Chapter 2A: Status of Water Quality in the Everglades Protection Area

Kenneth Weaver and Grover Payne

SUMMARY

This chapter provides a review of the water quality for each Everglades Protection Area (EPA) region during Water Year 2004 (WY2004) (May 1, 2003 through April 30, 2004). The focus of this chapter is to provide an update to the 2004 Everglades Consolidated Report (ECR). Status of EPA water quality was determined by an analysis of the water quality variables 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 Everglades National Park (ENP or Park). Discussions of any temporal or spatial trends observed for the variables identified as concerns or potential concerns are also provided. Annual excursion rates were summarized in a manner similar to methods employed in the 1999 Everglades Interim Report and previous ECRs. For the *2005 South Florida Environmental Report*, water quality variables that did not meet existing standards were 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 has been in compliance with existing state water quality criteria during WY2004.
- A site-specific alternative criterion (SSAC) for dissolved oxygen (DO) in the EPA was adopted by the Florida Department of Environmental Protection (FDEP) on January 26, 2004 and was subsequently approved by the U.S. Environmental Protection Agency as a revision to Florida Water Quality Standards. To fully account for seasonal and annual variability in marsh DO concentrations, ambient achievement of the SSAC is based on a comparison between the annual average of multiple (e.g., monthly) DO measurements made throughout the year and the average of the corresponding DO limits specified by the SSAC equation for the year.
- DO was categorized as a concern for the Refuge interior, WCA-2 inflows, WCA-2 interior, and WCA-3 interior. Additionally, DO was categorized as a potential concern for inflows to the Refuge and Park and for WCA-3 outflows.

Most of the interior marsh excursions occurred in areas known to be phosphorus enriched. When unenriched areas are evaluated separately, DO is classified as minimal concerns for unimpacted areas of the Park and WCA-2, a potential concern for WCA-3, and a concern for the Refuge.

- Similar to previous years, alkalinity was designated as a concern for the interior of the Refuge for WY2004 due to an excursion rate of 19.7 ± 4.5 percent. Although pH was not identified as either a concern or potential concern for any area based on regional assessments, localized high exceedance rates (7–44 percent) were recorded at several interior Refuge stations for the five-year period from WY2000–WY2004. This resulted in pH being classified as a concern for stations LOX5, LOX8, LOX11, and LOX13, and classified as a potential concern for stations LOX14 and LOX16.
- For WY2004, conductivity was categorized as a concern for WCA-2 interior and inflow stations, and a potential concern for Refuge inflows. The WY2004 exceedance frequency (27.9 ± 5.7 percent) for WCA-2 inflows was significantly elevated above both WY2003 (10.9 ± 4.2 percent) and the WY1978–WY2002 historical period (16.1 ± 1.5 percent). Conversely, the WY2004 exceedance frequency (11.2 ± 4.5 percent) in Refuge inflows was lower than the historical period (24.9 ± 1.4 percent).
- Fifteen specific conductance (conductivity) exceedances were recorded at interior sites (CA27 and CA28) on the northwestern side of WCA-2. Conductivity levels have apparently increased at the two interior sites over the past three years, with the most dramatic increases at CA28. It is likely that high conductivity water is now being conveyed to northwestern WCA-2 through STA-2 discharges.
- Like WY2002 and WY2003, un-ionized ammonia (NH_3) was categorized as a concern for WCA-2 inflows during WY2004 due to a large number of excursions (6) at sites E0 and F0 located within the spreader canal that receive inflows from the Hillsboro Canal. Elevated dissolved ammonia concentrations were the primary cause of the WY2004 excursions at stations E0 and F0.
- Twelve pesticides or breakdown products were detected between September 2002–2003. Only atrazine was classified as a concern. A total of five atrazine exceedances were recorded within inflow to the Refuge, WCA-2, and WCA-3. Additionally, atrazine was detected in 86 samples across all EPA areas.

PURPOSE

This chapter provides an assessment of water quality constituents exceeding water quality standards or causing or contributing to adverse impacts in the Everglades Protection Area (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 Water Year 2004 (WY2004) (May 1, 2003 through April 30, 2004). The water quality evaluation presented in this chapter updates previous analyses presented in the 1999 Everglades Interim Report and the 2000–2004 Everglades Consolidated Reports (ECRs). More specifically, this chapter and its associated appendices use water quality data collected during WY2004 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 specific conductance levels within the naturally low ionic strength waters of the Refuge and indicate temporal trends
4. Summarize sulfate concentrations in the EPA and indicate spatial and temporal trends
5. Provide an update concerning the status of an alternative criterion for dissolved oxygen (DO) in Everglades marsh waters
6. Present an updated review of pesticide and priority pollutant data made available during WY2004

METHODS

An approach similar to the regional synoptic approach used in previous ECRs was applied to WY2004 data to provide an overview of the status of compliance with water quality criteria in the EPA. The consolidation of 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 one-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 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 WCA-3A, and Taylor Slough in the Everglades National Park (ENP or Park) were obtained from the SFWMD's Everglades Research Database. Before water quality data are entered into either database, the SFWMD follows strict quality assurance/quality control (QA/QC) procedures approved by the Florida Department of Health under the National Environmental Laboratory Accreditation Conference (NELAC) certification process. Both sampling and analytical methods are documented in the SFWMD's Quality Assurance Manual and in Standard Operating Procedures (SOPs) that are reviewed and updated annually. Contract laboratories used by the District also must be NELAC certified and must maintain the appropriate Quality Assurance Manual and SOPs.

