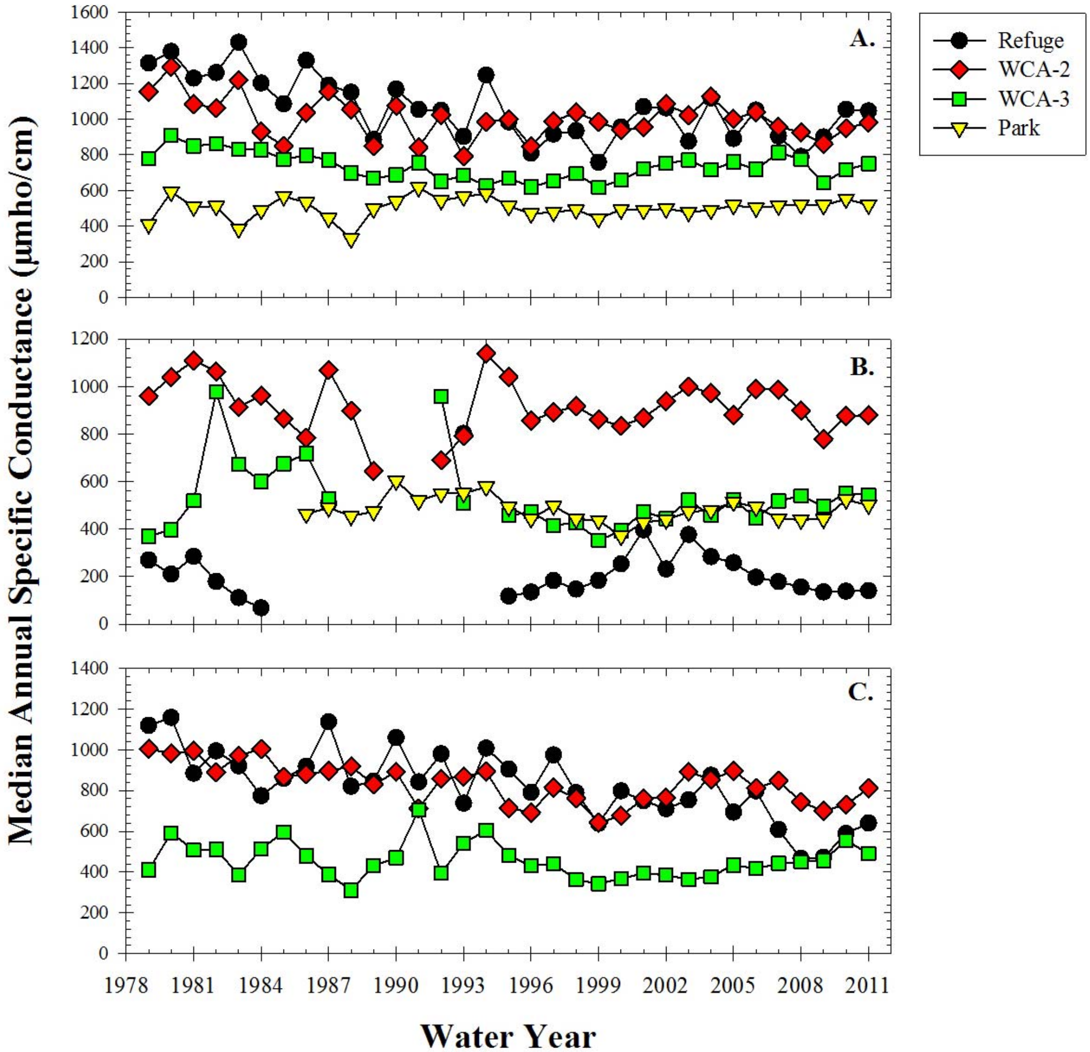

Figure 3A-6. Annual median specific conductance levels in the EPA (A) inflows, (B) interior, and (C) outflows for WY1978–WY2011.

Sulfate

The State of Florida has no surface water criterion for sulfate (SO_4^{2-}); however, research has provided evidence of a link between sulfur biogeochemistry in sediment and porewater and mercury methylation (Atkeson and Parks, 2002; Atkeson and Axelrad, 2003; Axelrad et al., 2005; Axelrad et al., 2006). SO_4^{2-} in the surface waters of the Everglades is derived from a variety of natural and human sources. The SO_4^{2-} monitoring results are presented in this chapter to provide an overview of current concentrations and to evaluate temporal and spatial patterns. **Table 3A-2** summarizes SO_4^{2-} concentrations for WY2011 and the Baseline, Phase I, and Phase II periods based on median, quartile, minimum, and maximum values. Individual station summaries are included in Appendix 3A-2 of this volume. Chapter 3B of this volume summarizes the current state of scientific understanding and uncertainties of the effects of SO_4^{2-} on the ecology and biogeochemical processes of the Everglades.

Table 3A-2. Sulfate (SO_4^{2-}) concentrations [milligrams per liter (mg/L)] for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

Region	Class	Period (Water Year)	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
Refuge	Inflow	1979-1993	307	8.3	39.0	61.0	90.0	436.0
		1994-2004	589	<0.10	33.0	48.0	66.0	461.0
		2005-2010	472	2.4	32.8	46.8	62.1	172.0
		2011	109	11.4	38.7	58.1	75.4	119.0
	Rim	1979-1993	84	2.5	12.0	36.0	72.0	140.0
		1994-2004	524	1.6	38.0	50.0	69.0	140.0
		2005-2010	170	3.2	28.8	44.5	65.1	110.0
		2011	0	NA	NA	NA	NA	NA
	Interior	1979-1993	325	2.5	5.5	9.8	16.0	663.0
		1994-2004	2,040	<0.10	0.6	2.4	19.0	2900.0
		2005-2010	1,559	<0.10	0.1	0.9	3.3	84.3
		2011	138	<0.10	<0.10	0.1	0.6	28.8
	Outflow	1979-1993	158	7.3	23.0	39.0	71.0	571.0
		1994-2004	232	1.4	28.0	41.0	58.0	419.0
		2005-2010	168	2.3	13.2	26.5	47.0	85.9
		2011	67	3.0	14.8	35.4	55.6	95.0
WCA-2	Inflow	1979-1993	194	7.3	35.0	51.0	72.0	644.0
		1994-2004	603	6.2	32.0	46.0	61.0	419.0
		2005-2010	434	2.5	28.0	40.7	55.2	106.0
		2011	108	<0.10	35.8	45.1	60.6	95.0
	Interior	1979-1993	742	2.5	23.0	37.0	51.0	344.0
		1994-2004	2,884	0.1	27.0	42.0	58.0	1400.0
		2005-2010	1,160	1.8	18.0	32.8	48.2	295.0
		2011	78	6.3	15.2	19.0	45.3	86.0
	Outflow	1979-1993	209	2.5	23.0	36.0	49.0	224.0
		1994-2004	190	2.3	19.0	28.0	37.0	73.0
		2005-2010	163	4.2	19.8	36.3	45.7	86.1
		2011	54	2.3	10.7	20.3	37.5	78.7

Table 3A-2. Continued.

Region	Class	Period (Water Year)	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
WCA-3	Inflow	1979-1993	580	1.0	11.0	22.0	45.0	286.0
		1994-2004	568	0.5	7.6	14.0	28.0	73.0
		2005-2010	458	<0.10	6.5	18.1	37.9	86.1
		2011	92	0.7	18.3	33.8	43.9	78.7
	Interior	1979-1993	459	2.0	6.3	11.0	17.0	262.0
		1994-2004	1,890	<0.10	1.3	3.4	10.0	120.0
		2005-2010	1089	<0.10	0.8	3.0	18.6	303.0
		2011	83	<0.10	0.3	2.3	13.4	59.9
	Outflow	1979-1993	278	1.0	6.7	13.0	21.0	113.0
		1994-2004	300	<0.10	0.3	1.7	8.5	36.0
		2005-2010	224	<0.10	0.1	1.3	10.1	69.3
		2011	32	<0.10	<0.10	0.5	6.4	23.7
Park	Inflow	1979-1993	265	1.0	6.6	12.0	21.0	113.0
		1994-2004	284	<0.10	0.5	2.2	8.1	36.0
		2005-2010	185	<0.10	0.1	1.4	8.4	35.8
		2011	24	<0.10	0.1	0.5	5.4	14.6
	Interior	1979-1993	568	0.8	2.5	4.3	7.3	206.0
		1994-2004	980	<0.10	1.0	2.2	4.9	403.0
		2005-2010	407	<0.10	0.5	1.7	4.8	242.0
		2011	60	<0.10	0.2	0.6	2.1	6.0

Given that one of the primary sources of SO_4^{2-} entering the EPA is runoff from the north, particularly the EAA, SO_4^{2-} concentrations in the inflow and interior marsh generally follow trends similar to those observed for TP and total nitrogen (TN); that is, SO_4^{2-} concentrations exhibit a general north-to-south gradient (**Figure 3A-7**). Stormwater runoff from the EAA contains high concentrations of SO_4^{2-} from both current and historical use of sulfur-containing fertilizers and soil amendments (Bates et al., 2002) and oxidation of the organic sediments.

