Chapter 2C: 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 natural ecosystem. The primary purposes of this chapter are to provide an update regarding the establishment of a numeric phosphorus criterion for the Everglades Protection Area (EPA), and to present an overview of the status of phosphorus and nitrogen levels in the surface waters within the EPA during Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005).

TOTAL PHOSPHORUS CRITERION

Given the importance of phosphorus in controlling the natural biological communities, the Florida Department of Environmental Protection (FDEP) has used the results of extensive research to numerically interpret the existing narrative nutrient criterion, as directed by the Everglades Forever Act (EFA), and develop a total phosphorus (TP) criterion of 10 micrograms per liter (µg/L), or 10 parts per billion (ppb), for the EPA. The 10-µg/L TP criterion was approved by the Environmental Regulation Commission (ERC) during a hearing on July 8, 2003. Subsequent to the approval by ERC, both environmental and agricultural interest groups filed administrative challenges to the phosphorus criterion rule. Following discussions with the FDEP concerning the application of the rule, all parties except the Miccosukee Tribe of Indians and the Friends of the Everglades withdrew their challenges. To resolve the remaining challenges, an administrative hearing was held during the period from November 2003–January 2004. The final order filed by the Administrative Law Judge on June 17, 2004 upheld all parts of the proposed rule finding that the rule "is not an invalid exercise of delegated legislative authority" by the FDEP. Following the Administrative Law Judge's ruling, the proposed rule [Section 62-303.540, Florida Administrative Code (F.A.C.)] was filed with the Florida Secretary of State by the FDEP on June 25, 2004. Subsequent to this filing, the rule was submitted to the U.S. Environmental Protection Agency (USEPA) for approval. During January 2005, the USEPA approved all

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portions of the rule, except the use of the assessment methodology specified in Appendix B of the Settlement Agreement in the Federal Everglades lawsuit, Case No. 88-1886-CIV-Hoeveler, U.S., as modified by Omnibus Order entered in the case on April 27, 2001, to evaluate achievement of the criteria in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). The FDEP revised the rule to apply the same four-part test as applied in Water Conservation Areas 2 and 3 (WCA-2 and WCA-3) to access achievement of the criteria to the Refuge. The revised rule was presented to the ERC and received unanimous approval on April 7, 2005. The revised rule was then filed with the Florida Secretary of State during May 2005 and resubmitted to the USEPA for approval on June 3, 2005. The phosphorus criterion rule received final approval from the USEPA in July 2005. The FDEP is currently working with the SFWMD and other interested parties to establish the monitoring networks to determine compliance with the rule. Future evaluations of the phosphorus status in the EPA will be conducted in accordance with the requirements of the final phosphorus criterion rule.

With the exception of the change in assessment methodology for the Refuge as described above, the final phosphorus criterion rule for the EPA remains unchanged from that included as Appendix 2C-1 of the *2005 South Florida Environmental Report – Volume I* (SFER) (Payne et al., 2005).

TOTAL PHOSPHORUS CONCENTRATIONS WITHIN THE EVERGLADES PROTECTION AREA

Because the monitoring networks necessary to apply the phosphorus criterion have not been finalized, the achievement methodology associated with the phosphorus criterion was not fully applied to the current data provided in this chapter. However, some of the provisions for determining achievement of the criterion set forth in the rule are used to evaluate the status of phosphorus concentrations in the EPA presented in this chapter. It is anticipated that subsequent versions of this chapter in future South Florida Environmental Reports will evaluate achievement of the criterion consistent with the requirements of the final phosphorus criterion rule. To provide an overview of the current nutrient status in the Everglades and to evaluate temporal and spatial patterns, TP concentrations measured during WY2005 are compared to both the limits set forth in the TP criterion and the levels found during previous monitoring periods.

As documented for previous years, TP concentrations measured during WY2005 exhibited a decreasing north-to-south gradient, with the highest levels present in the inflow to the Refuge and WCA-2, and with concentrations decreasing to a minimum within the Everglades National Park (ENP or Park). This gradient is indicative of the phosphorus-rich canal discharges, composed primarily of agricultural runoff originating in the Everglades Agricultural Area (EAA), entering the northern portions of the EPA with biogeochemical processes (e.g., settling, sorption, and biological assimilation), and resulting in decreasing concentrations as the water flows southward through the marsh.

Phosphorus concentrations measured across the EPA during WY2005 were affected by climatic extremes, including both multiple hurricanes with intense rainfall, and periods of little or no rainfall resulting in marsh dryout. Due to the effects of the extreme climatic conditions, annual TP concentrations measured during WY2005 were generally higher than those reported for WY2004 but were within the range observed during the WY1978–WY2003 historical period (**Table 2C-1**). TP concentrations at inflow and interior marsh sites generally responded differently to climatic and hydrologic changes. TP concentrations at inflow sites typically follow the rainfall pattern. That is, high rainfall amounts result in greater inputs of nutrient laden stormwater runoff, which in turn is reflected in peaks in phosphorus concentration at the inflow

Table 2C-1. Summary of total phosphorus (TP) concentrations (µg/L) in the Everglades Protection Area (EPA) for WY2005, WY2004, and WY1978–WY2003.

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	1978–2003	3107	66.9	2.3	72	2	1415
		2004	136	38.8	1.7	33	16	172
		2005	127	68.6	1.9	68	23	503
	Interior	1978–2003	2542	10.0	2.0	9	<2	494
		2004	252	9.3	1.8	9	<4	63
		2005	218	12.8	1.9	11	<4	180
	Outflow	1978–2003	1274	54.4	2.1	52	7	3435
		2004	65	31.7	2.1	29	10	381
		2005	57	53.8	2.4	47	11	515
	Rim	1978–2003	726	63.8	1.8	61	12	473
		2004	24	39.8	1.4	39	21	91.5
		2005	23	57.4	1.6	57	19	200
WCA-2	Inflow	1978–2003	2031	55.9	2.1	58	7	3435
		2004	165	24.0	1.9	23	9	91.5
		2005	166	26.6	2.3	19.8	8	196
	Interior	1978–2003	4971	16.8	3.1	13	<2	3189
		2004	255	11.8	2.5	11	<4	239
		2005	215	17.9	2.9	16	<4	530
	Outflow	1978–2003	1521	20.4	2.5	19	<2	556
		2004	75	19.4	1.8	20	6	86
		2005	73	16.6	2.1	15	6	179
WCA-3	Inflow	1978–2003	5522	34.3	2.5	34	<2	1286
		2004	416	26.4	1.8	25	7	181
		2005	405	23.9	1.9	22.5	6	219
	Interior	1978–2003	2331	8.8	2.4	8	<2	438
		2004	355	7.6	2.4	6	<4	110
		2005	227	9.6	2.4	8	<4	340
	Outflow	1978–2003	4235	10.9	2.1	10	<2	593
		2004	217	10.5	1.5	10	<4	38
		2005	182	16.4	2.1	14	5	189
Park	Inflow	1978–2003	4973	9.1	2.1	9	<2	593
		2004	321	7.7	1.6	7	<4	51
		2005	259	10.3	2.2	9	<4	189
	Interior	1978–2003	1660	5.5	2.4	5	<2	1137
		2004	103	4.3	1.7	4	<2	22
		2005	79	5.1	2.4	4	<2	64

structures. During WY2005, the highest TP concentrations occurred during the period from June–October 2004, corresponding to high rainfall amounts received during the wet season and the passing of hurricanes Charley, Frances, and Jeanne. During periods of low rainfall, inflow TP concentrations are generally at their lowest.

In contrast, TP concentrations at the interior marsh sites do not reflect the peaks in inflow concentration and in fact exhibit a nearly opposite trend than observed for the inflows. During periods of high rainfall when inflow concentrations are maximized, the TP concentrations at interior marsh sites are generally low, probably due to dilution. In contrast, when rainfall amount is low for extended periods, the water levels in the marsh fall, and as the marsh dries and the sediment is exposed to oxidation, the nutrients stored in the peat are released. When the rains return after a dryout, the nutrients released by the oxidized sediments are captured in the water column until the concentrations are reduced by settling, biogeochemical sorption, and dilution. During WY2005, peak TP concentrations at interior sites generally occurred during May–June 2004, when at least portions of the marsh dried out and exposed sediments to oxidation followed by sufficient rainfall to transport the released nutrients from the oxidized sediment. In some areas of the EPA (especially WCA-2 and the Park), a second peak in marsh TP concentrations occurred during February–March 2005 as a result of water levels again falling and portions of the marsh being dry. It is also important to note that the marsh concentration during these peaks that occur following dryout are often much higher than observed in the inflow, and are more reflective of the intensity and duration of dryout, type of sediment, and historic loading rather than recent inflow levels. During periods not being influenced by the extreme climatic/hydrologic conditions, both inflow and marsh TP concentrations return to levels comparable to those experienced during WY2004, when low levels were recorded throughout the EPA. This quick recovery to previous levels suggests that the extreme conditions experienced during WY2005 did not result in any long-lasting impacts to the system. In addition, the concentration of soluble orthophosphate (OP) in WY2005 exhibited similar trends as observed for TP concentrations with OP levels generally being higher than WY2004 concentrations as a result of the extreme climatic and hydrologic events that occurred during the year.

During WY2005, inflow geometric mean TP concentrations ranged from a high of 68.6 µg/L for WCA-1, to a minimum of 10.3 µg/L for ENP, compared to ranges from 38.8 to 7.7 µg/L and 66.9 to 9.1 µg/L for WY2004 and the WY1978–WY2003 historical period, respectively. Likewise, geometric mean TP concentrations at interior sites during WY2005 ranged from a maximum of 17.9 µg/L for WCA-2, to a low of 5.1 µg/L for ENP, compared to ranges from 11.8 to 4.3 µg/L and 16.8 to 5.5 µg/L for WY2004 and the WY1978–WY2003 historical period, respectively.

The annual geometric mean TP concentration across interior marsh sites in WCA-3 and the Park remained below the respective 10 and 11 µg/L five-year and annual provisions for assessing achievement set forth in the final phosphorus criterion rule. The geometric mean for the interior marsh sites in WCA-1 and WCA-2 were slightly above the annual 11 µg/L provision (i.e., 12.8 and 17.6 µg/L, respectively) due to the impacts from the abnormal climatic events experienced during WY2005. As discussed, the higher marsh TP levels measured during WY2005 obviously reflect the extreme climatic and hydrologic conditions experienced during the year and not a general worsening of nutrient conditions in the marsh or a reversal of the general decreasing concentration trend reported in Chapter 2C of the 2005 SFER – Volume I.

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 WY2005. As for phosphorus, this 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 and WCA-2, with levels decreasing to a minimum in the Park.

Total nitrogen concentrations measured across all portions of the EPA during WY2005 were variable in comparison to those observed during previous years. Except for the Park, the mean inflow total nitrogen concentrations during WY2005 were the same or lower than those reported for WY2004. In contrast, total nitrogen concentrations at interior sites during WY2005 were higher than levels reported for WY2004 in all areas due to the effects of marsh dryout and the associated nutrient release resulting from sediment oxidation. Mean TN concentrations at inflow stations during WY2005 ranged from 1.1 to 2.5 milligrams per liter (mg/L), with the mean concentration at interior marsh stations ranging from 1.3 to 2.3 mg/L.

PURPOSE

The primary purpose of this chapter is to provide an overview of the status of phosphorus (P) and nitrogen (N) levels in the surface waters within the Everglades Protection Area (EPA) during Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005). The water quality evaluations presented in this section update previous analyses presented in the 1999 Everglades Interim Report, the 2000–2004 Everglades Consolidated Reports (ECRs), and the *2005 South Florida Environmental Report – Volume I* (SFER). More specifically, this chapter and its associated appendices are intended to (1) summarize phosphorus and nitrogen concentrations measured in the 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 an update on the progress made towards the establishment of a phosphorus-specific criterion for the EPA.