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 of the state [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 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 2A-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 based on this categorization system. For example, 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 also 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 much of the water entering the interior of the Refuge is conveyed in rim canals that border the east and west levees 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-2A through the S-10 structures. The extent (distance) to which rim canal overflows permeate 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 2A-2** through **2A-5**.

The current SFWMD monitoring programs are described by Germain (1998). Sampling frequency varies by site depending on site classification, variable group, and hydrologic conditions (water depth and flow). Additionally, the District has created a Website describing its water quality monitoring projects, including project descriptions and objectives, found online at http://www.sfwmd.gov/org/ema/envmon/wqm. The District's Website currently provides limited, site-specific information. Generally, interior monitoring stations were sampled monthly for most variables reported in this chapter. Water control structures (inflows and outflows) were typically sampled biweekly when flowing, otherwise monthly.

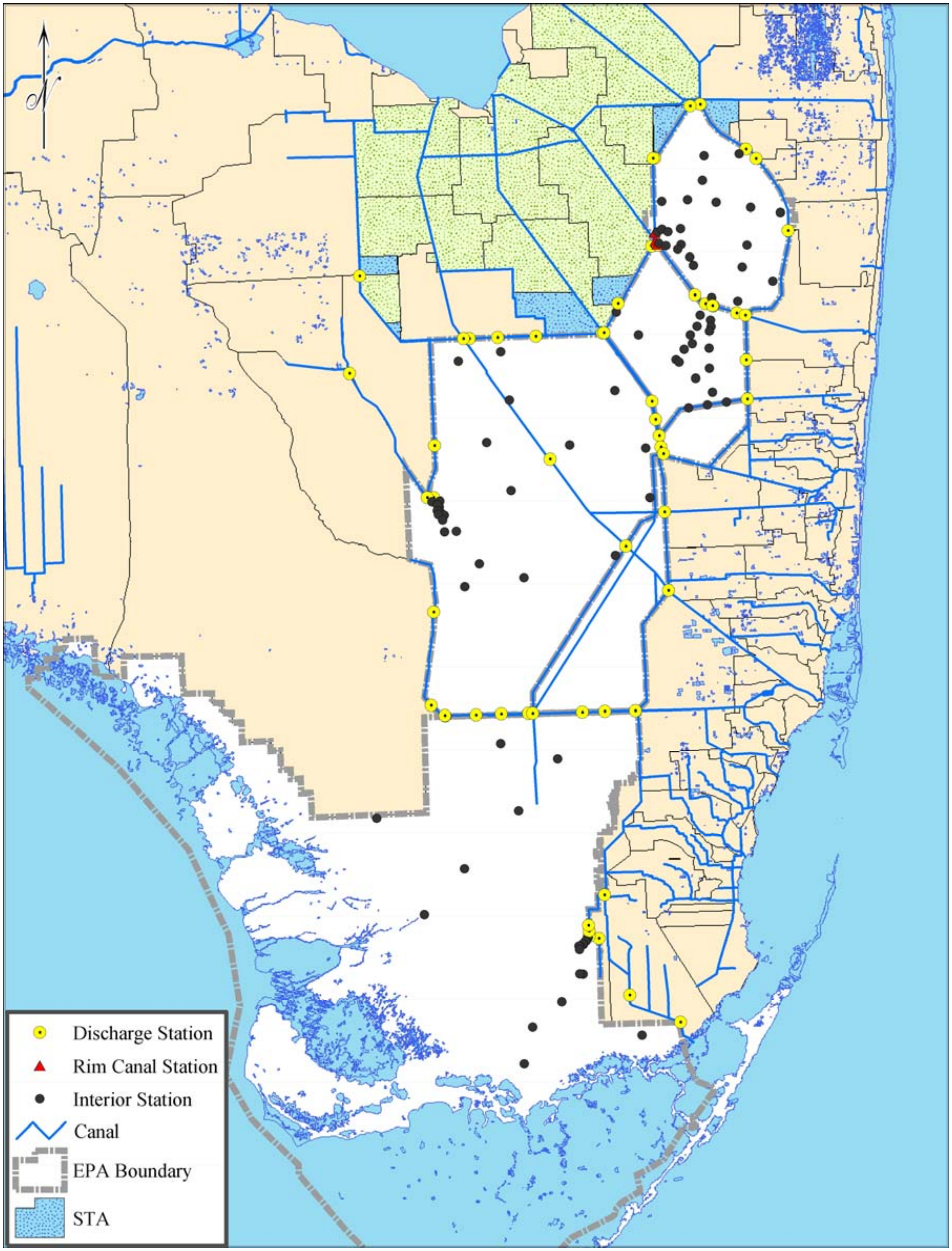

Figure 2A-1. Everglades Protection Area (EPA) regions and water quality monitoring stations.

