Chapter 3C: Status of Phosphorus and Nitrogen in the Everglades Protection Area

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SUMMARY

The Everglades ecosystem evolved as a highly oligotrophic (nutrient-poor), phosphorus-limited system, with the natural flora and fauna being adapted to successfully exist under these harsh conditions. Research has shown that relatively small additions of nutrients, especially phosphorus, can have dramatic effects on the biological conditions of the ecosystem. The primary purpose of this chapter is to provide an overview of the status of phosphorus and nitrogen levels in the surface water within the Everglades Protection Area (EPA) during Water Year 2006 (WY2006) (May 1, 2005 through April 30, 2006). The chapter also presents a template based on the approved total phosphorus (TP) criterion rule provided in Chapter 62-303, Florida Administrative Code (F.A.C.). The template is intended to provide a consistent framework for future TP criterion assessments for individual regions in the EPA.

TOTAL PHOSPHORUS STATUS WITHIN THE EVERGLADES PROTECTION AREA

To provide a comprehensive overview of the current nutrient status in the Everglades and to evaluate temporal and spatial patterns, TP concentrations measured during WY2006 are summarized and compared to levels obtained during previous monitoring periods as well as the limits set forth in the four-part TP criterion compliance test specified in the TP criterion rule.

As documented for previous years, TP concentrations measured during WY2006 exhibited a decreasing north-to-south gradient, with the highest levels present in the inflow to the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) and Water Conservation Area 2 (WCA-2), and with concentrations decreasing to a minimum within the Everglades National Park (ENP or Park). The gradient indicates that as water entering the EPA from the north flows southward, biogeochemical processes (e.g., settling, sorption, and biological assimilation) help to decrease TP concentrations in the discharges (primarily phosphorus-rich agricultural runoff) from the Everglades Agricultural Area (EAA) and Lake Okeechobee.

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Total phosphorus concentrations during WY2006 generally returned to pre-WY2005 levels following WY2005, when elevated phosphorus levels throughout the EPA resulted from climatic extremes, including multiple hurricanes with intense rainfall as well as periods of marsh dry-out following little or no rainfall. Annual TP concentrations measured at interior marsh stations during WY2006 were generally lower than those measured during WY2005 and near or below the average levels for the WY1978–WY2004 historical period. [2]

The largest decreases were observed for WCA-1 and WCA-2, which exhibited the greatest effects from the climatic extremes in WY2005. In WCA-2, the geometric mean TP concentration of 13.5 micrograms per liter (µg/L) is well below both the 17.7 µg/L and 16.5 µg/L mean concentrations reported for WY2005 and the WY1978–WY2004 period, respectively. The large decrease observed for WCA-2 likely reflects both the recovery from the climatic extremes experienced during the previous year and the generally improved conditions in the impacted portions of the marsh resulting from significantly reduced inflow of untreated water through the S-10 structures.

During WY2006, the geometric mean TP concentration at interior marsh sites within the Park was slightly higher than recorded for either WY2005 or the WY1978–WY2004 period. However, it should be noted that the WY2006 mean is highly influenced by two elevated measurements in May 2005, when water levels were low and portions of the marsh dried out. As both of these measurements were made at sites located in the middle of the marsh not near any anthropogenic inputs, the high measurements likely reflect the effects of the low water level and the consequential sediment oxidation and nutrient release in upstream areas and/or the difficulty in obtaining a representative sample during periods of low water level. Without these two unusually high measurements, the annual geometric mean for the Park interior is slightly reduced from 5.7 to 5.3 µg/L, which is below both the WY2005 and the WY1978–WY2004 period values.

Overall, interior marsh geometric mean TP concentrations ranged from 5.7 µg/L in the Park to 13.5 µg/L in WCA-2 during WY2006, as compared to ranges from 5.6 to 17.7 µg/L during WY2005, and 5.4 to 16.5 µg/L for the WY1978–WY2004 period. The annual geometric mean TP concentration across interior marsh sites in the Refuge, WCA-3, and the Park for WY2006 were below the respective 10.0 and 11.0 µg/L five-year and annual network limits for assessing achievement of the TP criterion rule. Even though TP levels at interior sites in WCA-2 have improved in recent years, the geometric mean for WY2006 (13.5 µg/L) remains above the annual 11.0 µg/L network limit.

Annual geometric mean TP concentrations at inflow sites during WY2006 were at or slightly below levels recorded for WY2005 and the WY1978–WY2004 period, except for the inflows to the Refuge. Overall, geometric mean TP concentrations for inflow sites during WY2006 ranged from 8.2 µg/L for the Park to 79.7 µg/L for the Refuge, as compared to ranges from 10.3 to 66.9 µg/L in WY2005 and 9.0 to 65.4 µg/L for the WY1978–WY2004 period. The Refuge mean inflow TP level of 79.7 µg/L during WY2006 is well above the WY2005 and WY1978–WY2004 values of 66.9 and 65.4 µg/L, respectively. The elevated TP inflow concentrations to the Refuge may have been driven by several factors including lower nutrient removal effectiveness of Stormwater Treatment Area (STA) 1W, caused by physical damage to the vegetative communities within STA-1W following the passage of Hurricane Wilma in October 2005;

[2] The WY1978–WY2004 historical period provided as a basis of comparison for the two most recent water years (WY2005 and WY2006). It should be noted that the WY1978–WY2004 period differs from the baseline period (WY1979–WY1988), federally required for the *Comparison of WY2006 Phosphorus Loads to the Baseline Settlement Agreement* section of this chapter.

numerous short-lived diversion events caused by periods of high rainfall; and efforts to lower water levels in Lake Okeechobee following the damage resulting from the 2004 and 2005 hurricanes. Despite the higher mean inflow concentrations, the TP load entering the Refuge during WY2006 was approximately 49 percent lower than the load during the previous year. In addition, the higher mean inflow concentrations were not reflected in the levels measured at interior marsh sites. The annual geometric mean TP concentration at interior marsh sites in the Refuge during WY2006 was significantly lower than in WY2005 and slightly lower than the WY1978–WY2004 period.

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 ecosystem. During WY2006, the concentrations of OP in the inflows to all areas within the EPA were lower than those reported for either WY2005 or the WY1978–WY2004 period. The greatest decreases in OP concentrations were observed for inflow to the Refuge and WCA-2, which exhibited the greatest effect from the WY2005 climatic conditions. In addition, the Refuge and WCA-2 have historically received the highest levels of OP and now receive most of their inflow from the STAs, which preferentially remove OP.

Annual geometric mean TP concentrations for individual interior marsh monitoring stations during WY2006 ranged from less than 4.0 µg/L at some unimpacted portions of the marsh to 77.2 µg/L at a WCA-3A site influenced by canal inputs and hydrologic impacts, and 63.7 percent of the interior marsh sites across the EPA exhibited annual geometric mean TP concentrations less than or equal to 10.0 µg/L. Additionally, 76.9 percent of the interior sites across the EPA had annual geometric mean TP concentrations of 15.0 µg/L or lower during WY2006. For comparison, 40.5 and 50.8 percent of the sites monitored during WY2005 and the WY1978–WY2004 period, respectively, had annual geometric mean TP concentrations less than or equal to 10 µg/L. During WY2005 and the WY1978–WY2004 period, 65.2 and 70.3 percent of the interior sites, respectively, exhibited annual geometric mean concentrations of 15 µg/L or less.

PHOSPHORUS CRITERION ACHIEVEMENT ASSESSMENT

The TP criterion rule for the EPA has been fully approved at both the state and federal levels, receiving final approval from the U.S. Environmental Protection Agency (USEPA) in July 2005. This chapter includes discussion of a TP criterion achievement assessment developed to serve as a template for future evaluations and to ensure consistency of future assessments. A detailed TP criterion achievement assessment was conducted based on the four-part test specified in the TP criterion rule using the available data from existing monitoring sites for the WY2002–WY2006 period. In certain portions of the EPA, available data are limited and additional monitoring sites are being considered to expand the existing monitoring network.

Four components of the assessment test must be achieved for a water body to be in compliance with the TP criterion, as defined in the *EPA Phosphorus Criterion Achievement Assessment* section of this chapter. The results of the assessment using WY2002–WY2006 data indicate that the unimpacted portions of each conservation area passed all four parts of the TP criterion achievement test for WY2006 and therefore are considered to achieve the criterion. Occasionally, an individual unimpacted area site exhibited an annual site geometric mean TP concentration above 10 µg/L, but none of the values for the unimpacted areas exceeded the 11-µg/L annual network limit or 10-µg/L five-year network limit for TP concentrations. Moreover, none of the annual geometric mean TP concentrations for the individual sites exceeded the 15-µg/L annual site limit during WY2006.

In contrast, the impacted (phosphorus-enriched) portions of each water body failed one or more parts of the test and therefore exceeded the criterion. The impacted portions of the WCAs consistently exceeded the 11-µg/L annual network limit and the 10-µg/L five-year network limit for TP concentrations. Occasionally, selected individual sites within the impacted areas exhibited annual geometric mean TP concentrations below the 15-µg/L annual site limit. Rarely, the annual geometric mean for an individual impacted site was below 10 µg/L; however, none of the impacted sites was consistently below the 10-µg/L five-year network limit. Future assessments conducted with more robust datasets are expected to provide a more complete picture of phosphorus concentrations in the EPA.

TOTAL NITROGEN CONCENTRATIONS WITHIN THE EVERGLADES PROTECTION AREA

As in previous years, total nitrogen (TN) concentrations in the EPA also exhibited a north-to-south gradient during WY2006. Similar to phosphorus, the TN gradient likely reflects the higher concentrations associated with agricultural discharges to the northern portions of the system, with a gradual reduction in levels southward as a result of assimilative processes in the marshes. The highest average TN concentrations were observed in the inflows to the Refuge with levels decreasing to a minimum at sites within the Park.