The following chapter represents a combination of the nutrient levels for total phosphorus (TP) and total nitrogen (TN) presented in the chapter evaluating the overall water quality status of the EPA (see Chapter 2A of the 2006 SFER – Volume I) and the information provided in previous Everglades Consolidated Reports (ECRs) detailing the development of the phosphorus-specific criterion for the EPA (Payne et al., 2002 and 2003).

It is anticipated that future versions of this section will be expanded to include a more detailed evaluation of the EPA marsh phosphorus levels consistent with the requirements of the final phosphorus criterion based on TP data from the monitoring network established in accordance with the rule.

METHODS

A regional synoptic approach used for water quality evaluations in previous ECRs was applied to phosphorus and nitrogen data for WY2005 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 for the evaluation of other water quality constituents, the majority of the water quality data evaluated in this chapter were retrieved from the South Florida Water Management District's (SFWMD's or District's) DBHYDRO database. Water quality data from the nutrient gradient sampling stations monitored by the Everglades Systems Research Division in the northern part of Water Conservation Area 2A (WCA-2A), the southwestern part of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), the west-central portion of Water Conservation Area 3A (WCA-3A), and Taylor Slough in Everglades National Park (ENP or Park) were obtained from the SFWMD's Everglades research database.

The phosphorus and nitrogen data summarized in this chapter were collected at the same monitoring stations described in Chapter 2A of the 2006 SFER – Volume I (see Figure 2A-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 report, some of the statistics for phosphorus and nitrogen presented in the *2006 South Florida Environmental Report* may be slightly different from those presented in previous 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 2A of this volume (see Figures 2A-2 through 2A-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 web site describing its water quality monitoring projects, including project descriptions and objectives. This web site currently provides limited site-specific information. Generally, interior monitoring stations were sampled monthly, with water control structures (inflows and outflows) typically being sampled biweekly when flowing, and monthly when not flowing. More information can be found on the District's web site at www.sfwmd.gov/org/ema/envmon/wqm/index.html.

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 2A of this volume. 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 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 natural ecosystem.

Until recently, phosphorus and nitrogen concentrations in the EPA's surface waters were regulated by the Class III narrative criterion alone. The narrative criterion specifies that nutrient concentrations in a water body cannot be altered to cause an imbalance in the natural populations of flora or fauna. Because of the importance of phosphorus in controlling the natural biological communities, the Florida Department of Environmental Protection (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. The status of the phosphorus criterion for the Everglades is further discussed below.

To evaluate spatial and temporal trends in nutrient levels within the EPA, phosphorus and nitrogen concentrations measured during WY2005 are further discussed in this chapter with a comparison to results from previous monitoring years. Once data are made available from the monitoring network, it is anticipated that future versions of this chapter will be expanded to include a more detailed evaluation of phosphorus levels in the EPA marshes, consistent with the requirements of the final criterion rule.

TOTAL PHOSPHORUS

STATUS OF PHOSPHORUS CRITERION RULEMAKING

The Everglades Forever Act [Section 373.4592, Florida Statutes (F.S.)] specifically states that waters flowing into a part of the remnant Everglades (also known as the EPA) contain excessive phosphorus levels, and a reduction in phosphorus levels will benefit the ecology of the EPA. The EFA further directs the FDEP to develop a numeric total phosphorus criterion by numerically interpreting the existing Class III narrative criterion as it applies to the EPA.

In response to the requirements of the EFA, the FDEP, and the District conducted an extensive research program to provide the data necessary to establish a numeric TP criterion. The research program consisted of field transect monitoring along existing, man-made nutrient gradients; dosing experiments; and laboratory experiments. To derive an appropriate numeric TP criterion, the FDEP conducted extensive analyses of the data from the District's research with data from other sources also being incorporated, where appropriate. Details of the FDEP's analyses and the derivation of the TP criterion are provided in previous ECRs (McCormick et al., 1999; Payne et al., 2001a; 2002; 2003), with additional detail provided in the FDEP's Everglades Phosphorus Criterion Development Technical Support Documents (Payne et al., 1999; 2000; 2001b). Results of the FDEP's analyses indicate that the maintenance of a long-term (five-year) annual geometric mean TP concentration at or below 10 µg/L would be protective of the natural flora and fauna, without being overly protective or below the natural background levels.

However, FDEP's analyses also indicate that, over shorter periods (less than or equal to one year), TP levels can naturally vary significantly above 10 µg/L without long-term biological impacts (Payne et al., 1999; 2000).

As previously noted, following a series of hearings, the Environmental Regulation Commission (ERC) approved the 10-µg/L TP criterion for the EPA during a July 8, 2003 hearing. Subsequent to the ERC approval, both environmental and agricultural interest groups filed administrative challenges to the phosphorus criterion rule. Following discussions with the FDEP concerning the application of the rule, all parties, except the Miccosukee Tribe of Indians and the Friends of the Everglades, withdrew their challenges. To resolve these remaining challenges, an administrative hearing was held from November 2003 through January 2004. The Administrative Law Judge issued a final order in the cases on June 17, 2004 that upheld all parts of the proposed rule finding that the rule "is not an invalid exercise of delegated legislative authority" by the FDEP. Following the Administrative Law Judge's ruling, the proposed rule [Section 62-303.540, Florida Administrative Code (F.A.C.)] was filed with the Florida Secretary of State on June 25, 2004. Subsequent to the formal adoption by the FDEP, the rule was submitted to the U.S. Environmental Protection Agency (USEPA) for approval. During January 2005, the USEPA approved all portions of the rule, except the use of the assessment methodology specified in Appendix B of the Settlement Agreement in the Federal Everglades lawsuit, Case No. 88-1886-CIV-Hoeveler, U.S., as modified by Omnibus Order entered in the case on April 27, 2001, to evaluate achievement of the criteria in the Refuge. The FDEP revised the rule to apply the same four-part test as applied in WCA-2 and WCA-3 to access achievement of the criteria to the Refuge. The revised rule was presented to the ERC and received unanimous approval on April 7, 2005. The revised rule was then filed with the Florida Secretary of State during May 2005 and resubmitted to the USEPA for approval on June 3, 2005. The phosphorus criterion rule received final approval from the USEPA in July 2005. The FDEP is currently working with the SFWMD and other interested parties to establish the monitoring networks necessary to determine compliance with the rule. Future evaluations of the phosphorus status in the EPA will be conducted in accordance with the requirements of the final phosphorus criterion rule based on data from the network.

With the exception of the change in assessment methodology for the Refuge as described above, the final phosphorus criterion rule for the EPA remains unchanged from that included as Appendix 2C-1 of the 2005 SFER – Volume I (Payne, et al., 2005). As specified above, in addition to establishing the numeric phosphorus criterion for the EPA, the rule also provides a methodology to determine achievement of the numeric TP criterion in an objective and scientifically reliable manner. The assessment methodology specified in the rule consists of two major components: (1) the maintenance of a long-term (five-year) geometric mean TP concentration across a network of evenly distributed marsh sites, and (2) a series of three components intended to protect against localized or shorter-term imbalances in the natural flora and fauna, while allowing for natural temporal and spatial variability. The adopted methodology specifies the following:

> The water body will have achieved the criterion if the five-year geometric mean is less than or equal to 10 µg/L. In order to provide protection against imbalances of aquatic flora or fauna, the following provisions must also be met:
>
> a. the annual geometric mean averaged across all stations is less than or equal to 10 ppb for three of five years; and
>
> b. the annual geometric mean averaged across all stations is less than or equal to 11 ppb; and
>
> c. the annual geometric mean at all individual stations is less than or equal to 15 ppb.

Achievement of the criterion in WCA-1 (Refuge), WCA-2, and WCA-3 shall be determined based upon the application of the above methodology to data collected monthly from stations that are evenly distributed and located in freshwater open-water sloughs within each water body (i.e., areas similar to those utilized during the derivation of the numeric TP criterion). Furthermore, achievement of the TP criterion in the impacted and unimpacted areas within each water body will be determined separately.

To ensure compatibility with the federal Settlement Agreement (i.e., Settlement Agreement dated July 26, 1991, entered in Case No. 88-1886-Civ-Hoeveler, U.S. District Court for the Southern District of Florida, as modified by the Omnibus Order entered in the case on April 27, 2001), the approved rule specifies that achievement of the TP criterion in the Park will be based on the methods set forth in Appendix A of the Settlement Agreement until this agreement is rescinded or terminated. If the Settlement Agreement is no longer in effect, achievement of the TP criterion in the Park will be determined based on the same four-part test applied in the other portions of the EPA.

The measurement methodology contained in the TP criterion is used to (1) provide for an objective and scientifically reliable assessment of the TP status at sampling stations representative of the EPA, (2) take into account natural spatial and temporal variability without being significantly biased by extreme events, and (3) allow the TP criterion to be applied so that it protects the natural biological communities present within the EPA without restricting the natural heterogeneity of the ecosystem or being below background levels.

PHOSPHORUS STATUS IN THE EVERGLADES PROTECTION AREA

Because the required monitoring networks are currently being established and the sites have not been classified as impacted or unimpacted, the TP criterion achievement methodology set forth in the rule cannot be applied to the current data. However, some of the provisions set forth in the rule are used as the basis for the evaluation of the status of phosphorus concentrations in the EPA presented in this chapter. It is anticipated that subsequent versions of this chapter in future South Florida Environmental Reports (after sufficient data are obtained from appropriate monitoring stations) will be expanded to include an assessment of achievement of the phosphorus criterion in EPA marshes consistent with methods set forth in the final phosphorus criterion rule. To provide an overview of the current nutrient status in the Everglades and to evaluate temporal and spatial patterns, TP concentrations measured during WY2005 are compared to the provisions set forth in the phosphorus criterion rule and the levels observed during previous monitoring periods.

In this chapter, TP concentrations measured during WY2005 are compared to the TP levels determined during WY2004, and the historical period from WY1978–WY2003. Table **2C-1** provides a summary of the TP concentrations measured within different portions of the EPA during WY2005, WY2004, and the WY1978–WY2003 historical period using both geometric mean and median values. Geometric means were used to summarize and compare TP concentrations based on requirements in the EFA and the phosphorus criterion rule that specify that achievement of the TP criterion be based on the long-term geometric mean. Given that the EFA and phosphorus 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.

WY2005 was a year of climatic extremes that included both multiple hurricanes with intense rainfall and periods of little or no rainfall resulting in marsh dryout. In addition to the hydrologic impacts, the effects of these extreme climatic conditions experienced during WY2005 are also reflected in the phosphorus concentrations measured during the year across the EPA. As documented during previous years, TP concentrations measured during WY2005 exhibited a decreasing north-to-south gradient, with the highest levels present in the inflow to the Refuge and WCA-2, and with 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.

Due to the effects of the extreme climatic conditions experienced, annual TP concentrations (expressed either as median or geometric mean values) measured during WY2005 were generally higher than those reported for WY2004 but were within the range observed during the WY1978–WY2003 historical period (**Table 2C-1**). **Figures 2C-1** through **2C-4** illustrate the response of TP concentrations at inflow and interior sites to the changes in climatic and hydrologic conditions that occurred during WY2004 and WY2005 in each portion of the system. As shown in these figures, TP concentrations at inflow and interior marsh sites generally responded differently to climatic and hydrologic changes. TP concentrations at inflow sites typically follow the rainfall pattern. That is, high rainfall amounts resulted in greater inputs of nutrient laden stormwater runoff, which in turn is reflected in peaks in TP concentration at the inflow structures. During WY2005, the highest TP concentrations occurred during the period from June–October 2004, which corresponds to high rainfall amounts received during the wet season and the passing of hurricanes Charley, Frances, and Jeanne. During periods of low rainfall, inflow TP concentrations were generally at their lowest.