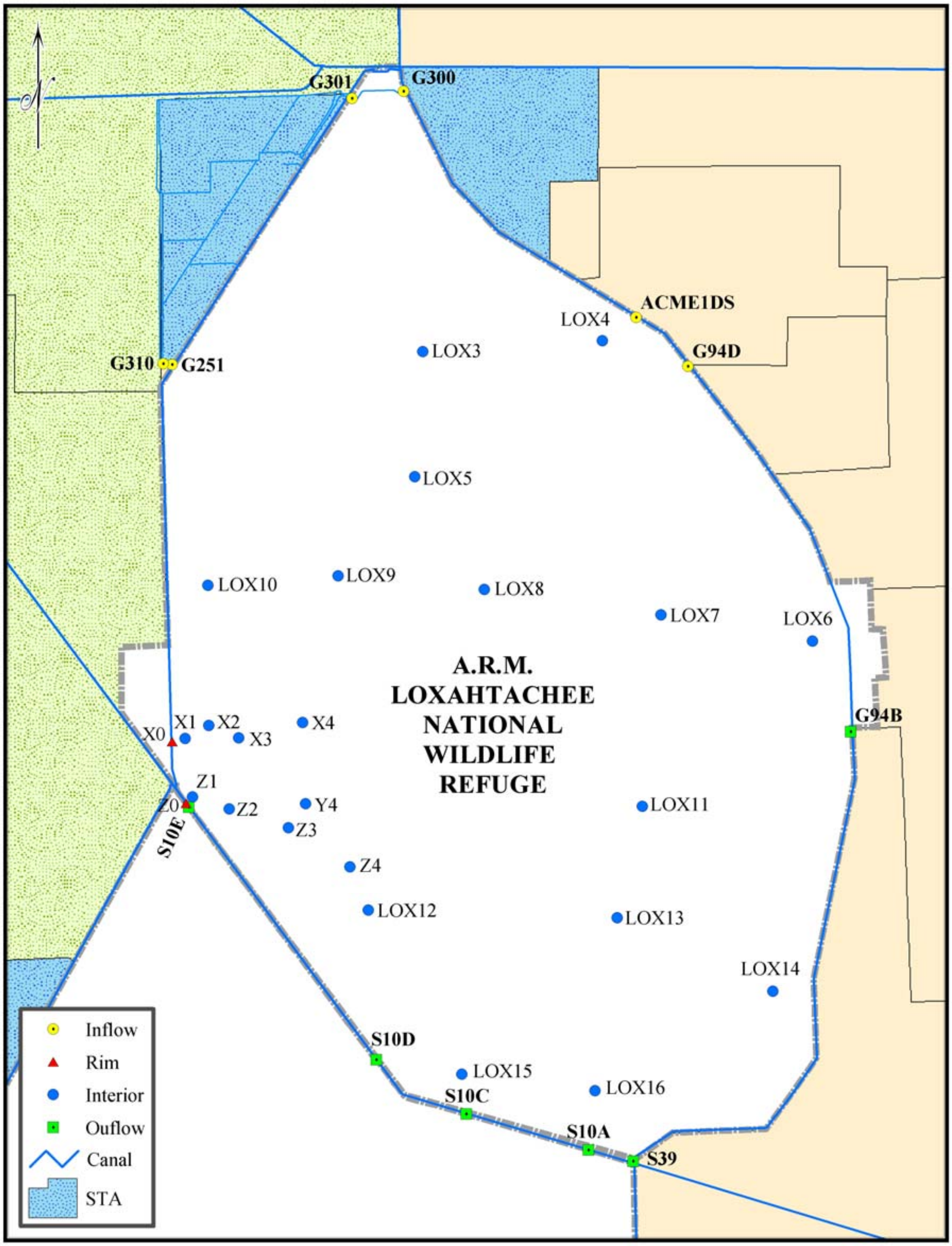

Figure 2A-2. Location and classification of water quality monitoring stations in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge).