Average total nitrogen concentrations measured during WY2006 at both inflow and interior sites in all areas of the EPA, except in the inflows to the Refuge, were lower than the values for either WY2005 or the WY1978–WY2004 period. The lower nitrogen levels likely reflect the return of more stable climatic conditions compared to WY2005, when multiple hurricanes and marsh dry-out strongly influenced nutrient levels throughout the EPA, affecting nutrient removal by the STAs and agricultural Best Management Practices (BMPs) that have been implemented. The average TN concentration for the inflows to the Refuge during WY2006 is higher than the level for WY2005, but within the historic range. The slightly elevated inflow TN concentrations during WY2006 may be caused by the factors previously noted as contributing to elevated TP concentrations.

In summary, average TN concentrations at inflow stations during WY2006 ranged from 0.99 mg/L in the Park to 2.40 mg/L in the Refuge, with average concentrations at interior marsh stations ranging from 1.22 in the Park to 2.23 mg/L in WCA-2.

PURPOSE

The primary purpose of this chapter is to provide an overview of the status of phosphorus and nitrogen levels in the surface water within the EPA during WY2006. The water quality evaluations presented in this section update previous analyses presented in earlier consolidated reports. More specifically, this chapter and its associated appendices are intended to (1) summarize phosphorus and nitrogen concentrations measured in surface waters within different portions of the EPA and describe spatial and temporal trends observed, (2) discuss factors contributing to any spatial and temporal trends observed, and (3) present a template for future phosphorus criterion achievement assessments for different areas within the EPA.

Because the TP criterion rule for the EPA received final approval from the USEPA in July 2005, this year's chapter differs from previous versions by including a template for assessing achievement of the TP criterion in addition to the annual update of the comprehensive overview of the nitrogen and phosphorus levels throughout the EPA. It is anticipated that future SFERs will continue to include more detailed evaluation to assess achievement of the TP criterion within the different portions of the EPA, as well as an annual update of the comprehensive overview of the nitrogen and phosphorus levels throughout the EPA.

METHODS

OVERVIEW OF EVERGLADES PROTECTION AREA NITROGEN AND PHOSPHORUS LEVELS

A regional synoptic approach used for water quality evaluations in previous consolidated reports was applied to phosphorus and nitrogen data for WY2006 to provide an overview of the nutrient status within the EPA. The consolidation of regional water quality data provides for analysis over time but limits spatial analysis within each region. However, spatial analysis can be performed between regions, because the majority of inflow and pollutants enter the northern one-third of the EPA, and the net water flow is from north to south.

As described in Chapter 3A of this volume, for the evaluation of other water quality constituents, the majority of the water quality data evaluated in this chapter was retrieved from the DBHYDRO database maintained by the South Florida Water Management District (SFWMD or District). Water quality data from the nutrient gradient sampling stations (monitored by the District's Everglades Regulation Division, Environmental Resource Regulation Department) in the northern part of WCA-2A, the southwestern part of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), the west-central portion of WCA-3A, and Taylor Slough in Everglades National Park (ENP or Park) were obtained from the SFWMD Everglades research database.

The phosphorus and nitrogen data summarized in this chapter were collected at the same monitoring stations described in Chapter 3A (Figure 3A-1). Likewise, the water quality sampling stations located throughout the Park and WCAs were categorized as inflow, rim canal, interior, or outflow sites within each region based on their location and function, as previously described. Due to minor changes to the station classifications and the addition of a small amount of data unavailable during the preparation of the previous SFER, some statistics for phosphorus and nitrogen presented may differ slightly from those presented in previous consolidated reports. The location and categorization of the monitoring stations used for the analysis of the phosphorus and nitrogen data in this chapter are the same as those utilized for the evaluation of other water quality constituents, as described in Chapter 3A (see Figures 3A-2 through 3A-5).

The current SFWMD monitoring programs are described by Germain (1998). The frequency of nutrient sampling varies by site depending on site classification and hydrologic conditions (water depth and flow). Additionally, the District has created a website describing its water quality monitoring projects, including project descriptions and objectives. This website currently provides limited site-specific information. Generally, interior monitoring stations were sampled monthly, with water control structures (inflows and outflows) typically sampled biweekly when flowing and monthly when not flowing. More information can be found on the District's website (www.sfwmd.gov) under the *What We Do*, *Environmental Monitoring*, *Water Quality Monitoring* section.

The quality assurance/quality control (QA/QC) procedures followed during data collection, as well as the data screening performed on the nutrient data presented in this chapter, are the same as those described in Chapter 3A. 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. All data presented in this chapter, including historical results, were handled consistently with regard to screening and MDL replacement.

PHOSPHORUS CRITERION ACHIEVEMENT ASSESSMENT

As the TP criterion rule for the EPA has been fully approved at both the state and federal levels, an evaluation to assess achievement of the TP criterion has been included in this year's chapter to provide a template for future evaluations, as noted earlier. A detailed TP criterion assessment was conducted based on the four-part test specified in the TP criterion rule using the available data from existing monitoring sites for the most recent five-year (WY2002–WY2006) period. A list of the existing monitoring sites used in this assessment and their classification as impacted or unimpacted is provided in Appendix 3C-2 of this volume. The location of these sites is provided in the maps of the overall monitoring program provided in Chapter 3A (Figures 3A-2 through 3A-4). The phosphorus data used in the TP criterion achievement assessment provided in this chapter were collected at the existing sites from various projects. It should be noted that available information is limited for certain portions of the EPA and additional monitoring sites are being considered to expand the existing monitoring network. Because the results of the TP criterion achievement assessment could be affected by this data limitation, the results of this evaluation should be interpreted with caution. It is expected that future assessments will be improved as additional data are added and a more consistent monitoring network is established.

The QA/QC procedures followed during data collection are the same as those described in Chapter 3A. Collected data were screened as specified in the protocol presented at the FDEP website at http://www.dep.state.fl.us/water/wqssp/everglades/docs/DataQualityScreeningProtocol.pdf. For purposes of this assessment, data reported as less than the MDL were assigned a value of one-half the MDL. All data presented in this chapter, including historical results, were handled consistently with regard to screening and MDL replacement.

In addition to establishing the numeric phosphorus criterion for the EPA, the TP criterion rule (Section 62-302.540, F.A.C.) also provides a four-part test to be used to determine achievement of the numeric TP criterion. The four-part test specifies limits for the annual and five-year geometric mean TP concentrations for individual sites and across the monitoring network in each water body. Assessing achievement of the TP criterion for the EPA requires calculation of annual and five-year geometric mean TP concentrations for individual sites and across the monitoring network in each portion of the EPA. The different methods for calculating the required annual and five-year geometric means could yield slightly different results. To avoid confusion in the future and to assure consistency of future calculations, the specific methods to be used by the Florida Department of Environmental Protection (FDEP) in assessing achievement of the Everglades TP criterion have been documented (Appendix 3C-1). The documented calculation methods were developed to be consistent with the derivation of the criteria and the accompanying four-part achievement test, where possible, and to provide an unbiased assessment of ambient water quality conditions within the EPA.

PHOSPHORUS AND NITROGEN IN THE EVERGLADES PROTECTION AREA

As primary nutrients, phosphorus and nitrogen are essential to the existence and growth of aquatic organisms in surface waters. The Everglades, however, evolved as a highly oligotrophic (nutrient-poor), phosphorus-limited system, with the natural flora and fauna being adapted to successfully exist under these harsh conditions. Research has demonstrated that relatively small additions of these nutrients, especially phosphorus, can have dramatic effects on the biological conditions of the ecosystem.

Until recently, phosphorus and nitrogen concentrations in EPA surface water were only regulated by the 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 the natural biological communities, the FDEP has numerically interpreted the narrative criterion, as directed by the Everglades Forever Act (EFA), to develop a TP criterion of 10 µg/L for the EPA.

This chapter discusses phosphorus and nitrogen concentrations measured during WY2006, with comparison to results from previous monitoring years, to support evaluation of spatial and temporal trends in nutrient levels within the EPA. Because the TP criterion rule for the EPA has been adopted and approved, an evaluation to assess achievement of the TP criterion was conducted based on the four-part test specified in the TP criterion rule using available data for the WY2002–WY2006 period. This chapter includes the assessment as a template to help ensure that future evaluations are conducted in a consistent manner.

TOTAL PHOSPHORUS

PHOSPHORUS STATUS IN THE EVERGLADES PROTECTION AREA

To provide an overview of the current nutrient status in the Everglades and to evaluate temporal and spatial patterns, TP concentrations measured during WY2006 are compared to the levels observed during previous monitoring periods and limits set forth in the TP criterion rule. For the purpose of this evaluation, TP concentrations measured during WY2006 are compared to the TP levels determined during WY2005 and the WY1978–WY2004 period. **Table 3C-1** provides a summary of the TP concentrations measured within different portions of the EPA during WY2006, WY2005, and the WY1978–WY2004 period using both geometric mean and median values. Geometric means were used to summarize and compare TP concentrations based on the EFA and TP criterion rule requirements that achievement of the TP criterion is based on the long-term, geometric mean. Given that the EFA and TP criterion were designed to provide long-term conditions that are ecologically protective, they require the use of geometric means. This methodology accounts for short-term variability in water quality data to provide a more reliable, long-term value for assessing and comparing the status of phosphorus.

Table 3C-1. Summary of total phosphorus (TP) concentrations (μg/L) in the Everglades Protection Area (EPA) for WY2006, WY2005, and WY1978–WY2004.