In contrast, **Figures 2C-1** through **2C-4** also show that the TP concentrations at the interior marsh sites during WY2005 do not reflect the peaks in inflow concentration and in fact exhibit a nearly opposite trend than that described for the inflows. During periods of high rainfall when inflow concentrations are maximized, the TP concentrations at interior marsh sites are generally low, probably due to dilution. In contrast, when rainfall amount is low for extended periods, the water levels in the marsh fall and at some point the marsh starts to dry out and the sediment is exposed to oxidation, which results in the release of nutrients stored in the peat. When the rains return after a dryout, the nutrients released by the oxidized sediments are captured in the water column until the concentrations are reduced by settling, biogeochemical sorption, and dilution. During WY2005, peak TP concentrations at interior sites generally occurred during May–June 2004, when at least portions of the marsh dried out and exposed sediments to oxidation followed by sufficient rainfall to transport the released nutrients from the oxidized sediment. In some areas of the EPA (especially WCA-2 and the Park), a second peak in marsh TP concentrations occurred during February–March 2005 as a result of water levels again falling and portions of the marsh being dry. It is also important to note that the marsh concentration during these peaks that occur following dryout are often much higher than observed in the inflow and are more reflective of the intensity and duration of dryout, type of sediment, and historic loading rather than recent inflow levels.

Figures 2C-1 through **2C-4** also indicate that during periods not being influenced by the extreme climatic/hydrologic conditions, both inflow and marsh TP concentrations return to levels comparable to those experienced during WY2004, when low levels were recorded throughout the EPA. This quick recovery to previous levels suggests that the extreme conditions experienced during WY2005 did not result in any long-lasting impacts to the system.

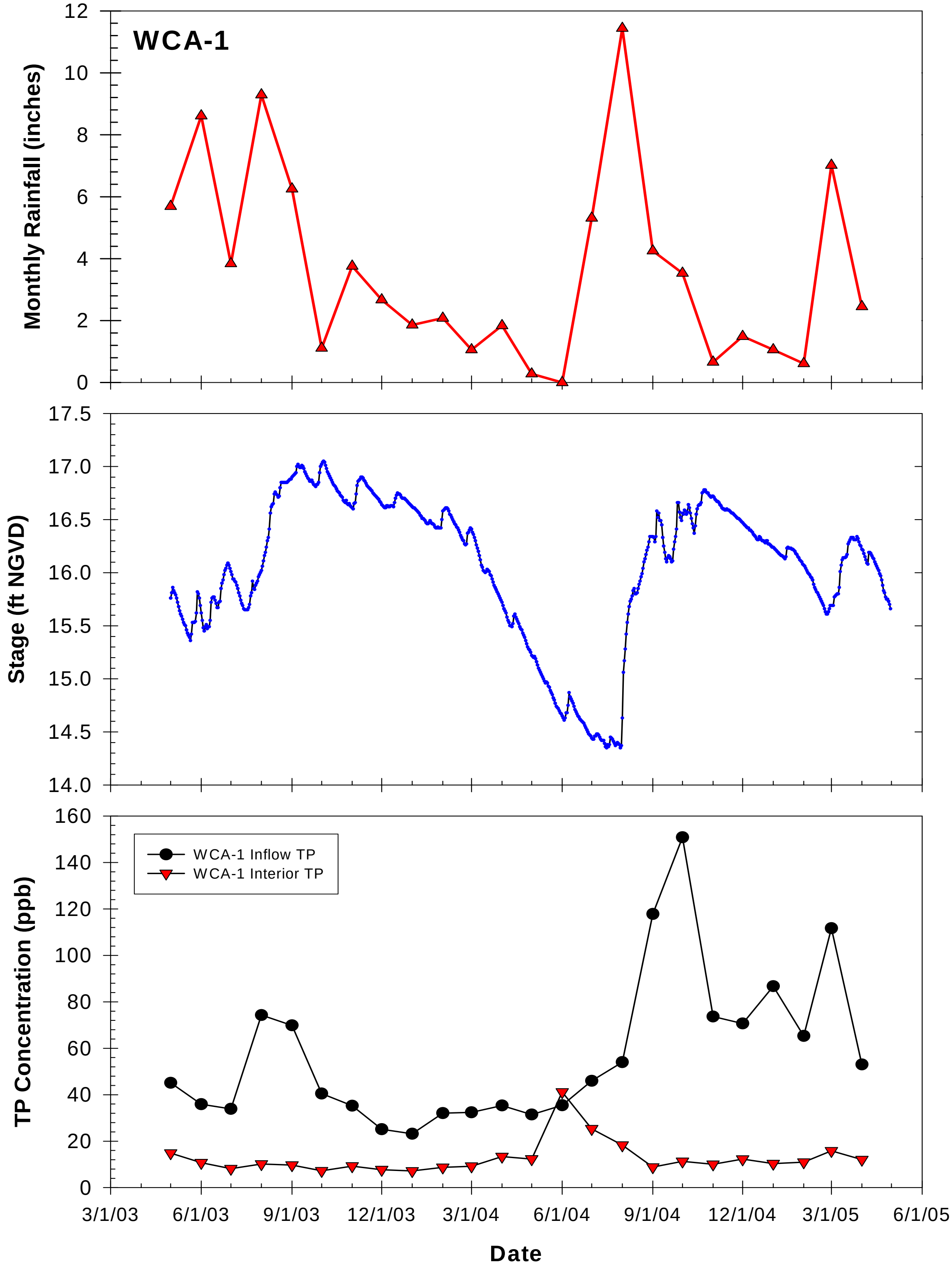


Figure 2C-1. Rainfall, stage, and monthly geometric mean TP concentrations (µg/L) for inflow and interior sites for WCA-1 (Refuge) during WY2004 and WY2005.

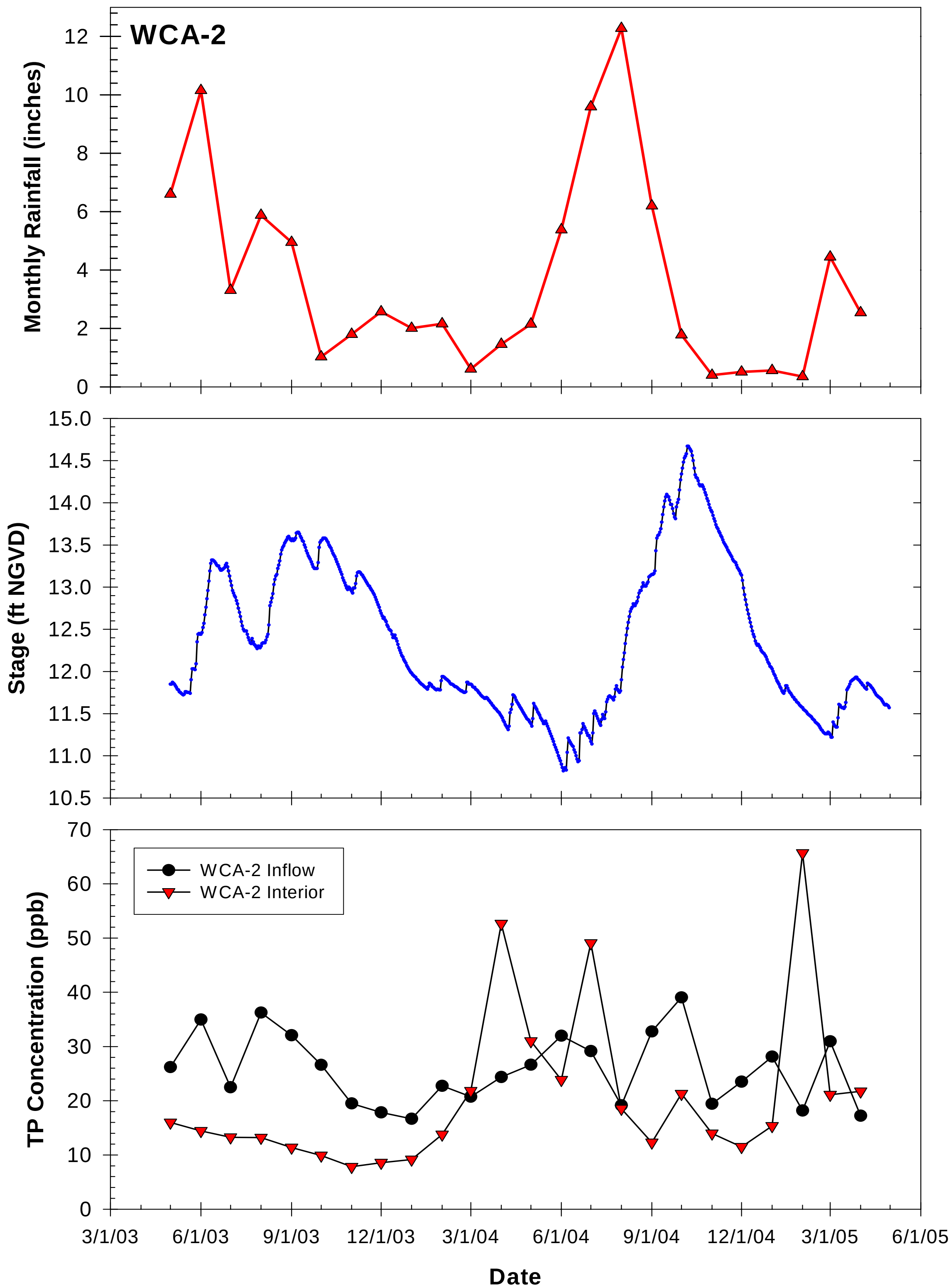


Figure 2C-2. Rainfall, stage, and monthly geometric mean TP concentrations (µg/L) for inflow and interior sites for WCA-2 during WY2004 and WY2005.

