Chapter 3A: Status of Water Quality in the Everglades Protection Area

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SUMMARY

This chapter provides a review of water quality within the Everglades Protection Area (EPA) during Water Year 2006 (WY2006) (May 1, 2005 through April 30, 2006). The focus of this chapter is to provide an update to the *2006 South Florida Environmental Report (SFER).* The status of EPA water quality was determined by an analysis of the water quality parameters that did not meet water quality criteria as specified in Section 62-302.530, Florida Administrative Code (F.A.C.). These criteria establish enforceable management and societal goals for water quality conditions within the EPA. The primary objective of this chapter is to provide a synoptic view of water quality standards compliance on a regional scale, including Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), Water Conservation Areas 2 and 3 (WCA-2 and WCA-3), and the Everglades National Park (ENP or Park). Discussions of any temporal or spatial trends observed for the parameters identified as concerns or potential concerns are also provided. Methods for summarizing annual excursion rates are similar to those used in past consolidated reports. In the *2007 SFER*, water quality parameters that did not meet existing standards are classified into three categories based on excursion frequencies that were statistically tested using the binomial hypothesis test. This chapter also provides a discussion of the factors contributing to excursions from applicable water quality criteria and an evaluation of the natural background conditions for which existing standards may not be appropriate. The results of the evaluation detailed in this chapter are summarized below.

- With few exceptions, water quality was in compliance with existing state water quality criteria during WY2006.
- Dissolved oxygen (DO) was categorized as a concern for the Refuge interior, Refuge inflows, WCA-2 interior, and WCA-3 interior. Additionally, DO was categorized as a potential concern for WCA-3 inflows and outflows and Park inflows. However, when unenriched areas were evaluated separately, DO was classified as a minimal concern for unimpacted areas of the Park and WCA-2, and a potential concern for the unenriched portions of the Refuge and WCA-3.
- As in previous years, alkalinity was designated as a concern for the interior of the Refuge for WY2006 due to an excursion rate of 13.1 ± 3.4 percent.
- Although pH was categorized as minimal concern for the Refuge interior based on the aggregated regional analysis, localized excursion resulted in pH being classified as a concern at monitoring site LOX11 and a potential concern at

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monitoring sites LOX3, LOX8, and LOX8. Because pH excursions within the interior of the marsh are linked to natural background conditions, the Florida Department of Environmental Protection (FDEP) does not consider pH levels within the interior of the Refuge to be in violation of state water quality standards.

- Conductivity was categorized as a concern for Refuge inflows, WCA-2 inflows, and WCA-2 interior. The WY2006 excursion frequency (21.0 ± 3.9 percent) for the WCA-2 interior was significantly greater than both WY2005 (7.5 ± 2.8 percent) and the WY1978–WY2004 historical period (10.3 ± 0.8 percent).
- Twelve pesticides or pesticide breakdown products were detected between February 1, 2005 and February 28, 2006. Of these pesticides, only atrazine and naled were classified as concerns.

PURPOSE

This chapter provides an assessment of water quality constituents exceeding water quality standards or causing or contributing to adverse impacts in the EPA. More specifically, the primary purpose of this chapter is to provide an overview of the status of water quality, relative to Class III criteria, in the EPA during WY2006. The water quality evaluation presented in this chapter updates previous analyses presented in past consolidated reports. More specifically, this chapter and its associated appendices use water quality data collected during WY2006 to achieve the following objectives:

1. Summarize areas and times where water quality criteria are not being met and indicate trends in excursions over space and time
2. Discuss factors contributing to excursions from water quality criteria and provide an evaluation of natural background conditions where existing standards may not be appropriate
3. Summarize sulfate concentrations in the EPA and indicate spatial and temporal trends
4. Present an updated review of pesticide and priority pollutant data made available during WY2006
5. Summarize water quality data in fulfillment of the non-Everglades Construction Project (non-ECP) permit

METHODS

An approach similar to the regional synoptic approach used in previous consolidated reports was applied to the WY2006 data to provide an overview of the status of compliance with water quality criteria in the EPA. Consolidating regional water quality data provides for analysis over time but limits spatial analyses within each region. However, spatial analyses can be made between regions because the majority of inflow and pollutants enter the northern third of the EPA and the net water flow is from north to south.

WATER QUALITY DATA SOURCES

The majority of the water quality data evaluated in this chapter was retrieved from DBHYDRO, the hydrometeorologic database maintained by the South Florida Water Management District (SFWMD or District). The DBHYDRO monitoring projects evaluated for WY2006 included C111D, CAMB, ENP, ENRR, EVER, EVPA, HOLY, LOXA, L31N, NECP, Stormwater Treatment Area 1W (STA-1W), and STA-2. Additionally, water quality data from the nutrient gradient sampling stations monitored by the District's Everglades

System Research Division (ESRD) in the northern part of WCA-3A, the southwestern part of the Refuge, the west-central portion of WCA-3A, and Taylor Slough in the Park were obtained from the ESRD database.

EVERGLADES PROTECTION AREA WATER QUALITY SAMPLING STATIONS

The surface water in the portion of the Everglades represented by the sampling stations used in this report is classified as Class III freshwater [Section 62-302.400, Florida Administrative Code (F.A.C.)]. Class III water quality criteria were established to protect recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife (Section 62-302.400, F.A.C.). Additionally, the Refuge and the Park are classified as Outstanding Florida Waters (Section 62-302.700, F.A.C.). Beyond the requirements of Class III water quality criteria, no degradation of water quality other than that allowed in Paragraphs 62-4.242(2) and (3), F.A.C., is to be permitted in Outstanding Florida Waters (Section 62-302.700, F.A.C.).

Water quality evaluations presented in this chapter were performed on a network of water quality monitoring stations selected from SFWMD long-term monitoring projects (**Figure 3A-1**). Chapter authors were careful to represent either EPA boundary conditions (i.e., inflow or outflow) or ambient marsh conditions (interior), and to select stations reported in past consolidated reports, to ensure consistent and comparable results. It should be noted that adoption of the total phosphorus (TP) criterion rule (Chapter 62-303, F.A.C.) is driving a revision of the monitoring network. The revised network is expected to include existing sites where possible, but also to incorporate stations previously under-represented interior marsh areas. The 2008 SFER will reflect these changes. When fully implemented, the revised network will provide a consistent framework for future analyses, yielding a broader and more accurate characterization of water quality conditions across the Everglades.

Water quality sampling stations located throughout the WCAs and the Park were categorized as inflow, interior, or outflow sites within each region based on their location and function (**Figure 3A-1**). This organization of monitoring sites allowed a more detailed analysis of the water quality status in each region of the EPA and assisted in the evaluation of potential causes for observed excursions from Class III water quality criteria. Several interior structures convey water between different regions in the EPA and therefore are designated as both inflow and outflow stations. For instance, the S-10 structures act as both outflow stations for the Refuge and inflow sites to WCA-2. Additionally, the S-11 structures are designated as outflows from WCA-2, as well as inflow points to WCA-3. The S-12 structures, S-355A, S-355B, and S-333 are outflows from WCA-3 and are inflow sites to the Park. The interior sites of each region consist of marsh and canal stations as well as structures that convey water within the area. In addition to inflow, outflow, and interior sites, the Refuge has an additional site category (rim canal sites) to account for the fact that the rim canals that border the east and west levees of the Refuge convey much of the water entering the interior of the Refuge. Waters discharged to the L-7 rim canal will either overflow into the Refuge interior when canal stages exceed the levee height or will bypass the marsh and be discharged to WCA-3A through the S-10 structures. The extent (distance) to which rim canal overflows penetrate the marsh depends on the relative stages of the L-7 rim canal and the Refuge interior. The location and classification of monitoring stations used in this report are presented in **Figures 3A-2** through **3A-5**.

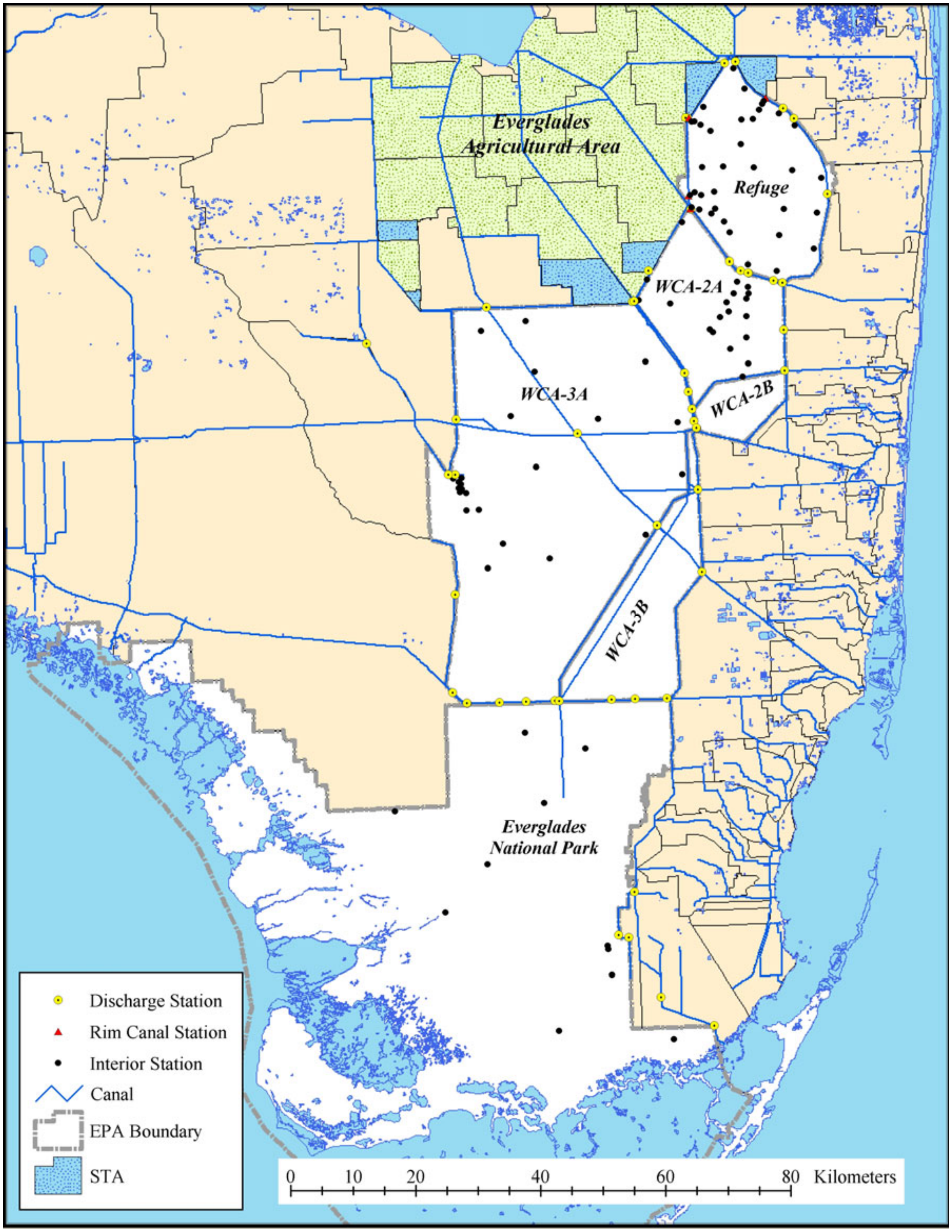

Figure 3A-1. Everglades Protection Area (EPA) regions and water quality monitoring stations.

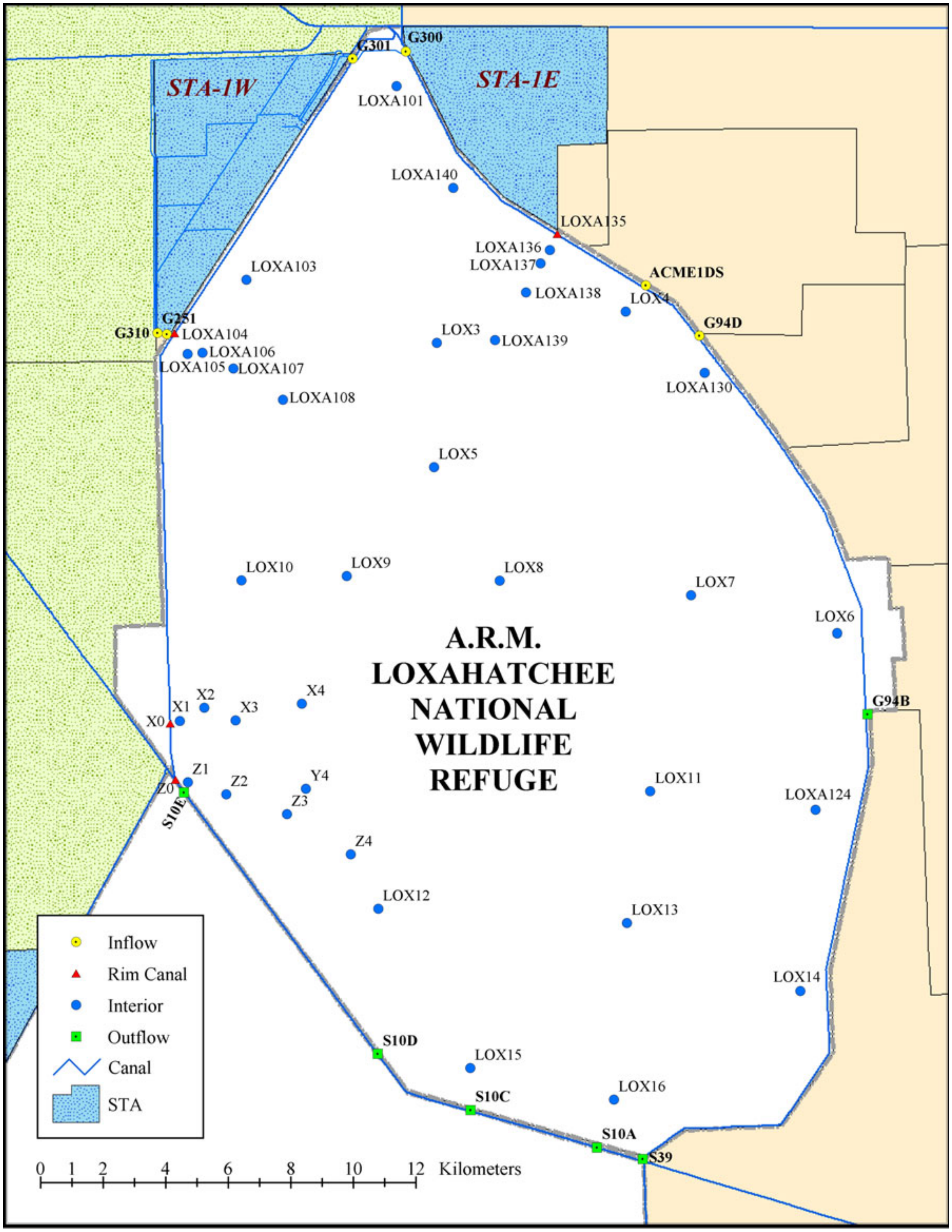

Figure 3A-2. Location and classification of water quality monitoring stations in the Arthur R. Marshall National Wildlife Refuge (Refuge).