During WY2011, the highest median SO_4^{2-} concentrations within the EPA were observed in the inflows to the Refuge (58.1 mg/L) and WCA-2 (45.1 mg/L). Despite elevated concentrations in inflows, the Refuge interior has remained relatively uninfluenced by the SO_4^{2-}-rich water because much of the surface water entering the area remains in the Rim Canal around the periphery and is discharged to WCA-2 through STA-2 and the S-10 structures

Among EPA marsh areas, the WCA-2 interior is most affected by EAA runoff and consequently exhibits the highest SO_4^{2-} concentrations. During WY2011, the WCA-2 interior sites exhibited a median SO_4^{2-} concentration of 19.0 mg/L compared to the lowest median concentrations of 0.1 mg/L and 0.6 mg/L observed at Refuge and Park interior sites, respectively. During WY2011, the SO_4^{2-} concentrations in the interior stations in all EPA areas were lower than the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2010) periods.

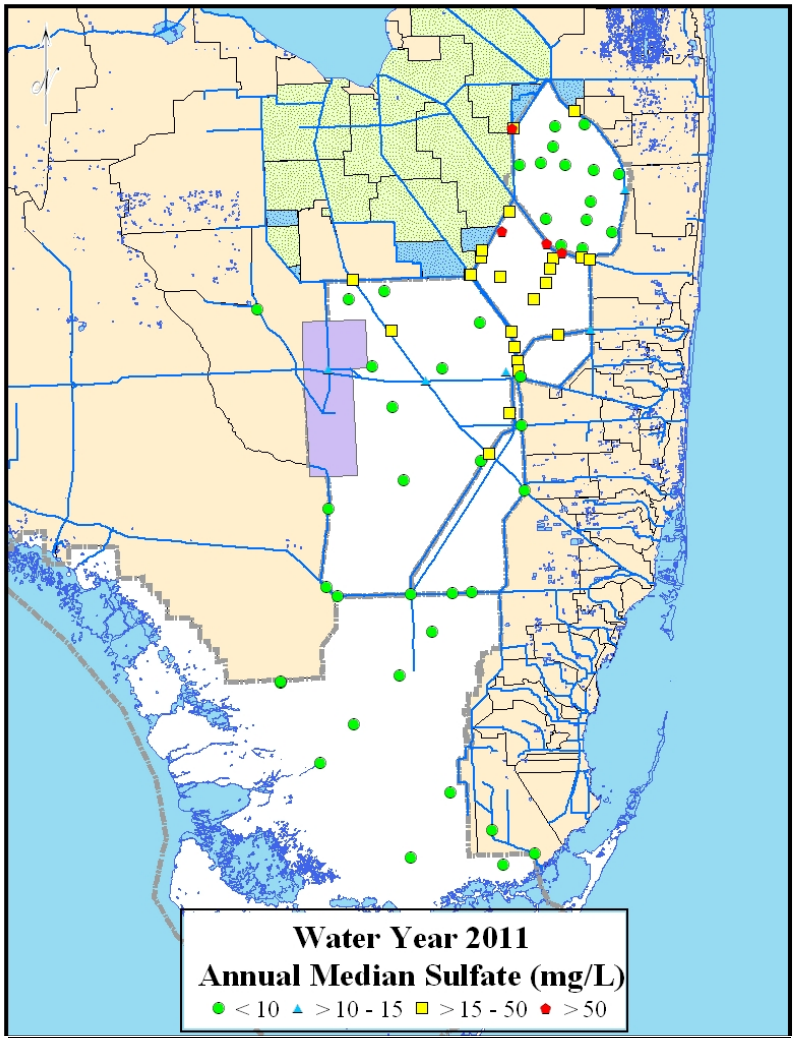

Figure 3A-7. Geometric mean sulfate (SO_4^{2-}) concentrations (mg/L) for WY2011 at stations across the EPA.

Pesticides

The District has maintained a pesticide monitoring program in South Florida since 1984. The pesticide monitoring network includes sites designated in Memorandum of Agreements with the Park and the Miccosukee Tribe and permits for Lake Okeechobee operations and non-Everglades Construction Projects (non-ECP). Results of monitoring conducted as part of these permits are provided in Volume III. The current EPA monitoring program, consisting of 29 sites, is conducted on a biannual basis (**Figure 3A-8**). These sites were grouped by basin for analysis.

Surface water concentrations of pesticides are regulated under criteria established in Chapter 62-302, F.A.C. Chemical-specific numeric criteria for a number of pesticides and herbicides (e.g., DDT, endosulphan, and malathion) are listed in Section 62-302.530, F.A.C. Compounds not specifically listed, including many contemporary pesticides (e.g., ametryn, atrazine, and diazinon), are evaluated based on acute and chronic toxicity. A set of toxicity-based guidelines for non-listed pesticides was presented by Weaver et al. (2001). These guidelines were developed based on the requirement in Subsection 62-302.530(62), F.A.C., which calls for Florida's surface waters to be free from "substances in concentrations, which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, plants, or animals."

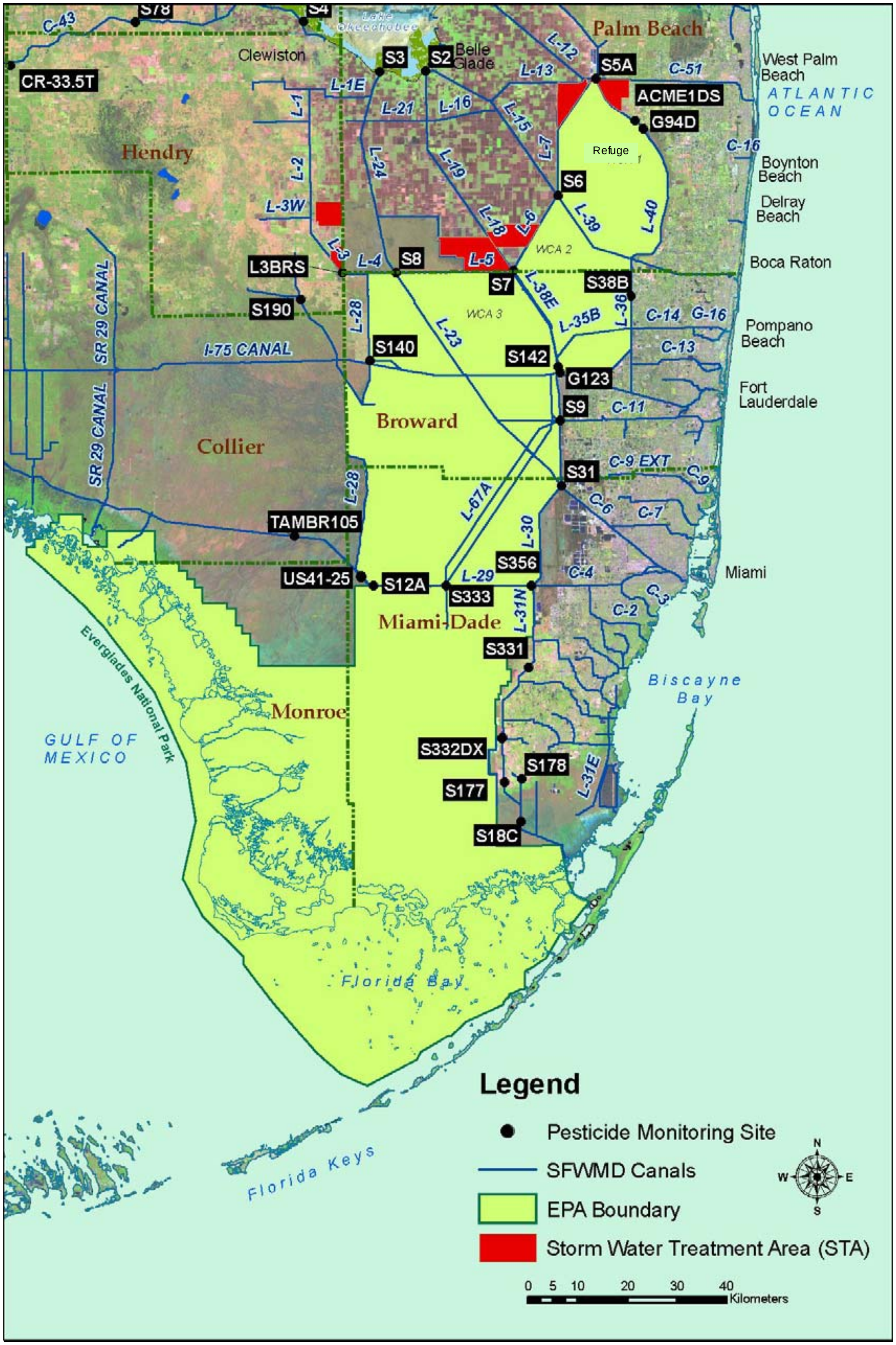

Figure 3A-8. South Florida Water Management District's pesticide monitoring sites in the EPA.

This chapter analyzes data collected during pesticide monitoring events conducted during WY2011 from September 2010 through March 2011. The POR was selected as an update to Chapter 3A of the 2011 SFER – Volume I. During WY2011, nine pesticides or pesticide breakdown products, including alpha endosulphan, ametryn, atrazine, atrazine desethyl, malathion, metolachlor, metribuzin, norflurazon, and simazine, were detected at levels above the MDL within the EPA (**Table 3A-3**). Of the nine pesticides detected, seven were also detected during WY2010. Only malathion and alpha endosulphan were not detected during the previous year. As in previous years, only atrazine exceeded the toxicity guideline concentrations, and no parameters exceeded state water quality criteria during WY2011. The atrazine concentration of 2 µg/L in a sample collected on April 27, 2011 at the S-8 inflow to WCA-3, exceeded the 1.8 µg/L guideline concentration and resulted in atrazine being classified as a concern for WCA-3 inflow (**Table 3A-3**). No other parameters exceeded state water quality criteria during WY2011.