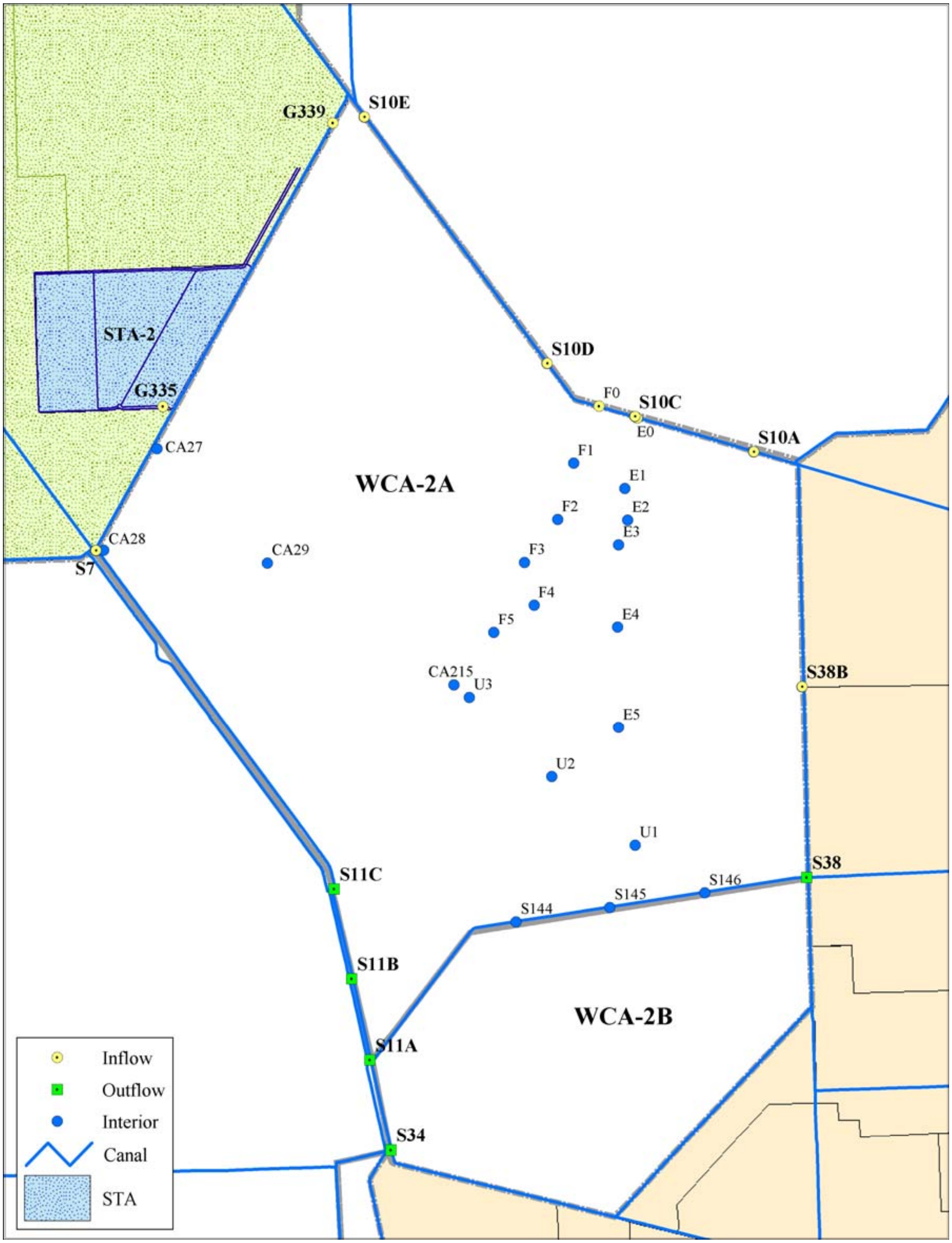

Figure 2A-3. Location and classification of water quality monitoring stations in Water Conservation Area 2 (WCA-2).