Region	Class	Period	Sample Size (N)	Geometric Mean (μg/L)	Std. Deviation (Geometric Mean)	Median (μg/L)	Min. (μg/L)	Max. (μg/L)
Refuge	Inflow	1978–2004	3243	65.4	2.3	70	2	1415
		2005	133	66.9	1.9	65	23	503
		2006	137	79.7	1.6	74	31	378
	Interior	1978–2004	2794	10.0	2.0	9	<2	494
		2005	304	14.6	2.1	12	4	238
		2006	340	9.8	1.8	9	2	80
	Outflow	1978-2004	1339	53.0	2.1	50	7	3435
		2005	60	52.1	2.4	44	11	515
		2006	49	42.1	1.9	36	16	256
	Rim	1978–2004	750	62.9	1.8	60	12	473
		2005	44	71.9	2.0	72	19	653
		2006	48	76.2	1.6	73	34	216
WCA-2	Inflow	1978–2004	2196	52.5	2.1	55	7	3435
		2005	168	26.5	2.3	20	8	196
		2006	151	26.7	1.8	22	10	245
	Interior	1978–2004	5327	16.5	3.0	13	<2	3189
		2005	240	17.7	2.7	16	2	530
		2006	306	13.5	2.3	12	2	272
	Outflow	1978–2004	1596	20.4	2.4	19	<2	556
		2005	76	16.7	2.1	16	6	179
		2006	96	14.3	1.6	14	7	38
WCA-3	Inflow	1978–2004	5938	33.7	2.4	33	<2	1286
		2005	396	23.6	1.9	22	6	219
		2006	427	24.3	2.1	21	7	236
	Interior	1978–2004	2725	8.6	2.4	8	<2	438
		2005	235	9.6	2.4	8	2	340
		2006	346	9.1	2.4	8	2	180
	Outflow	1978–2004	4452	10.9	2.1	10	<2	593
		2005	183	16.4	2.1	14	5	189
		2006	188	11.9	1.7	10	5	116
Park	Inflow	1978–2004	5294	9.0	2.1	9	<2	593
		2005	263	10.3	2.2	9	2	189
		2006	250	8.2	1.6	7	3	79
	Interior	1978–2004	1763	5.4	2.4	5	<2	1137
		2005	84	5.6	2.7	5	<2	151
		2006	89	5.7	2.1	5	2	291

Total phosphorus concentrations during WY2006 generally decreased to pre-WY2005 levels, following the previous year of climatic extremes, multiple hurricanes with intense rainfall, and periods of little or no rainfall with consequent marsh dry-out, which in turn brought elevated phosphorus levels. As documented for previous years, TP concentrations measured during WY2006 exhibited a decreasing north-to-south gradient, with the highest levels present in the inflow to the Refuge and concentrations decreasing to a minimum within the Park. This gradient results from the phosphorus-rich canal discharges, composed primarily of agricultural runoff originating in the EAA, entering 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.

Annual TP concentrations measured at interior marsh stations during WY2006 (expressed as either median or geometric mean values) generally were lower than those measured during WY2005 and near or below the average levels for WY1978–WY2004 (**Table 3C-1**). The largest decreases during WY2006 were observed for WCA-1 and WCA-2, which exhibited the greatest effects from the climatic extremes in WY2005. **Figure 3C-1** illustrates the temporal changes in annual geometric mean TP concentrations at inflow and interior sites for each area within the EPA for the WY1978–WY2006 period.

In WCA-2, the geometric mean TP concentration of 13.5 µg/L was well below both the 17.7 and 16.5 µg/L mean concentrations reported for WY2005 and the WY1978–WY2004 period, respectively. The large decreases observed for WCA-2 likely reflect both the recovery from the climatic extremes experienced during the previous year and improved conditions in the portions of the marsh impacted by the significantly reduced inflow from the S-10 structures.

During WY2006, the geometric mean TP concentrations at interior marsh sites within the Park were slightly higher than either WY2005 or the WY1978–WY2004 period. However, it should be noted that the WY2006 mean is highly influenced by two elevated measurements in May 2005, when water levels were low and portions of the marsh dried out **(Figure 3C-2)**.

A measurement of 291 µg/L was collected at station P36 in May 2005 that was more than ten times higher than the next-highest measurement at that site during the year. In addition, the second-highest measurement (75 µg/L at station P33) was also collected in May 2005 and was nearly five times the next-highest measurement at that site during the year. As both of these sites are located in the middle of the marsh away from anthropogenic inputs, these high measurements likely reflect the effects of the low water level and consequent sediment oxidation and nutrient release in upstream areas, and/or result from the difficulty in obtaining a representative sample during periods of low water level. Without these two unusually high measurements, the annual geometric mean for the Park interior is reduced from 5.7 to 5.3 µg/L, which is below the values for both WY2005 and the WY1978–WY2004 period. Overall, interior marsh geometric mean TP concentrations ranged from a 5.7 µg/L in the Park to 13.5 µg/L in WCA-2 during WY2006, as compared to ranges from 5.6 to 17.7 µg/L for WY2005, and from 5.4 to 16.5 µg/L for WY1978–WY2004 (**Table 3C-1**). The annual geometric mean TP concentration across interior marsh sites in the Refuge, WCA-3, and the Park for WY2006 were below the 10.0-µg/L five-year limit and 11.0-µg/L annual limit for assessing achievement with the TP criterion rule. Although TP levels at interior sites in WCA-2 have improved in recent years, the geometric mean for WY2006 (13.5 µg/L) remains slightly above the annual 11.0-µg/L annual limit.

Annual geometric mean TP concentrations at inflow sites during WY2006 were at or slightly below levels recorded for WY2005 and the WY1978–WY2004 period, except for the inflows to the Refuge. The Refuge mean inflow TP level of 79.7 µg/L during WY2006 is well above the WY2005 and WY1978–WY2004 values of 66.9 and 65.4 µg/L, respectively (**Table 3C-1**).

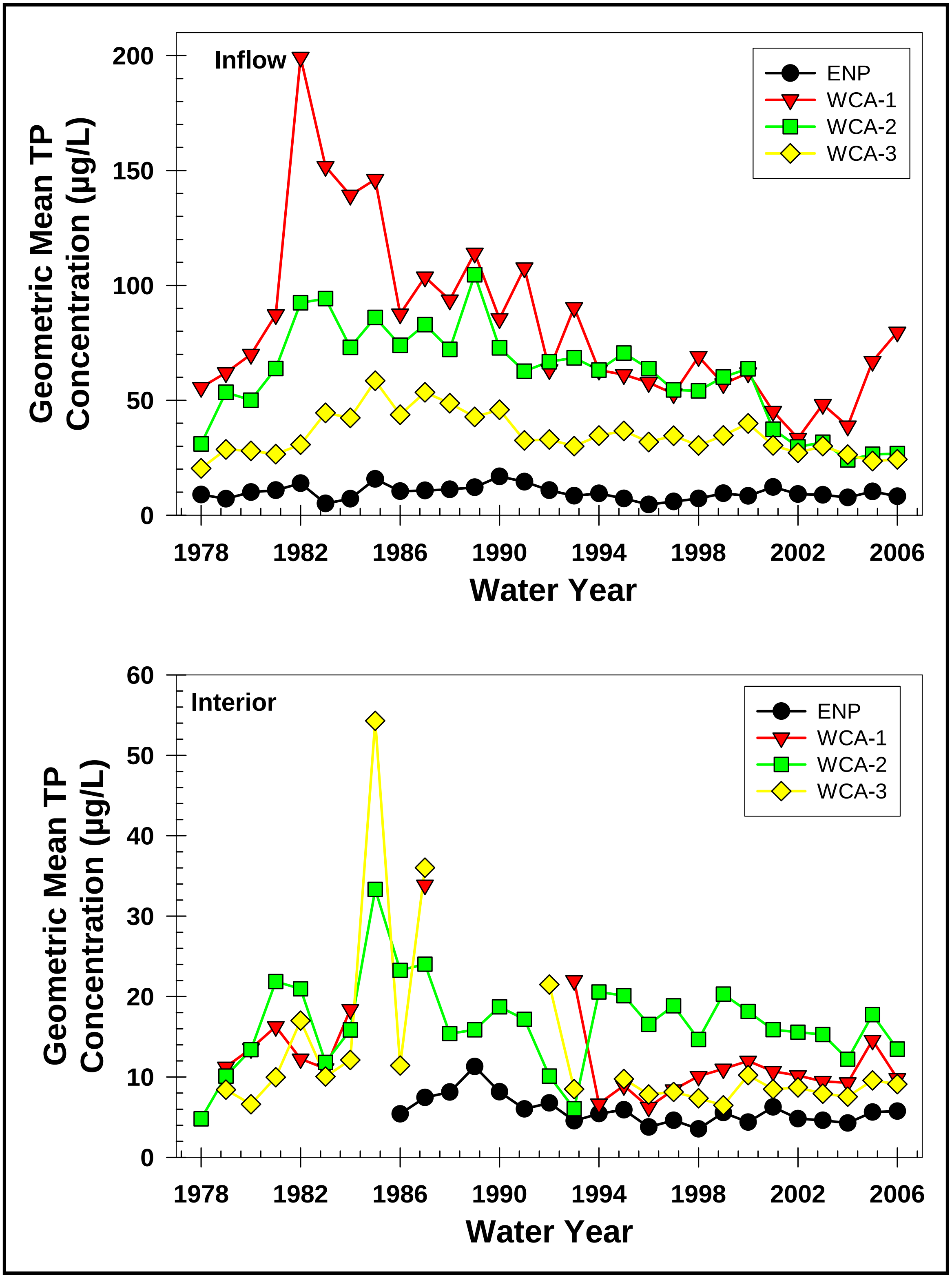

Figure 3C-1. Annual geometric mean TP concentrations (µg/L) for inflow (upper graph) and interior (lower graph) for each area within the EPA during the WY1978–WY2006 period.