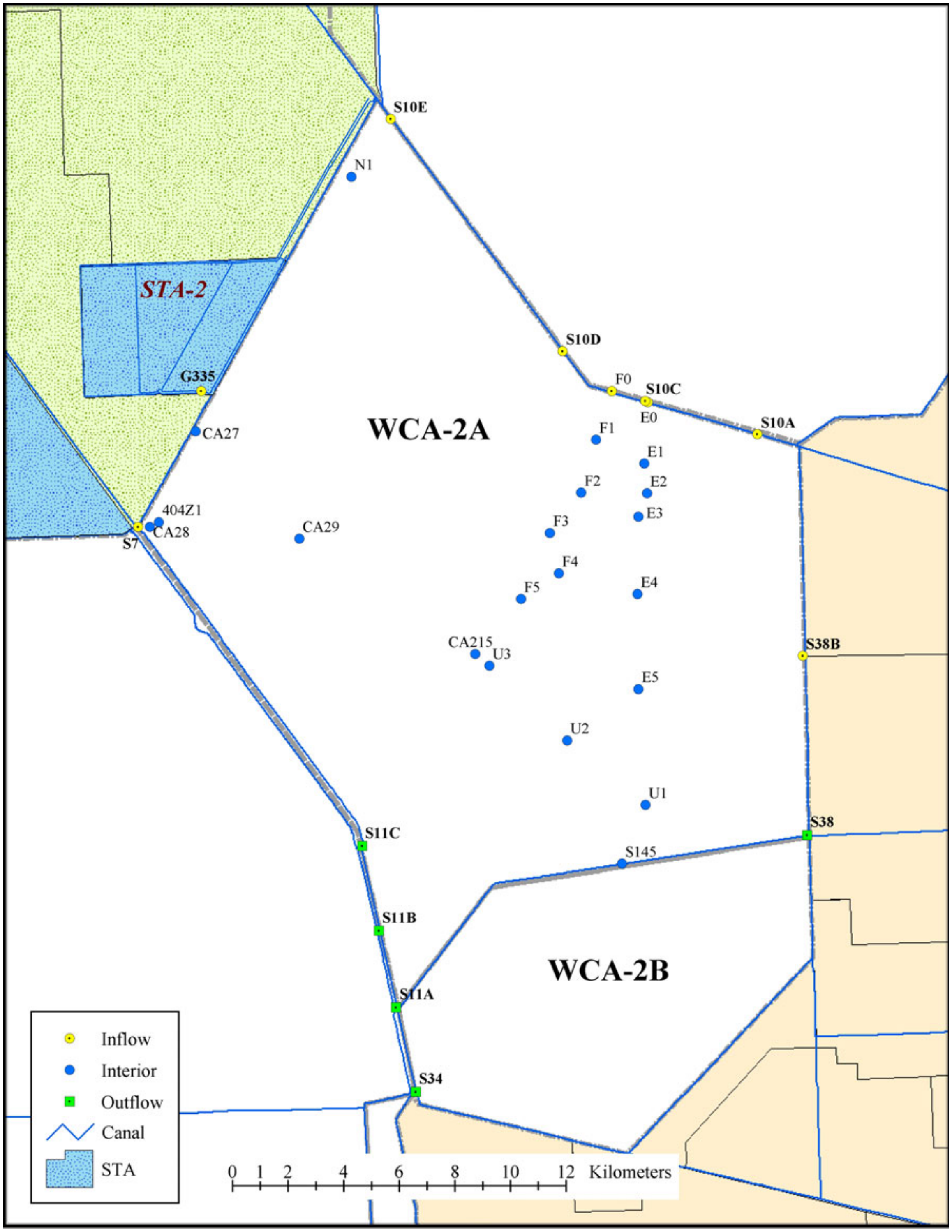

Figure 3A-3. Location and classification of water quality monitoring stations in Water Conservation Area 2 (WCA-2).

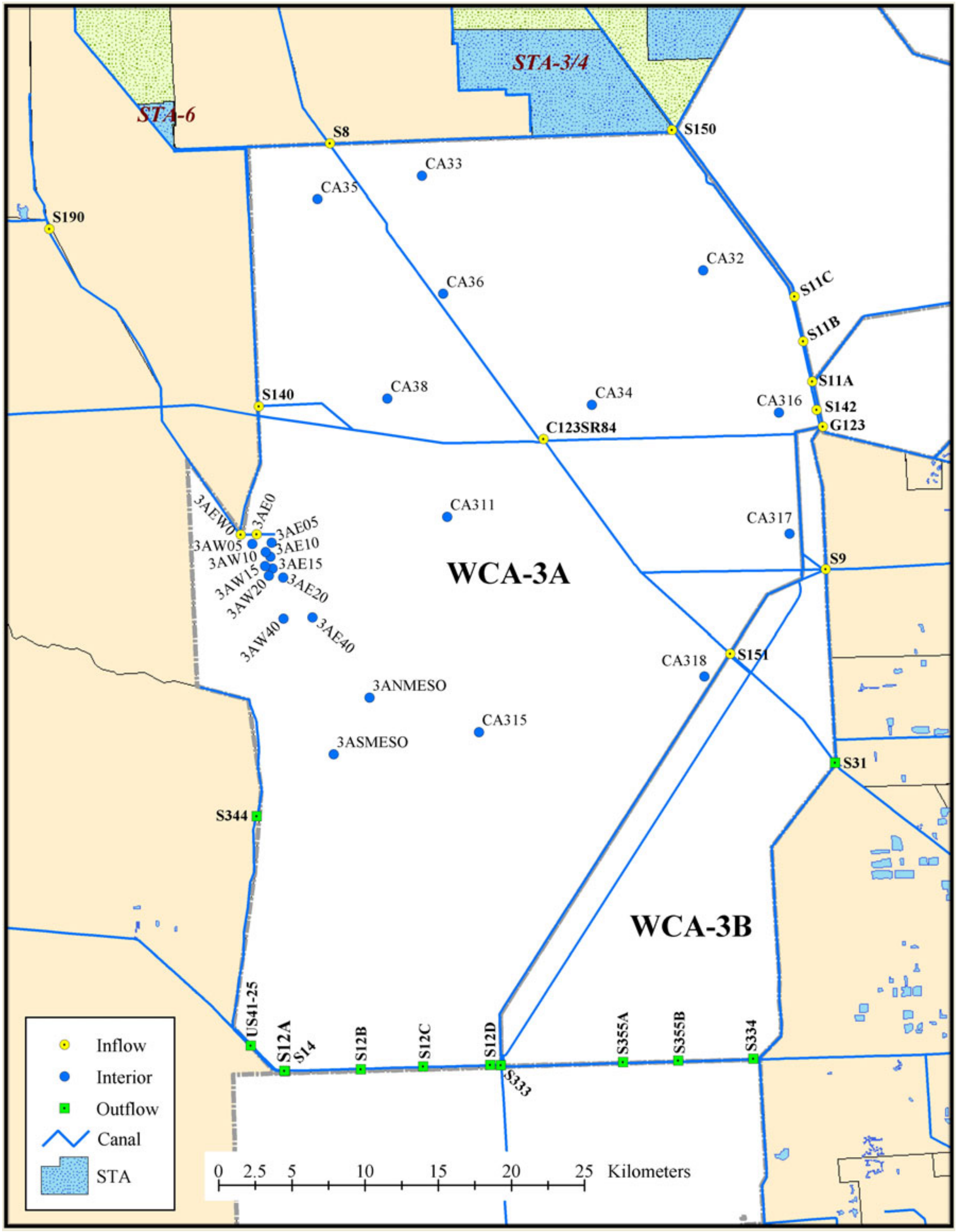

Figure 3A-4. Location and classification of water quality monitoring stations in WCA-3.

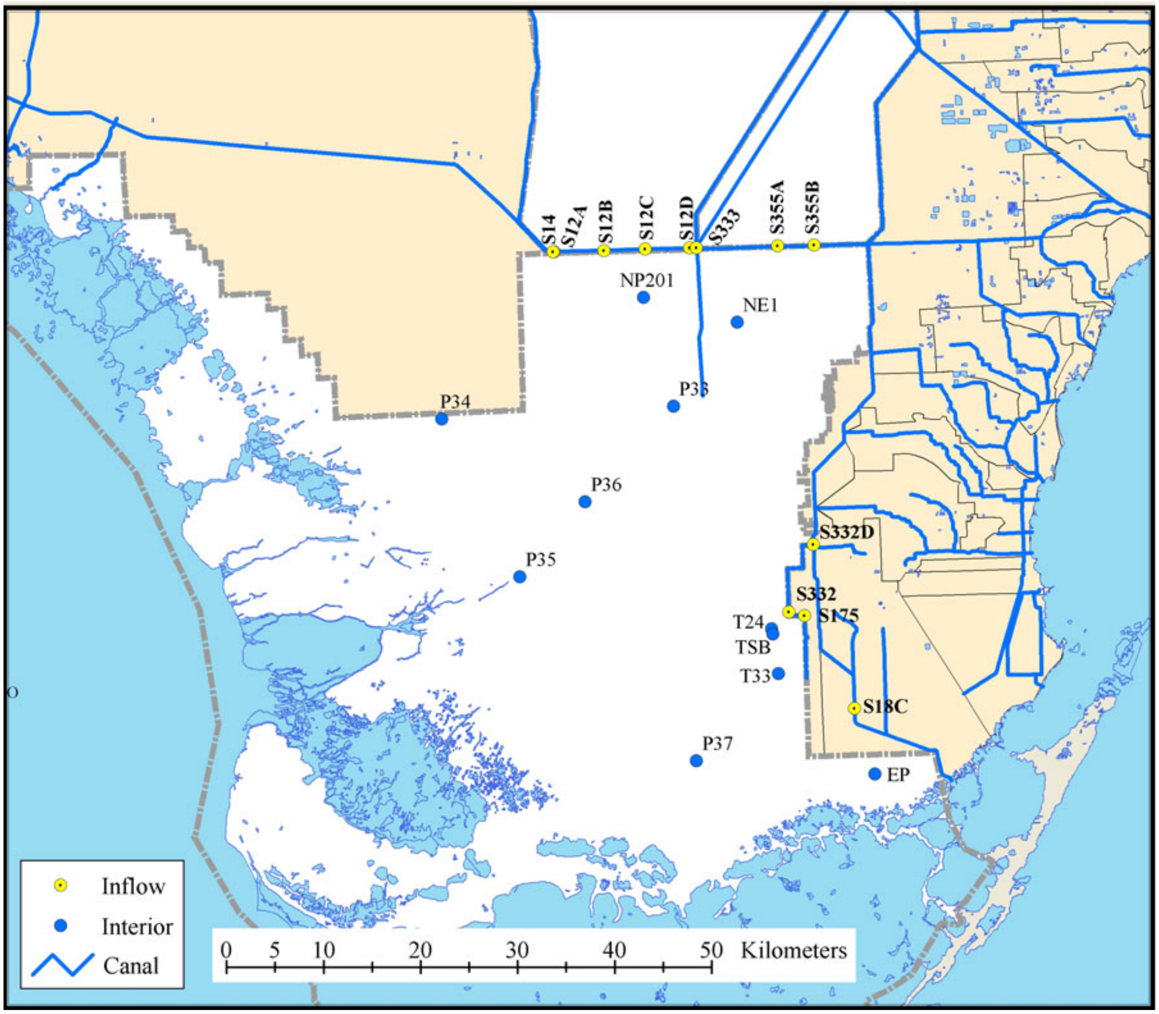

Figure 3A-5. Location and classification of water quality monitoring stations in the Everglades National Park (Park).