Table 3A-3. Pesticide detection and exceedance categories in EPA inflows, canals, and structures for WY2011.[1]

Parameter	Refuge[2]	WCA-2[3]	WCA-3[4]	Park[5]	Typical MDL (µg/L)
Atrazine	PC (7:7)	PC (8:8)	C (12:27)	PC (3:16)	0.01
Ametryn	PC (6:7)	PC (3:4)	PC (5:25)	(0:16)	0.0095
Atrazine Desethyl	PC (5:7)	PC (3:8)	PC (4:25)	PC (1:13)	0.0095
Norflurazon	(0:7)	(0:4)	PC (4:22)	(0:15)	0.019
Metribuzin	PC (2:7)	(0:3)	PC (1:24)	(0:16)	0.019
Alpha Endosulphan	(0:7)	(0:4)	(0:28)	PC (1:16)	0.0038
Malathion	(0:7)	(0:4)	(0:21)	PC (1:12)	0.0029
Metolachlor	PC (1:7)	(0:4)	(0:14)	(0:8)	0.058
Simazine	PC (1:7)	(0:3)	(0:24)	(0:16)	0.0095

[1]The categories of "concern" and "potential concern" are denoted by "C" and "PC," respectively; all others are considered "no concern." Number of detections and total number of samples are in parentheses. Typical Method Detection Limit (MDL) values are the median MDLs for the given period of record.

[2]ACME1DS, G-94D, and S-5A (via STA-1W)

[3]S-38B, S-6 (via STA-2), and S-7

[4]G-123, L3BRS, S-140, S-190, S-8, S-9, S-142, and S-31

[5]S-12C, S-18C, and US41-25

PHOSPHORUS

As primary nutrients, phosphorus and nitrogen are essential to the existence and growth of aquatic organisms in surface waters. The native flora and fauna in the Everglades, though, are adapted to nutrient-poor conditions; hence, relatively small additions of nutrients, especially phosphorus, have dramatic effects on the ecosystem.

Until the recent adoption of the numeric phosphorus criteria, both phosphorus and nitrogen concentrations in EPA surface water were only regulated by Class III narrative criterion. The narrative criterion specifies that nutrient concentrations in a water body cannot be altered to cause an imbalance in the natural populations of aquatic flora or fauna. Because of the importance of phosphorus in controlling natural biological communities, the FDEP has numerically interpreted the narrative criterion, as directed by the EFA, to establish a 10.0 µg/L TP criterion for the EPA. Currently, nitrogen does not have a numeric criterion and is still regulated by only the narrative criteria.

In addition to presenting analyses of individual TP and TN levels, this chapter provides an evaluation of spatial and temporal trends in nutrient levels within the EPA as measured during WY2011 and compares the results with previous monitoring periods to provide an overview of the changes in nutrient levels within the EPA.

Total Phosphorus Concentrations

One of the primary objectives of this chapter is to document temporal changes in TP concentrations across the EPA using long-term geometric means to summarize and compare TP concentrations in accordance with the EFA and TP criterion rule requirements. The EFA and TP criterion were designed to provide long-term, ecologically protective conditions and require the use of geometric means due to the log-normal distribution of natural TP concentrations in the environment. The geometric mean employed by the criterion and the methodology used in this chapter to assess the nutrient levels account for short-term variability in water quality data, while providing more reliable, long-term values for evaluation and comparison of nutrient status.

Figures 3A-9 and **3A-10** illustrate the temporal changes in annual geometric mean TP concentrations during the POR from WY1978–WY2011 at both inflow and interior sites of the Refuge, WCA-2, WCA-3, and Park. The figures also provide the geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2010), and WY2011 periods for comparison. **Table 3A-4** provides a summary of the TP concentrations measured within different portions of the EPA during WY2011, and the Baseline, Phase I, and Phase II periods using both geometric mean and median values.

During the Baseline period, annual geometric mean TP concentrations at inflow and interior marsh sites across the EPA reached peak historic levels and were highly variable as shown in **Figures 3A-9** and **3A-10**. As the agricultural BMP and STA programs were initiated and became operational during the Phase I period, annual mean TP concentrations were reduced markedly and became less variable compared to levels observed during the Baseline period. Effectiveness of continued optimization and enhancement of BMPs and STAs on phosphorus levels during Phase II has been difficult to assess due to climatic extremes that have occurred during this period.

TP levels during the early and mid-portions of the Phase II period were dramatically influenced by climatic extremes, including active hurricane seasons with intense rainfall and periods of extended drought with little or no rainfall and subsequent marsh dryout. In general, the greatest effect from climatic extremes was experienced during WY2005 and WY2006 when tropical activity (e.g., Hurricane Wilma) resulted in elevated inflow concentrations, in concert with storm damage to STA vegetative communities, which resulted in decreased STA nutrient removal for many months. Decreased rainfall in WY2005 led to prolonged periods of marsh dryout, which resulted in increased oxidation of the organic sediment and the subsequent release of phosphorus into the water column. This release, in turn, resulted in elevated TP concentrations at marsh sites across the EPA.

During WY2006, much of the EPA experienced varying levels of recovery from the climatic events of WY2005. However, TP levels in portions of the EPA were again influenced by extended periods of limited rainfall and the subsequent marsh dryout experienced during WY2007, WY2008, and portions of WY2009 (**Figures 3A-9** and **3A-10**). As the Phase II BMP and STA implementation period is expanded, results will most likely be influenced less by single atypical years (e.g., WY2005), and the long-term effects of continuing restoration efforts will become more clear.

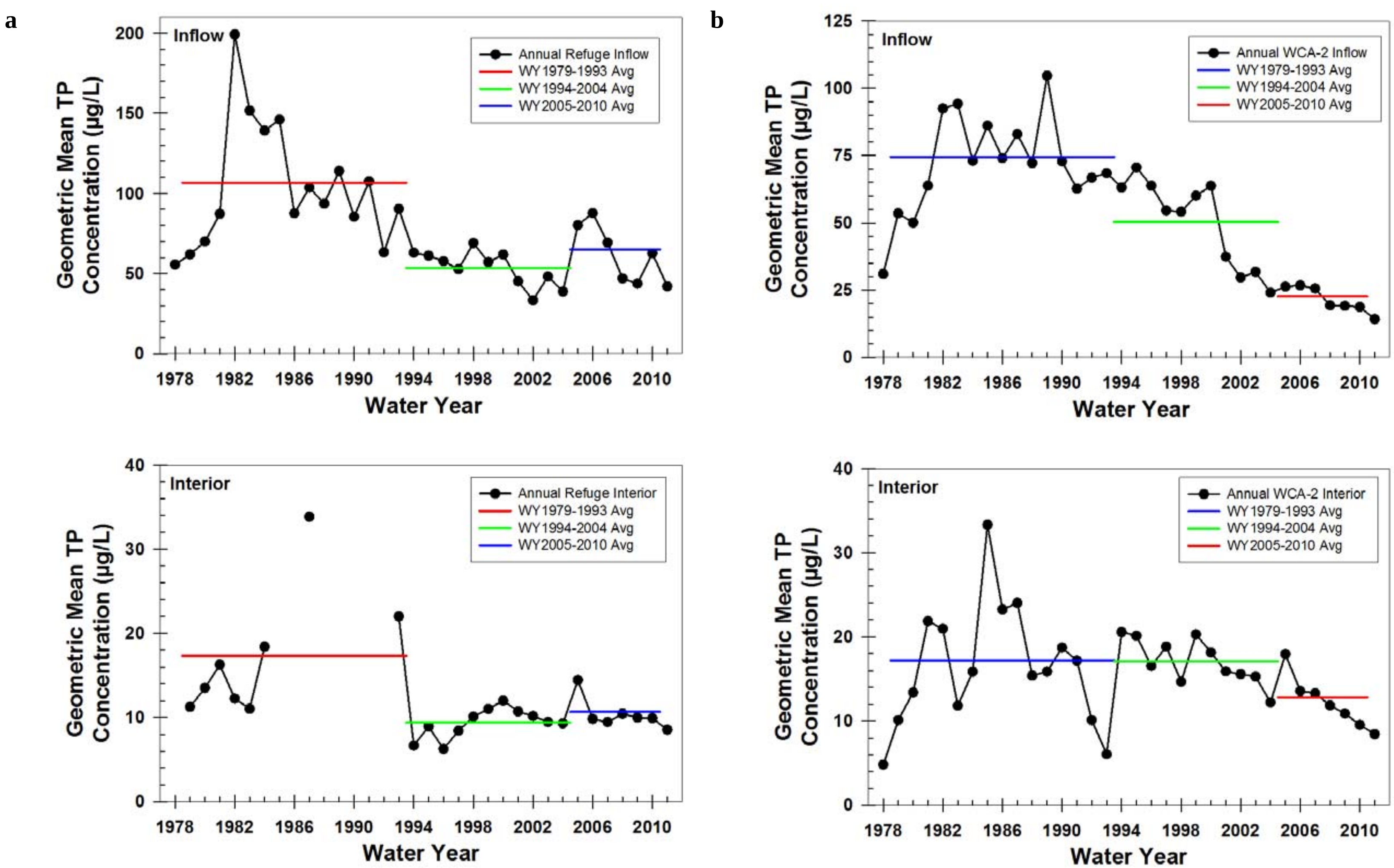

Figure 3A-9. Annual geometric mean TP concentrations [microgram per gram (µg/L)] for inflow (upper graph) and interior (lower graph) areas of (a) the Refuge and (b) WCA-2 from WY1978–WY2011. The horizontal lines indicate the average (Avg) annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