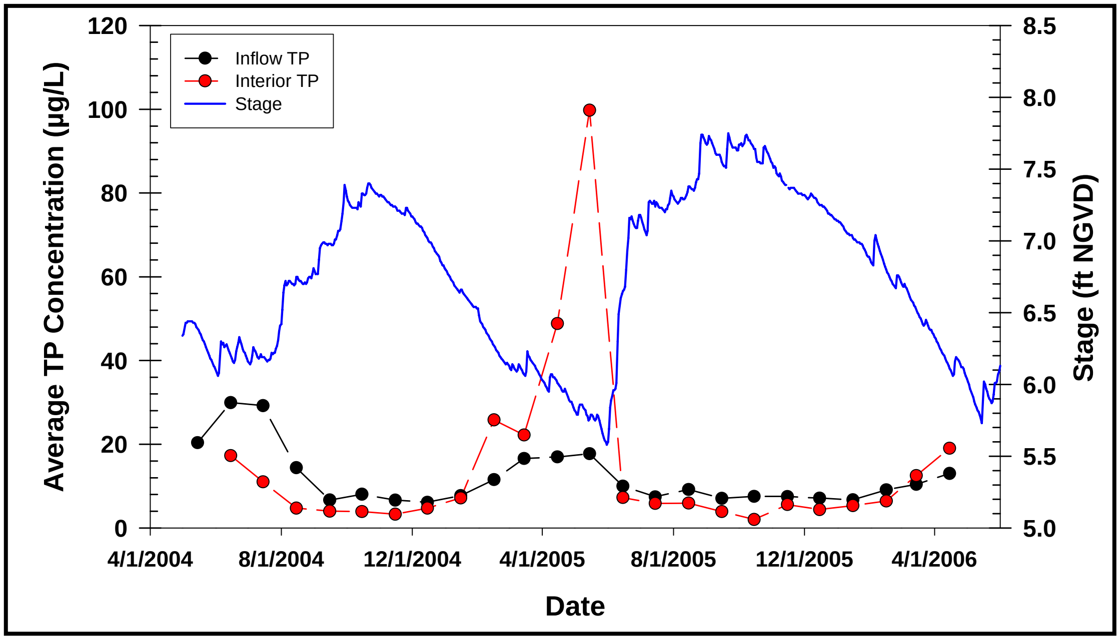

Figure 3C-2. Comparison of average monthly TP concentrations at inflow and interior sites with stage in Everglades National Park (ENP or Park).

The elevated inflow concentrations to the Refuge may have been driven by the multiple factors noted earlier. The total phosphorus load entering the Refuge during WY2006 was reduced by more than 40 percent compared to the load during the previous year, despite the higher mean inflow concentrations. In addition, the higher mean inflow concentrations were not reflected in the levels measured at interior marsh sites. The annual geometric mean TP concentration at interior marsh sites in the Refuge during WY2006 was significantly lower than in WY2005 and slightly lower than the WY1978–WY2004 period (**Table 3C-1**). Geometric mean TP concentrations for inflow sites during WY2006 ranged from 8.2 µg/L for the Park to 79.7 µg/L for the Refuge, compared to ranges from 10.3 to 66.9 µg/L in WY2005 and from 9.0 to 65.4 µg/L for WY1978–WY2004.

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 ecosystem. During WY2006, OP concentrations in the inflows to all areas within the EPA were lower than WY2005 or the WY1978–WY2004 period (**Table 3C-2**). The greatest decreases in OP concentrations were observed for inflow to the Refuge and WCA-2, which exhibited the greatest effect from the WY2005 climatic conditions. In addition, the Refuge and WCA-2, which historically received the highest levels of OP, now receive most of their inflow from the STAs, which preferentially remove OP.

Annual geometric mean TP concentrations for individual interior marsh monitoring stations having four or more samples during WY2006 ranged from less than 4.0 to 77.2 µg/L, with 63.7 percent of the interior marsh sites across the EPA exhibiting annual geometric mean TP concentrations that were less than or equal to 10.0 µg/L. Additionally, 76.9 percent of the interior sites across the EPA had annual geometric mean TP concentrations of 15.0 µg/L or below during WY2006. For comparison, 40.5 and 50.8 percent of the sites monitored during WY2005 and the WY1978–WY2004 period, respectively, had annual geometric mean TP concentrations less than or equal to 10.0 µg/L.

Table 3C-2. Summary of orthophosphate (OP) concentrations (µg/L) measured in the EPA during WY2006, WY2005, and WY1978–WY2004.

Region	Class	Period	Sample Size (N)	Geometric Mean (µg/L)	Std. Deviation	Median (µg/L)	Min. (µg/L)	Max. (µg/L)
Refuge	Inflow	1978–2004	2569	21.8	3.9	25	<2	1106
		2005	131	26.0	3.1	26	2	249
		2006	133	18.1	3.6	23	2	215
	Interior	1978–2004	1984	<2.0	2.3	2	<2	380
		2005	244	4.6	2.3	4	2	193
		2006	236	2.5	1.6	2	2	31
	Outflow	1978–2004	1321	16.6	3.7	18	<2	1290
		2005	61	18.8	3.3	17	2	461
		2006	49	6.6	3.9	5	2	196
	Rim	1978–2004	526	22.0	3.3	27	<2	408
		2005	42	27.0	3.6	38	2	544
		2006	36	22.2	3.9	24	2	180
WCA-2	Inflow	1978–2004	1676	16.2	3.7	17	<2	1290
		2005	128	10.7	3.0	7	2	183
		2006	109	4.1	2.8	2	2	190
	Interior	1978–2004	3867	3.8	4.0	2	<2	2790
		2005	194	6.8	2.8	6	2	405
		2006	244	2.9	2.1	2	2	91
	Outflow	1978–2004	1587	5.3	3.3	5	<2	396
		2005	80	6.8	2.1	6	2	153
		2006	96	2.7	1.7	2	2	16
WCA-3	Inflow	1978–2004	4569	8.9	3.9	8	<2	586
		2005	208	6.7	2.5	6	2	180
		2006	225	4.6	2.9	2	2	94
	Interior	1978–2004	2500	<2.0	2.6	2	<2	190
		2005	185	3.1	1.9	2	2	42
		2006	297	2.6	2.0	2	2	50
	Outflow	1978–2004	3392	2.8	2.1	2	<2	149
		2005	140	2.8	1.7	2	2	20
		2006	155	2.1	1.4	2	2	70
Park	Inflow	1978–2004	3901	2.7	2.0	2	<2	97
		2005	162	2.5	1.6	2	2	20
		2006	159	2.1	1.2	2	2	7
	Interior	1978–2004	1605	2.7	1.7	2	2	63
		2005	76	3.2	1.6	4	2	10
		2006	74	2.2	1.4	2	2	19

During WY2005 and the WY1978–WY2004 period, 65.2 and 70.3 percent of the interior sites, respectively, exhibited annual geometric mean concentrations of 15.0 µg/L or less. Given that the location of interior monitoring sites has remained relatively constant in recent years, the temporal comparison of statistics from individual sites can be used to distinguish changes in measured concentrations. However, as the monitoring sites are unevenly distributed across the EPA, it is impractical to estimate accurately the percentage of the marsh exceeding a TP concentration of 10.0 µg/L based on these results.

Spatially, interior marsh TP concentrations measured during WY2006 exhibited the same north-to-south gradient observed during previous periods (Bechtel et al., 1999, 2000; Weaver et al., 2001, 2002, 2003; Payne and Weaver, 2004, Payne et al., 2006). Typically, the highest TP concentrations obtained during WY2006 were collected from the northern WCAs and declined throughout WCA-3 and the Park. During WY2006, 45.0 percent of the monitoring sites in WCA-2 had annual geometric mean TP concentrations of 10.0 µg/L or less, with an increase to 90.9 percent in the Park (**Figure 3C-3**). Likewise, 60 percent of interior sites within WCA-2 had annual geometric mean TP concentrations of 15.0 µg/L or less for WY2006, with an increase to 100 percent in the Park.

As previously noted, the only site in the Park exhibiting an annual geometric mean TP concentration above 10 µg/L for WY2006 was station P36, where an exceptionally high measurement of 291 µg/L measurement was collected in May 2005. This unusually high measurement was made during a low water period and may not be representative of ambient conditions. Without this single measurement, the site geometric mean is well below 10 µg/L.

During WY2006, geometric mean TP concentrations exceeded 10 µg/L (with a range from 10.3 to 19.8 µg/L) at only two sites, CA34 and P36, located in areas relatively uninfluenced by canal inflows (**Figure 3C-3**). None of the sites located in the relatively unimpacted portions of the EPA exhibited a geometric mean TP concentration above the 15-µg/L annual site limit specified in the TP criterion for individual sites. A more detailed, site-specific summary of the TP concentrations for WY2006 is provided in Appendix 3C-2. Calculated TP loads for individual water control structures within the EPA (EAA and non-ECP sites) are presented in Chapter 3C of the 2005 SFER – Volume I.

Over the entire EPA (all areas and site classifications), approximately 86.6 percent of the TP measurements collected during WY2006 were below 50.0 µg/L, 58.6 percent were below 15.0 µg/L, and 42.6 percent were at or below 10.0 µg/L. In comparison, TP concentrations in 84.5 percent of the samples were less than 50.0 µg/L, with 50.3 percent being at or below 15.0 µg/L, and 31.2 percent of the measured concentrations were at or below 10.0 µg/L during WY2005, when phosphorus levels were affected by extreme climatic conditions.

The distribution of TP concentrations in samples collected at inflow, interior, and outflow stations from each EPA region for WY2006 is presented in **Figure 3C-4**. By far, inflow stations to the Refuge had the highest percentage of measurements above 50.0 µg/L (84.7 percent) during WY2006. In contrast, less than 0.5 percent of the TP measurements at the Park inflow sites were above 50.0 µg/L, with 74.8 percent below 10.0 µg/L. Likewise, WCA-2, the most highly phosphorus-enriched area, exhibited the lowest percentage of samples from interior sites at or below 10.0 µg/L (45.1 percent), while 67.7 and 71.4 percent of samples collected from the interior of the Refuge and WCA-3, respectively, had TP concentrations of 10.0 µg/L or below. Additionally, more than 85 percent of the samples collected in the interior of the Park had TP concentrations of 10.0 µg/L or less.