Several additional stations have been added to the interior water quality monitoring networks within the Refuge (LOXA101, LOX103, LOXA104, LOXA105, LOXA106, LOXA107, LOXA108, LOXA124, LOXA130, LOXA136, LOXA137, LOXA138, and LOXA140) and WCA-2A (N1 and 404Z1). These additions represent changes from the networks used to assess water quality conditions in previous reports. The added stations are now part of either the proposed provisional phosphorus criterion ambient compliance network or STA-1W and STA-1E downstream transect monitoring, which have pre-existing water quality data from the experimental monitoring in the Refuge or monitoring associated with the U.S. Army Corps of Engineers Section 404 Permit in WCA-2A. Data from these projects had not incorporated in past consolidated reports due to the short-term and time-limited nature of the projects, which would have resulted in inconsistent water quality evaluations from year to year. The changes documented in this SFER are an interim step towards implementing a standard network for water quality standard compliance evaluations in the EPA. Additional changes in the interior monitoring networks for all EPA areas are anticipated in the next year following full implementation of the Everglades TP-criterion monitoring network. Additionally, at least five years (i.e., until WY2011) will be required before sufficient data can be obtained to fully evaluate water quality standards compliance across the entire network including all new sites.

Germain (1998) described the current SFWMD monitoring programs. Sampling frequency varies by site depending on site classification, parameter group, and hydrologic conditions (water depth and flow). The District provides detail on its water quality monitoring projects, including project descriptions, objectives, and limited site-specific information at the District website (www.sfwmd.gov) under the *What We Do, Environmental Monitoring, Water Quality Monitoring* section. Water control structures (inflows and outflows) were typically sampled biweekly when flowing; otherwise, sampling was performed monthly. Generally, interior monitoring stations were sampled monthly for most parameters reported in this chapter.

WATER QUALITY DATA EVALUATION

The District monitors approximately 109 water quality parameters within the EPA (Bechtel et al., 1999, 2000). Given this chapter's focus on water quality criteria, the evaluation was primarily limited to parameters with Class III criteria pursuant to Chapter 62-302, F.A.C. The parameters evaluated included sulfate, 62 pesticides, and the following 18 water quality constituents:

alkalinity	total arsenic	total nickel
DO (in situ)	total beryllium	total selenium
specific conductance @ 25 degrees Celsius (°C) (in situ)	total cadmium	total thallium
pH (in situ)	total copper	total zinc
total silver	total iron	turbidity
total antimony	total lead	un-ionized ammonia

DATA SCREENING AND HANDLING

Water quality data were screened based on laboratory qualifier codes, consistent with the state's Quality Assurance Rule (Chapter 62-160, F.A.C.). Any datum with an associated fatal qualifier (H, J, K, N, O, V, Q, Y, or ?) was removed from the analysis (SWFMD, 2005). Values that exceeded possible physical or chemical measurement constraints (e.g., resulting pH > 14) had temperatures well outside seasonal norms (e.g., 6°C in July) or represented data transcription errors were excluded. Statistical outlier analysis was not performed for these data. Overall, 2.8 percent of the WY2006 data, including nutrients, were excluded due to quality assurance/quality control (QA/QC) issues (Appendix 3A-1). Qualification with a V, J, or ? qualifier accounted for a majority (90.5 percent) of the data exclusions. All data passing the qualifier screening was used in the analysis. Multiple samples collected at the same location on the same day were considered as one sample, with the arithmetic mean used to represent the sampling period.

Additional considerations in the handling of water quality data are the accuracy and sensitivity of the laboratory method used. Each analytical method for a particular water quality constituent has a Method Detection Limit (MDL) that defines the minimum concentration or the level at which the constituent can be identified. The MDL is usually statistically above the background noise level associated with the analytical method. A constituent present in a concentration at or below the MDL may not be quantified within established limits of accuracy or precision using that method. The Practical Quantitation Limit (PQL) represents a practical and routinely achievable quantification level with a relatively good certainty that a value determined using that method is reliable (APHA, 1995). For purposes of summary statistics presented in this chapter, data reported as less than the MDL were assigned a value of one-half the MDL unless otherwise noted. All data presented in this chapter, including historical results, are handled consistently with regard to screening and MDL replacement. The percentages of results below detection (< MDL) for each constituent are reported in Appendix 3A-1.

EXCURSION ANALYSIS

The FDEP and the District have developed and clearly documented an excursion analysis protocol for use in SFERs (Weaver and Payne, 2005). The primary objective of the protocol is to provide a synoptic view of water quality standards compliance on a regional scale (Refuge, WCA-2, WCA-3, and Park). This protocol was developed to balance consistency with previous versions of this report, other state of Florida ambient water quality evaluation methodologies [e.g., Impaired Waters 303(d) designations], and the U.S. Environmental Protection Agency (USEPA) exceedance frequency recommendations, as well as to provide a concise summary to decision makers and the public. This methodology is being used in order to ensure that the results will be compatible with information provided to water managers from other sources.

A multi-tiered categorical system was used in this chapter to rank the severity of excursions from state water quality criteria (**Table 3A-1**). Categories were assigned based on sample excursions frequencies evaluated using a statistically valid assessment methodology (i.e., binomial hypothesis test) that accounted for uncertainty in monitoring data. The basis for selecting the binomial approach is presented in Weaver and Payne (2004, 2005). Parameters without excursions were categorized as "no concern" and are not discussed further in this chapter. For any parameter with excursions and at least 28 samples during the period of record, the binomial hypothesis test at the 90 percent confidence level was applied to evaluate whether the given parameter was a concern; that is, whether it exhibited an excursion rate greater than 10 percent. If the binomial hypothesis test failed to reject the null hypothesis ($H0\colon f \leq 0.10$; $HA\colon f > 0.10$), then the binomial test at the 90 percent confidence level was used to determine whether the parameter was a potential concern (excursion rate from 5 to 10 percent, i.e., $HA\colon f > 0.05$) or a minimal concern (an excursion rate of 5 percent or less, i.e., $H0\colon f \leq 0.05$).

Table 3A-1. Definitions of excursion categories for water quality constituents in the EPA. For conventional water quality constituents with at least 28 samples, frequencies were statistically tested using the binomial hypothesis test at the 90 percent confidence level.

Excursion Category	Conventional Water Quality Constituents	Pesticides
Concern	> 10% Excursion[1]	Class III criterion and/or toxicity levels exceeded
Potential Concern	> 5% and ≤ 10% Excursions[2]	≥ MDL[3]
Minimal Concern	≤ 5% Excursions	N/A
No Concern	No Excursions	< MDL

1. For sample sizes fewer than 28, an excursion frequency of greater than 20 percent was used to define the concern category.
2. For sample sizes fewer than 28, an excursion frequency of less than or equal to 20 percent was used to define the potential concern category.
3. MDL = Method Detection Limit

N/A Not applicable

Because the binominal hypothesis test does not adequately balance statistical error rates at sample sizes of less than 28, parameters with reported excursions and fewer than 28 samples were initially categorized as a concern and potential concern based on excursion frequencies (raw scores) of greater than 20 percent and less than 20 percent, respectively. It is assumed that an observed excursion frequency greater than 20 percent provides substantial reason to suspect that the true exceedance frequency may exceed 10 percent and warrants further investigation. Furthermore, given the high degree of uncertainty associated with small sample sizes (fewer than 28), any excursions warrant further review. However, extreme caution must be exercised when interpreting results drawn from such small samplings. To reduce uncertainty, any parameter initially identified as a concern or potential concern based on fewer than 28 samples was further evaluated based on longer-term (five-year) excursion rates. Utilization of a longer period of record assumes that exceedance frequencies are constant among years, that is, there is no trend. Parameters with human health-based criteria were evaluated under the assumption that the Class III criteria values represent instantaneous maximum concentrations for which any exceedance constitutes a non-attainment of designated use.

Additionally, methods to detect and delineate localized exceedance patterns within each water body were utilized to supplement and refine the regional analyses (Weaver and Payne, 2005). The binomial hypothesis test and excursion criterion were applied to individual station data. Because there are insufficient data (fewer than 28 samples) over a single annual period, to confidently estimate station level exceedance frequencies for most water quality parameters, a longer period of record was necessary. Individual station assessments were based on the most recent five water years (WY2002–WY2006), rather than on the single year used for regional analyses. Use of a five-year period provided sufficient data for most parameters. No determination was made for any parameter with less than 28 samples. If one or more monitoring stations were categorized at a higher level of concern than the region as a whole, then a localized exceedance was recorded. Localized exceedances are noted in the summary tables of this chapter.

Because the USEPA recommended that a 10 percent excursion frequency does not apply to pesticides (USEPA, 1997 and 2002), the pesticide evaluation method presented in this chapter is identical to the method used in past consolidated reports. Pesticides were categorized based on the exceedance of Class III criteria or chronic toxicity values and detection (measurement ≥ MDL) frequency (**Table 3A-1**).

WATER YEAR 2006 RESULTS

WY2006 data for water quality parameters with Class III numeric criteria are summarized by region and monitoring station in Appendices 3A-1 and 3A-2, respectively. Comparisons of WY2006 water quality data with applicable Class III water quality criteria resulted in excursions for five identified water quality parameters: DO, alkalinity and pH, specific conductance, and un-ionized ammonia. Similar to previous periods these excursions were localized to specific areas of the EPA, with the exception of DO, which exhibited excursions in all regions (**Table 3A-2**). Because Everglades DO is assessed as an annual station average rather than as point measures, there were insufficient data to confidently apply the binomial hypothesis test to the regional assessment units on an annual basis. Therefore, excursion categories for DO were assessed based on a five-year period of record (WY2002–WY2006) for all areas. DO was categorized as a concern for the Refuge interior, WCA-2 interior, and WCA-3 interior and a potential concern for WCA-2, WCA-3, and Park inflows. Alkalinity was categorized as a concern for the Refuge interior. Specific conductance was classified as a concern for Refuge inflows, WCA-2 inflows, and the WCA-2 interior. Additionally, pH and un-ionized ammonia were categorized as minimal concerns for several EPA regions due to infrequent and localized excursions. Water quality parameters that were classified as minimal concerns will not be discussed further in this chapter unless significant localized exceedance patterns were additionally noted. Twelve pesticides, or pesticide breakdown products, were detected between February 1, 2005 and February 28, 2006. Of these pesticides, only atrazine and naled were classified as concerns. No other parameters exceeded state water quality criteria during WY2006.

To help identify any temporal trends, **Table 3A-3** summarizes WY1978–WY2004, WY2005, and WY2006 excursion frequencies and categories associated with parameters for which excursions occurred in WY2002–WY2006. Excursion categories for all periods are based on the methodology previously described (**Table 3A-1**). Additionally, excursion frequencies and categories for individual monitoring stations are summarized in Appendix 3A-2. Excursion frequencies for WY2006 were generally within the range of the historical periods for most water quality parameters, with the exception of increased specific conductance excursion rates for the WCA-2 interior. Water quality parameters categorized as concerns or potential concerns for WY2006 are reviewed in detail below. The review discusses the environmental significance and potential causes of the excursions, and notes actions taken to resolve the associated concerns, including evaluation of the applicable criteria and natural background conditions within the EPA.

Table 3A-2. Summary of water quality data and excursions from applicable criteria in the EPA for WY2006. Only water quality parameters with excursions in the given region and class are listed.

Area	Class	Parameter	Units	Class III Criteria	N	Mean	Standard Deviation	Min	Max	Excursion	
										% ± 90% C.I.	Category[1]
Refuge	Inflow	Dissolved Oxygen (DO)	mg/L	SSAC[2]	4	3.10	2.03	0.11	9.72	25.0 ± 35.6	C[4]/NA
		Specific Conductance	µmho/cm	≤ 1,275[3]	136	1,073	244	480	1,455	19.9 ± 5.6	C
		Un-ionized Ammonia	mg/L	≤ 0.02	78	0.0031	0.0037	< 0.0001	0.02	1.3 ± 2.1	MC
	Rim	Specific Conductance	µmho/cm	≤ 1,275[3]	45	992	224	334	1,354	6.7 ± 6.1	MC
	Interior	Alkalinity	mg/L	≥ 20	260	75	66	5	268	13.1 ± 3.4	C
		DO	mg/L	SSAC	36	3.98	2.25	0.28	11.20	27.8 ± 12.3	C
		pH	units	≥ 6.0, ≤ 8.5	334	6.72	0.37	5.72	7.90	2.1 ± 1.3	MC (C)
WCA-2	Inflow	Specific Conductance	µmho/cm	≤ 1,275[3]	147	1,029	259	339	1,498	18.4 ± 5.3	C
		Un-ionized Ammonia	mg/L	≤ 0.02	90	0.0046	0.0081	< 0.0001	0.04	6.7 ± 4.3	MC (C)
	Interior	DO	mg/L	SSAC	20	2.63	1.86	0.08	8.00	50.0 ± 18.4	C[4]/C
		Specific Conductance	µmho/cm	≤ 1,275[3]	295	1,034	259	403	1,800	21.0 ± 3.9	C
WCA-3	Inflow	DO	mg/L	SSAC	14	4.02	2.04	0.28	11.60	7.1 ± 11.3	PC[4]/PC
		pH	units	≥ 6.0, ≤ 8.5	375	7.46	0.33	6.41	8.70	0.3 ± 0.4	MC
	Interior	DO	mg/L	SSAC	23	2.93	1.77	0.03	8.41	47.8 ± 17.1	C[4]/C
		pH	units	≥ 6.0, ≤ 8.5	344	7.28	0.27	4.72	7.99	0.3 ± 0.5	MC
	Outflow	DO	mg/L	SSAC	12	3.52	1.52	0.51	7.44	8.3 ± 13.1	PC[4]/MC
Park	Inflow	DO	mg/L	SSAC	11	3.51	1.94	0.18	9.15	9.1 ± 14.3	PC[4]/PC
	Interior	Un-ionized Ammonia	mg/L	≤ 0.02	74	0.0016	0.0057	< 0.0001	0.05	1.4 ± 2.2	MC

1. Categories entries denote data not available (NA), and categories of concern (C), potential concern (PC), and minimal concern (MC). Parentheses indicate a localized exceedance rate greater than the regional (area and class) classification; that is, one or more stations had higher exceedance rates between WY2002–WY2006 than in WY2006.
2. The Everglades dissolved oxygen (DO) site-specific alternative criterion (SSAC) is based on a mathematical equation that models the sinusoidal diel cycle and seasonal variability of DO in the Everglades and is assessed as an annual average by station. The SSAC is discussed in the DO section of this chapter.
3. Specific conductance shall not be increased 50 percent above background or 1,275 micromhos per centimeter (µmhos/cm), whichever is greater. Assessment present in this report is based only on the 1,275 µmhos/cm component of the criterion.
4. Insufficient sample size to apply binomial hypothesis test to WY2006 data alone; analysis was based on a five-year period of record from WY2002 through WY2006.