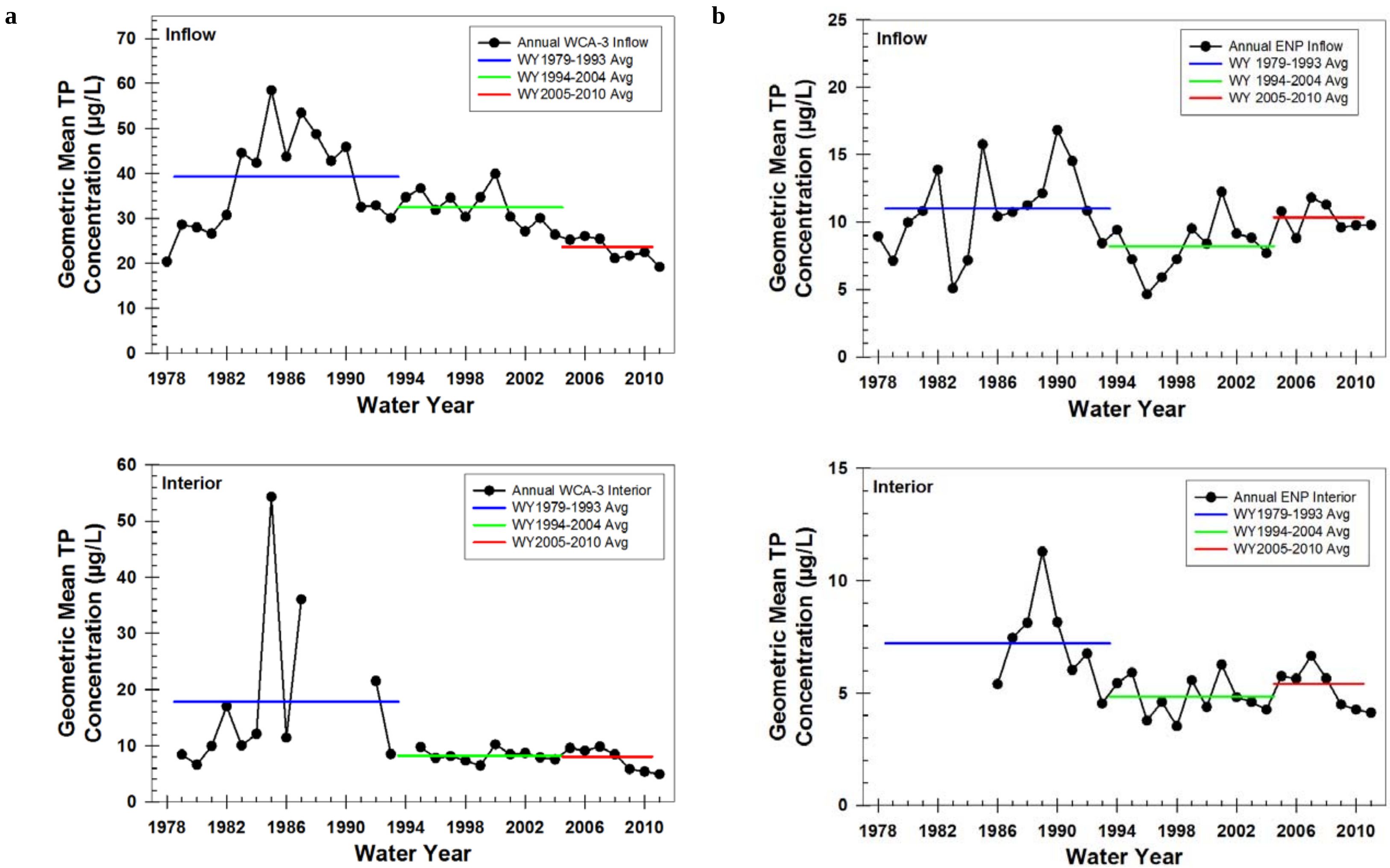

Figure 3A-10. Annual geometric mean TP concentrations (µg/L) for inflow (upper graph) and interior (lower graph) areas of (a) WCA-3 and (b) the Park from WY1978–WY2011. The horizontal lines indicate the average (Avg) annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

Table 3A-4. TP concentrations (µg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

Region	Class	Period	N	Geometric Mean	Standard Deviation of Geometric Mean	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	1213	90.7	2.3	97.5	6	1415
		1994-2004	1975	53.8	2.2	54	2	722
		2005-2010	1543	61.9	2.2	58	12	929
		2011	260	42.0	2.3	28.8	11.5	261
	Interior	1979-1993	364	13.3	2.6	12	<2	494
		1994-2004	2430	9.6	1.9	9	2	200
		2005-2010	1997	10.5	1.9	9	2	333
		2011	268	8.5	1.8	7	3	99
	Outflow	1979-1993	613	65.0	2.1	63	8	3435
		1994-2004	702	45.4	1.9	43	10	495
		2005-2010	349	29.5	2.1	26	8	515
		2011	75	17.4	1.5	16	9	56
	Rim	1979-1993	118	75.7	1.9	81	12	473
		1994-2004	632	60.7	1.7	57	17	290
		2005-2010	231	44.5	2.0	43	4	653
		2011	24	28.9	1.6	26.5	15	68
WCA-2	Inflow	1979-1993	789	69.8	2.0	68	10	3435
		1994-2004	1383	45.0	2.1	49	7	493
		2005-2010	935	22.3	1.9	19.5	4	245
		2011	138	14.2	1.4	14	8	33
	Interior	1979-1993	1698	16.2	3.4	13	<2	3189
		1994-2004	3599	16.9	2.8	14	<2	2400
		2005-2010	1714	12.3	2.4	11	<2	575
		2011	178	8.4	2.0	7	3	278
	Outflow	1979-1993	893	23.2	2.6	23	<2	556
		1994-2004	682	17.6	2.2	17	2	199
		2005-2010	490	14.3	1.8	13	3	179
		2011	68	11.7	1.5	12	4	34
WCA-3	Inflow	1979-1993	2537	37.4	2.6	37	<2	933
		1994-2004	3325	31.5	2.3	30	2	1286
		2005-2010	2556	23.7	2.0	22	3	949
		2011	386	19.2	1.7	18	7	161
	Interior	1979-1993	628	10.2	3.2	10	<2	438
		1994-2004	2097	8.1	2.2	7	<2	310
		2005-2010	1603	7.9	2.1	7	2	560
		2011	175	4.9	1.7	5	2	59
	Outflow	1979-1993	1971	12.1	2.3	11	<2	593
		1994-2004	2412	10.1	2.0	10	2	171
		2005-2010	1307	13.2	1.9	12	2	1083
		2011	238	10.9	1.8	9.25	3	72

Table 3A-4. Continued.

Region	Class	Period	N	Geometric Mean	Standard Deviation of Geometric Mean	Median	Minimum	Maximum
Park	Inflow	1979-1993	2172	10.6	2.3	10	<2	593
		1994-2004	3053	8.0	1.9	8	2	145
		2005-2010	1768	10.3	1.9	9	2	1083
		2011	263	9.8	1.8	9	4	64
	Interior	1979-1993	564	7.0	2.9	6	<2	1137
		1994-2004	1199	4.7	2.1	5	<2	117
		2005-2010	589	5.4	2.0	5	<2	291
		2011	77	4.1	1.9	4	<2	69

As documented in previous years, TP concentrations measured during WY2011 exhibited a general decreasing gradient from the highest levels present in Refuge inflows in the north and concentrations decreasing to a minimum within the Park to the south. This gradient results from the phosphorus-rich canal discharges, which are composed primarily of agricultural runoff originating in the EAA that enter the northern portions of the EPA. Settling, sorption (both adsorption and absorption), biological assimilation, and other biogeochemical processes result in decreasing concentrations as the water flows southward through the marsh (**Figure 3A-11**). A detailed, site-specific summary of the TP concentrations for WY2011 is provided in Appendix 3A-4 of this volume.

Annual geometric mean inflow TP concentrations during WY2011 ranged from 42.0 µg/L in the Refuge to 9.8 µg/L in the Park with WCA-2 and WCA-3 inflow levels being the lowest of the four monitoring periods (**Table 3A-4**, **Figures 3A-9** and **3A-10**). WY2011 inflow TP concentrations in the Refuge and WCA-2 generally continued to decrease following the elevated concentrations observed in WY2005 with the Refuge, WCA-2, and WCA-3 inflows having the lowest concentrations of the four monitoring periods.

During WY2011, Refuge inflows had a geometric mean TP concentration of 62.0 µg/L compared to levels of 90.7, 53.8, and 61.9 µg/L for the Baseline, Phase I, and Phase II periods, respectively (**Table 3A-4**). Likewise TP levels in WCA-2 inflows have progressively decreased from 69.8 µg/L in the Baseline period to 45.0 µg/L in the Phase I period, 22.3 µg/L in the Phase II period, and 14.2 µg/L in WY2011 (**Table 3A-4**). WCA-3 inflow TP concentrations have also exhibited a continual but less dramatic decrease, dropping from 37.4 µg/L in the Baseline period to 19.2 µg/L in WY2011. The lower TP concentrations in WCA-2 and WCA-3 inflows over the four monitoring periods are likely the result of multiple variables, including improved treatment by STAs, lower stormwater volumes resulting from periods of limited rainfall, and general recovery from the damage resulting from the WY2005 hurricanes. Meanwhile, TP levels in Park inflows have remained low with a geometric mean concentration of 9.8 µg/L being observed for WY2011, which is slightly lower than the 10.3 and 10.6 µg/L mean concentrations reported for the Phase II and Baseline periods, respectively, but is slightly higher than the 8.0 µg/L reported for the Phase I period (**Table 3A-4**).