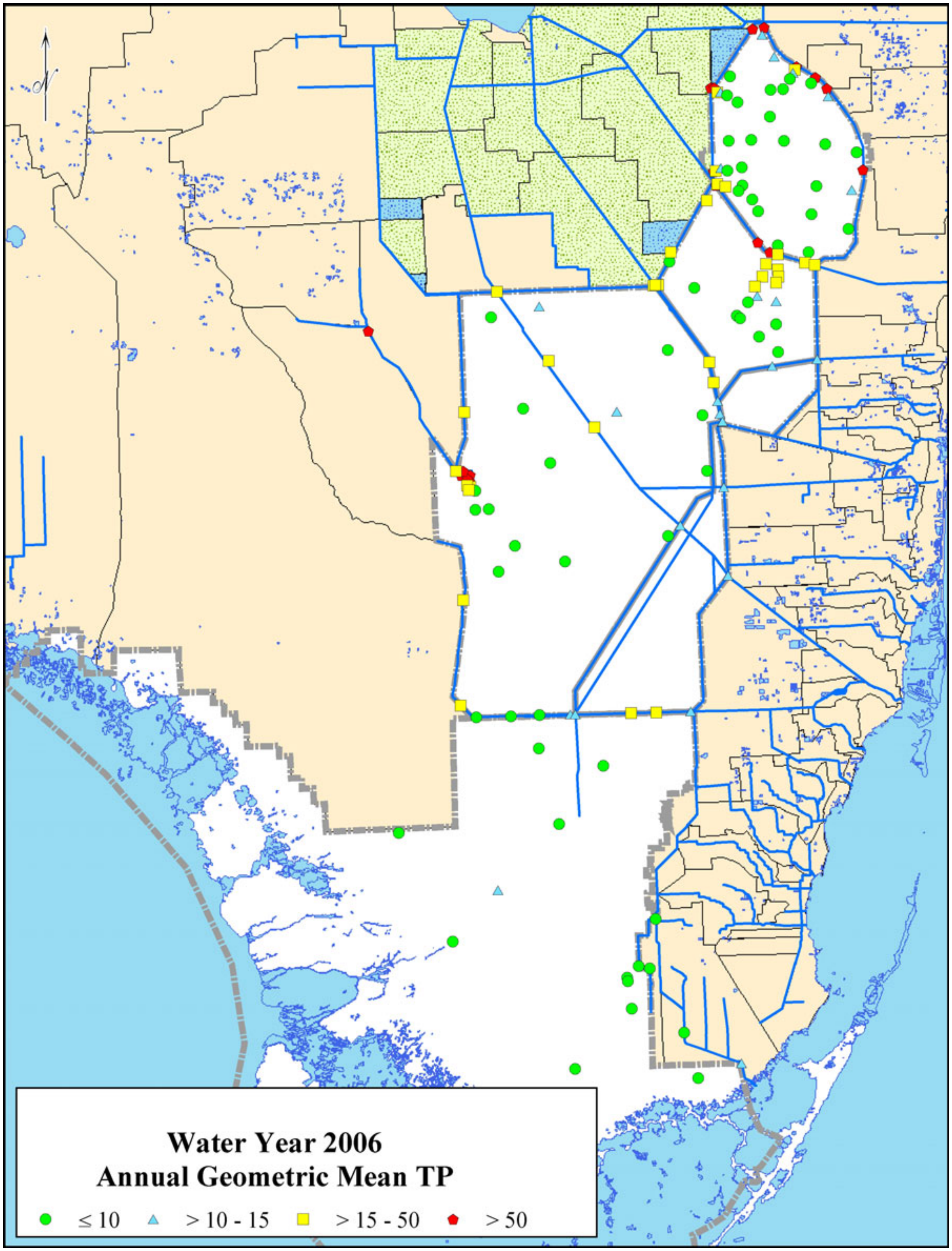

Figure 3C-3. Summary of geometric mean TP concentrations (µg/L) for WY2006 at stations across the EPA. Geometric mean TP concentrations are classified utilizing four levels: ≤ 10 µg/L, 10–15 µg/L, 15–50 µg/L, and > 50 µg/L.

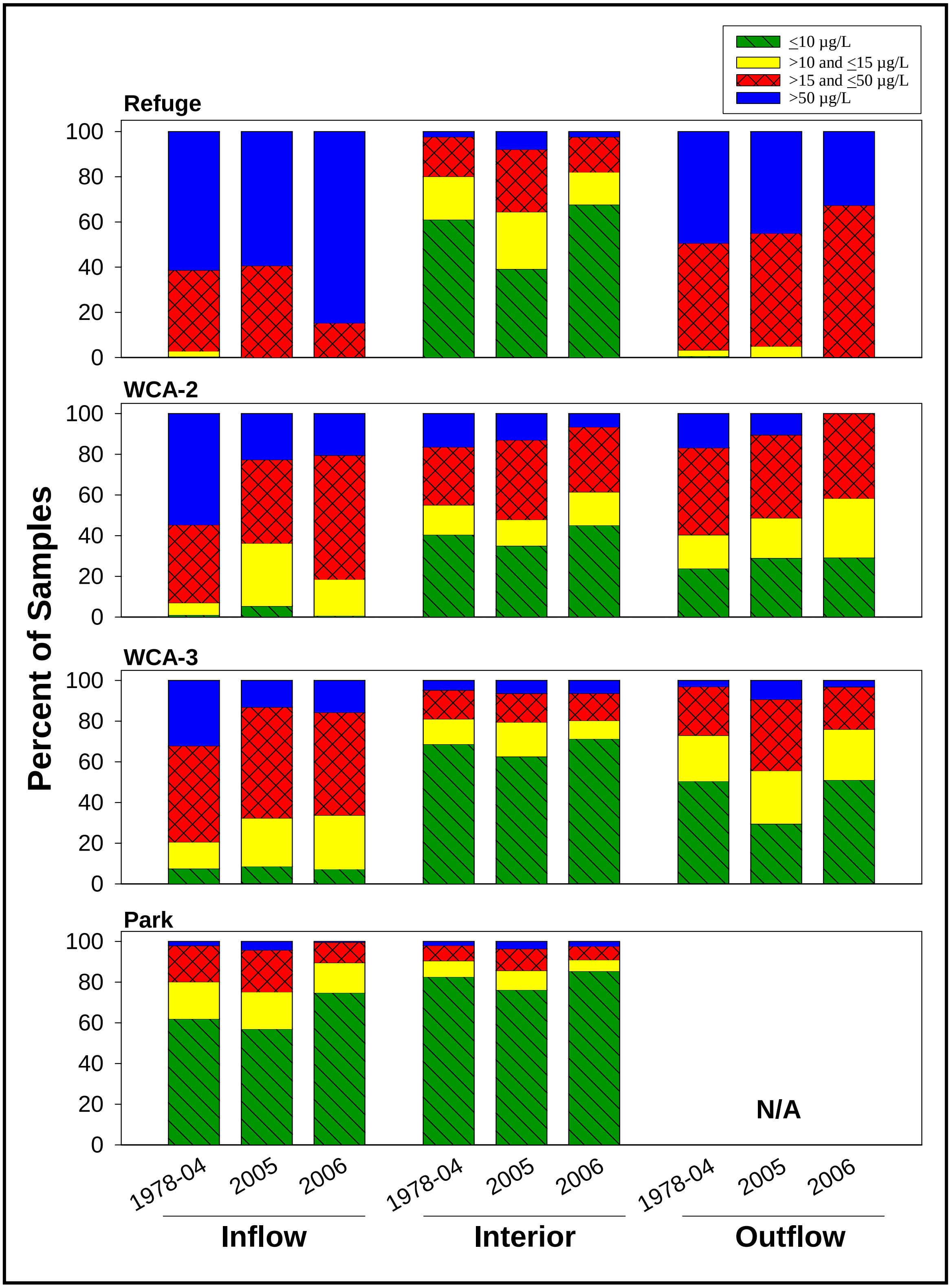

Figure 3C-4. Comparison of TP concentrations (µg/L) measured in samples collected in the EPA during WY2006, WY2005, and the WY1978–WY2004 period. N/A = Not available. Outflow is not monitored for the Park.

Figure 3C-4 also provides a comparison of the concentrations measured in samples collected during WY2006 to the levels reported for WY2005 and the WY1978–WY2004 period. In general, TP levels for WY2006 across all areas and classes of sites, except inflows to the Refuge, were similar to or lower than those for WY2005 and were within the range exhibited during the period.

TP concentrations observed during WY2005 were strongly influenced by the extreme climatic conditions experienced during 2004 and 2005, from periods of low rainfall to the passing of multiple hurricanes. Low rainfall conditions and subsequent marsh dry-out resulted in elevated phosphorus levels at interior sites, while the more intense rainfall caused peak inflow concentrations, which were not reflected at the interior marsh sites.

During WY2006, TP levels for both inflow (except for inflows to the Refuge) and interior sites returned to more stable (pre-WY2005) levels after typical climatic and hydrologic conditions were restored. This suggests that no long-lasting impacts from the highly fluctuating conditions experienced during WY2005 have occurred. The WY2006 geometric mean TP concentration for the Refuge inflows increased beyond WY2005 levels and likely resulted from the multiple factors previously mentioned. Future SFERs are expected to continue to track long-term trends in phosphorus levels throughout the EPA.