Table 3A-3. Summary of excursions from Class III criteria in the EPA for WY2006, WY2005, and historical data (WY1978–WY2004).

Area	Class	Parameter	1978-2004		2005		2006	
			Number of Excursions[1]	Percent Excursions[2]	Number of Excursions	Percent Excursions	Number of Excursions	Percent Excursions
Refuge	Inflow	DO	23 (134)	17.2 (C)	1 (5)	20.0 (C*)	1 (4)	25.0 (C*)
		pH	13 (2,724)	0.5 (MC)	1 (135)	0.7 (MC)	0 (136)	0.0 (NC)
		Specific Conductance	639 (2,737)	23.3 (C)	1 (131)	0.8 (MC)	27 (136)	19.9 (C)
		Turbidity	62 (2,143)	2.9 (MC)	0 (77)	0.0 (NC)	0 (80)	0.0 (NC)
		Un-ionized Ammonia	39 (2,174)	1.8 (MC)	0 (74)	0.0 (NC)	1 (78)	1.3 (MC)
	Rim	Specific Conductance	107 (752)	14.2 (C)	1 (43)	2.3 (MC)	3 (45)	6.7 (MC)
	Interior	Alkalinity	570 (2,342)	24.3 (C)	38 (251)	15.1 (C)	34 (260)	13.1 (C)
		DO	66 (222)	29.7 (C)	17 (35)	48.6 (C)	10 (36)	27.8 (C)
		pH	225 (2,446)	9.2 (PC)	17 (301)	5.6 (MC)	7 (334)	2.1 (MC)
		Un-ionized Ammonia	3 (1,879)	0.2 (MC)	1 (238)	0.4 (MC)	0 (234)	0.0 (NC)
	Outflow	pH	5 (1,293)	0.4 (MC)	0 (61)	0.0 (NC)	0 (49)	0.0 (NC)
		Specific Conductance	155 (1,316)	11.8 (C)	0 (59)	0.0 (NC)	0 (49)	0.0 (NC)
		Turbidity	11 (1,280)	0.9 (MC)	2 (60)	3.3 (MC)	0 (49)	0.0 (NC)
WCA-2	Inflow	DO	44 (138)	31.9 (C)	0 (8)	0.0 (NC*)	0 (7)	0.0 (NC*)
		pH	8 (1,874)	0.4 (MC)	0 (168)	0.0 (NC)	0 (147)	0.0 (NC)
		Specific Conductance	321 (1,898)	16.9 (C)	15 (167)	9.0 (PC)	27 (147)	18.4 (C)
		Turbidity	15 (1,453)	1.0 (MC)	2 (81)	2.5 (MC)	0 (68)	0.0 (NC)
		Un-ionized Ammonia	68 (1,651)	4.1 (MC)	11 (99)	11.1 (PC)	6 (90)	6.7 (MC)
	Interior	DO	118 (268)	44.0 (C)	10 (21)	47.6 (C*)	10 (20)	50.0 (C*)
		pH	21 (4,189)	0.5 (MC)	3 (227)	1.3 (MC)	0 (280)	0.0 (NC)
		Specific Conductance	427 (4,132)	10.3 (PC)	18 (240)	7.5 (PC)	62 (295)	21.0 (C)
		Un-ionized Ammonia	12 (3,494)	0.3 (MC)	1 (177)	0.6 (MC)	0 (238)	0.0 (NC)
	Outflow	DO	26 (119)	21.8 (C)	0 (5)	0.0 (NC*)	0 (5)	0.0 (NC*)
		pH	7 (1,576)	0.4 (MC)	0 (79)	0.0 (NC)	0 (93)	0.0 (NC)
		Specific Conductance	27 (1,588)	1.7 (MC)	0 (81)	0.0 (NC)	0 (96)	0.0 (NC)

1. In Number of Excursions columns, parenthetic entries indicate the total number of samples for the period.
2. In Percent Excursions columns:
   - Parenthetic entries denote categories of concern (C), potential concern (PC), and minimal concern (MC).
   - An asterisk (*) associated with an excursion category indicates an insufficient sample size (≤ 28) to confidently characterize the excursion frequency; categorization is preliminary, and further evaluation is required.

Table 3A-3. Continued.

Area	Class	Parameter	1978-2004		2005		2006	
			Number of Excursions	Percent Excursions	Number of Excursions	Percent Excursions	Number of Excursions	Percent Excursions
WCA-3	Inflow	DO	96 (331)	29.0 (C)	1 (14)	7.1 (PC*)	1 (14)	7.1 (PC*)
		pH	35 (5,184)	0.7 (MC)	0 (393)	0.0 (NC)	1 (375)	0.3 (MC)
		Specific Conductance	69 (5,233)	1.3 (MC)	0 (392)	0.0 (NC)	0 (379)	0.0 (NC)
		Total Beryllium[3]	4 (22)	18.2 (PC*)	—	—	—	—
		Turbidity	56 (4,247)	1.3 (MC)	0 (188)	0.0 (NC)	0 (205)	0.0 (NC)
		Un-ionized Ammonia	11 (4,336)	0.3 (MC)	1 (195)	0.5 (MC)	0 (209)	0.0 (NC)
	Interior	DO	51 (154)	33.1 (C)	7 (22)	31.8 (C*)	11 (23)	47.8 (C*)
		pH	0 (2,531)	0.0 (NC)	1 (198)	0.5 (MC)	1 (344)	0.3 (MC)
	Outflow	DO	36 (195)	18.5 (C)	0 (10)	0.0 (NC*)	1 (12)	8.3 (PC*)
		pH	44 (4,265)	1.0 (MC)	0 (187)	0.0 (NC)	0 (199)	0.0 (NC)
		Turbidity	3 (3,338)	0.1 (MC)	0 (149)	0.0 (NC)	0 (164)	0.0 (NC)
Everglades National Park (ENP or Park)	Inflow	DO	26 (204)	12.7 (PC)	0 (11)	0.0 (NC*)	1 (11)	9.1 (PC*)
		pH	54 (5,067)	1.1 (MC)	0 (269)	0.0 (NC)	0 (261)	0.0 (NC)
		Specific Conductance	1 (5,104)	0.0 (MC)	0 (257)	0.0 (NC)	0 (252)	0.0 (NC)
		Turbidity	3 (3,821)	0.1 (MC)	0 (168)	0.0 (NC)	0 (160)	0.0 (NC)
	Interior	DO	3 (177)	1.7 (MC)	1 (9)	11.1 (PC*)	0 (9)	0.0 (NC*)
		pH	22 (1,541)	1.4 (MC)	0 (80)	0.0 (NC)	0 (80)	0.0 (NC)
		Specific Conductance	22 (1,659)	1.3 (MC)	0 (80)	0.0 (NC)	0 (80)	0.0 (NC)
		Un-ionized Ammonia	21 (1,474)	1.4 (MC)	0 (80)	0.0 (NC)	1 (74)	1.4 (MC)

3. A dash (—) indicates that no samples were collected for the parameter during the period of record.

DISSOLVED OXYGEN

Oxygen gas dissolved in water is vital to the existence of most aquatic organisms. Oxygen is a key component in cellular respiration for both aquatic and terrestrial life. The concentration of DO in an aquatic environment is an important indicator of that environment's quality. Within any water body, the maximum quantity of oxygen that can be held in solution (i.e., saturation concentration) is controlled by the solubility of oxygen in water. The solubility of oxygen in water is inversely related to temperature and chlorinity or salinity of the water. That is, higher concentrations of DO can be maintained under conditions of lower temperature and salinity than is possible under warmer, more saline conditions. In any biologically active aquatic system, the actual concentration of DO within the water column is regulated by a variety of sources and sinks which are balanced in healthy systems, resulting in sufficient levels of DO to support a variety of aquatic life.

A site-specific alternative criterion (SSAC) for DO in the EPA was adopted by the FDEP on January 26, 2004 and was subsequently approved by the USEPA as a revision to the Florida Water Quality Standards. Because a single value criterion does not adequately account for the wide-ranging natural daily (diel) fluctuations observed in the Everglades marshes, the SSAC provides a mechanism to account for the major factors (e.g., time of day and season) influencing natural background DO variation in the Everglades (Weaver, 2004). The SSAC is based on an algorithm that uses sample collection time and water temperature to model the observed natural sinusoidal diel cycle and seasonal variability. This model provides a lower DO limit (DOL) for an individual monitoring station and is described by the equation:

$$DOL_i = [-\,3.70 - \{1.50 \cdot \text{sine}\,(2\pi/1440 \cdot t_i) - (0.30 \cdot \text{sine}\,[4\pi/1440 \cdot t_i])\} + 1/(0.0683 + 0.00198 \cdot C_i + 5.24{\cdot}10^{-6} \cdot C_i^2)] - 1.1$$

Where:

DOL_i = lower limit for the i^{th} annual DO measurement in milligrams per liter (mg/L)

t_i = sample collection time in minutes (Eastern Standard Time) since midnight of the *i*th annual DO measurement

C_i = water temperature associated with the i^{th} annual DO measurement in degrees Celsius

To account fully for seasonal and annual variability in marsh DO concentrations, ambient assessment with the SSAC is based on a comparison between the annual average of monthly DO measurements and the average of the corresponding DO limits specified by the above equation for that year. In other words, annual average observed DO at a monitoring station is compared to the annual average of all DOL_i determinations for that year. DO excursion results for individual stations are provided in Appendix 3A-3.

Because DO is assessed as an annual station average rather than as point measures, there were insufficient data to confidently apply the binomial hypothesis test to the regional assessment units. Therefore, excursion categories for DO were assigned based on a five-year period of record (WY2002–WY2006) for all areas. DO was categorized as a concern for the Refuge interior, WCA-2 interior, and WCA-3 interior. Additionally, DO was categorized as a potential concern for WCA-2 inflows, WCA-3 inflows, and Park inflows. Furthermore, no conclusions regarding differences (trends) in DO excursion rates between individual water years and the historic period can or should be made, given the large disparity in sample sizes among periods.

One group of stations failing to meet the SSAC in WY2006 was influenced either by altered hydrogeomorphic conditions caused by canal construction and water control structure operation or by nutrient enrichment. Similar to the results reported in previous SFERs (Weaver et al., 2001, 2002, 2003; Weaver and Payne, 2004, 2005, 2006), several water control structures (inflow and outflow sites) failed the SSAC test. This pattern of non-compliance likely results from multiple factors, including the disturbance of bottom sediments, intrusion of low DO groundwater into the surface water at these structures, and effects of nutrient enrichment. Sediments that commonly mix with canal surface waters during pumping events can increase oxygen demand within the water column, reducing DO concentrations (Environmental Services and Permitting, Inc., 1992). Groundwater intrusion is common at the Everglades pumping stations and canals dug below the water table. The influence of groundwater on DO at these structures represents a potentially "human-induced condition, which cannot be controlled or abated" (Section 62-302.800, F.A.C.) and should be addressed separately.

The second group of stations failing the SSAC consisted of interior marsh stations known to be biologically impaired because of phosphorus enrichment (e.g., E1, F1, Z1, and 3AW05). Conditions at these stations are expected to remain impaired until phosphorus concentrations in surface water and sediment are reduced and the biological communities recover.

The excursion categories assigned to the WCA interior regions were influenced by the high spatial monitoring intensity within enriched marsh areas. When unenriched areas are evaluated separately, DO is classified as a minimal concern for unimpacted areas of WCA-2 (11.1 ± 8.6 percent), and a potential concern for the Refuge (13.6 ± 5.6 percent) and WCA-3 (15.0 ± 7.6 percent). DO excursions within the unimpacted Refuge marsh were localized in one area. Between WY2002 and WY2006, ten exceedances were recorded among sites X3, X4, and Y4 on the west-central side of the Refuge. The cause of these exceedances is uncertain, although nutrient enrichment does not appear to be a major factor. Five-year average geometric mean TP concentrations were less than or equal to 10 micrograms per liter (µg/L) at all three sites (1-sided Student's t-test: $p = 0.14–0.98$).