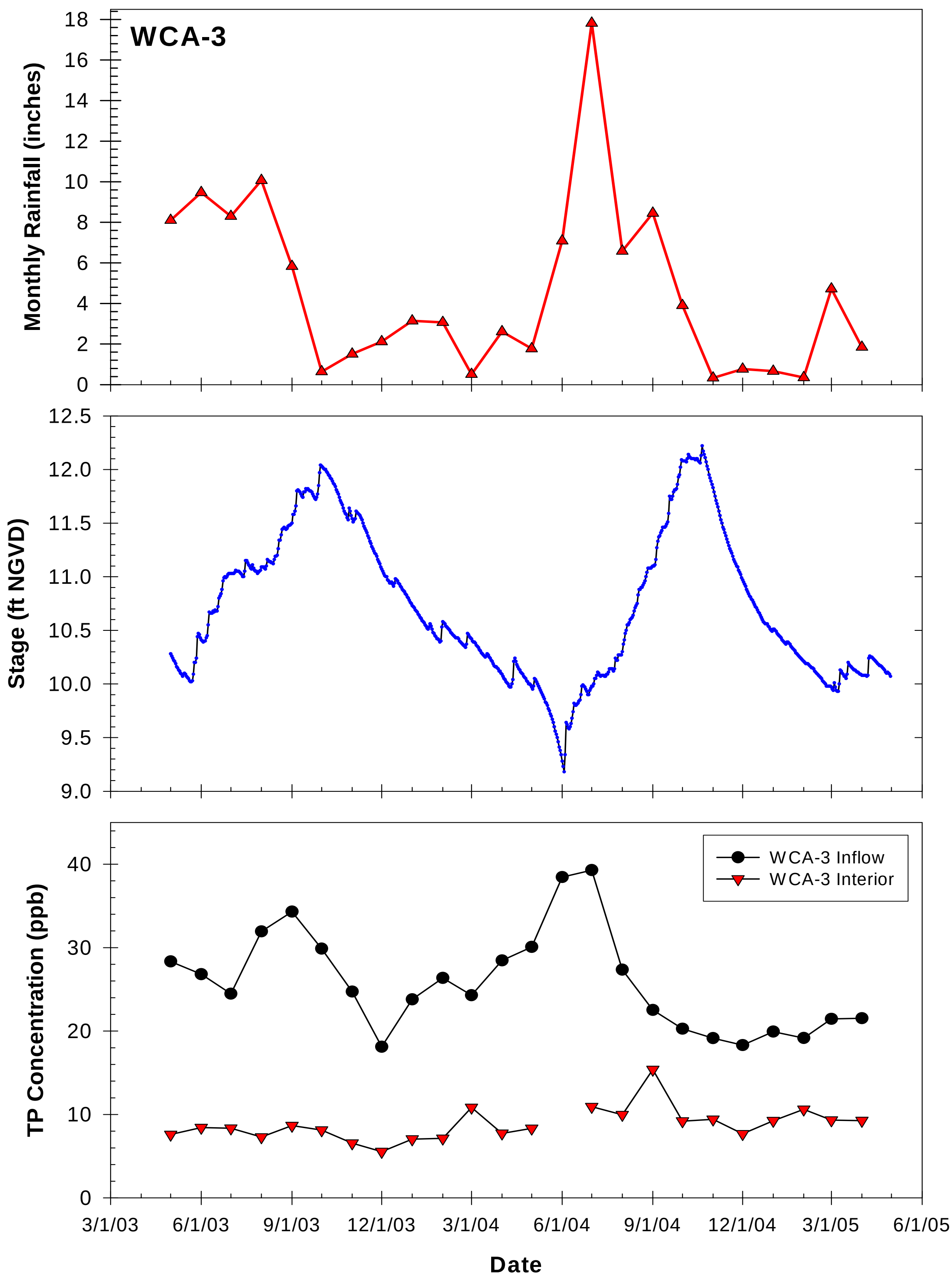


Figure 2C-3. Rainfall, stage, and monthly geometric mean TP concentrations (µg/L) for inflow and interior sites for WCA-3 during WY2004 and WY2005.

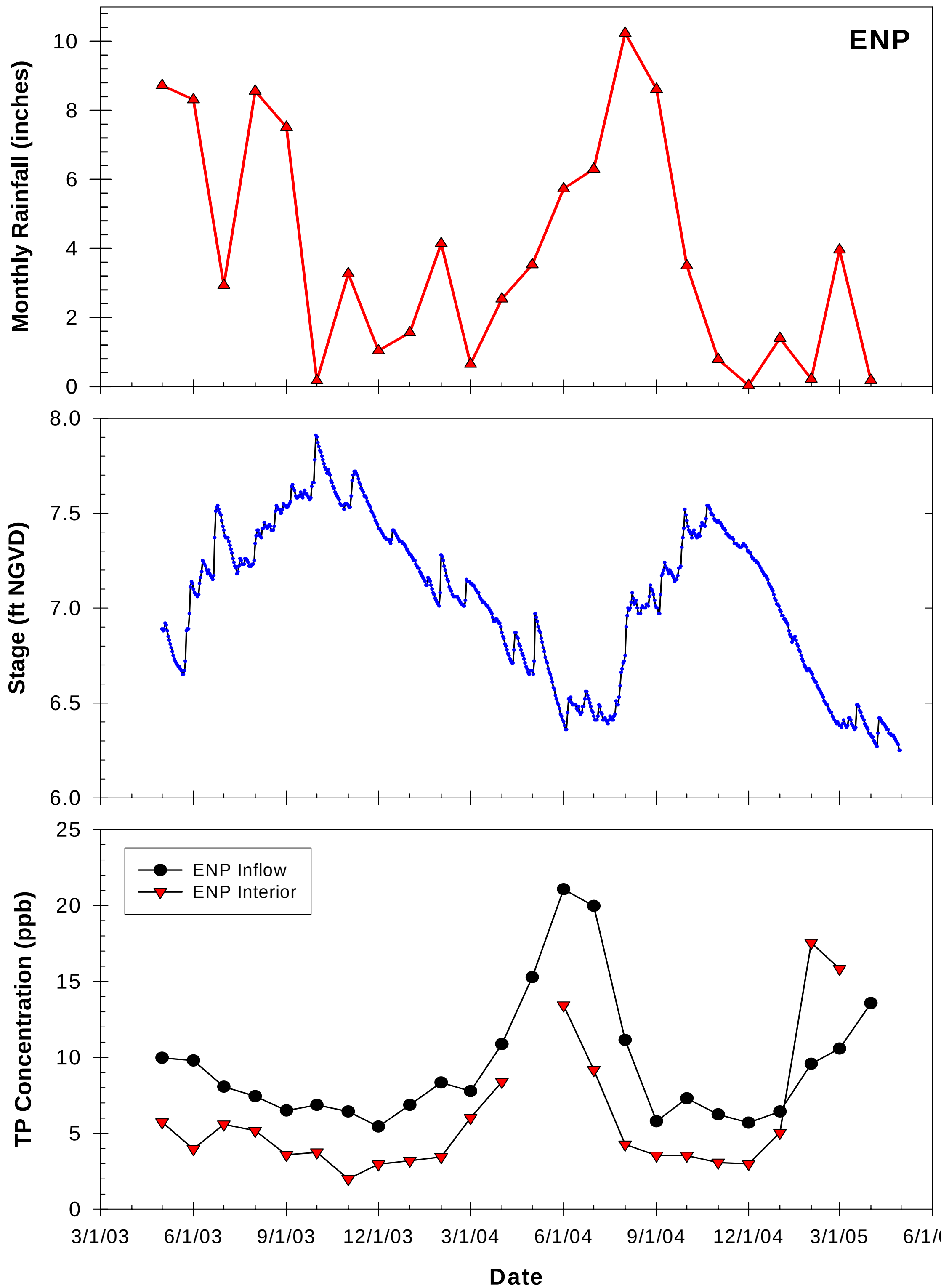
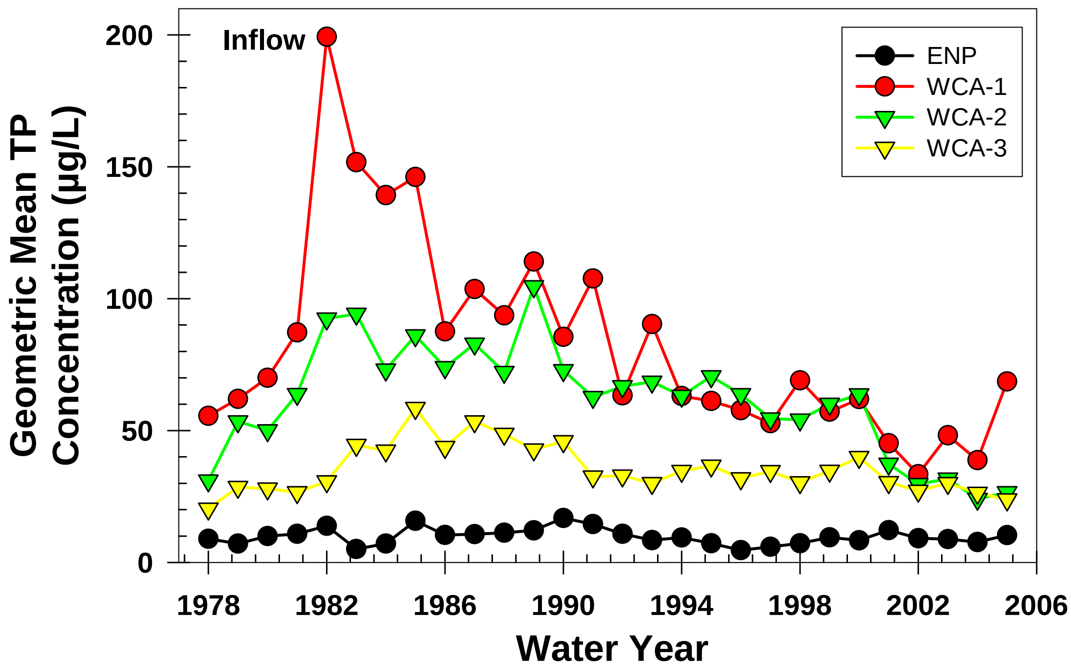


Figure 2C-4. Rainfall, stage, and monthly geometric mean TP concentrations (µg/L) for inflow and interior sites for Everglades National Park (ENP or Park) during WY2004 and WY2005.

More specifically, the annual geometric mean TP concentration for WY2005 in the inflows to all portions of the EPA, except WCA-3, were slightly higher than the levels reported for WY2004 but within the range captured by the WY1978–WY2003 historical period (**Table 2C-1**). **Figure 2C-5** illustrates the trend in the annual geometric mean TP concentrations in the inflows to all portions of the system. As shown, the largest increase in mean inflow TP concentration occurred in the Refuge where the greatest impact from the hurricanes is observed (**Figures 2C-1** and **2C-5**). The peak in monthly geometric mean TP concentrations following the hurricanes reached more than 150 µg/L, which is approximately four times typical levels and double the peak inflow concentrations that occurred during WY2004. The hurricanes had a less dramatic impact on other portions of the system and consequently resulted in smaller increases in mean inflow concentrations in these areas. The greatest impact from the hurricanes being observed in the Refuge can be expected since a greater portion of the inflow is comprised of direct stormwater runoff and discharges from the Stormwater Treatment Areas (STAs). The inflow to more southerly portions of the EPA is increasingly comprised of outflows from upstream portions of the marsh. The upstream portions of the system act to moderate the influence of the storms through the same biogeochemical processes that creates the normal north-to-south gradient in the EPA as discussed previously.



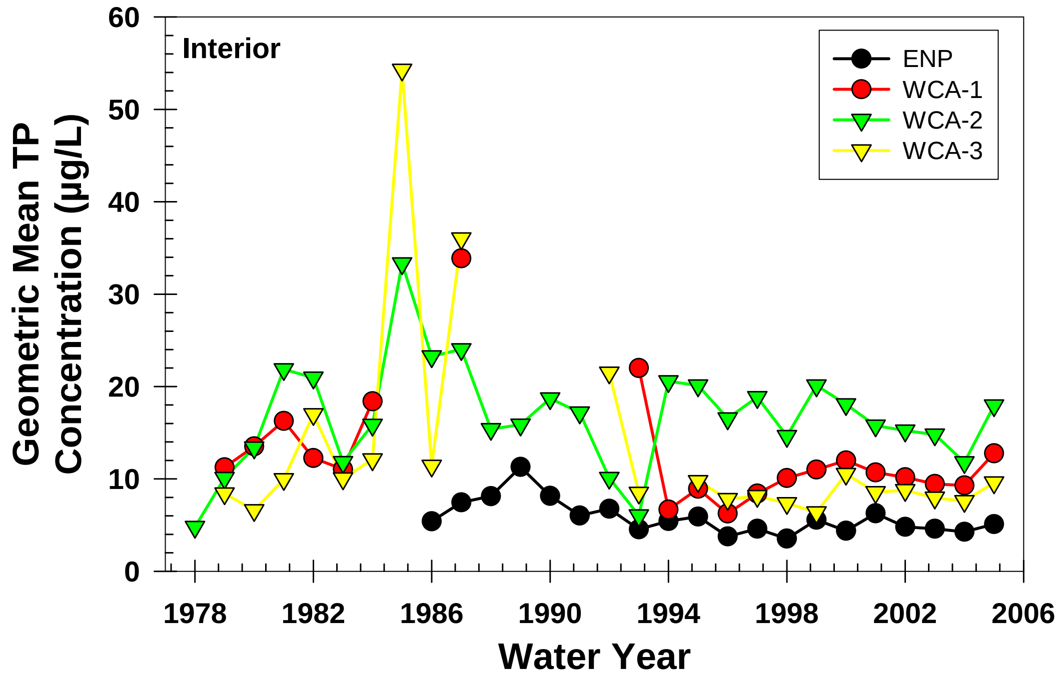


Figure 2C-5. Annual geometric mean TP concentrations (µg/L) for inflow (upper graph) and interior (lower graph) for each area within the EPA during the period from WY1978–WY2005.