PHOSPHORUS LOADS TO THE EVERGLADES PROTECTION AREA

The EPA is a complex system of marsh areas, canals, levees, and inflow and outflow water control structures covering almost 2.5 million acres. In addition to rainfall inputs, surface water inflows regulated by water control structures from agricultural tributaries, such as the EAA and the C-139 basin, feed the EPA from its 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 water inflows from the tributaries to the EPA are based on a complex set of operational emergency management decisions that account for environmental system requirements, water supply for urbanized and natural areas, aquifer recharge, and flood control.

Each year, the EPA receives variable amounts of surface water inflows based on the hydrologic variability within the upstream basins. These inflows, regulated according to the above-mentioned operational decisions, also contribute a certain amount of TP loading into the EPA. Detailed estimates of TP loads by structure are presented in **Table 3C-3**. This table summarizes contributions from all connecting tributaries to the EPA: Lake Okeechobee, the EAA, the C-139 basin, other agricultural and urbanized areas, and the STAs. In some cases, surface water inflows represent a mixture of water from several sources as the water passes from one area to another before being received by the EPA. For instance, water discharged from Lake Okeechobee can pass through the EAA and then through an STA-3/4 before entering into the EPA. Similarly, runoff from the C-139 basin can pass through STA-5 and then into the EAA before ultimately entering into the EPA.

It is also recognized that a certain amount of TP loading into the EPA is derived from atmospheric deposition. The long-term average range of atmospheric deposition of TP is between 107 and 143 metric tons (mt) per year as the total contribution to the WCAs. Deposition rates are highly variable and very expensive to monitor and, therefore, atmospheric inputs of TP are not routinely monitored. The range (20–35 $mg/m^2/yr$) used in this report is based on data obtained from long-term monitoring reported in Redfield (2002).

Table 3C-3. WY2006 summary of flow and TP by structure.*

Into STA1 Inflow Basin

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S5A_P	209.017	56887	221
S5A from EAA	180.161	44535	
S5Afrom East Beach	14.582	8732	
S5A from Lake	13.679	3541	
S5AW from Lake	0.933	169	
S5AW from L8 Basin	0.236	43	
Mass Balance Addjustment	-0.574	-133	
S5AS	6.021	1344	**181**
S5AS from Lake	4.606	1028	
S5AS from L8 Basin	1.415	316	
G300	0.006	2	280
G301	0.140	26	148
G311	13.800	4066	239
Total	**228.984**	**62324**	**221**

From STA1 Inflow Basin

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S5AS	13.078	2754	**171**
from EAA	10.363	1993	
from East Beach	0.839	391	
from Lake	1.105	212	
from L8 Basin	0.095	16	
from WCA-1	0.008	1	
Mass Balance Addjustment	0.667	141	
G300	20.682	6042	**237**
G301	26.126	7965	**247**
G302	142.68	37415	213
from EAA	113.058	27075	
from East Beach	9.151	5308	
from Lake	12.060	2880	
from L8 Basin	1.036	218	
From WCA1	0.092	17	
from G311	8.660	2472	
Mass Balance Adjustment	-1	-556	**327**
G311	24.796	7367	**241**
from EAA	19.648	5331	
from East Beach	1.590	1045	
from Lake	2.096	567	
from L8 Basin	0.180	43	
From WCA1	0.016	3	
from G311	1.505	487	
Mass Balance Adjustment	0	-109	
Total	**227.359**	**61543**	**219**

Into WCA1

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
G300 & G301	46.808	14007	243
from EAA	36.828	10009	
from East Beach	2.981	1962	
from Lake	3.928	1065	
from L8 Basin	0.337	81	
From WCA1	0.030	6	
from G311	2.821	914	
Mass Balance Adjustment	-0.117	-30	
S362 (from STA-1E)	40.540	7292	146
from EAA	31.896	5211	
from East Beach	2.582	1022	
from Lake	3.402	554	
from L8 Basin	0.292	42	
From WCA1	0.026	3	
from G311	2.443	476	
Mass Balance Adjustment	-0.102	-16	
G251 (from STA-1W)	34.187	4533	107
from EAA	26.898	3239	
from East Beach	2.177	635	
from Lake	2.869	345	
from L8 Basin	0.246	26	
From WCA1	0.022	2	
from G311	2.060	296	
Mass Balance Adjustment	-0.086	-10	
G310 (from STA-1W)	103.703	14732	115
from EAA	81.592	10527	
from East Beach	6.604	2064	
from Lake	8.703	1120	
from L8 Basin	0.748	85	
From WCA1	0.066	7	
from G311	6.250	961	
Mass Balance Adjustment	-0.260	-31	
ACME1 (from Basin B)	14.161	1403	80
ACME2 (from Basin B)	12.767	1832	116
Total	**252.167**	**43,799**	**141**

From WCA1

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S10A	35.118	1126	26
S10C	25.267	1594	51
S10D	57.178	8574	122
S39	57.106	2610	37
G300	0.006	2	280
G301	0.140	26	148
G94A	0.002	1	515
G94B	7.558	373	40
G94C	24.179	1371	46
Total	**206.553**	**15677**	**62**

* Due to the EAA boundary changes during WY2005, the total flows and loads to the EPA from the EAA in this table do not represent the EAA model reported total value. Some calculations are based on proportional distribution assumptions and data are subject to review.

Table 3C-3. Continued.

Into WCA2

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
G335 (from STA-2)	322.303	8238	21
S7	456.691	10841	19
from STA 3/4	*304.736*	*46089*	[1]
From Lake O	23.917	7756	
from EAA	234.731	29520	
From C-139	11.987	3787	
From STA-5	20.894	2599	
From SFCD	7.398	1454	
From SSDD	5.810	974	
From diversion (G371)	*4.044*	*395*	
from Lake O	*4.044*	*395*	
from EAA	*0.000*	*0*	
STA3/4 reduction		*-25732*	[2]
Mass Balance Adjustment	*147.910*	*-9911*	
S10A (from WCA1)	35.118	1126	26
S10C (from WCA1)	25.267	1594	51
S10D (from WCA1)	57.178	8574	122
N. Springs Improv. District	0.000	0	n/a
Total	**896.557**	**30373**	27

From WCA2

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S7	0.042	1	29
S11A (from WCA2)	493.520	8454	14
S11B (from WCA2)	153.30	1875	10
S11C (from WCA2)	98.357	1529	13
S38	199.216	2461	10
S34	187.299	3045	13
Total	**1131.732**	**17365**	**12**

Table 3C-3. Continued.

Into WCA3

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S140 (from L28 Canal)	203.575	12507	50
S190 (from Feeder Canal)	150.359	28717	155
L3 Borrow Canal (from C139-G409)	78.545	43306	447
STA6	26.312	848	26
S8	447.46	16964	31
From STA3/4	*298.577*	*45158*	
From Lake O	23.433	7599	
From EAA	*229.987*	*28923*	
From C-139	11.744	*3710*	
From STA-5	*20.472*	*2546*	
From SFCD	*7.249*	*1425*	
From SSDD	*5.692*	*955*	
From diversion (G373)	*57.337*	*6519* [3]	
From Lake O	*6.968*	*1285*	
From EAA	*11.529*	*927*	
From C-139	1.648	*531*	
From STA-5	*36.462*	*3676*	
From SFCD	*0.004*	*1*	
From SSDD	*0.725*	*100*	
From Rotenberger	*0.922*	*48*	
From Lake O	*0.373*	*14*	
From EAA	*0.080*	*1*	
From C-139	*0.000*	*0*	
From STA-5	*0.462*	*33*	
From SFCD	*0.000*	*0*	
From SSDD	*0.006*	*0*	
G204/G205/G206 (from Holey Land)	*1.726*	*41*	
STA5	90.710	10218	
STA3/4 reduction		*-45655*	
Mass Balance Adjustment	*-1.811*	*634*	
S150	38.35	749	16
from STA 3/4	*25.590*	*3870*	
From Lake O	*2.008*	*651*	
From EAA	*19.711*	*2479*	
From C-139	*1.007*	*318*	
From STA-5	*1.755*	*218*	
From SFCD	*0.621*	*122*	
From SSDD	*0.488*	*82*	
From diversion (G371)	*0.340*	*27*	
from Lake O	0.340	*27*	
from EAA	0.000	*0*	
STA3/4 reduction		-1778	
Mass Balance Adjustment	*12.419*	*-1370*	
G404 & G357	104.022	4598	36
From STA3/4	*69.411*	*10498*	
From Lake O to G409	5.448	1766	
From EAA	*53.466*	*6724*	
From C-139	2.730	*863*	
From STA-5	*4.759*	*592*	
From SFCD	*1.685*	*331*	
From SSDD	*1.323*	*222*	
From diversion (G373)	13.329	1767 [3]	
From Lake O	*1.620*	*348*	
From EAA	*2.680*	*251*	
From C-139	*0.383*	*144*	
From STA-5	*8.477*	*996*	
From SFCD	*0.001*	*0*	
From SSDD	*0.169*	*27*	
From Rotenberger	*0.214*	*13*	
From Lake O	*0.087*	*4*	
From EAA	*0.019*	*0*	
From C-139	*0.000*	*0*	
From STA-5	*0.107*	*9*	
From SFCD	*0.000*	*0*	
From SSDD	*0.002*	*0*	
STA5	21.088	2770	
STA3/4 reduction		*-9736*	
Mass Balance Adjustment	*-0.020*	*-714*	
S11A (from WCA2)	493.520	8454	14
S11B (from WCA2)	153.30	1875	10
S11C (from WCA2)	98.357	1529	13
G123 (from N. New River)	0.000	0	n/a
S9 (from C-11 West)	128.470	3055	19
S9A (from C-11 West)	61.345	1207	16
Total	**1983.612**	**123809**	**51**

From WCA3

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S150	0.000	0	n/a
S8	0.000	0	n/a
S31	110.317	1569	12
S337	38.388	803	17
S343A	50.879	639	10
S343B	51.527	641	10
S344	24.583	363.87	12.00
S12A	201.959	1857	7
S12B	214.994	1751	7
S12C	425.980	3692	7
S12D	421.622	5712	11
S333[4]	169.686	3115	15
S355A/S355B	1.821	19.9	9
Total	**1711.758**	**20163**	**10**

Table 3C-3. Continued.