ALKALINITY AND PH

Alkalinity provides a measure of water's acid neutralization capacity, in turn indicating the water's buffering capacity. In most surface water bodies, the buffering capacity is primarily the result of the equilibrium between carbon dioxide molecules and bicarbonate and carbonate ions (CO_2, HCO_3^-, and CO_3^{2-}). The dissociation of calcium carbonate, magnesium carbonate, or other carbonate-containing compounds entering the surface water through weathering of carbonate-containing rocks and minerals (e.g., limestone and calcite) contributes to water's buffering capacity. Therefore, in certain areas (such as the Park, WCA-2, and WCA-3) influenced by canal inflows that are primarily composed of mineral-rich agricultural runoff and groundwater, alkalinity levels are relatively high. Conversely, other areas, such as the interior of the Refuge, which receive most of their hydrologic load through rainfall, have very low alkalinities. Alkalinity protects aquatic life against dramatic pH changes. Rapid pH changes are difficult for living organisms to adapt to, result in severe stress, and may be lethal to sensitive species. Therefore, it is important that surface waters exhibit some minimal level of alkalinity or buffering capacity to restrict dramatic pH swings. The current Class III criterion for alkalinity specifies that this parameter shall not be lowered below 20 milligrams of calcium carbonate per liter (mg $CaCO_3$/L).

Excursions from the state Class III water quality criteria for alkalinity have historically occurred in the interior of the Refuge (Bechtel et al., 1999, 2000; Weaver et al., 2001, 2002, 2003; Weaver and Payne, 2004, 2005, 2006). As in previous years, alkalinity was designated as a concern for the interior of the Refuge for WY2006 due to an excursion rate of 13.1 ± 3.4 percent. As stated above, the low alkalinities and pH values in the Refuge are primarily caused by the hydrologic nature of the area. Most of the water entering the Refuge (approximately 54 percent) is low-alkalinity rainwater (SFWMD, 1992). Along the western periphery of the Refuge, harder (i.e., more mineral rich) canal waters permeate into the marsh along the L-7 rim canal; however, canal waters tend to penetrate only a few kilometers into the marsh and, thus, have little or no influence on the softwater conditions within the interior. The dichotomy of the softwater interior and the hardwater periphery creates steep pH, alkalinity, and other ionic gradients in the Refuge from the canals into the marsh (Swift and Nicholas, 1987; Richardson et al., 1990; Weaver et al., 2001; Weaver and Payne, 2004). Alkalinity within the Refuge decreases with distance from the rim canal (Payne et al., 2000; Weaver et al., 2001; Weaver and Payne, 2004; **Figure 3A-6**). In fact, stations in the central region of the Refuge have the lowest alkalinity levels, with median concentrations at or below the state criterion of 20 mg $CaCO_3$/L. Therefore, alkalinity excursions within the Refuge are not a result of a controlled discharge or pollution source but rather the natural soft water, rainfall-driven nature of the system. The low alkalinity values represent the normal background conditions typical of this ecosystem; therefore, the FDEP does not consider these low values in the interior of the Refuge to be in violation of state water quality standards.

An apparent significant decline in alkalinity excursions occurred between WY2006 (13.1 ± 3.4) and WY2005 (15.1 ± 3.7) and the historic period (24.3 ± 1.5). However, this change is most likely related to the addition of Refuge monitoring sites (**Figure 3A-2**), in areas of higher alkalinity, to the Refuge interior monitoring network for the past two water years, as opposed to changes in the water quality within the interior of the Refuge. This conclusion is supported by the fact that no significant trends, either as concentration or as percent below 20 mg/L, have been detected at any site, such as LOX3, LOX10, X3, or Z4, with long-term data (11–15 years).

Although pH was categorized as a minimal concern for the Refuge interior based on the aggregated regional analysis, localized excursions resulted in pH being classified as a concern at LOX11 and a potential concern at LOX3, LOX8, and LOX8. The pH excursions occurred at sites well within the interior of the refuge; as described in previous reports, these excursions related to pH are naturally low alkalinities within the Refuge's interior marsh. Because pH excursions within the interior of the marsh are linked to natural background alkalinity conditions, the FDEP does not consider pH levels within the interior of the Refuge to be in violation of state water quality standards.

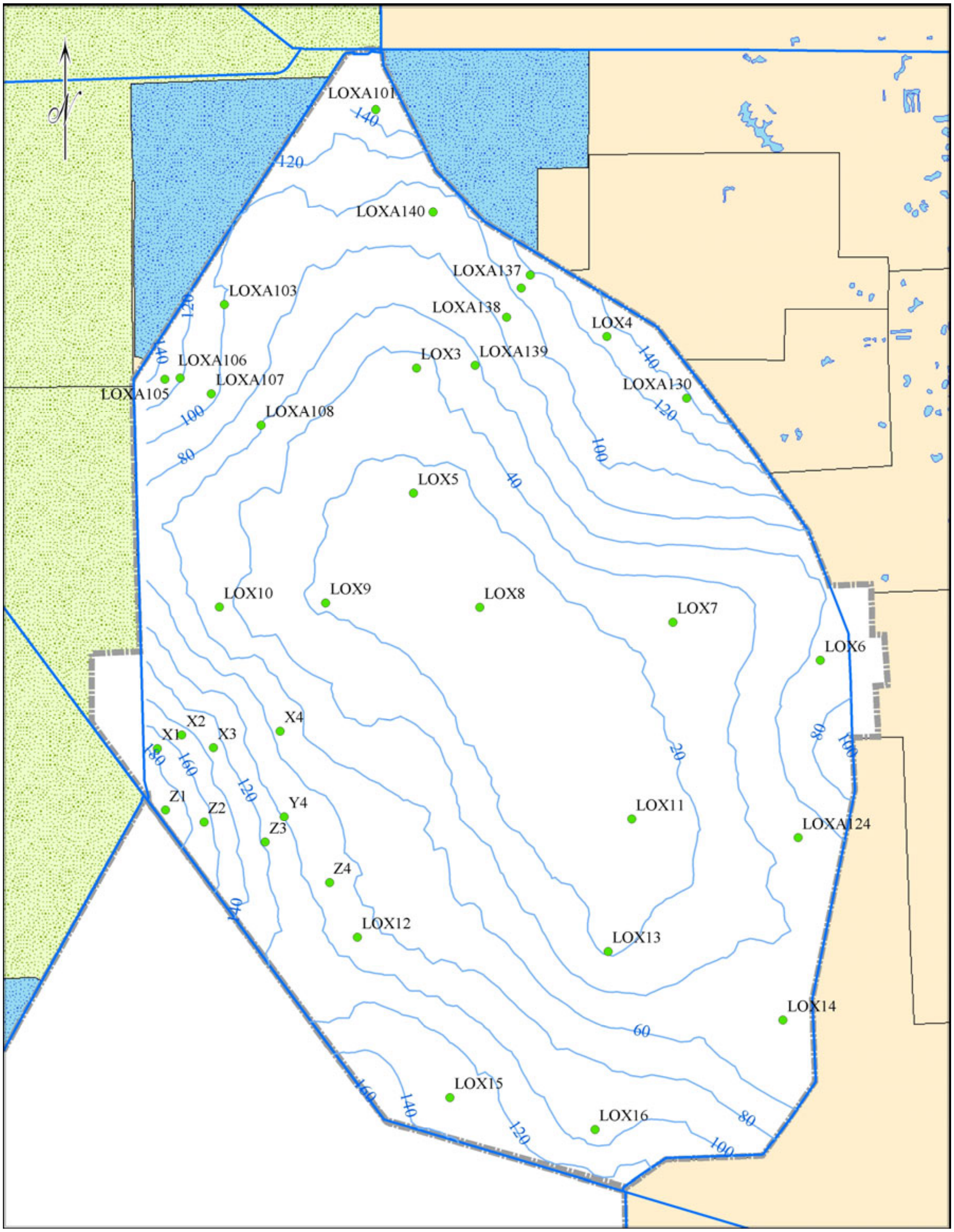

Figure 3A-6. Alkalinity concentration (mg/L) contours within the Refuge. Values are expressed as the median for data collected at the rim canal, inflow, and interior marsh stations over past five water years (WY2002–WY2006). Contours were based on all available alkalinity of data for the period of record, including all sites from the Refuge expanded monitoring project.

SPECIFIC CONDUCTANCE

Specific conductance is a measure of water's ability to conduct an electrical current and is an indirect measure of the water's total concentration of ionized substances (e.g., Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{2-}). Conductivity will vary with the concentration and type of ions in solution. In some cases, it can be used to differentiate among various water sources, such as groundwater, rainwater, agricultural runoff, and municipal wastewater. Changes in conductivity beyond natural background variability can result in potentially deleterious effects to aquatic life. For instance,very high conductivities would be detected under conditions of saltwater intrusion. The current state water quality criteria for Class III freshwaters, which allows for a 50 percent increase in the specific conductance or 1,275 micromhos per centimeter (µmhos/cm), whichever is greater, is intended to preserve natural background conditions and protect aquatic organisms from stressful ion concentrations. Given the low background conductivities within the EPA, excursions were calculated using the 1,275 µmhos/cm criterion (Weaver et al., 2001 and 2002).

For WY2006, conductivity was categorized as a concern for Refuge inflows, WCA-2 inflows, and WCA-2 interior. The WY2006 excursion frequency (21.0 ± 3.9 percent) for the WCA-2 interior was significantly greater than both WY2005 (7.5 ± 2.8 percent) and the WY1978–WY2004 historical period (10.3 ± 0.8 percent). Similar to previous periods, the WY2006 excursions in WCA-2 were localized to a few monitoring stations, which resulted in specific conductance being categorized as a concern for the interior stations F1, F2, F3, CA27, CA28, 404-C2, 404-Z1, N1, and G-335. Eighty-five percent of the excursions at WCA-2 inflows occurred at the G-335 structure. Previous consolidated reports explained that the elevated conductivity levels at water control structures (e.g., G-335) and stations near canal inflows were probably linked to groundwater intrusion into canal surface waters (Weaver et al., 2001 and 2002). This groundwater intrusion can occur due to seepage into canals, via pumping station operation (which can pull additional groundwater into surface water), and because of agricultural dewatering practices.

All WY2006 exceedances at sites F1, F2, and F3 occurred during periods of no recorded flows through the upstream structures (S-10A, S-10C, and S-10D). Furthermore, over the previous five water years, the majority (88.7 percent) of exceedances at these stations occurred during periods of no flow. The excursions during these periods may be related to either the concentration of ions associated with the evaporation of marsh water or the seepage of groundwater into the WCA-2 marsh, practically near site F1. Recent studies south of the S-10 structures support the hypothesis that groundwater seepage occurs during dry periods (Krest and Harvey, 2003).

UN-IONIZED AMMONIA

Ammonia (NH_3) is unique among regulated water quality constituents because it is both a source of nitrogen (a nutrient required for life) and an endogenously produced toxicant for which organisms have developed a variety of strategies to excrete as a waste product. The concentration of ammonia necessary to become toxic is highly variable because the toxicity is affected by temperature, pH, DO and CO_2 concentrations, previous acclimation to ammonia, and the presence of other toxic compounds. High external ammonia concentrations reduce or reverse diffusion gradients used by organisms to excrete excess ammonia. This excess ammonia can accumulate in the organism, thereby resulting in altered metabolism, loss of equilibrium, hyperexcitability, increased respiratory activity and oxygen uptake, and increased heart rate. Even slightly elevated concentrations of ammonia have been associated with a reduction in hatching success in some animals, a reduction in growth rate and morphological development in others, and injuries to gill tissue, liver, and kidneys. In fish, extremely high levels of ammonia can result in convulsions, coma, and even death.

The current state Class III water quality criterion for ammonia is ≤ 0.02 mg/L. The amount of ammonia is calculated using pH, temperature, and total dissolved ammonia measurements from the same sample. During WY2006, six calculated ammonia values above 0.02 mg/L were recorded. Based on the aggregated regional analysis, ammonia was categorized as a minimal concern for WCA-2 inflows; however, all WCA-2 WY2006 excursions were localized at two inflow stations (E0 and F0). Furthermore, ammonia was categorized as a localized concern for E0 and F0 based on an analysis of WY2002–WY2006 data.

The localization of ammonia excursions at E0 and F0 continues a pattern initially noted in the *2003 Everglades Consolidated Report*. Stations E0 and F0 are located within the WCA-3A spreader canal, which receives Hillsboro Canal discharges from the S-10A, S-10C, and S-10D structures and, in turn, overflows into the marsh when canal stages exceed the height of a low berm. A review of hydrologic and water quality monitoring records suggests that the high ammonia levels at sites E0 and F0 were likely related to the stagnant (i.e., low DO), low water conditions in the spreader canal during WY2002–WY2006. The spreader canal can become stagnant and anaerobic during periods of no or low flow, such as when the S-10A, S-10C, and S-10D structures are closed, resulting in substantial changes in biogeochemical conditions and constituent concentrations within the canal. Flow records indicate that discharges via the S-10A, S-10C, and S-10D structures were limited during recent years with the ammonia excursion episodes occurring following periods of no flow.

As discussed in past consolidated reports, the elevated total dissolved ammonia concentrations measured in the canal most likely arose from internal nitrogen cycling. Nutrient-enriched surface water within the spreader canal can support substantial growth of algae that accumulate when the canal is stagnant and is not being flushed by incoming water from the Hillsboro Canal. When the accelerated growth of algae can no longer be supported, the algae die, fall to the bottom, and decay, resulting in the release of ammonia under anaerobic conditions. Because the anaerobic conditions inhibit the oxidation of the released ammonia into nitrite and nitrate, the ammonia accumulates (i.e., concentration increases) within the canal.