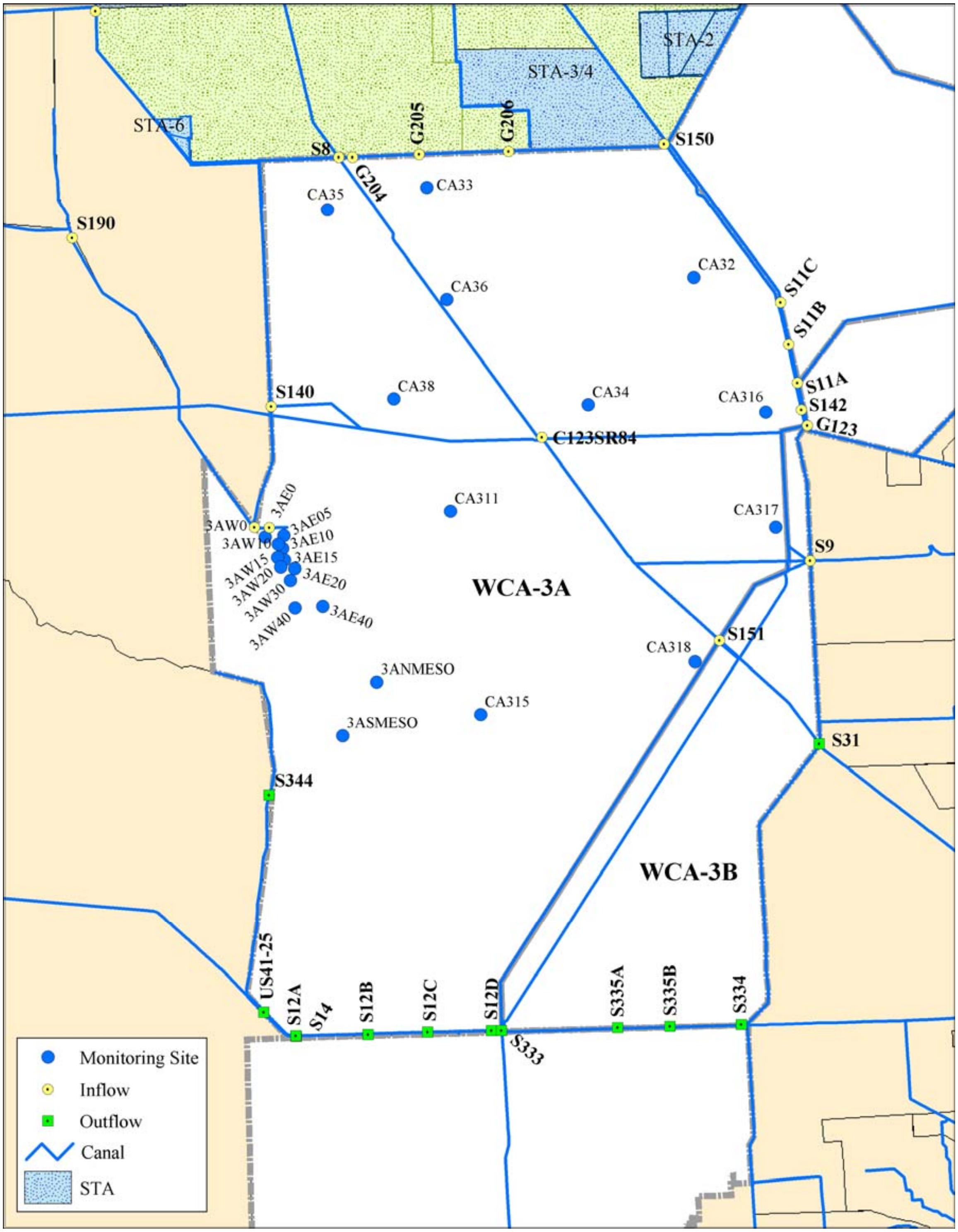

Figure 2A-4. Location and classification of water quality monitoring stations in WCA-3.