Orthophosphate is a fraction of TP that is soluble and readily utilized by biological organisms and therefore has the greatest and most rapid effect on the ecosystem. During WY2005, the concentration of OP in the inflows to the EPA followed much the same trend as described for TP (**Table 2C-2**) with annual geometric mean concentrations being higher or comparable to WY2004 levels. Similar to TP, the greatest increases in OP concentrations were observed for inflow to the Refuge and WCA-2 with the WY2005 inflow levels in WCA-3 and the Park being comparable to WY2004 levels. As with TP, OP concentrations in the inflows to all areas, except the Park, exhibited peaks in July–October 2004 that correspond to peak inflows following the passing of the multiple hurricanes during this period. In the Park, OP concentrations showed no peak in concentration likely due to preferential biological absorption of OP in upstream waters.

As observed for the inflows, the geometric mean TP concentrations measured across interior marsh stations in all portions of the EPA during WY2005 were greater than WY 2004 but within the range experienced during the historical period. As discussed previously, TP concentrations in the interior marsh did not follow the same trend observed for inflow concentrations. In fact, low interior TP concentrations were generally associated with high water levels and the accompanying peak in inflow concentrations. In contrast, the peak interior TP concentrations during WY2005 were observed when water levels were very low and portions of the marsh had been exposed to dryout and rewetting (**Figures 2C-1** through **2C-4**). As described earlier, if the marsh is dried, the sediments are exposed to oxidation resulting in releases of nutrients bound in the peat. The level of nutrients released depends on the duration and intensity of dryout, sediment type, and historical loading (i.e., level of nutrients in the sediment). As expected, the greatest peak TP concentrations were observed for WCA-2, which has experienced the greatest historical loading and apparently experienced the most prolonged and repeated dryout and rewetting (**Figure 2C-2**). The highest interior TP concentrations occurred during the period from April–July 2004, with WCA-2 and ENP experiencing a second peak in February 2005 that was also associated with drying of the marsh. It is important to note that these peak interior concentrations do not reflect inflow concentrations and in fact are often much higher than inflow concentrations at that time and during the preceding months (**Figure 2C-2**).

During WY2005, interior marsh geometric mean TP concentrations ranged from a high of 17.9 µg/L in WCA-2 to a minimum of 5.1 µg/L in the Park compared to ranges from 11.8 to 4.3 µg/L, and 16.8–5.5 µg/L for WY2004 and the WY1978–WY2003 historical period, respectively (**Table 2C-1**). The annual geometric mean TP concentration across interior marsh sites in WCA-3 and the Park remained below the respective 10 and 11 µg/L five-year and annual provisions for assessing achievement set forth in the final phosphorus criterion rule. The geometric mean for the interior marsh sites in WCA-1 and WCA-2 were slightly above the annual 11 µg/L provision (i.e., 12.8 and 17.6 µg/L, respectively) due to the impacts from the abnormal climatic events experienced during WY2005.

As discussed, the higher marsh TP levels measured during WY2005 obviously reflect the extreme climatic conditions experienced during the year and not a general worsening of nutrient conditions in the marsh or a reversal of the general decreasing concentration trend reported in Chapter 2C of the 2005 SFER – Volume I.

Table 2C-2. Summary of orthophosphate (OP) concentrations (µg/L) measured in the EPA during WY2005, WY2004, and WY1978–2003.

Region	Class	Period	Sample Size (N)	Geometric Mean (µg/L)	Std. Deviation	Median (µg/L)	Min. (µg/L)	Max. (µg/L)
Refuge	Inflow	1978–2003	2438	22.8	4.0	27	<2	1106
		2004	131	9.5	2.1	8	4	122
		2005	125	27.5	3.1	29	<4	249
	Interior	1978–2003	1756	1.6	2.3	1	<2	380
		2004	228	3.1	1.8	2	<4	42
		2005	186	3.8	1.9	4	<4	110
	Outflow	1978–2003	1256	17.2	3.7	19	<2	1290
		2004	65	8.1	3.0	7	<4	297
		2005	58	19.7	3.3	18	<4	461
	Rim	1978–2003	502	23.5	3.2	28.3	<2	408
		2004	24	5.5	2.0	5	<4	18
		2005	21	21.5	3.3	32	<4	110
WCA-2	Inflow	1978–2003	1547	17.5	3.7	19	<2	1290
		2004	129	6.4	2.3	6	<4	121
		2005	126	10.8	3.0	7	<4	183
	Interior	1978–2003	3523	3.7	4.1	2	<2	2790
		2004	241	4.4	2.0	5	<4	57
		2005	169	7.3	2.9	6	<4	405
	Outflow	1978–2003	1510	5.2	3.4	5	<2	396
		2004	77	6.9	1.7	6	<4	43
		2005	77	7.1	2.1	6	<4	153
WCA-3	Inflow	1978–2003	4359	9.0	3.9	8	<2	586
		2004	210	7.2	2.4	6	<4	116
		2005	214	6.7	2.5	6	<4	180
	Interior	1978–2003	2177	1.7	2.7	2	<2	190
		2004	321	2.8	2.0	2	<4	67
		2005	185	3.1	1.9	2	<4	42
	Outflow	1978–2003	3217	2.8	2.1	2	<2	149
		2004	175	2.7	1.6	2	<4	10
		2005	139	2.8	1.7	2	<4	20
Park	Inflow	1978–2003	3701	2.7	2.0	2	<2	97
		2004	199	2.5	1.5	2	<4	10
		2005	159	2.5	1.6	2	<4	20
	Interior	1978–2003	1505	2.8	1.8	2	<2	63
		2004	100	2.6	1.5	2	<4	8
		2005	71	3.2	1.6	4	<4	10

Annual geometric mean TP concentrations for individual interior marsh monitoring stations having four or more samples during WY2005 ranged from less than 4.0 to 73.5 µg/L, with 47.2 percent of the interior marsh sites across the EPA exhibiting annual geometric mean TP concentrations that were less than or equal to 10 µg/L. Additionally, 70.8 percent of the interior sites across the EPA had annual geometric mean TP concentrations of 15 µg/L or below during WY2005. For comparison, 66.2 and 51.3 percent of the sites monitored during WY2004 and the WY1978–WY2003 historical period, respectively, had annual geometric mean TP concentrations less than or equal to 10 µg/L. During WY2004 and the WY1978–WY2003 historical period, 79.7 and 70.2 percent of the interior sites, respectively, exhibited annual geometric mean concentrations of 15 µg/L or less. Given that the location of interior monitoring sites has remained relatively constant over the past several years, the temporal comparison of statistics from individual sites can be used to distinguish changes in measured concentrations. However, as the monitoring sites are not evenly distributed across the EPA, it is not possible to accurately estimate the percentage of the marsh exceeding a TP concentration of 10 µg/L, or any other specified level based on these results.

Spatially, interior marsh TP concentrations measured during WY2005 exhibited the same north-to-south gradient observed during previous periods (Bechtel et al., 1999; 2000; Weaver et al., 2001a; 2002; 2003; Payne and Weaver, 2004). Typically, the highest TP concentrations obtained during WY2005 were collected from the northern WCAs, and declined throughout WCA-3 and the Park. During WY2005, 27.8 percent of the monitoring sites in WCA-2 had annual geometric mean TP concentrations of 10 µg/L or less, with that percentage increasing to 100 percent in the Park (**Figure 2C-2**). Likewise, 50 percent of interior sites within WCA-2 were determined to have annual geometric mean TP concentrations of 15 µg/L or less for WY2005 with higher percentages in other areas of the EPA.

During WY2005, geometric mean TP concentrations at several individual sites, including LOX3, LOX4, X3, X4, Y4, CA33, U1, and U3, located in areas relatively uninfluenced by canal inflows exceeded 10 µg/L (ranged from 10.3 to 19.8 µg/L) (**Figure 2C-6**). Only a couple of sites, Lox 3 and X4, located in the relatively unimpacted portion of the Refuge exhibited a geometric mean TP concentration above the 15 µg/L annual limit specified in the phosphorus criterion for individual sites. This further supports the conclusion that the higher phosphorus levels determined for WY2005 are not the result of inflows to the EPA. Instead, the higher WY2005 concentrations result from the climatic extremes experienced during the year, as described previously. A more detailed, site-specific summary of the TP concentrations for WY2005 is provided in Appendix 2C-2. Calculated TP loads for individual water control structures within the EPA (EAA and non-ECP sites) are presented in Chapter 3 of the 2005 SFER – Volume I.

Over the entire EPA (all areas and site classifications), approximately 85 percent of the TP measurements collected during WY2005 were below 50 µg/L, with 51 percent being below 15 µg/L and 32 percent of the measurements being at or below 10 µg/L. In comparison, TP concentrations in 93 percent of the samples were less than 50 µg/L, with 58.9 percent being at or below 15 µg/L, and 43.5 percent of the measured concentrations at or below 10 µg/L during WY2004 when phosphorus levels were low throughout the system.

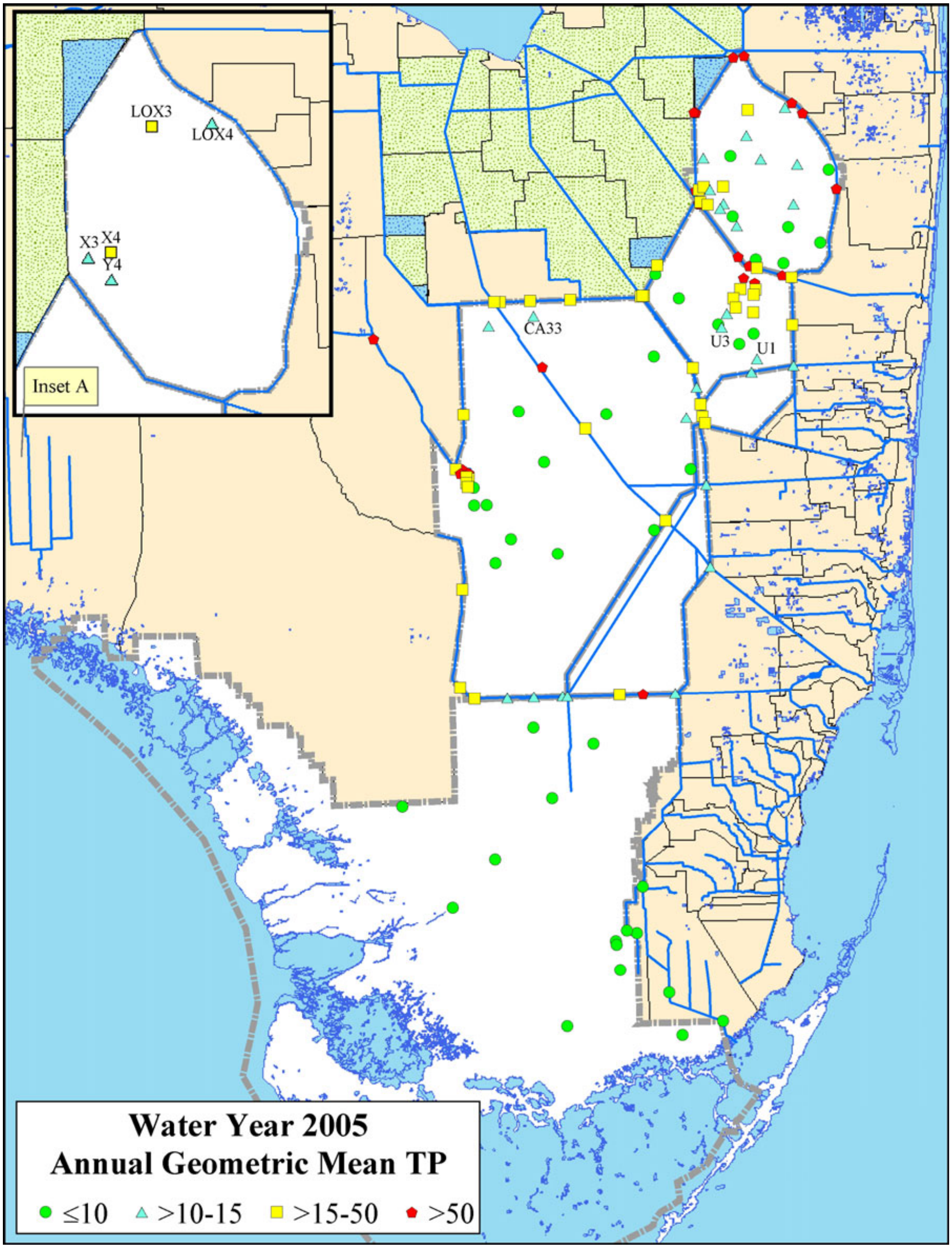


Figure 2C-6. Summary of geometric mean TP concentrations (µg/L) at stations across the EPA for WY2005. Geometric mean TP concentrations are classified utilizing four levels: ≤ 10 µg/L, 10–15 µg/L, 15–50 µg/L, and > 50 µg/L. Labeled sites are interior sites located in areas relatively unimpacted by discharges with annual geometric mean concentrations above 10 µg/L.