The elevated total dissolved ammonia levels continue to be the proximal cause of the E0 and F0 ammonia excursions (**Figure 3A-7**), which is expected if the cause were related to the release of ammonia under low flow or stagnant conditions, as described above. For WY2006, the median total dissolved ammonia concentrations at sites E0 and F0 were 0.38 mg/L and 0.72 mg/L, respectively. Furthermore, during the entire monitoring record (WY1994–WY2006) at these two stations, elevated, total dissolved ammonia concentrations were the proximal cause of all 75 ammonia excursions within the WCA-2 spreader canal (Weaver and Payne, 2004, 2005, 2006).

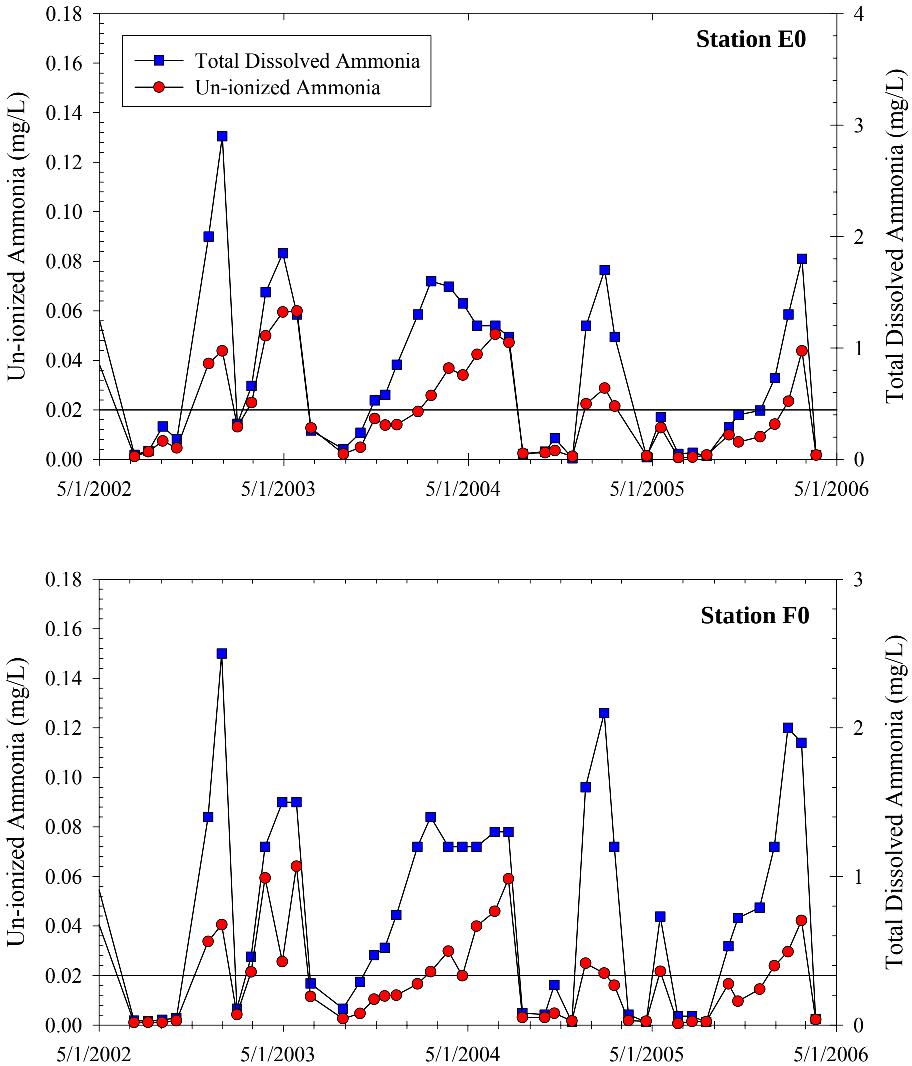

Figure 3A-7. Total dissolved ammonia concentrations and calculated ammonia values for sites E0 (top) and F0 (bottom) during WY2002–WY2006. Horizontal solid black line is the Class III ammonia criterion (0.02 mg/L).

SULFATE

Currently, the state has no surface water criterion for sulfate (SO_4^{2-}); however, recent research has provided evidence of a link between sulfur biogeochemistry in sediment and pore water and mercury methylation, as reported in Chapter 3B of the 2006 SFER – Volume I and previous reports (Atkeson and Parks, 2002; Atkeson and Axelrad, 2003; Axelrad et al., 2005; 2006). Sulfate in the surface waters of the Everglades is derived from a variety of natural and human sources. Bates et al. (2002) found that the major source of sulfate within the EPA was drainage from the Everglades Agricultural Area (EAA). Stormwater runoff from the EAA contains high concentrations of sulfate that arise from both the current and historical use of sulfur-containing fertilizers and soil amendments (Bates et al., 2002). Additionally, under some conditions in the Everglades, groundwater containing elevated sulfate levels can rise to the surface (Atkeson and Parks, 2002).

The sulfate monitoring results in the EPA are presented in this chapter to provide an overview of current concentrations and evaluate temporal and spatial patterns. Sulfate concentrations are summarized in **Table 3A-4** for WY2006, WY2005, and WY1978–WY2004 based on arithmetic mean and median values. Given that EAA stormwater runoff is a primary source of sulfate entering the EPA, sulfate concentrations in the inflow and interior marsh generally follow trends similar to those observed for TP and total nitrogen (TN); that is, sulfate concentrations exhibit a general north-to-south gradient extending from the sources in the north to relatively unenriched areas in the south. High inflow concentrations in EAA runoff enter the Refuge, WCA-2 and, to a lesser extent, WCA-3. The highest concentrations within the EPA have been observed at the Refuge and WCA-2 inflow stations. However, as previously discussed, a significant amount of the surface water entering the Refuge does not permeate deeply in the marsh but remains around the periphery in the rim canal and is discharged to WCA-2 through the S-10 structures. This hydrologic characteristic has helped the Refuge interior to remain relatively uninfluenced by the inflow of sulfate-rich water. Of the EPA marsh areas, the interior of WCA-2 exhibits the highest sulfate concentrations and is most affected by EAA runoff, with a WY2006 median concentration of 43 mg/L. Although sulfate concentrations at stations in the WCA-3 interior also have been elevated by inputs of sulfate-enriched runoff, this is not readily apparent in WY2006, with its median sulfate concentration of 2.9 mg/L. As demonstrated in the 1995, 1996, and 1999 USEPA Regional Environmental Monitoring and Program studies, a pronounced north-to-south sulfate gradient is evident within WCA-3 (Atkeson and Parks, 2002). This gradient is apparent within the District's monitoring network (**Figure 3A-8**). The highest WY2006 sulfate concentrations within the WCA-3 interior were observed at station CA317 (median = 29.5 mg/L) in the northeastern portion of this area. Concentrations decreased through the marsh, following the southerly flow of water. The lowest median sulfate concentration observed during WY2006 at sites in the WCA-3 marsh (median < 0.10 mg/L) was at station CA315, the most southerly sampling location in WCA-3.

Table 3A-4. Summary of sulfate concentrations (mg/L) in the EPA for WY1978–WY2004, WY2005, and WY2006.

Region	Class	Period	N	Arithmetic Mean	Std. Deviation	Median	Min.	Max.
Refuge	Inflow	1978–2004	896	59	42	52	<0.1	461
		2005	60	54	19	52	14	94
		2006	57	70	23	73	18	116
	Rim	1978–2004	608	54	27	49	1.6	140
		2005	44	47	18	44	8.3	100
		2006	46	62	27	65	7.9	110
	Interior	1978–2004	2365	15	64	3.6	<0.1	2900
		2005	284	10	16	2.7	<0.1	84
		2006	340	7.0	15	1.3	<0.1	78
	Outflow	1978–2004	390	48	46	41	1.4	571
		2005	26	46	20	46	4.0	77
		2006	20	49	25	52	9.3	86
WCA-2	Inflow	1978–2004	797	52	40	47	6.2	644
		2005	72	49	20	44	4.0	99
		2006	65	55	22	55	9.5	106
	Interior	1978–2004	3626	44	35	41	0.1	1400
		2005	183	45	18	45	5.2	100
		2006	254	47	22	43	11	110
	Outflow	1978–2004	399	36	26	31	2.3	224
		2005	27	40	13	41	15	69
		2006	30	43	19	42	9.7	86
WCA-3	Inflow	1978–2004	1148	25	25	17	0.5	286
		2005	78	24	18	18	1.6	69
		2006	85	24	21	16	2.1	86
	Interior	1978–2004	2349	9.8	14	4.6	<0.1	262
		2005	195	12	17	2.3	<0.1	57
		2006	310	8.5	13	2.9	<0.1	84
	Outflow	1978–2004	605	12	16	8.0	<0.1	113
		2005	50	7.8	11	<0.1	<0.1	36
		2006	39	8.6	12	7.4	<0.1	69
Everglades National Park	Inflow	1978–2004	576	12	16	7.6	<0.1	113
		2005	49	6.9	9.6	1.9	<0.1	36
		2006	27	5.6	6.4	2.5	<0.1	17
	Interior	1978–2004	1548	6.3	18	2.8	<0.1	403
		2005	80	7.0	27	1.4	<0.1	242
		2006	74	5.6	16	2.1	<0.1	136

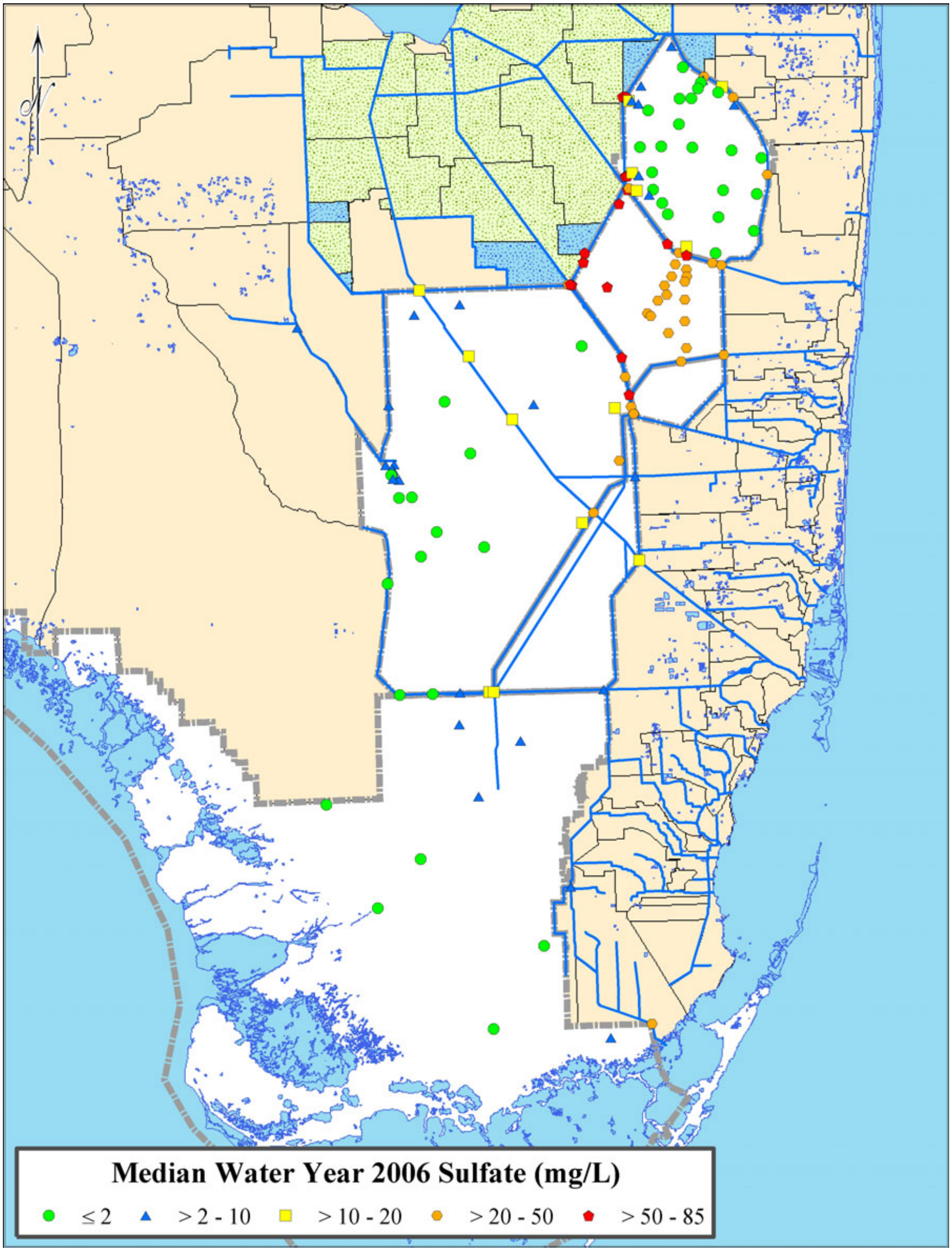

Figure 3A-8. Summary of median WY2006 sulfate concentrations (mg/L) at stations across the EPA. Median sulfate concentrations are classified utilizing five levels: ≤ 2 mg/L, > 2–10 mg/L, > 10–20 mg/L, > 20–50 mg/L, and > 50–85 mg/L.

PESTICIDES

The SFWMD has maintained a pesticide monitoring program in South Florida since 1984. The pesticide monitoring network includes sites designated in the Park Memorandum of Agreement (MOA), the Miccosukee Tribe MOA, the Lake Okeechobee Operating Permit, and the non-ECP Structure Permit. The current monitoring program in the EPA consists of 29 sites (**Figure 3A-9**). These sites were grouped by basin for analysis.