Low annual geometric mean TP concentrations were also observed at interior sites across the EPA during WY2011 with mean TP levels for interior marsh sites in all areas being the lowest of the four reporting periods. During WY2011 interior mean TP concentrations ranged from 8.5 µg/L in the Refuge to 4.1 µg/L in the Park. For the second straight year, the WY2011 geometric mean TP concentrations for interior sites in all areas of the EPA were below the 10.0 µg/L five-year and 11.0 µg/L annual limits for assessing achievement of the TP criterion, with the mean concentrations in the Park and WCA-3 being well below these limits. As reported for previous years, the geometric mean TP concentrations for all individual Park interior sites were below 10 µg/L.

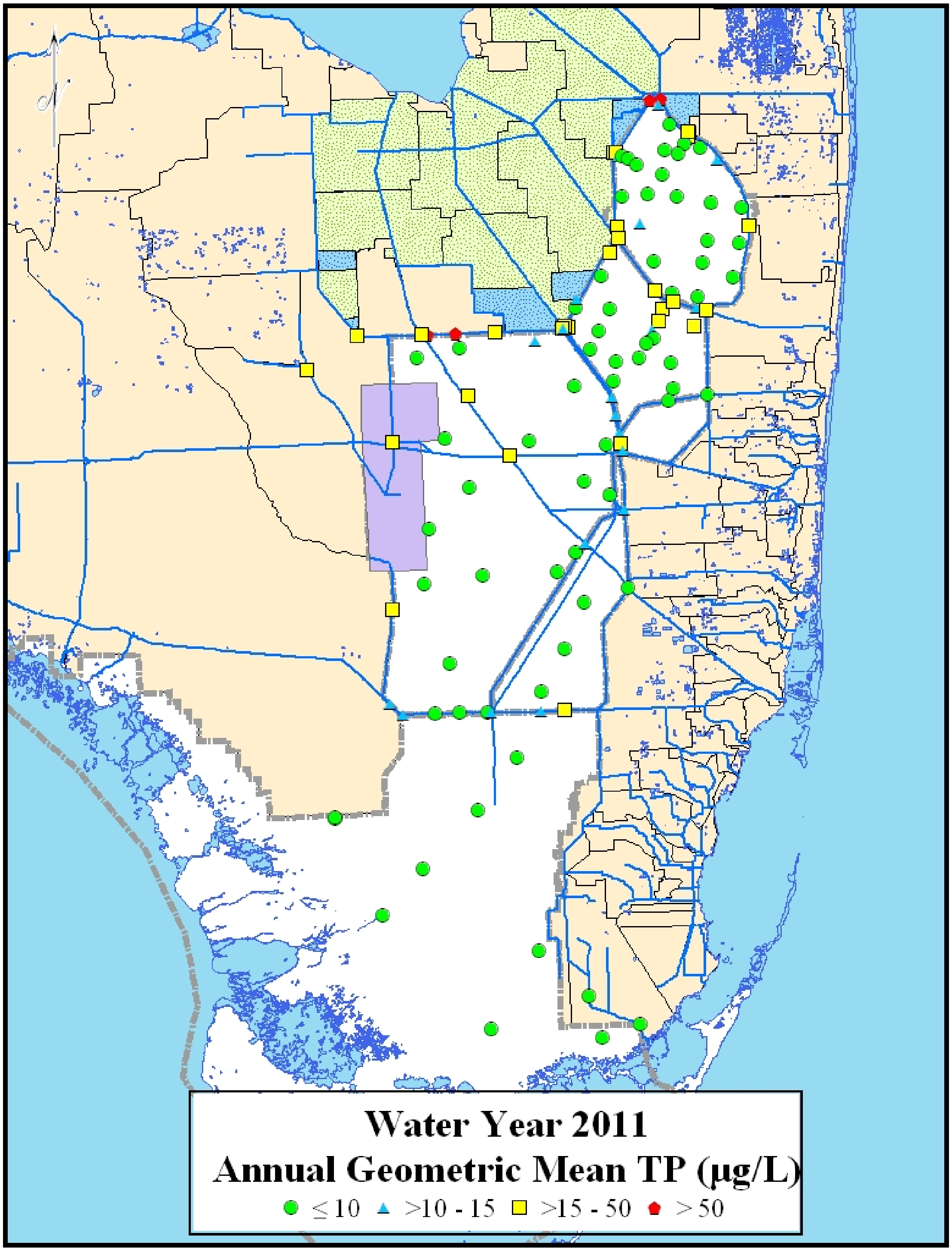

Figure 3A-11. Geometric mean TP concentrations (µg/L) for WY2011 at stations across the EPA.

The most dramatic decreases in interior marsh TP concentrations in recent years have been observed for WCA-2 and WCA-3. The geometric mean TP concentrations in WCA-2 have decreased from 16.2 µg/L and 16.9 µg/L during the Baseline and Phase I periods, respectively, to 12.3, and 8.4 µg/L for the Phase II and WY2011 periods, respectively. Likewise, mean TP levels at WCA-3 interior sites have fallen from 10.2 µg/L during the Baseline period to 8.1, 7.9, and 4.9 µg/L for the Phase I, Phase II, and WY2011 periods, respectively (**Table 3A-4** and **Figures 3A-9b** and **3A-10a**). For WCA-2, the geometric mean TP concentration of 8.4 µg/L observed for WY2011 represents the second straight year that the area mean TP concentration has been below 10 µg/L and is also the lowest level observed since WY1993 when only 15 samples were collected at three sites in the WCA-2 interior (**Table 3A-4** and **Figure 3A-9b**). The limited amount of data collected in WY1993 resulted in an annual mean concentration that was well below 10 µg/L; however, that concentration is probably not representative of overall conditions in WCA-2 during that year. The continued decreases in TP levels observed in WCA-2 and WCA-3 likely reflect recovery from the recent climatic extremes, improved treatment of the inflows to these areas (which is supported by similar decreases in inflow concentrations), and improved conditions in the impacted portions of the marsh. This includes the area downstream of the S-10 structures, which is one of the areas most highly impacted by historical phosphorus enrichment, where the quantity of discharge has been significantly reduced and the quality of the discharge has improved since STA-2 began operation.

Annual geometric mean TP concentrations for individual interior marsh monitoring stations sampled four or more times during WY2011 ranged from less than 3.0 µg/L in some unimpacted portions of the marsh to 32.8 µg/L at a Refuge site that is highly influenced by canal inputs. Across the entire EPA, 78.2 percent of the interior marsh sites exhibited annual geometric mean TP concentrations of 10.0 µg/L or less, which is comparable to the 69.8 and 69.7 percent observed in WY2009 and WY2010, respectively. In comparison, 50.0, 65.1, and 62.7 percent of the interior marsh sites each year exhibited geometric mean TP concentrations less than or equal to 10.0 µg/L during the Baseline, Phase I, and Phase II periods, respectively. Additionally, 87.2 percent of the interior sites had annual geometric mean TP concentrations of 15.0 µg/L or less during WY2011 compared to 85.4 percent reported in WY2010. During the three historical periods, 70.7, 79.8, and 80.3 percent of the interior sites, respectively, had annual geometric mean concentrations of 15.0 µg/L or less. The greater percent of sites meeting the 10 and 15 µg/L limits observed for WY2011 reflects the continued recovery from recent climatic extremes, improved treatment of the inflows, and overall improvement in phosphorus conditions within the interior marsh due to restoration activities. Given the relatively constant location of interior monitoring sites in recent years, temporal comparison of statistics from individual sites can be used to distinguish changes in measured concentrations. However, it should be noted that since the existing monitoring network was not designed to allow results to accurately estimate the percentage of the marsh exceeding a TP concentration of 10.0 µg/L (or other threshold), it is not appropriate to use the results for that purpose.

Orthophosphate Concentrations

Orthophosphate (OP) is an inorganic, soluble form of phosphorus readily utilized by biological organisms and, therefore, has the greatest and most rapid effect on the Everglades ecosystem. During WY2011, geometric mean OP concentrations at inflow, interior, and outflow stations in all areas within the EPA were lower than levels observed during the Baseline, Phase I, and Phase II periods (**Table 3A-5**).