The distribution of TP concentrations in samples collected at inflow, interior, and outflow stations from each EPA region for WY2005 is presented in **Figure 2C-7**. Inflow stations to the Refuge and the WCAs had the highest percentage of measurements above 50 µg/L (11.6 to 26.5 percent) during WY2004. In contrast, less than 0.5 percent of the TP measurements at the Park inflow sites were above 50 µg/L, with 73.2 percent below 10 µg/L. Likewise, WCA-2, the most highly phosphorus-enriched area, exhibited the lowest percentage of samples from interior sites at or below 10 µg/L (47.4 percent), while 63.8 and 73.5 percent of samples collected from the interior of the Refuge and WCA-3, respectively, had TP concentrations of 10 µg/L or below. Additionally, more than 96 percent of the samples collected in the interior of the Park had TP concentrations of 10 µg/L or less.

Figure 2C-7 also provides a comparison of the concentrations measured in samples collected during WY2005 to the levels reported for WY2004 and the WY1978–WY2003 historical period. In general, phosphorus levels for WY2005 across all areas and classes of sites were higher than those for WY2004 and were within the range exhibited during the historical period.

As stated previously, TP concentrations observed during WY2005 were strongly influenced by the extreme climatic conditions experienced during the year. Periods of both low rainfall, resulting in marsh dryout, and high rainfall from the passing of multiple hurricanes, resulting in large storm water inputs and high marsh water levels, occurred during WY2005. The periods of low rainfall and resulting subsequent marsh dryout resulted in elevated phosphorus levels at interior sites while the periods of intense rainfall caused peak TP concentrations in the inflow, which were not reflected at the interior marsh sites. Phosphorus levels for both inflow and interior sites returned to normal (pre-WY2005) levels soon after typical climatic and hydrologic conditions were restored. This suggests that no long lasting impacts from the abnormal conditions experienced during WY2005 are expected to be observed. In addition, it is important not to draw any conclusions regarding the long-term trend in phosphorus conditions within the EPA based on the phosphorus levels determined during WY2005 due to the temporary impacts resulting from the extreme conditions experienced during the year. Future SFERs will continue to track long-term trends in phosphorus levels throughout the EPA.

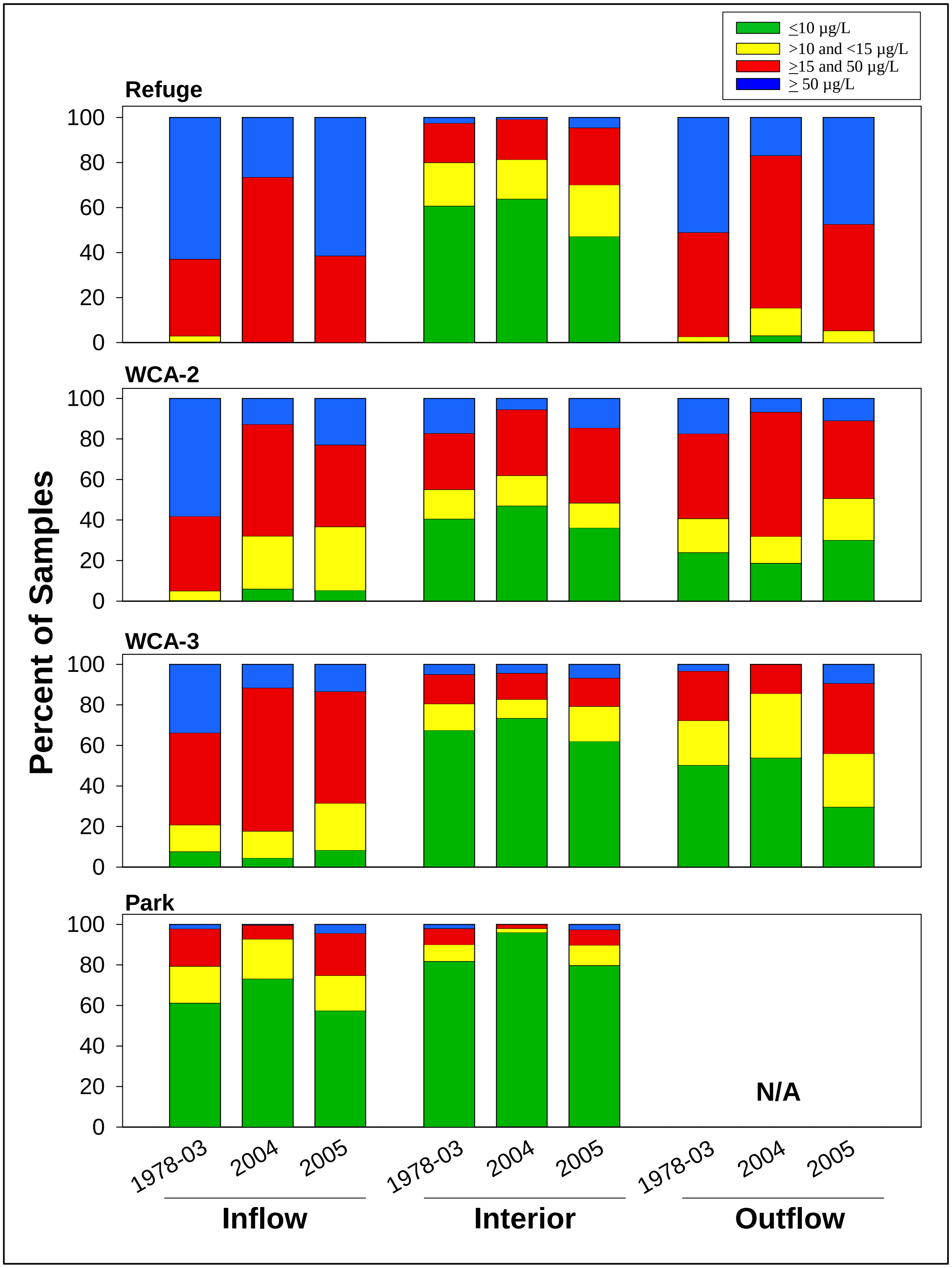


Figure 2C-7. Comparison of TP concentrations (µg/L) measured in samples collected in the EPA during WY2005, WY2004, and the WY1978–WY2003 historical period. "N/A" indicates that the outflow is not monitored for the ENP.

PHOSPHORUS LOADS TO THE EVERGLADES PROTECTION AREA

The Everglades Protection Area 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 the north 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.

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 previously mentioned operational decisions, also contribute a certain amount of TP loading to the EPA system. Detailed estimates of TP loads by structure are presented in **Table 2C-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 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.

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

Table 2C-3. WY2005 summary of flow and TP by structure[1].

Into STA1 Inflow Basin

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S5A_P	437.187	124151	230
S5A from EAA	332.412	*86768*	
S5Afrom East Beach	21.544	*11912*	
S5A from Lake	51.464	*14343*	
S5AW from Lake	1.192	418	
S5AW from L8 Basin	30.575	10710	
S5AS	19.367	4324	**181**
S5AS from Lake	*15.338*	3424	
S5AS from L8 Basin	*4.029*	900	
G300	2.089	289	112
G301	7.648	1350	143
Total	**466.291**	**130113**	**226**

From STA1 Inflow Basin

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S5AS	37.421	8336	**181**
from EAA	*0.000*	*0*	
from East Beach	*0.000*	*0*	
from Lake	*38.171*	*7691*	
from L8 Basin	*0.000*	*0*	
from WCA-1	*0.814*	*98*	
Mass Balance Addjustment	*-1.564*	*547*	
G300	31.849	12083	**308**
G301	37.216	14949	**326**
G302	341.099	103872	**247**
from EAA	*281.120*	*69923*	
from East Beach	*18.219*	*9599*	
from Lake	*17.829*	*6646*	
from L8 Basin	*29.265*	*9356*	
From WCA1	*8.922*	*1541*	
Mass Balance Addjustment	*-14.256*	*6807*	
Total	**447.585**	**139241**	**252**

Into WCA1

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
G300 & G301	69.064	27032	*317*
from EAA	*51.293*	*16845*	
from East Beach	*3.324*	*2313*	
from Lake	*11.994*	*3848*	
from L8 Basin	*5.340*	*2254*	
From WCA1	*0.000*	*0*	
Mass Balance Addjustment	*-2.886*	*1772*	
S362	15.921	7601	387
G251 (from STA-1W)	62.846	7786	101
G310 (from STA-1W)	320.518	38703	98
ACME1 (from Basin B)	12.317	2021	133
ACME2 (from Basin B)	11.246	2948	212
Total	**491.913**	**86091**	**142**

From WCA1

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S10A	88.060	16115	148
S10C	119.875	1812	12
S10D	91.765	16261	144
S10E	0.000	0	n/a
S39	51.828	3458	54
G300	2.089	289	112
G301	7.648	1350	143
G94A	28.476	10152	289
G94B	2.918	108	30
G94C	18.641	5220	227
Total	**411.301**	**54765**	**108**

Table 2C-3. Continued.