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

This chapter analyzes data collected during pesticide monitoring events conducted between February 1, 2005 and February 28, 2006. The period of record was selected as an update to the 2006 SFER and the availability of data at the time this report was written. Monitoring results were evaluated relative to Class III water quality criteria, chronic toxicity guidelines, and detected concentrations. Pesticides exceeding either the Class III criteria or chronic toxicity guideline concentrations were classified as concerns for the basin in which the exceedance occurred. Parameters classified as "concerns" have a likelihood of resulting in an impairment of the designated use of the water body. Detected water quality constituents (≥ MDL) that did not exceed either a guideline or criterion were categorized as a "potential concern." This classification signifies that the water quality constituent is known to be present within the basin at concentrations reasonably known to be below levels that can result in adverse biologic effects, but may only result in a problem at some future date or in interaction with other compounds. The "no concern" category was used to designate pesticides that were not detected at sites within a given area.

Twelve pesticides, or degradation products, were detected between February 1, 2005 and February 28, 2006 (**Table 3A-5**). Only atrazine and naled were classified as concerns within the EPA. One atrazine (guidance concentration = 1.8 µg/L) excursion was recorded at the S-38 inflow structure to WCA-3A, due to an atrazine concentration of 3.3 µg/L on May 27, 2006. An excursion from the toxicity guideline for naled (0.018 µg/L) occurred on February 1, 2006, at Refuge inflow station G94D. The reported naled concentration of 0.2 µg/L was below the analytical PQL and only slightly above the detection limit (0.16 µg/L).

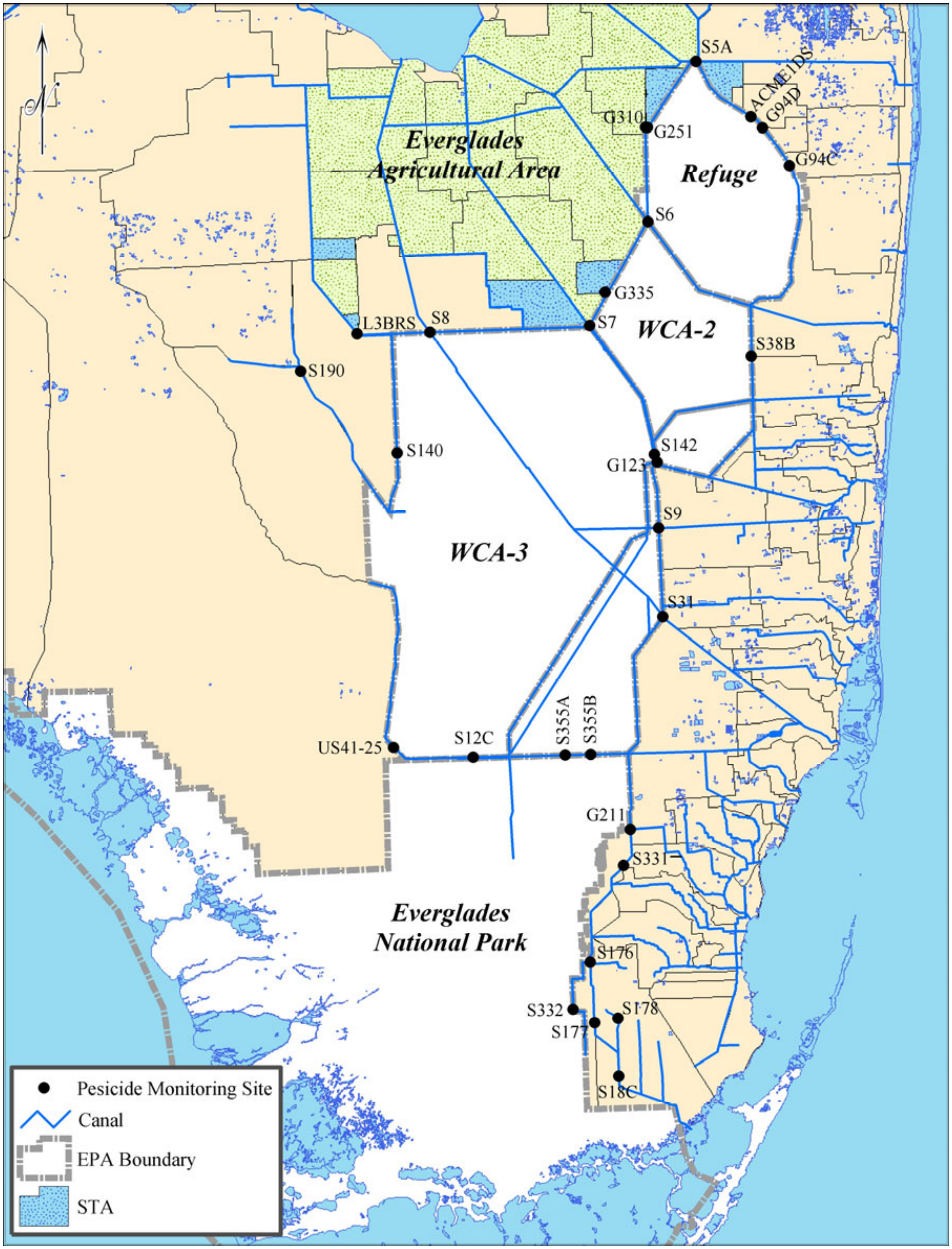

Figure 3A-9. SFWMD pesticide monitoring sites in the EPA.

Table 3A-5. Pesticide detection and exceedance categories in the EPA inflows, canals, and structures between February 1, 2005 and February 28, 2006. The categories of "concern" and "potential concern" are denoted by "C" and "PC," respectively; all others are considered "no concern." Number of detections and total number of samples are in parentheses.

Parameter	Refuge[1]	WCA-2[2]	WCA-3[3]	Park[4]	C-111[5]
Ametryn	PC (17:20)	PC (8:9)	PC (14:31)	(0:21)	(0:15)
Atrazine	PC (20:20)	C (10:10)	PC (27:37)	PC (13:18)	PC (11:13)
Atrazine Desethyl	PC (11:20)	PC (8:9)	PC (7:35)	(0:18)	PC (1:11)
Atrazine Desisopropyl	(0:16)	PC (3:8)	(0:29)	(0:17)	(0:11)
Diuron	PC (2:20)	(0:10)	(0:40)	(0:21)	(0:15)
Endosulfan (alpha + beta)[6]	(0:20)	(0:10)	(0:37)	PC (2:21)	PC (7:15)
Endosulfan Sulfate	(0:19)	(0:10)	(0:37)	(0:21)	PC (7:15)
Hexazinone	PC (17:17)	PC (1:9)	PC (4:34)	(0:14)	(0:12)
Metolachlor	PC (3:20)	PC (1:9)	PC (1:32)	(0:17)	PC (1:15)
Naled	C (1:16)	(0:8)	(0:22)	(0:10)	(0:6)
Norflurazon	(0:20)	(0:9)	PC (11:37)	(0:21)	(0:15)
Simazine	PC (2:12)	PC (1:8)	PC (2:37)	(0:21)	(0:15)

1. ACME1DS, G-251, G-94D, G-310, and S-5A via Stormwater Treatment Area 1W.
2. S-38B, S-6 (via STA-2), and S-7.
3. G-123, L3BRS, S-140, S-190, S-8, S-9, S-142, and S-31.
4. S-12C, S-18C, S-332, S-335A, S-355B, and US41-25.
5. G-211, S-176, S-177, S-178, and S-331.
6. Both alpha and beta endosulfan were detected, but are combined in the total and considered a single constituent.

WATER QUALITY MONITORING AND ANALYSIS FOR NON-ECP STRUCTURES

The non-ECP permit requires District monitoring of all discharges for phosphorus, the parameter of primary concern, in addition to general water quality parameters to track the progress toward achieving compliance with water quality standards. The District is responsible for carrying out the programs mandated by the Everglades Forever Act (EFA) through compliance requirements stipulated in permits issued by the FDEP. On April 20, 1998, the FDEP issued the non-ECP permit (Permit No. 06.502590709) pursuant to Section 9(k) of the EFA. The permit authorizes the continued operation of water control structures that are operated, maintained, and controlled by the District that discharge waters "into," "within," or "from" the EPA but were not included in the permits issued for the ECP. Specific Condition 5 of the non-ECP permit requires the District to submit an annual report that includes results of the evaluation of water quality data and the Mercury Screening Program. Information contained in this volume of the *2007 South Florida Environmental Report* fulfills the reporting requirements as detailed in the specific conditions of the non-ECP permit. The requirements are summarized in **Table 3A-6.** This information was previously described in detail by Trost et al. (2001).

The purpose of this sub-section is to address water quality at the "into," "within," and "from" structures relative to the EPA. There are eight basins discharging directly to the EPA that are not part of the ECP. Five of these basins have "into" structures that are operated and maintained by the District and are permitted under the non-ECP permit: C-11 West, North New River Canal (NNRC), Feeder Canal, L-28, and C-111 basins. The three remaining non-ECP basins that discharge directly to the EPA are not permitted under the non-ECP permit because the discharge structures are not owned or operated by the SFWMD; these three basins are the Village of Wellington's (VOW) ACME Improvement District, North Springs Improvement District (NSID), and Boynton Farms. These basins have structures that discharge to the EPA and are owned and operated by private or local drainage district entities. The location of non-ECP structures, the boundaries of the respective hydrologic contributing basins, and the EPA boundaries are indicated in Appendix 3A-4, Figure 1.

Non-ECP permit conditions require the District to document the accuracy of collected data and to measure progress toward achieving and maintaining compliance with state water quality standards. The non-ECP water quality sampling sites, monitoring schedule, and flow volumes are presented in Appendix 3A-4a. Although phosphorus is of primary concern, the permit specifies that all state water quality standards should be met. To fulfill the requirements of the permit conditions, the District has completed an annual analysis of water quality data at non-ECP structures by comparing the data with state water quality standards. Unlike the ECP basins that are required to decrease TP levels in discharges based on historical loads, there is no phosphorus-specific requirement established at the point of discharge for the non-ECP basins in WY2006. Hence, new technology based effluent limitations have been drafted for all non-ECP basins with discharge.

To document the accuracy of the collected data and measure progress toward achieving and maintaining compliance with state water quality standards, the District has compared WY2006 water quality data from non-ECP structures to state water quality standards. **Table 3A-7** provides a WY2006 summary of flow-weighted mean (FWM) TP concentrations for each non-ECP basin. Results of all water quality analyses are included in Appendix 3A-4 of this volume.

Table 3A-6. Non-ECP permit reporting requirements.

Specific Condition	Reporting Requirement	Comment or Location in 2007 SFER[2]
4[1]	New permit or permit modifications	Renewal in April 21, 2008
5	Submittal of Annual Report	Chapters 1, 3A, 3B, 4, 5, 7, and 8
6	Land acquisition and water treatment facility status update	2007 SFER – Volume II
7	First and second data evaluation reports	Completed in 1998 Annual Report
8	Regulatory Action Report	Chapter 4
9	Update on implementation of schedules and strategies	Chapters 1, 3A, 3B, 4, 5, 7, and 8
10	Laboratory Quality Assurance Manual	Current FDEP-approved manual
11	Mercury Screening Program Report	Chapters 3A and 3B
12	Annual Report, data requirements	See Specific Conditions 12 (b) – 12 (h)
12 (b)	Dates of sampling	Appendix 3A-4
12 (c)	Field Quality Assurance Manual	Current FDEP-approved manual
12 (d)	Map of sampling locations	Appendix 3A-4, Figure 1
12 (e)	Statement of sampling authenticity	Appendix 5-1
12 (f)	Quality Assurance Manual	Current FDEP-approved manual
12 (g) (i-v)	Water quality data and associated information	Appendix 3A-4
12 (g) (iv)	Monthly flow volumes	Appendix 3A-4
12 (h)	Water quality data evaluation	Appendix 3A-4
12(i)	Recommendations for improving water quality monitoring	Completed in 1998 Annual Report
12 (j)	Implementation of strategies	Chapters 1, 3A, 3B, 4, 5, 7, and 8
16	Monitoring Locations Report	Submitted to the FDEP in 1998
19	Additional strategies (if developed)	Not applicable at this time

1. Specific conditions 1–3 do not deal with reporting requirements and therefore are not referenced in this table.
2. Cross-referenced chapters and appendices are applicable to this SFER volume unless noted otherwise.

Table 3A-7. Non-ECP basins annual flow-weighted mean TP concentrations and loads for WY2006.