Table 3A-5. Orthophosphate concentrations (μg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

Region	Class	Period	N	Geometric Mean	Standard Deviation of Geometric Mean	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	1175	32.1	4.4	44	<2	1106
		1994-2004	1231	15.8	3.0	14	<4	294
		2005-2010	1363	10.4	5.6	12	<2	854
		2011	259	5.3	5.7	2	<2	140
	Interior	1979-1993	370	1.5	2.1	<2	<2	72
		1994-2004	1610	1.8	2.3	2	<1	380
		2005-2010	1252	2.1	2.3	2	<2	193
		2011	101	1.0	1.2	<2	<2	2
	Outflow	1979-1993	605	20.0	4.3	25	<2	1290
		1994-2004	691	14.7	3.0	13	<4	383
		2005-2010	325	4.0	4.0	2	<2	461
		2011	62	1.4	1.8	<2	<2	12
	Rim	1979-1993	118	28.9	3.2	35	<2	408
		1994-2004	408	20.4	3.2	24	<1	190
		2005-2010	152	10.6	4.6	9.5	<2	544
		2011	0					
WCA-2	Inflow	1979-1993	759	25.2	3.8	31	<2	1290
		1994-2004	836	11.6	3.0	9	<4	352
		2005-2010	733	3.0	3.2	2	<2	190
		2011	134	1.4	1.8	<2	<2	17
	Interior	1979-1993	1689	3.3	4.2	2	<2	2398
		1994-2004	2079	4.4	3.8	4	<1	2790
		2005-2010	1184	2.3	2.6	2	<2	405
		2011	70	1.3	1.5	<2	<2	5
	Outflow	1979-1993	882	5.0	3.8	4	<2	396
		1994-2004	684	5.9	2.5	6	<4	156
		2005-2010	496	2.2	2.4	2	<2	153
		2011	68	1.2	1.6	<2	<2	8
WCA-3	Inflow	1979-1993	2349	9.1	4.4	9	<2	586
		1994-2004	2084	8.8	3.2	7	<4	297
		2005-2010	1324	3.5	3.2	2	<2	322
		2011	204	1.8	2.5	<2	<2	42
	Interior	1979-1993	617	1.9	2.8	<2	<2	152
		1994-2004	1878	1.8	2.5	2	<1	190
		2005-2010	1049	1.9	2.2	2	<2	180
		2011	82	1.1	1.5	<2	<2	6
	Outflow	1979-1993	1704	2.7	2.3	2	<2	149
		1994-2004	1603	2.9	1.7	2	<4	97
		2005-2010	866	1.6	1.7	2	<2	70
		2011	171	1.2	1.8	<2	<2	26
Park	Inflow	1979-1993	1902	2.6	2.2	2	<2	77
		1994-2004	1913	2.8	1.7	2	<4	97
		2005-2010	1056	1.6	1.6	2	<2	43
		2011	189	1.2	1.7	<2	<2	26
	Interior	1979-1993	546	2.9	1.9	2	<4	63
		1994-2004	1059	2.7	1.6	2	<4	45
		2005-2010	404	1.7	1.7	2	<2	19
		2011	52	1.1	1.4	<2	<2	4

Geometric mean OP concentration measured at inflow stations during WY2011 ranged from 5.3 µg/L in the Refuge to 1.2 µg/L in the Park. Likewise, the OP levels at interior sites during WY2011 were low, with the annual geometric mean concentrations being less than 2.0 µg/L for all areas. The lower OP levels determined for both inflows and interior sites during WY2010 further show the continued recovery from the recent extreme climatic events, the preferential removal of OP by the STAs, and the effects of restoration activities to improve the overall phosphorus conditions in the interior marsh areas.

Total Phosphorus Loads

Each year, the EPA receives variable amounts of surface water inflows based on the hydrologic variability within the upstream basins. These regulated inflows contribute to the TP loading to the EPA system. **Table 3A-6** provides estimates of the inflow and TP load to each portion of the EPA for WY2011. Flows and TP loads are also provided for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2010) periods for comparison.

Table 3A-6. Annual average flow, flow-weighted mean (FWM) TP concentrations, and TP loads in the EPA for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

Area	Period	Average Annual Flow (1,000 acre-feet*)	Average Annual FWM TP (µg/L)	Average Annual Load (kilograms)
Refuge	WY1979-1993	506	186	111,436
	WY1994-2004	647	100	83,977
	WY2005-2010	291	84	30,067
	WY2011	153	25	4,681
WCA-2	WY1979-1993	581	119	78,670
	WY1994-2004	704	65	57,391
	WY2005-2010	798	29	28,946
	WY2011	467	18	10,398
WCA-3	WY1979-1993	1,181	72	108,357
	WY1994-2004	1,396	49	84,335
	WY2005-2010	1,295	32	51,020
	WY2011	834	20	20,470
Park	WY1979-1993	815	12	11,450
	WY1994-2004	1,477	9	15,912
	WY2005-2010	906	9	10,533
	WY2011	710	10	8,456

*1 acre-feet = 0.1233 hectare-meter

In addition to inflow, atmospheric deposition contributes to the TP loading into the EPA. The long-term average range of TP atmospheric deposition to the WCAs is between 107 and 143 metric tons (mt) per year. Atmospheric TP deposition rates are highly variable and very expensive to monitor; therefore they are not routinely monitored. The range [expressed spatially as 20 to 35 milligrams per square meter per year ($mg/m^2/yr$)] is based on data obtained from long-term monitoring evaluated by the District (Redfield, 2002).

Detailed estimates of TP loads by structure for WY2011 are presented in Appendix 3A-5. This appendix summarizes contributions from all tributaries connecting to the EPA: Lake Okeechobee, EAA, C-139 basin, other agricultural and urbanized areas, and STAs. In some cases, surface water inflows represent a mixture of water from several sources as it passes from one area to another before finally arriving in the EPA. For example, water discharged from Lake Okeechobee can pass through the EAA and then through an STA before arriving in the EPA. Similarly, runoff from the C-139 basin can pass through STA-5 and then into the EAA before ultimately arriving in the EPA.

As detailed in Appendix 3A-5, TP loads from surface sources to the EPA totaled approximately 29.9 mt, with a flow-weighted mean (FWM) TP concentration of 19 µg/L. Another 193 mt of TP is estimated to have entered the EPA through atmospheric deposition. Surface discharges from the EPA account for approximately 8.6 mt of TP. The 29.9 mt TP load in EPA surface inflows represents a decrease of approximately 65 percent compared to WY2010 (85.2 mt). The lower TP loads to the EPA during WY2011 partially resulted from reduced flow volumes associated with drought conditions. The 1,300,584 acre-feet (ac-ft) of surface water flow to the EPA determined for WY2011 is approximately 46 percent lower than the 2,410,280 ac-ft reported for WY2010 (Payne et al., 2010).

Figures 3A-12 and **3A-13** provide a summary of the annual flows and TP loads to each portion of the EPA for WY1979–WY2011 along with the annual averages for the Baseline, Phase I, and Phase II periods. The effectiveness of the BMP and STA phosphorus removal efforts is demonstrated by decreased TP loading to WCA-2 and WCA-3 during the Phase I and Phase II periods compared to the Baseline period despite increased flows (**Figures 3A-12b** and **3A-13a**). The effects are less apparent in the Park, where inflow concentrations have remained near background levels and TP loading responds more directly to changes in flow and climatic conditions (**Figure 3A-13b**).

The average flow and TP loads to the EPA, especially the Refuge, during the Phase II and WY2011 periods have been highly influenced by climatic extremes as previously discussed. For example, the total TP load from all sources to the Refuge was approximately 4.7 mt during WY2011, which represents an approximate 78 percent decrease from WY2010 (21.3 mt). There was a significant decrease (51 percent) in the amount of water discharged to the Refuge from the structures in WY2011 (152,639 ac-ft) compared to WY2010 (310,179 ac-ft). The FWM concentration decreased from 56 µg/L in WY2010 to 25 µg/L in WY2011. Additional years of monitoring are needed before the effects of Phase II BMP and STA optimization projects can be observed.

Total Phosphorus Criterion Achievement Assessment

The TP criterion rule specifies that while the federal Settlement Agreement (Case No. 88-1886-CIV-MORENO) is in effect, compliance with the criterion in the Park will be assessed in accordance with the methodology specified in Appendix A of the Settlement Agreement using FWM TP concentrations at inflow sites instead of ambient marsh TP concentrations, as done in the other portions of the EPA. The Settlement Agreement assessments for the Park are conducted by the District and reported on a quarterly basis to satisfy other mandates and are not replicated here. The quarterly Settlement Agreement reports prepared by the District are available online at www.sfwmd.gov/toc.