Into WCA2

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
G335 (from STA-2)	371.023	9228	20
S7 (prior to 9/3/04)	132.889	3,405	21
From EAA	*65.718*	*285*	
from Lake O	*20.271*	*2648*	
from STA 3/4	*46.900*	*472*	
S7 (after 9/3/04, from STA 3/4)	176.777	2584	12
S10A (from WCA1)	88.060	16115	148
S10C (from WCA1)	119.875	1812	12
S10D (from WCA1)	91.765	16261	144
S10E (from WCA1)	0.000	0	n/a
N. Springs Improv. District	0.354	9	20
Total	**980.744**	**49414**	41

From WCA2

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S7	0	0	n/a
S11A	n/a	n/a	n/a
S11B	218.356	2562	10
S38	137.578	3023	18
S34	91.185	2023	18
Total	**447.119**	**7608**	**14**

Into WCA3

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S140 (from L28 Canal)	137.976	7215	42
S190 (from Feeder Canal)	94.581	11288	97
L3 Borrow Canal (from C139-G409)	16.461	9450	465
STA6	22.187	520	19
S8 (prior to 1/8/05)	260.582	6724	21
From EAA	*60.680*	*356*	
From Lake O	*11.132*	*2336*	
From C-139	*8.310*	*1255*	
From STA3/4	124.657	*791*	
From STA-5	*34.441*	*1440*	
From Rotenberger	*17.478*	*211*	
SSDD	*3.880*	*335*	
G204/G205/G206 (from Holey Land)	*0.000*	*0*	*n/a*
S8 (after 1/8/05, from STA 3/4)	67.870	1284	**15**
S150 (prior to 9/3/04)	30.865	1304	**34**
S150 (from EAA)	*23.002*	*1099*	
S150 (from Lake)	*0.164*	*27*	
S150 (from STA3/4)	*7.700*	*128*	
S150 (after 9/3/04)	55.520	850	12
G404 & G357 (prior to 1/8/05)	52.827	1842	28
From EAA	*17.990*	*424*	
From C-139	*0.619*	*40*	
From STA-5	*1.381*	*191*	
from Rotenberger	*1.202*	*18*	
From Lake O to G409	*17.453*	*935*	
from SSDD	*0.593*	*68*	
from STA3/4	*13.591*	*166*	
G404 & G357 (after 1/8/05)	18.898	432	19
S11A (from WCA2)	0.000	0	n/a
S11B (from WCA2)	218.356	2562	10
S11C (from WCA2)	196.800	3256	13
G123 (from N. New River)	0.000	0	n/a
S9 (from C-11 West)	93.403	2140	19
S9A (from C-11 West)	56.584	832	12
Total	**1322.911**	**49699**	**30**

From WCA3

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S150	0.000	0	n/a
S8	0.255	21	33
S31	95.862	1470	12
S337	41.989	829	16
S343A	19.054	233	10
S343B	19.054	243	10
S344	10.982	149	11
S12A	82.298	1019	10
S12B	87.388	709	7
S12C	162.246	1382	7
S12D	222.510	3111	11
S333	183.327	2614	12
S14	0.000	0	n/a
Total	924.965	11780	10

Into Everglades National Park

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S12A (from WCA3)	82.298	1019	10
S12B (from WCA3)	87.388	709	7
S12C (from WCA3)	162.246	1382	7
S12D (from WCA3)	222.510	3111	11
Tamiami Canal	36.808	534	12
S14 (from WCA3)	0.000	0	n/a
S174 (from L-31W)	30.059	39	10
S332D (from L-31W)	76.480	1307	14
C-111 Canal	98.330	971	8
Total	**796.119**	**9072**	**9**

Note: Inflow to ENP from Tamiami Canal is calculated as the difference between S-333 and S-334, using the S-333 concentration.
Inflow to ENP from C-111 Canal is calculated as the difference between S-18C and S-197, using the S-18C concentration.

From ENP

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S334	146.520	2080	12
S197	2.359	17	6
Total	**148.879**	**2097**	**11**

FWMC = flow-weighted mean concentration

[1] 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.

Comparison of WY2005 Phosphorus Loads to the 1979–1988 Baseline

The following section provides an overview of phosphorus loading into the EPA for WY2005. The period from October 1978 through September 1988 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 (SWIM) Plan for the Everglades (SFWMD, 1992a; 1992b; 1992c), the design of the Everglades Construction Project, the federal Settlement Agreement, and the Everglades Forever Act, as amended. During this 10-year period, annual TP loads in surface inflows to the EPA ranged from approximately 100 mt to over 350 mt, with an average of 270 mt (1992 Everglades SWIM Plan). 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 1979–1988 baseline period, TP loads in surface 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 metric tons 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 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, and
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) of the technical group developing the load reduction estimates. For the period from 1994–2004, the actual BMP reduction was approximately 50 percent, or twice the assumed reduction. 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 impossible to compare the actual load reduction attributable to conversion of lands to STAs, although the 6 percent compares well with the percent of land taken out of production. For modeling purposes associated with Appendix C, the historical load and flow from each basin were reduced to account for low-flow water-supply deliveries from Lake Okeechobee, i.e., 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 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 (1979–1988) 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. This 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 SFWMD Rule 40E-63 (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 of the water year loads does not substitute for the compliance review activities of the TOC but is simply a public presentation of relevant data, as requested by the TOC.

TP loads to the EPA during WY2005 were significantly lower than the 1979–1988 baseline period, due primarily to a reduction in the volume of Lake Okeechobee discharges sent to the Everglades during the year. Future years may have more or less Lake Okeechobee releases in response to stages in the lake. As shown in **Table 2C-3**, TP loads from surface sources to the EPA totaled approximately 143.8 mt, with a flow-weighted mean concentration of 49 ppb. Another 193 mt of TP is estimated to have entered the EPA through atmospheric deposition. Surface discharges from the EPA account for approximately 9.9 mt. The 143.8-mt surface inflow is an almost 22 percent increase from the previous year (112 mt) due to unprecedented hurricanes in WY2005. It should be recognized that this entire load did not come from the EAA. TP loads to the WCAs from the EAA were calculated as:

1. A proportion of STA-1W and STA-2 discharges, adjusted to reflect contributions from non-EAA sources [STA-1W (from EAA: 86 percent), STA-2 (from EAA: 95 percent)],
2. STA-6 discharges, and
3. Direct EAA discharges from the S-7, S-8, S-150, G-300, and G-301 structures.

TP loads to the WCAs from the EAA during WY2005 totaled about 71.8 mt, much higher than the previous year (40.8 mt). The four-year average load to the WCAs from the EAA is about 46.2 mt, which is slightly higher than the expected 10-year average of 40.2 mt. This relatively high average load is significant considering that STA-1E and STA-3/4 were not fully operational during WY2005. The flow-weighted mean TP concentration entering the WCAs from the EAA, STA-1W, STA-2, STA-3/4, STA-6, and bypass flows during WY2005 was approximately 62 ppb, which is below the annual maximum of 76 ppb established by the TOC methodology.

TP loads from all sources to the Refuge during WY2005 totaled approximately 78.5 mt, which is an almost 252 percent increase from the previous year (22.3 mt). A portion of this load was recirculated into STA-1W from the Refuge during a two-week flow test. The TP load to the Refuge from the EAA during WY2005 was approximately 60.6 mt, including more than 27 mt that were directly diverted into the Refuge because insufficient hydraulic capacity existed in the inflow structure to STA-1W; some of this load could have been captured and treated in STA-1E had it been in flow-through operation. The three-year average of loads from the EAA to the Refuge was 15.4 mt, slightly below the anticipated 10-year average load of 15.5 mt. The flow-weighted mean TP concentration for WY2005 from STA-1W into the Refuge was 98 ppb; the 10-year (1994–2004) flow-weighted mean TP concentration from STA-1W into the Refuge was 38 ppb, 24 percent lower than the 50-ppb objective in the Settlement Agreement. The flow-weighted mean TP concentration entering the Refuge from the EAA, STA-1W, and bypass flows during WY2005 was approximately 132 ppb, which is above the annual maximum of 76 ppb established by the TOC methodology and higher than the 52 ppb observed during the previous water year.

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 (NO3+NO2). For this report, TN values were calculated only for samples for which both TKN and NO_3+NO_2 results were available.

Table 2C-4 provides a summary of the TN concentrations measured in the different portions of the EPA during WY2005, WY2004, and the WY1978–WY2003 historical period. As with phosphorus, TN concentrations during WY2005 were influenced by the extreme climatic and hydrologic conditions experienced during the year with the magnitude and timing of the impact being depended on area and class of site. **Figures 2C-8** through **2C-11** show measured TN concentrations at inflow and interior sites during WY2004 and WY2005. TN concentrations at inflow sites closely followed rainfall and water level patterns. The highest inflow TN concentrations during WY2005 generally occurred from June–September 2004 (**Figures 2C-8** through **2C-11**) following periods of high rainfall from the passage of multiple hurricanes. In contrast, the highest TN concentrations at interior sites were associated with dry conditions and marsh dryout when sediment oxidation likely resulted in nutrient releases.

Mean and median TN concentrations measured across all portions of the EPA during WY2005 were variable in comparison to those observed during WY2004 and the historical period from WY1978–WY2003. Except for the Park where inflows are largely composed of outflows from other portions of the system, the mean inflow TN concentrations during WY2005 were the same or lower than those reported for WY2004. Inflow nitrogen concentrations for the Park during WY2005 were slightly higher than for the previous year and similar to the mean for the WY1978–WY2003 historical period. In contrast, TN concentrations at interior sites during WY2005 were higher than levels reported for WY2004 in all areas. The higher mean interior nitrogen concentrations resulted from high concentrations that occurred when the marsh dried and nutrients were released into the water column through sediment oxidation.

In summary, during WY2005, mean TN concentrations at inflow stations ranged from 1.1 to 2.5 mg/L and median TN concentrations ranged from 1.1 to 2.2 mg/L. Similarly, mean TN concentrations at the interior marsh stations during WY2005 ranged from 1.3 to 2.3 mg/L, and median TN concentrations ranged from 1.1 to 2.2 mg/L.

As in previous years, TN concentrations in the EPA exhibited a general north-to-south gradient during WY2005. 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.

Table 2C-4. Summary of total nitrogen (TN) concentrations (mg/L) measured in the EPA during WY2005, WY2004, and WY1978–2003.

Region	Class	Period	Sample Size (N)	Arithmetic Mean (mg/L)	Std. Deviation	Median (mg/L)	Min. (mg/L)	Max. (mg/L)
Refuge	Inflow	1978–2003	2785	3.44	2.30	2.83	0.25	48.23
		2004	77	2.20	0.45	2.21	1.23	3.36
		2005	70	2.17	0.54	2.12	1.19	4.11
	Interior	1978–2003	2036	1.62	1.26	1.36	0.45	36.71
		2004	210	1.43	0.55	1.25	0.64	3.20
		2005	174	1.52	0.76	1.32	0.71	6.41
	Outflow	1978–2003	1259	2.63	1.64	2.22	0.25	22.84
		2004	64	1.90	0.50	1.72	1.26	3.30
		2005	47	2.09	0.77	1.89	1.25	4.88
	Rim	1978–2003	688	2.71	1.42	2.30	0.68	10.91
		2004	22	2.62	0.52	2.71	1.90	3.35
		2005	19	2.21	0.67	2.11	1.51	4.60
WCA-2	Inflow	1978–2003	1889	2.90	1.51	2.61	0.25	22.84
		2004	112	2.54	0.92	2.33	1.26	5.19
		2005	108	2.46	0.90	2.26	1.14	5.13
	Interior	1978–2003	4304	2.48	1.62	2.21	0.25	37.17
		2004	221	1.95	0.68	1.89	0.80	5.60
		2005	162	2.32	0.66	2.20	1.08	6.27
	Outflow	1978–2003	1516	2.13	0.85	1.95	0.25	7.65
		2004	74	1.76	0.56	1.63	1.07	4.26
		2005	65	1.90	0.38	1.93	1.09	2.90
WCA-3	Inflow	1978–2003	4794	2.03	1.01	1.76	0.25	10.80
		2004	244	1.66	0.73	1.45	0.88	5.80
		2005	257	1.68	0.40	1.68	0.98	3.30
	Interior	1978–2003	1968	1.53	0.83	1.30	0.25	10.01
		2004	308	1.13	0.33	1.06	0.60	2.63
		2005	185	1.53	0.59	1.43	0.74	4.50
	Outflow	1978–2003	3171	1.42	0.67	1.33	0.25	14.86
		2004	155	0.99	0.29	0.93	0.48	2.03
		2005	127	1.24	0.38	1.17	0.53	2.70
Park	Inflow	1978–2003	3651	1.29	0.69	1.20	0.25	14.86
		2004	177	0.87	0.32	0.80	0.45	2.03
		2005	147	1.11	0.40	1.11	0.49	2.70
	Interior	1978–2003	1491	1.34	1.41	1.14	0.25	40.84
		2004	81	0.97	0.31	0.94	0.50	1.72
		2005	75	1.31	0.75	1.13	0.47	3.98