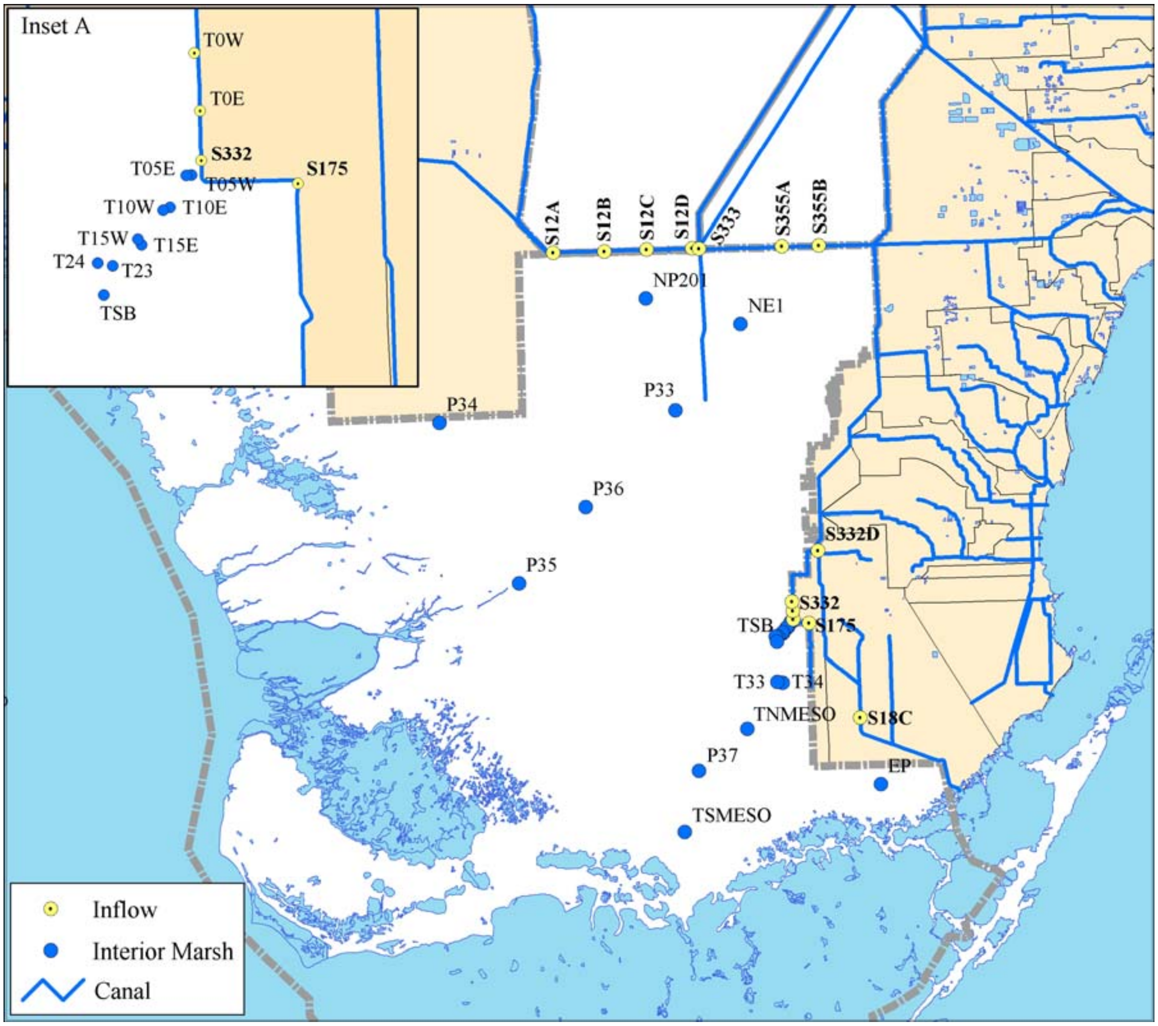

Figure 2A-5. Location and classification of water quality monitoring stations in the Everglades National Park (ENP). Inset A provides the location of transect monitoring stations downstream of C-111 inflows in Taylor Slough.

EVERGLADES PROTECTION AREA DATA ANALYSIS PERIOD

Water quality data collected from monitoring stations within the EPA regions during WY2004 are evaluated and discussed in this chapter. Additionally, pesticide data presented in this chapter were collected during quarterly sampling events conducted between September 2002–2003. The period of record for pesticides was selected as an update to the data presented in the *2004 Everglades Consolidated Report*, rather than reflected by the water year.

WATER QUALITY DATA EVALUATION

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

- Alkalinity
- Dissolved oxygen (DO) (in situ)
- Specific conductance @ 25°C (in situ)
- pH (in situ)
- Total silver
- Total antimony
- Total arsenic
- Total beryllium
- Total cadmium
- Trivalent chromium
- Total copper
- Total iron
- Total lead
- Total selenium
- Total thallium
- Total zinc
- Turbidity
- NH_3

DATA SCREENING AND HANDLING

Water quality data were screened based on laboratory qualifier codes. Any datum with an associated fatal qualifier (e.g., contamination, out-of-holding time, matrix interference, or reversal) was removed from the analysis. Values that exceeded possible physical or chemical measurement constraints (e.g., pH greater than 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, 1.32 percent of the WY2004 data including nutrients were excluded due to QA/QC issues (Appendix 2A-1). All data passing the qualifier screening were used in the analysis. 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 at a concentration that is 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 2A-1.

EXCURSION ANALYSIS

The FDEP and the District have developed and clearly documented an excursion analysis protocol for use in the *2005 South Florida Environmental Report*. 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 ECRs, other state of Florida ambient water quality evaluation methodologies (e.g., Impaired Waters 303(d) designations), and 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 of this evaluation will be compatible with information provided to water managers from other sources.

To evaluate compliance with water quality criteria in WY2004, constituent concentrations were compared to their respective Class III criteria specified in Chapter 62-302, F.A.C. In addition to Class III criteria, pesticides were evaluated against known chronic toxicity values. An excursion was recorded when a reported value above the given MDL exceeded the applicable numeric criteria (Chapter 62-302.530, F.A.C.) or exceeded the chronic toxicity value. The excursions for each region of the EPA were tabulated, providing both the total number of samples and the percent of samples exceeding the criteria.

Prior to the *2003 Everglades Consolidated Report*, the ECRs utilized a raw-score approach to rank and categorize the severity of excursions from state water quality criteria (Bechtel et al., 1999 and 2000; Weaver et al., 2001 and 2002). Using this raw-score method, a variable was classified as a “concern” when more than five percent of the measurements exceeded numeric criteria. The underlying premise of this approach is that a variable is considered to be a management “concern” if its true exceedance (excursion) probability exceeds five percent. However, since the true exceedance probability cannot be measured, it must be estimated from a set of samples (i.e., a subset of the entire population), which introduces statistical uncertainty. The degree of uncertainty in the estimate depends on the true exceedance probability and sample size (e.g., smaller sizes are associated with greater uncertainty). For example, one out of six measurements above the criterion is clearly a weaker (more uncertain) case for impairment than six out of thirty-six, although both cases result in an excursion frequency of 16.7 percent (NRC, 2001). A statistically valid assessment of the estimate requires that some accounting for uncertainty in the estimate be incorporated into the analysis (Riggs and Aragon, 2002). Smith et al. (2001) and the NRC (2001) suggested that a binomial hypothesis test that evaluates the statistical significance of the frequency of excursions could be used in water quality evaluations to account for sampling uncertainty. Adoption of the state’s Impaired Waters Rule (IWR) (Chapter 62-303, F.A.C.) that uses a binomial hypothesis test to delineate impaired waters establishes precedence for the use of this statistical method in Florida. In support of the development of the IWR, Lin et al. (2000) reviewed statistical procedures for standards compliance assessments, and recommended a nonparametric procedure for identifying impaired water body reaches in Florida based on a binomial distribution theory.