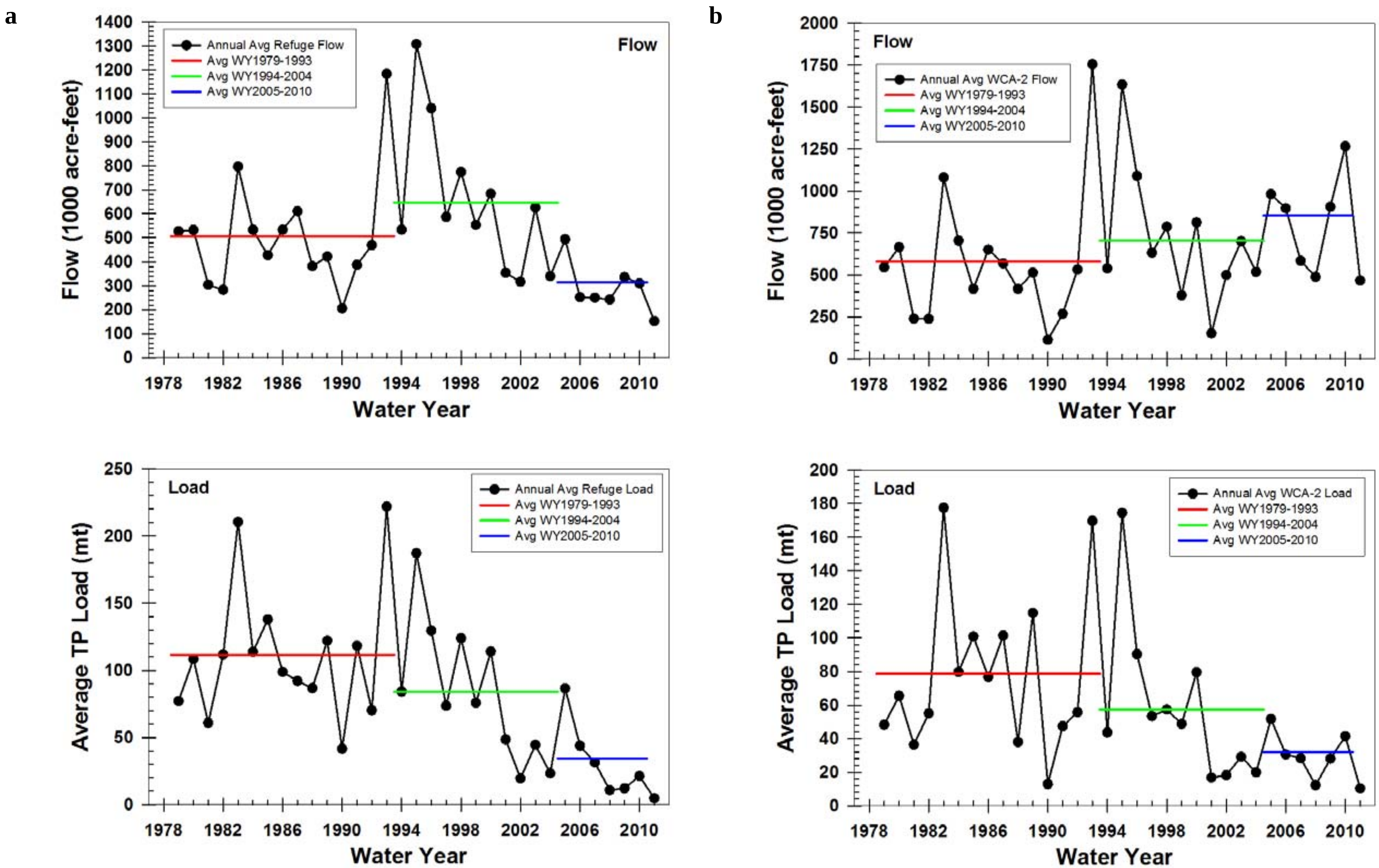

Figure 3A-12. Annual flow (upper graph) and average TP load (lower graph) to (a) the Refuge and (b) WCA-2 from WY1979–WY2011. The horizontal lines indicate the average (Avg) annual flows and loads for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

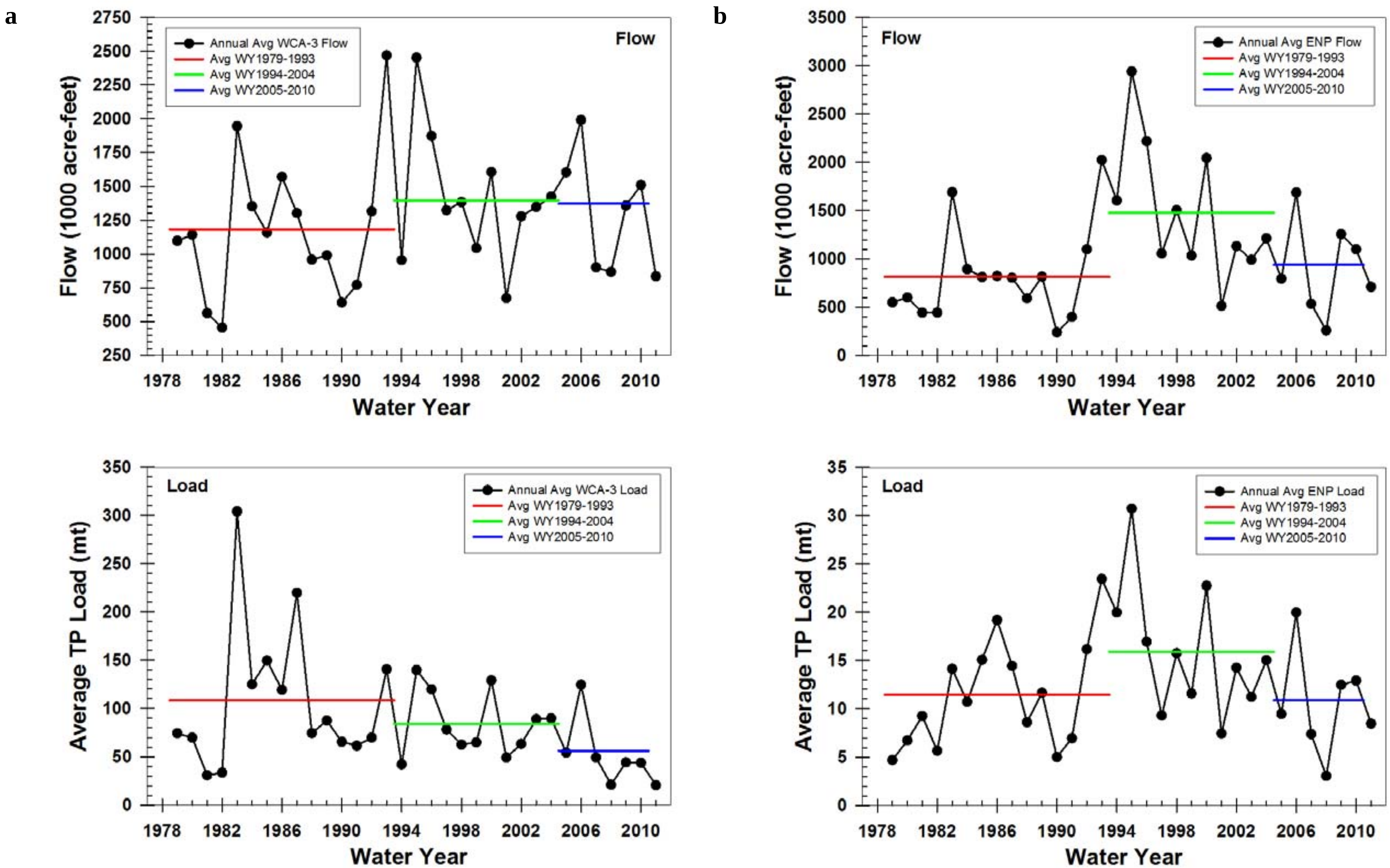

Figure 3A-13. Annual flow (upper graph) and average TP load (lower graph) to (a) WCA-3 and (b) the Park from WY1979–WY2011. The horizontal lines indicate the average (Avg) annual flows and loads for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

In addition to establishing numeric TP criterion, Section 62-302.540, F.A.C. also provides a four-part test to be used to determine achievement of the criterion. Each component must be achieved for a water body to be considered in compliance. Appendix 3A-6 provides results of the preliminary evaluation to assess TP criterion achievement using available data for the most recent five-year period, WY2007–WY2011. As described previously, the results of this assessment were affected by data limitations in many parts of the EPA during some years caused in part by the extremely dry conditions that have prevailed throughout the area. Additionally, monitoring at nine new sites (added to the existing sites to form the TP criterion monitoring network) was not initiated until January 2007. During WY2011, 56 of the 58 TP criterion monitoring network sites had sufficient data (i.e., six or more samples specified by the screening protocol referenced by the TP Criterion Rule, per Section 62-302.540, F.A.C.) to be included in the TP criterion assessment. In contrast, only 30 of the 58 sites had a sufficient number of samples during WY2007, with less than 50 percent of the Refuge and WCA-3 monitoring sites having the minimum number of samples required for inclusion in the TP criterion assessment.

The results of the WY2007–WY2011 TP criterion assessment indicate that, even with the data limitations, the unimpacted portions of each WCA passed all four parts of the compliance test (as expected) and are therefore in compliance with the 10 µg/L TP criterion. Occasionally, individual sites within the unimpacted portions of the conservation areas exhibited an annual site geometric mean TP concentration above 10 µg/L, as expected, but in no case did the values for the individual unimpacted sites cause an exceedance of the annual or long-term network limits. None of the annual geometric mean TP concentrations for the individual unimpacted sites during the WY2007–WY2011 period exceeded the 15 µg/L annual site limit.

In contrast, the impacted (i.e., phosphorus-enriched) portions of each water body failed one or more parts of the test and therefore exceeded the criteria. The impacted portions of the WCAs routinely exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively. During the WY2007–WY2011 period, numerous individual sites within the impacted areas exhibited annual geometric mean TP concentrations below the 15 µg/L annual site limit. In a few instances, the annual mean for individual impacted sites was below 10 µg/L; however, none of the impacted sites were consistently below the 10 µg/L long-term limit.

In all cases the annual network geometric mean TP concentrations for WY2011 in both the impacted and unimpacted portions of all three WCAs were the lowest of the five-year assessment period. Future TP criterion achievement assessments conducted with more robust datasets are expected to provide a better understanding of EPA phosphorus concentrations.

TOTAL NITROGEN CONCENTRATIONS

The concentration of TN in surface waters is not measured directly but is calculated as the sum of total Kjeldahl nitrogen (TKN; organic nitrogen plus ammonia) and nitrite plus nitrate ($NO_3 + NO_2$). The TN values for this chapter were calculated only for those samples for which both TKN and $NO_3 + NO_2$ results were available. **Table 3A-7** provides a summary of the TN concentrations measured in the different portions of the EPA during the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2010) periods, as well as WY2011.

As in previous years, TN concentrations during WY2011 exhibited a general north-to-south spatial gradient across the EPA. This gradient likely reflects the higher concentrations associated with discharges to the northern portions of the system from agricultural areas and Lake Okeechobee. A gradual reduction in TN levels results from assimilative processes in the marsh as water flows southward. The highest geometric mean TN concentrations were observed in Refuge (2.25 mg/L) and WCA-2 (1.93 mg/L) inflows and decreased to a minimum concentration in Park inflows (1.00 mg/L) and at Park (1.03 mg/L) and Refuge (1.02 mg/L) interior sites.

Table 3A-7. Total nitrogen concentrations (mg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2010), and WY2011 periods.