Hydrologic Basin	Structure	Water Quality Station ID	Total Flow Volume (ac-ft)	Number of Days with Positive Flow	Sample Type	Sample Size (Grab)	Arithmetic Average (Grab) (ppb)	Sample Size (Comp)	Flow-Weighted Mean[1] Concentration (ppb)	Flow-Weighted Mean[2] Concentration (ppb)	TP Load (kilograms)
ACME Improvement District	ACME1DS	ACME1DS	14,161[3]	93[3]	G	15	69	0	75[4]	75[4]	1,309
	ACME1	VOW1	14,161	93	A, G	20	66	25	80	80	1,403
	G-94D	G94D	12,767[3]	110[3]	G	15	83	0	103[4]	107[4]	1,679
	ACME2	VOW2	12,767	110	A, G	21	90	28	112	116	1,832
North Springs Improvement District (NSID)	NSID1	NSIDSP01	0	0	A, G	33	19	12	NDF	NDF	0
		S-38B (WCA-2A near NSID1)	0[5]	0[5]	G	0	0	0	NDF	NDF	0
North New River Canal	G-123	G123	0	0	A, G	51	15	0	N/F	N/F	0
C-11 West	S-9	S9	128,470	91	A, G	18	13	19	19	19	3,055
	S-9A	S9A	61,345	186	A, G	51	12	29	16	16	1,207
C-111	S-174	S174	9,203	50	A, G	10	11	9	14	14	156
	S-332D	S332D	153,803	279	A, G	48	7	36	10	11	2,055
	S-18C	S18C	188,505	228	A, G	51	5	29	13	14	3,298
L-28	S-140	S140	203,575	219	A, G	51	41	45	49	50	12,507
Feeder Canal	S-190	S190	150,359	212	A, G	20	68	26	153	155	28,717
Boynton Farms	Various[6]	Various[6]	N/D	N/D	G	0	N/D	N/D	N/D	N/D	N/D

1. Based on days of flow and monitored TP data only
2. Based on estimation algorithm to determine TP concentration on non-monitored days combined with monitored days
3. Flow data from upstream pump structures, ACME1 and ACME2, is representative of the flow through the ACME1DS and G94D culverts, respectively
4. Calculated using the flow data at upstream structures
5. Flow data from upstream structure NSIDSP01 is representative of flow into the EPA at S-38B
6. Pumps that have no flow recording devices attributed include the following: BFBAFCP, BFBAFNP, BFBAFSP, BFBDFCP, BFBDFNP, BFBDFSP, BFBDFWP, and BFBMFSP.

G Samples collected by grab sampling methodology
A Samples collected by automatic composite samples
NDF No data with flow available
N/F No flow
N/D No data available

In compliance with Specific Condition 5, the appendices of this chapter include an annual update of the non-ECP permit monitoring program, report non-ECP program monitoring results, and a comparison of WY2006 water quality data from samples collected at non-ECP structures to state water quality standards. The comparisons fulfill non-ECP permit requirements to document the accuracy of the collected data and measure progress toward achieving and maintaining compliance with state water quality standards. The data for the groups of water quality parameters, including physical parameters, nutrients, major ions, and trace metals, were evaluated for WY2006. The evaluation indicated that few excursions from Class III water quality standards were found in samples collected at non-ECP structures, except for various incidences of DO. The excursions include results for pH at G-123, and Specific Conductance at S-197. Based on the analysis provided in Appendix 3A-4 of this volume, the quarterly surface water and semiannual sediment pesticide sampling events at the 14 non-ECP sites for WY2006 were conducted during May 2005, April 2005, December 2005, and January 2006. None of the surface water samples where pesticides were detected was identified as sites of concern. Pesticides detected in the sediment samples collected during WY2006. Pesticides with concentrations greater than the PQL were assigned to the "potential concern" excursion category. Dichlorodiphenyldichloroethylene (DDE, an environmental dehydrochlorination product of DDT), endosulfan, endosulfan sulfate, and bromacil, were detected at several locations at levels of "potential concern."

The non-ECP permit was amended on January 21, 2005, to remove the S-10E structure because it is no longer needed and has been decommissioned. The non-ECP permit was again amended on May 18, 2005, to remove monitoring of all trace metals and all major ions (except sulfate), and some nutrient and physical parameters. Hence, monitoring reporting for these parameters was discontinued in WY2006. The non-ECP permit was amended on July 13, 2006, to reclassify the S-332 and S-175 structures as "within" structures, to incorporate the S-332D and S-174 structures as "into" structures, and to add berm B3 as a "within" structure, and to take out the G-71 structure as a structure required to be monitored, as this structure has been decommissioned and was removed in 2002.

Past consolidated reports (e.g., Chapter 11 in 2001, Chapter 8B in 2002–2004, and Chapter 3 in 2005) included comparisons of state water quality standards to water quality data obtained from non-ECP structures. These historical analyses found that few excursions from Class III numeric water quality criteria for any parameter in the eight non-ECP contributing basins except for DO. There were excursions from the existing standard for DO, but the FDEP has completed an evaluation of DO levels in the EPA and developed an SSAC to formally recognize the natural background conditions in the EPA marshes. Additional information on the DO SSAC can be found in this chapter.

As phosphorus is the primary parameter of concern for Everglades restoration, it is the focus of water quality considerations for the non-ECP basins. Although no load limitations have been established for the basins, TP concentrations are monitored to determine progress toward the goals established in the non-ECP permit. **Table 3A-7** summarizes the FWM TP concentrations, total flow volumes, and TP loads for all non-ECP basins during WY2006.

The WY2006 flows reported in **Table 3A-7** from ACME Improvement District were higher than in WY2005; however, the TP load from this basin decreased in WY2006 when compared to the WY2005 TP load. Some of the highest TP concentrations for non-ECP structures discharging directly to the EPA during WY2006 were observed for Feeder Canal through S-190 and the ACME Improvement District basin through monitoring locations at the ACME1DS and G-94D culverts and at the upstream pump stations, ACME1 (auto-sampler VOW1) and ACME2 (auto-sampler VOW2). The ACME1DS and G-94D culverts, operated by the Village of Wellington (VOW), remain open at all times and discharge to the Refuge when upstream pump stations ACME1 or ACME2 are operating. Fifteen District data collection trips to the ACME1DS culvert monitoring locations resulted in nine sampled flow events; 15 District data collection trips to the G-94D culvert monitoring locations resulted in nine sampled flow events. The monitoring agreement with VOW resulted in a sufficient number of samples (45 at VOW1 and 49 at VOW2) collected by both grab and auto-sampler techniques upstream of the pump stations to cover a broad range of flows (43 samples at VOW1 and 48 samples at VOW2 collected during pumping events) and adequately characterize the TP concentrations.

As shown in Appendix 3A-4b, Table 3, more than 75 percent of the data collected at the upstream VOW1 monitoring sites were below 77 parts per billion (ppb), with median TP values ranging between 69 ppb (auto) and 60 ppb (grab). More than 75 percent of the data collected at the upstream VOW2 monitoring sites were below 105 ppb, with median TP values ranging from 67 ppb (auto) to 77 ppb (grab). Discharge data were not available for the ACEM1DS and G-94D culverts, although discharge data from the upstream pump stations during WY2006 [14,161 acre-feet (ac-ft) and 12,767 ac-ft for ACME1 and ACME2, respectively] can be used as an indication of the magnitude and occurrence of flow through the downstream culverts.

There were no flows and therefore there were no TP loads from the NNRC and NSID basins for WY2006. A comparison of WY2006 and WY 2005 data shows a decrease in TP load from the ACME Improvement District and an increase in TP loads from C-11 West, the Feeder Canal, L-28, and C-111 basins. The changes in loads from these basins are predominantly associated with changes in flow volumes, which were higher for C-11W through S-9 and S9A, Feeder Canal through S-190, L-28 through S-140, C-111 through S-174, S332D, and S-18C.

The FWM TP concentrations vary greatly among different basins. In WY2006, the highest TP concentrations are identified in the Feeder Canal basin and ACME Improvement District, whereas the NSID and C-11 West basins have TP concentrations below 50 ppb. There was a slight increase in TP concentration for the L-28 basin (flow-weighted TP of 50 ppb for WY2006 versus 42 ppb in WY2005). The TP concentrations observed for the Feeder Canal basin showed median TP concentrations of 61 ppb for grab samples, and 125 ppb for auto samplers; the TP concentrations observed for the L-28 basin showed median TP concentrations of 39 ppb for grab samples and 43 ppb for auto samplers. During WY2006, the Feeder Canal basin discharged 150,359 ac-ft, and the L-28 basin discharged 203,575 ac-ft into the western portion of WCA-3A. Though many of these concentrations are relatively low, all concentrations greater than approximately 10 ppb will have to be addressed further (as discussed in Chapter 3C).

Table 3A-7 also presents information for the S-9A and S-9 pump stations. This year, the FWM TP concentration of water discharged from the S-9A pump station was 16 ppb, compared with a FWM TP concentration of 19 ppb through the S-9 pump station. The total flows pumped through the S-9 and S-9A stations increased by 35 percent at S-9 and 8.4 percent at S-9A, respectively, for WY2006 (128,470 ac-ft for S-9 and 61,345 ac-ft for S-9A) compared to WY2005 (93,403 ac-ft for S-9 and 56,584 ac-ft for S-9A). Furthermore, the total flow through both structures combined had a FWM TP concentration of 18 ppb in WY2006, which was slightly higher than in WY2005 (16 ppb).

Operational changes implemented by NSID and the District in WY 2006 did not cause flow into the EPA at the NSID1 and G-123 structures, respectively. The C-111 basin had the lowest TP concentrations, observed at S-174, S-332D, and S-18C, which discharge to ENP, specifically to Taylor Slough (by way of the L-31N borrow and L-31W borrow canals) and the ENP's panhandle (by way of the C-111 canal). The TP data for these monitoring locations had an observed median concentration of 5 ppb (grab) and 7 ppb (auto) for S-18C; 7 ppb (grab) and 8 ppb (auto) for S-332D; 11 ppb (grab) and 14 ppb for S-174; 75 percent of the samples having concentrations below 6 ppb (grab); 12 ppb (auto) for S-18C; 12 ppb (grab) and 15 ppb (auto) for S-174; and 8 ppb (grab) and 10 ppb (auto) for S-332D. During WY2006, the S-174 discharged only 9,203 ac-ft, and S-332D discharged 153,803 ac-ft to the Park. The S-18C structure discharged approximately 188,505 ac-ft to the lower C-111 canal.

Historically, the Boynton Farms basin exhibits the highest TP concentrations (average of 973 ppb, see Chapter 3 of the 2005 SFER – Volume I) of any basin. This average is based on a total of 63 samples at 11 locations, collected in 18 sampling events from April 2000 to November 2003. Three sampling locations at one farm were dropped during WY2006 because the farm has removed the pumps and no longer discharges to the refuge. Because no flow data were available for this basin, no FWM concentrations could be determined. The Boynton Farms basin water quality monitoring program still is on going, but no TP data are available for WY2006.

It is anticipated that the implementation of the water quality improvement plans as recommended in the Long-Term Plan for the non-ECP basins will significantly contribute to achieving long-term water quality standards in the EPA. Water quality data are tracked for increasing and decreasing trends so that the action plan may be modified, as necessary, through an adaptive management process to ensure optimization measures for TP reduction and for other parameters of concern.

Based on the analysis provided in Appendix 3A-4 of this volume, none of the pesticides detected during the quarterly surface water sampling was found to be of concern. The biannual sediment pesticide sampling indicated that four pesticides (endosulfan, endosulfan sulfate, bromacil, and DDE, an environmental dehydrochlorination product of DDT) were detected at several locations at levels of potential concern.

An evaluation of the non-ECP basin data indicates that the quality of water discharging into the EPA is generally acceptable. However, there are exceptions for phosphorus, DO, and occasional excursions from standards for pH and specific conductance. Analysis of TP concentrations in WY2006 continues to indicate significant differences among non-ECP basins. Phosphorus is categorized as a concern (> 50 ppb) for the ACME Improvement District, Feeder Canal and the L-28 basins and as a potential concern (10 ppb < TP < 50 ppb) for the C-11 West and C-111 basins. There was no discharge in North Springs Improvement District and NNRC basins. Except for phosphorus levels, the quality of water discharging into the EPA is generally acceptable. The portion of the District's water quality monitoring program that has been implemented as a result of the EFA and the non-ECP permit indicates that phosphorus concentrations are greater than 10 ppb in discharges from seven of the eight non-ECP basins. There were no TP data available for WY2006 from Boynton Farms. The District will continue to monitor water quality in accordance with the non-ECP permit to measure progress toward achieving compliance with state water quality standards.

LITERATURE CITED

APHA. 1995. *Standard Methods for the Examination of Water and Wastewater*, 19th Edition. A.D. Eaton, L.S. Clesceri and A.E. Greenberg, eds. American Public Health Association, Washington, D.C.

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

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

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

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

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

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

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

Environmental Services & Permitting, Inc. 1992. Preliminary Review of Potential Water Quality Enhancements from a Main Canal Maintenance Program. Environmental Services & Permitting, Inc., Gainesville, FL.

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

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

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

Richarson, J.R., W.L. Bryant, W.M. Kitchens, J.E. Mattson and K.E. Pope. 1990. An Evaluation of Refuge Habitats and Relationships to Water Quality, Quantity, and Hydropattern. Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, FL.

SFWMD. 1992. Surface Water Improvement and Management Plan for the Everglades, Supporting Information Document. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2005. Field Sampling Quality Manual, version 2. South Florida Water Management District, West Palm Beach, FL.

Swift, D.R. and R.B. Nicholas. 1987. Periphyton and Water Quality Relationships in the Everglades Water Conservation Areas, 1978–1982. Technical Publication 87-2, South Florida Water Management District, West Palm Beach, FL.

Trost, S., D. Meiers, M. Bell, S. Van Horn et al. 2001. Chapter 11: The Everglades Stormwater Program. G. Redfield, ed. In: *2001 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

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

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

Weaver, K. 2004. Everglades Marsh Dissolved Oxygen Site Specific Alternative Criterion Technical Support Document. Florida Department of Envrionmental Protection, Tallahassee, FL. Online at http://www.dep.state.fl.us/water/wqssp/everglades/docs/DOTechSupportDOC2004.pdf, November 20, 2006.

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

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

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

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

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

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