Although the binomial hypothesis test provides a better accounting for uncertainty than a raw-score approach, the sample size is still an important consideration in the reliability of excursion frequency estimation. Specifically, in water quality attainment decisions, both the Type I error (probability of falsely listing as a concern; false positive) and Type II error (probability of not listing when there truly is a concern; false negative) are of concern. Sample sizes of at least 28 and 40 balance average error rates to below 15 and 10 percent, respectively, when a binomial approach is utilized (Smith et al., 2001; Riggs and Aragon, 2002)[1]. Riggs and Aragon (2002) stated that error rates for samples sizes less than 28 are probably too high to be acceptable to most regulators. As long as sample sizes are maintained at acceptable levels (≥ 28), binomial methodologies better balance and manage error rates than the previously utilized raw-score approach[2].

An additional weakness of the evaluation methodology employed in previous ECRs is that the 5-percent excursion frequency selected to categorize a variable as a concern does not reflect current USEPA guidance, which recommends that a 10-percent exceedance rate (excursion) from applicable water quality standards be used to delineate impaired water bodies for conventional pollutants (e.g., DO, metals, conductivity, turbidity, NH_3, and dissolved ions) (USEPA, 1997 and 2002). Essentially the conventional pollutants are constituents, which are expected to naturally occur and vary within the environment due to natural biogeochemical processes. The USEPA's 10-percent guidance frequency accounts for natural background variability as well as for sampling and measurement errors. This guidance does not apply to pollutants with human health-based criteria (e.g., beryllium and 2,4-dinitrophenol) or to unconventional pollutants (e.g., pesticides and herbicides). Given that the authors are seeking to increase consistency among assessments, the excursion categories were revised from previous ECRs to reflect the USEPA guidance for water quality assessments, while maintaining a multitiered categorical system similar to that employed in previous ECRs (**Table 2A-1**). Based on these considerations and a review of the literature (e.g., Lin et al., 2000; Smith et al., 2001; Donohue and Looij, 2001; Riggs and Aragon, 2002), the raw-score approach was replaced in the 2003 and 2004 Everglades Consolidated Reports with a binomial hypothesis test.

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[1] Error rates for the raw-score approach are also substantially above acceptable levels at sample sizes less than 28 to 30. Furthermore, Type I error rates (greater than 40 percent) associated with the raw-score approach are unacceptably high even at large sample sizes (Smith et al., 2001) (e.g., at sample sizes greater than 100, the Type I error rate exceeds 40 percent).

[2] At sample size less than 20, neither a binomial nor a raw-score approach can be confidently employed to adequately control error rates (Smith et al., 2001; Riggs and Aragon, 2002).

Table 2A-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 less than 28, an excursion frequency of greater than 20 percent was used to define the concern category.

2. For sample sizes less 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

The binomial hypothesis test was utilized to evaluate water quality criteria excursions in the 2005 South Florida Environmental Report for conventional water quality constituents (i.e., constituents other than pesticides or with human health-based criterion, such as beryllium). Variables without excursions were categorized as no concern and are not discussed further in this chapter. For any variable 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 variable 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: $f \leq 0.10$; HA: $f \geq 0.10$), then the binomial test at the 90-percent confidence level was used to determine whether the variable was a potential concern (excursion rate from 5–10 percent, i.e., HA: $f \geq 0.05$), or a minimal concern (an excursion rate of 5 percent or less, i.e., H0: $f \leq 0.05$).

Because the binominal hypothesis test does not adequately balance statistical error rates at sample sizes of less than 28, variables with reported excursions and fewer than 28 samples, were initially categorized as concern and potential concern based on excursion frequencies (raw scores) of greater than 20 percent and less than 20 percent, respectively[3]. It is assumed that an observed

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[3] At sample sizes less than 28, the binomial hypothesis test is associated with unacceptably high Type II error rates (greater than 20 to 93 percent). A 20-percent raw-score criterion was selected because it provides a better balance between error rates than either a binomial test or a 10-percent raw score, i.e., at sample sizes between 1 and 27, both Type I and II error rates are intermediate (between) those associated with a binomial test, or 10-percent raw score. However, this error rate compromise does not fully address the uncertainty inherent in the analysis of such small samples. Analysis of longer periods of record or increased sampling frequencies is required to confidently categorize excursion frequencies and acceptably balance Type I and II error rates.

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 (< 28), any excursions warrant further review. However, extreme caution must be exercised when interpreting results drawn from such small samplings. As a means to reduce uncertainty, any variable 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. Variables 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.

The excursion categories are meant to provide some guidance in the interpretation of monitoring results by providing a means to rank the severity of excursions from water quality criteria, allow tracking of temporal and spatial trends, and provide a selection criterion for more detailed evaluations. The system can be thought of as a report card, with grades designated as passing (A–B), satisfactory (C), unsatisfactory (D), and failing (F). Not only does this system provide the public and decision makers with a measure of the overall water quality of the Everglades, but it also guides and prioritizes further review.