Region	Class	Period	N	Geometric Mean	Standard Deviation of Geometric Mean	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	1206	3.68	1.79	3.83	0.25	18.68
		1994-2004	1601	2.42	1.59	2.33	0.25	48.23
		2005-2010	754	2.18	1.41	2.22	0.47	7.61
		2011	129	2.25	1.36	2.26	0.98	5.89
	Interior	1979-1993	359	2.41	1.63	2.32	0.72	36.71
		1994-2004	1887	1.28	1.47	1.22	0.45	9.50
		2005-2010	1203	1.21	1.40	1.18	0.56	7.91
		2011	97	1.02	1.21	1.00	0.67	1.56
	Outflow	1979-1993	602	2.65	1.69	2.58	0.25	22.84
		1994-2004	696	2.00	1.53	1.89	0.25	7.91
		2005-2010	317	1.56	1.41	1.50	0.78	6.33
		2011	75	1.54	1.26	1.52	0.94	2.50
	Rim	1979-1993	118	2.76	1.65	2.64	0.80	10.91
		1994-2004	592	2.38	1.51	2.26	0.68	9.66
		2005-2010	162	1.97	1.40	2.08	0.87	5.22
		2011	0	1.00	1.00	0.00	0.00	0.00
WCA-2	Inflow	1979-1993	784	2.91	1.66	2.91	0.25	22.84
		1994-2004	1192	2.40	1.49	2.42	0.67	7.91
		2005-2010	640	2.05	1.39	2.07	0.70	6.33
		2011	108	1.93	1.24	1.99	0.96	2.75
	Interior	1979-1993	1669	2.62	1.56	2.50	0.25	37.17
		1994-2004	2914	2.03	1.42	2.10	0.25	37.10
		2005-2010	1173	1.98	1.32	1.99	0.75	10.10
		2011	77	1.73	1.26	1.76	0.89	3.35
	Outflow	1979-1993	894	2.25	1.41	2.18	0.75	7.65
		1994-2004	675	1.66	1.35	1.65	0.25	4.44
		2005-2010	473	1.73	1.26	1.77	0.91	3.93
		2011	62	1.53	1.27	1.63	0.90	2.29
WCA-3	Inflow	1979-1993	2401	2.02	1.57	1.95	0.25	10.80
		1994-2004	2561	1.67	1.44	1.59	0.54	7.79
		2005-2010	1599	1.62	1.30	1.63	0.75	12.25
		2011	248	1.60	1.28	1.64	0.81	5.08
	Interior	1979-1993	590	1.91	1.55	1.87	0.43	10.01
		1994-2004	1686	1.18	1.39	1.15	0.25	9.00
		2005-2010	1055	1.32	1.36	1.32	0.46	3.66
		2011	81	1.24	1.25	1.23	0.72	1.86
	Outflow	1979-1993	1721	1.51	1.47	1.51	0.25	14.86
		1994-2004	1534	1.05	1.44	1.09	0.25	4.10
		2005-2010	923	1.18	1.32	1.19	0.52	3.39
		2011	179	1.10	1.35	1.08	0.53	2.39
Park	Inflow	1979-1993	1929	1.37	1.63	1.45	0.25	14.86
		1994-2004	1828	0.88	1.59	0.93	0.25	3.60
		2005-2010	1142	1.03	1.39	1.04	0.49	3.39
		2011	197	1.00	1.39	0.96	0.51	2.39
	Outflow	1979-1993	565	1.28	1.90	1.37	0.25	40.84
		1994-2004	1007	1.03	1.64	1.06	0.25	5.70
		2005-2010	390	1.03	1.62	1.02	0.03	7.68
		2011	60	1.03	1.37	1.03	0.56	2.12

During WY2011, the geometric mean TN concentrations for Refuge and WCA-2 interior sites remained at levels lower than either the Baseline or Phase I periods. The low TN concentrations observed during WY2011 may be the result of improved nutrient removal effectiveness of the STAs, especially during low water conditions. During WY2011, geometric mean TN concentrations at inflow stations ranged from 1.00 mg/L in the Park to 2.25 mg/L in the Refuge. Geometric mean TN concentrations at interior sites ranged from 1.02 mg/L in the Refuge to 1.23 mg/L in WCA-2.

As described in the 2011 SFER, there is a strong correlation between TN and total organic carbon (TOC) (Payne et al., 2011). This strong correlation indicates that the primary source of the TN measured within the marsh is the organic material that naturally occurs in abundance in the wetland and enters the marsh from the oxidized sediments in the EPA. This finding, and the low NO_3 + NO_2 concentrations observed, also indicates that inorganic forms of nitrogen from anthropogenic sources are generally not important sources of nitrogen to the EPA.

LITERATURE CITED

Atkeson, T. and D. Axelrad. 2003. Chapter 2B: Mercury Monitoring, Research and Environmental Assessment. In: *2003 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Atkeson, T. and P. Parks. 2002. Chapter 2B: Mercury Monitoring, Research and Environmental Assessment. In: *2002 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Axelrad, D.M., T.D. Atkeson, C.D. Pollman and T. Lange. 2006. Chapter 2B: Mercury Monitoring, Research and Environmental Assesment in South Florida. In: *2006 South Florida Envirnonmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Axelrad, D.M., T.D. Atkeson, C.D. Pollman, T. Lange, D.G. Rumbold and K. Weaver. 2005. Chapter 2B: Mercury Monitoring, Research and Environmental Assesment in South Florida. In: *2005 South Florida Envirnonmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Bates, A.L., W.H. Orem, J.W. Harvey and E.C. Spiker. 2002. Tracing Sources of Sulfur in the Florida Everglades. *Journal of Environmental Quality*, 31: 287-299.

Bechtel, T., S. Hill, N. Iricanin, K. Jacobs, C. Mo, V. Mullen, R. Pfeuffer, D. Rudnick and S. Van Horn. 1999. Chapter 4: Status of Water Quality Criteria Compliance in the Everglades Protection Area and Tributary Waters. In: *1999 Everglades Interim Report*, South Florida Water Management District, West Palm Beach, FL.

Bechtel, T., S. Hill, N. Iricanin, C. Mo and S. Van Horn. 2000. Chapter 4: Status of Water Quality Criteria Compliance in the Everglades Protection Area and at Non-ECP Structures. In: *2000 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Germain, G.J. 1998. Surface Water Quality Monitoring Network, Technical Memorandum 356. South Florida Water Management District, West Palm Beach, FL.

Krest, J.M. and J.W. Harvey. 2003. Using Natural Distributions of Short-lived Radium Isotopes to Quantify Groundwater Discharge and Recharge. *Limnology and Oceanography*, 48(1): 290-298.

Payne, G., T. Bennett, K. Weaver and F. Nearhoof. 2001 Everglades Phosphorus Criterion Development Support Document, Part 2: Water Conservation Area 1. Everglades Technical Support Section, Division of Water Resource Management, Tallahassee, FL.

Payne, G., K. Weaver, T. Bennett and F. Nearhoof. 2000. Everglades Phosphorus Criterion Development Support Document, Part 1 Water Conservation Area 2 Everglades Technical Support Section, Division of Water Resource Management, Tallahassee, FL.

Payne, G., K. Weaver, and S. Xue. 2007. Chapter 3C: Status of Phosphorus and Nitrogen in the Everglades Protection Area. In: *2007 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Payne, G., S. Xue, K. Hallas and K. Weaver. 2011. Chapter 3A: Status of Water Quality in the Everglades Protection Area. In: *2011 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Payne, G., S. Xue, K. Hallas and K. Weaver. 2010. Chapter 3A: Status of Water Quality in the Everglades Protection Area. In: *2010 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Redfield, G. 2002. Atmospheric Deposition Phosphorus: Concepts, Constraints and Published Depostion Rates for Ecosytem Management. Technical Publication EMA 403, South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2008. Field Sampling Quality Manual. SFWMD-FIELD-QM-001-04. South Florida Water Management District, West Palm Beach, FL.

USEPA. 2002. Consolidated Assessment and Listing Methodology, First Edition. United States Environmental Protection Agency, Washington, D.C.

USEPA. 1997. Guidelines for Preparation of the Comprehensive State Water Quality Assessments. EPA-841-B-97-003A and 002B. United States Environmental Protection Agency, Washington, D.C.

Weaver, K. 2004. Everglades Marsh Dissolved Oxygen Site-Specific Alternative Criterion Technical Support Document. Water Quality Standards and Special Projects Program, Division of Water Resource Management, Florida Department of Environmental Protection, Tallahassee, FL.

Weaver, K. and G. Payne. 2006. Chapter 2A: Status of Water Quality in the Everglades Protection Area. In: *2006 South Florida Envirnonmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Weaver, K. and G. Payne. 2005. Chapter 2A: Status of Water Quality in the Everglades Protection Area. In: *2005 South Florida Envirnonmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Weaver, K. and G. Payne. 2004. Chapter 2A: Status of Water Quality in the Everglades Protection Area. In: *2004 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Weaver K., T. Bennett, G. Payne, G. Germain, T. Bechtel, S. Hill and N. Iricanin. 2002. Chapter 3A: Status of Water Quality Criteria in the Everglades Protection Area. In: *2002 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Weaver, K., T. Bennett, G. Payne, G. Germain, S. Hill and N. Iricanin. 2001. Chapter 4: Status of Water Quality Criteria Compliance in the Everglades Protection Area. In: *2001 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Weaver, K., G. Payne and T. Bennett. 2003. Chapter 2A: Status of Water Quality Criteria in the Everglades Protection Area. In: *2003 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Weaver, K., G. Payne and S. Xue. 2007. Chapter 3A: Status of Water Quality in the Everglades Protection Area. In: *2007 South Florida Envirnonmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.