Into Everglades National Park

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S12A (from WCA3)	201.959	1857	7
S12B (from WCA3)	214.994	1751	7
S12C (from WCA3)	425.980	3692	7
S12D (from WCA3)	421.622	5712	11
S-333-S334 (from WCA3)[5]	42.480	785	15
S355A/S355B (from WCA3)	1.821	19.9	9
S174 (from L-31W)	9.203	156	14
S332D	153.803	2055	11
S18C	188.505	3298	**14**
Total	**1660.368**	**19326**	**9**

From ENP

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S197	65.837	4726	58
Total	**65.837**	**4726**	**58**

FWMC = flow-weighted mean concentration

[1] The values are proportionally calculated based on summation of EAA model outputs of S7 and S8 Basins.

[2] The values are proportionally calculated based on STA3/4 treatment.

[3] The values are proportionally calculated based on Sutron Report and EAA model outputs.

[4] The value included S334 from WCA3.

[5.] Flow was calculated using S333-S334 and TP load was calculated using concentrtion at S333 and flow of S333-S334.

Comparison of WY2006 Phosphorus Loads to the WY1979–WY1988 Baseline

For this overview of WY2006 phosphorus loading into the EPA, the period from October 1, 1978 through September 30, 1988 (WY1979–WY1988) has been identified as a comparative baseline period (known as the 1979–1988 baseline period) for various planning purposes, including the Surface Water Improvement and Management Act Plan for the Everglades (SFWMD, 1992a; 1992b; 1992c), the design of the Everglades Construction Project, the federal Settlement Agreement (Case No. 88-1886-CIV-MORENO), and EFA Section 373.4592, Florida Statutes (F.S.), as amended. During this 10-year period, annual TP loads in surface water inflows to the EPA ranged from approximately 100 mt to over 350 mt, with an average of 270 mt (SFWMD, 1992c). Included in this 270-mt annual average were approximately 205 mt to the WCAs from the EAA, Lake Okeechobee, and the L-8 and C-51W basins through the S-5A, S-6, S-7, S-150, and S-8 structures. This 205-mt annual average for this 10-year baseline period was the basis of design for the four original STAs of the Settlement Agreement. During the WY1979–WY1988 baseline period, TP loads in surface water inflows to the Refuge ranged from approximately 40 mt to over 150 mt per year, with a 10-year average of about 110 mt per year (SFWMD, 1992a; 1992b). Included in this 110-mt annual average were approximately 105 mt from the EAA, Lake Okeechobee, and the L-8 and C-51W basins through the S-5A and S-6 pump stations. This 105-mt annual average for the 10-year baseline period to the Refuge was the basis of design for the original design of STA-1 and STA-2 of the Settlement Agreement.

Appendix C of the Settlement Agreement identifies several assumptions which, when combined in series, are expected to yield approximately an 80 percent reduction of TP loads from the EAA to the WCAs. These assumptions are as follows:

1. The EAA BMPs will achieve 25 percent load reduction.
2. Water retention due to implementation of EAA BMPs will equal 20 percent of the 10-year base flow.
3. The STAs will achieve 70 percent load reduction.
4. A further load reduction of 6 percent was assumed by conversion of existing agricultural land to STAs.

Because no long-term performance results for BMPs and STAs at this scale were available, these assumptions were based on the best professional judgment at the time (1991) that the technical group developed the load reduction estimates. For the WY1994–WY2006 period, the actual BMP reduction was approximately 50 percent, or twice the assumed reduction (i.e., 25 percent). The water retention due to implementation of EAA BMPs has averaged about 5 percent, much less than assumed, while the STAs have achieved the assumed reduction of 70 percent. It is not possible to compare the actual load reduction attributable to conversion of lands to STAs, although the 6 percent compares relatively well with the percent of land taken out of production. For modeling purposes associated with Appendix C of the Settlement Agreement, the historical load and flow from each basin were reduced to account for low-flow water supply deliveries from Lake Okeechobee, that is, canal flows that do not impact WCA marshes. The STAs were then sized to achieve a long-term annual flow-weighted mean concentration of 50 parts per billion (ppb) at each inflow point. Accomplishment of the 50-ppb objective was assumed to provide the load reduction of approximately 80 percent from the EAA into the EPA. Using the loads that occurred during the baseline period (WY1979–WY1988) and the Appendix C assumptions, the anticipated 10-year average load equating to this 80 percent reduction is approximately 40.2 mt from the EAA to the WCAs.

Similarly, the Settlement Agreement also envisions an approximate 85 percent reduction of phosphorus loads from the EAA to the Refuge, if the STAs achieve a long-term annual flow-weighted mean concentration of 50 ppb. Using the loads that occurred during the baseline period (1979–1988) and the Appendix C assumptions, the anticipated 10-year average load equating to this 85 percent reduction is approximately 15.5 mt from the EAA to the Refuge.

In 2002, the Technical Oversight Committee (TOC) established, pursuant to the Settlement Agreement, a methodology developed by Walker (1996) for reviewing the load reductions based on annual TP concentrations of water entering the WCAs and the Refuge. The TOC-established methodology assumes compliance with the reduction requirements unless the annual phosphorus inflow concentration to the WCAs (and the Refuge) from the EAA and bypassed flows is greater than 76 ppb in any water year or is greater than 50 ppb in three or more consecutive water years (Walker, 1996). Compliance will not be tested in water years when the EAA adjusted annual rainfall is above 63.8 inches, as defined in the criterion rule provided in Chapter 40E-63 F.A.C. (http://fac.dos.state.fl.us/faconline/chapter40.pdf). Compliance will also not be tested in water years when the EAA adjusted rainfall is below 35.1 inches, if sufficient water is not available to maintain wet conditions in the STAs.

The following discussion is intended simply as a general presentation of relevant water year load data as required by the TOC on an ongoing basis. It does not substitute for TOC compliance review activities, which are described on the District's website (www.sfwmd.gov) under the *What We Do, Environmental Monitoring, Technical Oversight Committee* section.

EFA Section 373.4592, F.S., and the Settlement Agreement require the construction and operation of STAs to achieve compliance with state water quality standards. The initial design goal was a long-term flow-weighted mean total phosphorus concentration of 50 ppb or less at points of discharge from the STAs to the EPA. This was a technology-based effluent limitation (TBEL) in accordance with the EFA. It was assumed that the initial 50-ppb TBEL would be revised, consistent with the iterative adaptive implementation of Best Available Phosphorus Reduction Technology being implemented through the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) under the EFA (Burns & McDonnell 2003; SFWMD, 2004; 2005). Through this process, the TBEL will be revised as appropriate until discharges achieve compliance with the 10-ppb TP criterion within the EPA in accordance with Chapter 62-302.540, F.A.C.

A methodology for determining achievement of the initial 50-ppb TBEL was first derived by Walker (1996). This 1996 methodology estimated the year-to-year variability in performance of the STAs above and below the 50-ppb TBEL, based on the variability of phosphorus concentrations at inflows to the EPA at that time. Phosphorus outflow data from STA-1W, 2, 5, and 6 were used to update and refine the estimated year-to-year variability in performance above and below the initial 50-ppb TBEL (Nearhoof et al., 2005).

TP loads to the EPA during WY2006 were significantly lower than the WY1979–WY1988 baseline period, due primarily to the effectiveness of the EAA BMPs and STAs. As shown in **Table 3C-3**, TP loads from surface sources to the EPA totaled approximately 175.6 mt, with a flow-weighted mean concentration of 56 ppb. Another 193 mt of TP is estimated to have entered the EPA through atmospheric deposition. Surface discharges from the EPA account for approximately 18.6 mt. The 175.6-mt surface water inflow is an almost 19.0 percent increase from the previous year (147.5 mt) due to an 11.8 percent flow increase in WY2006 over WY2005, i.e., 2,555,272 acre-feet (ac-ft) compared with 2,285,580 ac-ft, respectively. It should be recognized that not all of this load came from the EAA. Based on TOC-approved methodology, phosphorus loads to the WCAs from the EAA were calculated as:

1. A proportion of STA-1W, STA-1E, STA-2 and STA-3/4 discharges, adjusted to reflect contributions from non-EAA sources: STA-1W and STA-1E (85 percent from EAA), STA-2 (98 percent from EAA), and STA-3/4 (75 percent from EAA)
2. STA-6 discharges
3. Direct EAA discharges from the S-7, S-8, S-150, G-300, G-301, S-362, and G-404/G-357 structures

Phosphorus loads to the WCAs from the EAA during WY2006 totaled about 112.7 mt, higher than those for WY2005 (62.7 mt), due to the extraordinary flows and loads associated with the 2005 hurricanes. The 3-year average load to the WCAs from the EAA is about 72.1 mt, which is higher than the expected 10-year average of 40.2 mt. STA-1E was in flow-through operations during WY2006.

The flow-weighted mean TP concentration entering the WCAs from the EAA, STA-1W, STA-1E, STA-2, STA-3/4, STA-6, and bypass flows during WY2006 was approximately 36 ppb, which is below the annual maximum of 76 ppb established by the TOC methodology.