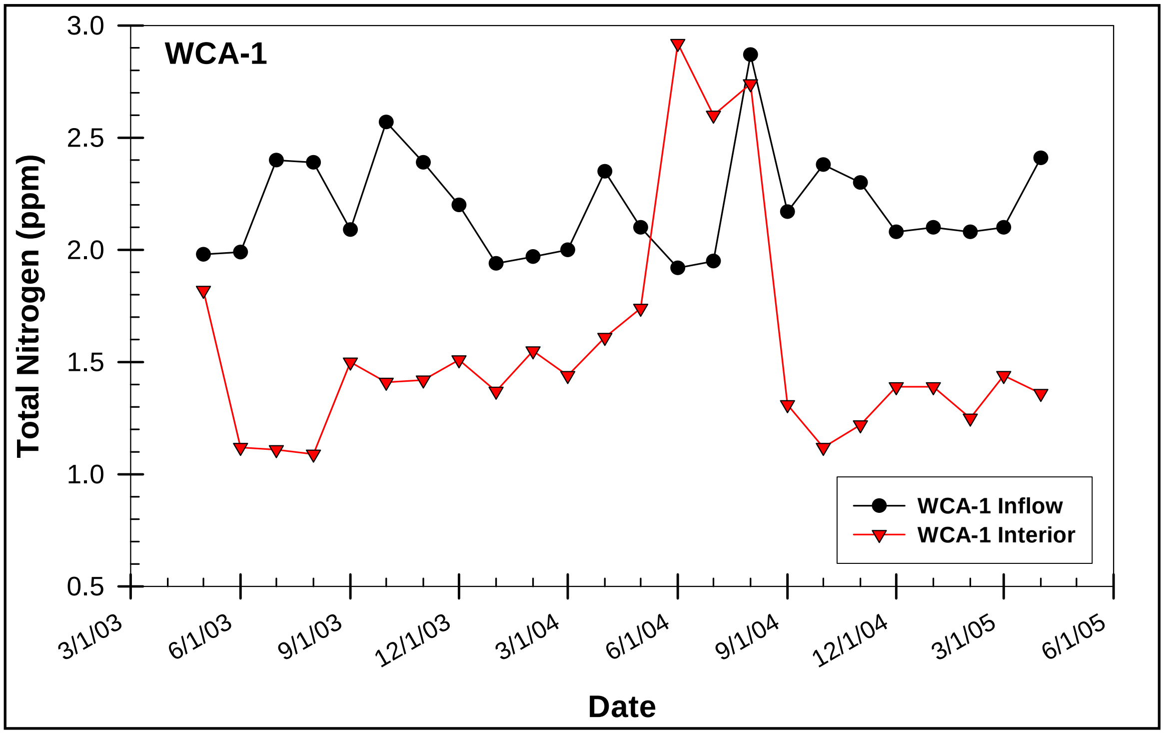


Figure 2C-8. Monthly average TN concentrations (mg/L) measured at inflow and interior sites in WCA-1 during WY2004 and WY2005.

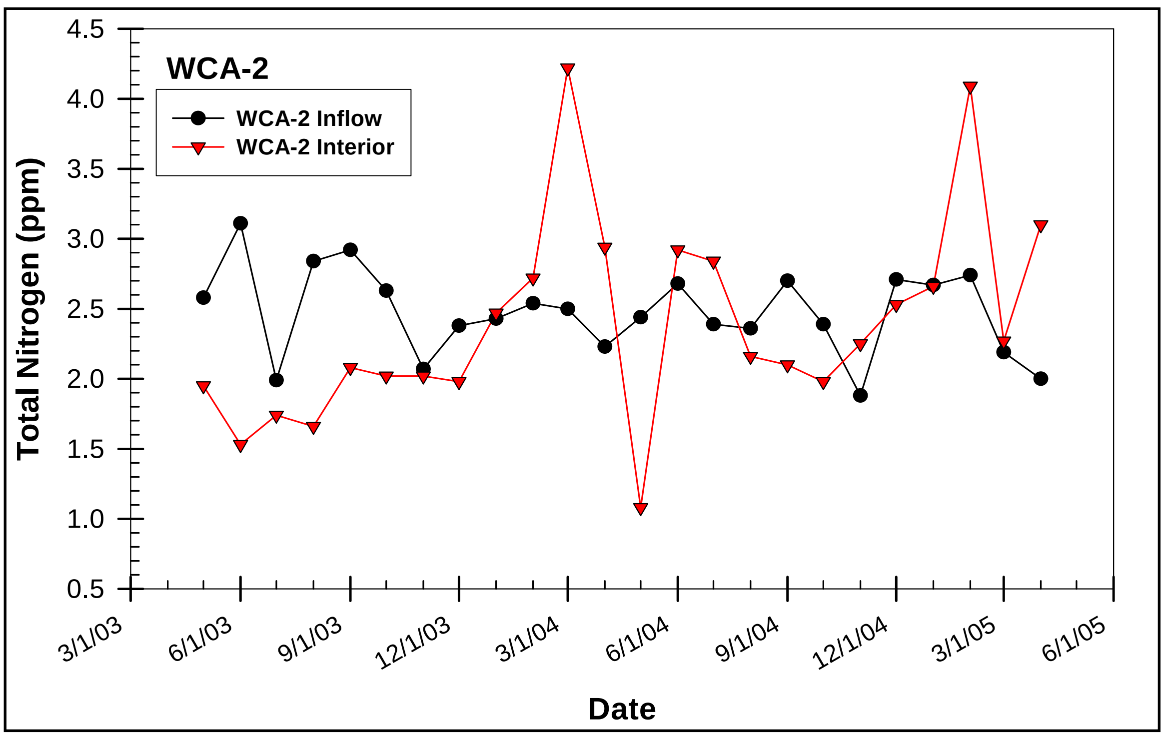


Figure 2C-9. Monthly average TN concentrations (mg/L) measured at inflow and interior sites in WCA-2 during WY2004 and WY2005.

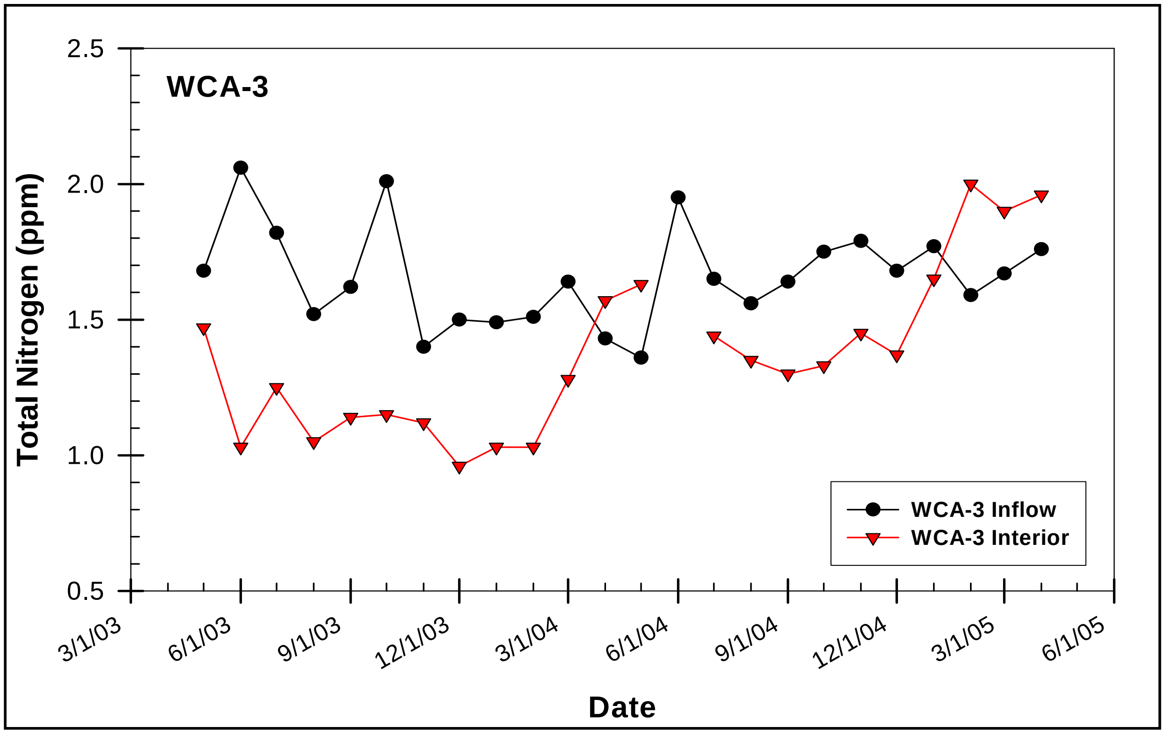


Figure 2C-10. Monthly average TN concentrations (mg/L) measured at inflow and interior sites in WCA-3 during WY2004 and WY2005.

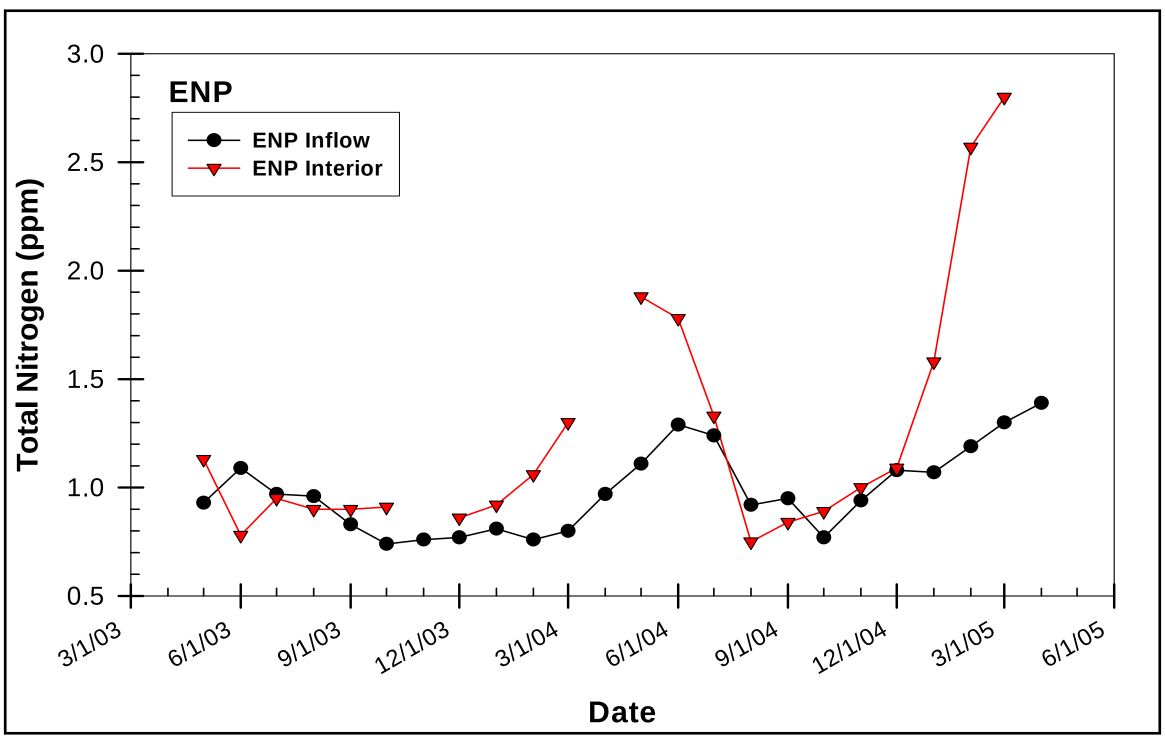


Figure 2C-11. Monthly average TN concentrations (mg/L) measured at inflow and interior sites in the ENP during WY2004 and WY2005.

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