TP loads from all sources to the Refuge during WY2006 totaled approximately 43.8 mt, which is an almost 49 percent lower than the loads during the previous year (86.1 mt). The TP load to the Refuge from the STAs plus bypass during WY2006 was approximately 40.6 mt, including more than 14 mt that were directly diverted into the Refuge because STA-1E was only receiving flow in the western flow-way and two-thirds of the STA-1W flow-ways were offline. The flow-weighted mean TP concentration for WY2006 from STA-1W into the Refuge was 107 ppb at G-251 and 115 ppb at G-310; the 10-year (WY1995–WY2005) flow-weighted mean TP concentration from STA-1W into the Refuge was 38 ppb at G-251, 24 percent lower than the 50-ppb objective in the Settlement Agreement. The 6-year (WY2000–WY2005) flow-weighted mean TP concentration from STA-1W into the Refuge was 64 ppb at G-310, 28 percent higher than the 50-ppb objective in the Settlement Agreement. The flow-weighted mean TP concentration for WY2006 from STA-1E into the Refuge was 146 ppb at S-362. The flow-weighted mean TP concentration entering the Refuge from the EAA, STA-1W, STA-1E, and bypass flows during WY2006 was approximately 146 ppb, which is above the annual maximum of 76 ppb established by the TOC methodology and higher than the 140 ppb observed during WY2005.

Everglades Protection Area Phosphorus Criterion Achievement Assessment

The TP criterion rule for the EPA has been fully approved at both the state and federal levels, receiving final approval from the USEPA in July 2005. As noted earlier this year's chapter provides a template to provide a consistent framework for future TP criterion assessments for individual regions in the EPA.

The evaluation to determine achievement of the TP criterion was conducted based on the four-part test specified in the TP criterion rule, using the available data from existing sites from various monitoring programs for the WY2002–WY2006 period. Appendix 3C-2 of this volume presents existing monitoring sites used in this assessment and their classification as impacted or unimpacted in accordance with the TP criterion rule. The location of these sites is provided in the maps of the overall monitoring program provided in Chapter 3A of this volume (Figures 3A-2 through 3A-4). It should be noted that the available data are limited for certain portions of the EPA and additional monitoring sites are being considered to expand the existing monitoring networks. Because the results of the TP criterion compliance assessment presented in this chapter could be affected by this data limitation, the results of this evaluation should be interpreted with caution.

The TP criterion rule specifies that while the Settlement Agreement 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 flow-weighted mean 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 SFWMD and reported on a quarterly basis to satisfy other mandates, and therefore are not replicated here. The quarterly Settlement Agreement reports prepared by the SFWMD can be found at http://www.sfwmd.gov/org/ema/reports/settlement/.

In addition to establishing the numeric TP criterion for the EPA, the TP criterion rule (Section 62-302.540, F.A.C.) also provides a four-part test to be used to determine achievement of the numeric TP criterion. The following four components of the assessment test must be achieved for a water body to be considered to comply with the TP criterion:

	Component	***TP Criterion Achievement Value***	***Noted Herein As***
1.	Five-year geometric mean TP concentration averaged across the monitoring network	10 µg/L or less	five-year network limit
2.	Annual geometric mean TP concentration averaged across all stations	10 µg/L or less for three out of each five years	multi-year network limit
3.	Annual geometric mean TP concentration averaged across all stations	11 µg/L or less	annual network limit
4.	Annual geometric mean TP concentration at all individual monitoring stations	15 µg/L or less	annual site limit

The results of the preliminary evaluation to assess achievement of the TP criterion using available data for WY2002–WY2006 are provided in Appendix 3C-3. The results of this assessment indicate that the unimpacted portions of each conservation area passed all four parts of the compliance test as expected and therefore are 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 but in no case did the values for the individual unimpacted sites cause an exceedance of the annual or long-term network limits. During WY2006, none of the annual geometric mean TP concentrations for the individual sites exceeded the 15 µg/L annual site limit and during the WY2002–WY2006 period, only one exceedence of the 15-µg/L annual site limit occurred at an unimpacted site. The single exceedance (19.8 µg/L) occurred at station X4 in the Refuge during WY2005 when TP levels throughout the EPA were elevated due to climatic extremes as discussed in detail in the 2006 SFER (Payne et al., 2006). Of the more than 125 TP measurements collected at station X4 since it was established in 1996, the highest value (130 µg/L) was observed on March 10, 2005, when water levels were increasing following a dry period with low water stage in the marsh. This highly elevated value is nearly nine times the five-year average for this site and much higher than the TP concentration in the inflows and surrounding sites during this period. Because this site is not located near any anthropogenic inputs, the high measurement likely reflects the effects of the low water levels during this period and/or the difficulty in collecting a representative sample during periods of low water level. During WY2006, the TP concentrations measured for station X4 returned to more typical levels, with an annual geometric site mean less than 10 µg/L. It is expected that changes in TP concentrations at station X4 and other sites throughout the marsh will continue to be tracked in future SFERs.

In contrast, the impacted (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 water conservation areas consistently exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively. Occasionally, selected individual sites within the impacted areas exhibited annual geometric mean TP concentrations below the 15 µg/L annual site limit. Rarely, the annual mean for individual impacted sites was below 10 µg/L; however, none of the impacted sites was consistently below the 10 µg/L long-term limit.

Future TP criterion achievement assessments conducted with more robust datasets are expected to provide a better understanding of phosphorus concentrations in the EPA.

TOTAL NITROGEN

The concentration of total nitrogen (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 SFER were calculated only for samples for which both TKN and NO_3+NO_2 results were available.

Table 3C-4 provides a summary of the TN concentrations measured in the different portions of the EPA during WY2006, WY2005, and the WY1978–WY2004 period. As in previous years, TN concentrations during WY2006 exhibited a general north-to-south spatial gradient across the EPA. This gradient likely reflects the higher concentrations associated with agricultural discharges to the northern portions of the system. A gradual reduction in TN levels results from assimilative processes in the marsh as water flows southward. The highest average TN concentrations were observed in the inflows to the Refuge and WCA-2, and decreased to a minimum concentration in the Park.

Average total nitrogen concentrations measured during WY2006 at both inflow and interior sites in all areas of the EPA, except in the inflows to the Refuge, were generally comparable to but slightly lower than the values for either WY2005 or the WY1978–WY2004 period. This is likely due to the more stable conditions experienced in the marsh over the water year, particularly as a result of less direct hurricane impacts and marsh dry-out in the EPA, as well as the continued effectiveness of agricultural Best Management Practices and continued nutrient removal by the Stormwater Treatment Areas

The average nitrogen concentration for the inflows to the Refuge during WY2006 is higher than the level for WY2005, but within the historic range. The slightly elevated inflow concentrations during WY2006 may be caused by several factors including reduced nutrient removal effectiveness of STA-1W caused by physical damage to the vegetative communities within the STA following the passage of Hurricane Wilma in October 2005; and efforts to lower water levels in Lake Okeechobee following the damage resulting from the 2004 and 2005 hurricanes.

During WY2006, mean TN concentrations at inflow stations ranged from 0.99 mg/L in the Park to 2.40 mg/L in the Refuge, and median TN concentrations ranged from 0.94 to 2.45 mg/L. Similarly, mean TN concentrations at the interior marsh stations during WY2006 ranged from 1.22 in Park to 2.23 mg/L in WCA-2, with median concentrations ranging from 1.11 to 2.10 mg/L.

Table 3C-4. Summary of total nitrogen concentrations (mg/L) measured in the EPA during WY2006, WY2005, and WY1978–WY2004.

Region	Class	Period	Sample Size (N)	Arithmetic Mean (mg/L)	Std. Deviation	Median (mg/L)	Min. (mg/L)	Max. (mg/L)
Refuge	Inflow	1978–2004	2862	3.40	2.28	2.78	0.25	48.23
		2005	74	2.16	0.53	2.12	1.19	4.11
		2006	79	2.40	0.72	2.45	0.99	5.17
	Interior	1978–2004	2246	1.61	1.21	1.33	0.45	36.71
		2005	221	1.56	0.71	1.40	0.71	6.41
		2006	235	1.28	0.43	1.20	0.54	2.65
	Outflow	1978–2004	1323	2.60	1.61	2.19	0.25	22.84
		2005	50	2.07	0.75	1.88	1.25	4.88
		2006	49	2.07	0.93	1.83	1.07	5.52
	Rim	1978–2004	710	2.70	1.40	2.31	0.68	10.91
		2005	38	2.17	0.55	2.06	1.51	4.60
		2006	42	2.68	0.80	2.48	1.31	5.22
WCA-2	Inflow	1978–2004	2001	2.88	1.49	2.58	0.25	22.84
		2005	109	2.45	0.90	2.25	1.14	5.13
		2006	109	2.35	0.87	2.13	0.93	5.48
	Interior	1978–2004	4613	2.45	1.58	2.20	0.25	37.17
		2005	187	2.36	0.65	2.21	1.08	6.27
		2006	260	2.23	0.66	2.10	1.10	6.10
	Outflow	1978–2004	1590	2.11	0.84	1.93	0.25	7.65
		2005	68	1.91	0.37	1.96	1.09	2.90
		2006	96	1.86	0.48	1.80	0.94	3.93
WCA-3	Inflow	1978–2004	5038	2.01	1.00	1.75	0.25	10.80
		2005	249	1.68	0.40	1.68	0.98	3.30
		2006	270	1.59	0.53	1.49	0.83	6.11
	Interior	1978–2004	2276	1.47	0.80	1.26	0.25	10.01
		2005	185	1.53	0.59	1.43	0.74	4.50
		2006	311	1.27	0.40	1.21	0.49	3.30
	Outflow	1978–2004	3326	1.40	0.66	1.31	0.25	14.86
		2005	128	1.25	0.38	1.17	0.53	2.70
		2006	104	1.13	0.26	1.14	0.65	1.71
Park	Inflow	1978–2004	3828	1.27	0.69	1.19	0.25	14.86
		2005	150	1.12	0.40	1.11	0.49	2.70
		2006	123	0.99	0.28	0.94	0.55	1.71
	Interior	1978–2004	1572	1.32	1.38	1.13	0.25	40.84
		2005	80	1.38	0.86	1.20	0.47	4.90
		2006	64	1.22	0.98	1.11	0.53	7.68

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