As a supplement to the binomial hypothesis test, 90-percent confidence intervals (90% C.I.) were calculated around the estimated exceedance frequencies for WY2004. Inclusion of confidence intervals provides a measure of uncertainty associated with frequency estimates and excursion analyses. For example, if the lower confidence bound (frequency minus the 90 percent C.I.) is greater then 10 percent, then it can be concluded with at least 90-percent certainty that that the variable is a concern. However, if the confidence bound includes 10 percent (or 5 percent), then it cannot be concluded that the variable is a concern (or potential concern).

Use of the binomial hypothesis test assumes a constant exceedance probability across all monitoring stations within an area and class (i.e., regional assessment units such as WCA-2 interior, Park inflows)[4]. If this assumption is violated, then there is a chance that a regional concern level will be incorrectly elevated due to the influence of a high localized exceedance frequency. Conversely, there is a chance of masking localized high exceedances frequencies within the regionally aggregated frequency. For example, if a region represented by 10 stations had total of 120 samples with 10 exceedances at only one station, then the water quality variable would be categorized as a potential concern for the entire region; however, in reality the variable is likely not a concern at nine stations but may be a concern at one. The assumption of homogeneous exceedance probabilities may not hold for every water quality variable within an area as large as the Everglades. Subdividing each region into smaller, more homogenous sub-water bodies is a potential approach to ensure adherence to this assumption. However, this method does not meet the chapter's objective of providing regional summaries at the water body level (i.e., Refuge, WCA-2, WCA-3, and Park). Therefore, methods to detect and delineate localized exceedance patterns within each water body were utilized to supplement and refine the regional analyses. The binomial hypothesis test and excursion criterion were applied to individual station data. Because there are insufficient data (< 28 samples) over a single annual period, to confidently estimate station level exceedance frequencies for most water quality variables, a

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[4] Constant exceedance probability is also an assumption of the previously used raw-score approach.

longer period of record was necessary. Individual station assessments were based on the previous five years (WY2000–WY2004), rather than on the single year used for regional analyses. Use of a five-year period provided sufficient data for most variables. No determination was made for any variable 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 were noted in the summary tables and discussed in greater detail.

Because the USEPA recommended that a 10-percent excursion frequency does not apply to pesticides, the pesticide evaluation method presented in this chapter is identical to the method used in previous ECRs. Pesticides were categorized based on the exceedance of Class III criteria or chronic toxicity values and detection (measurement $\geq$ MDL) frequency (**Table 2A-1**).

SUMMARY OF FINDINGS FROM PREVIOUS EVERGLADES CONSOLIDATED REPORTS

1999–2003 EVERGLADES CONSOLIDATED REPORTS

Previous Everglades Consolidated Reports (ECRs) have demonstrated that, with few exceptions, water quality has been in compliance with existing state water quality criteria, though some excursions have been noted (Bechtel et al., 1999 and 2000; Weaver et al., 2001–2003). Reported excursions have generally been localized to specific areas of the EPA, with the exception of DO, which exhibited excursions in all areas. Furthermore, alkalinity, conductivity, and pH were identified as concerns for at least one EPA region in all previous ECRs. Additionally, the 1999 Everglades Interim Report and 2000 Everglades Consolidated Report identified NH_3 as a concern in localized areas of the EPA. The 2003 and 2004 ECRs identified a localized NH_3 concern at two WCA-2 inflow sites (E0 and F0) to WCA-2. Previous ECRs have also evaluated pesticide monitoring results and have identified atrazine, chloriphyros ethyl, endosulfan, ethion, parathion methyl, diazinon, dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethene (DDE), and dichlorodiphenyldichloroethane (DDD) as concerns in localized areas for various years during the period of record.

Each of the previous ECRs have delineated DO as a concern for the entire Everglades, with nearly all monitoring stations exhibiting excursions during each year. However, a majority of the DO excursions were the result of natural conditions and processes within the marsh and therefore do not constitute violations of state water quality standards. To more accurately characterize the natural DO regime within the marsh, a site-specific alternative criterion (SSAC), which used a mathematical model to describe the relationship between DO, time of day, and temperature to define a measurement methodology, was developed by the FDEP and was presented in the *2001 Everglades Consolidated Report*. Application of the present SSAC for DO resulted in a significant reduction in the number of interior marsh stations at which DO was designated as a concern.

2004 EVERGLADES CONSOLIDATED REPORT

Chapter 2A of the *2004 Everglades Consolidated Report* (Weaver and Payne, 2004) provided an overview of the status of compliance with water quality criteria in the EPA for WY2003 (May 1, 2002 through April 30, 2003). The chapter built upon and provided an update to water quality analyses presented in previous ECRs. Comparisons of WY2003 water quality data with applicable Class III water quality criteria resulted in excursions for seven identified water quality variables. These excursions were localized to specific areas of the EPA, with the exception of DO, which exhibited excursions in all regions. Alkalinity and conductivity were classified as concerns for the Refuge interior and the WCA-2 interior, respectively. Additionally, total iron and turbidity were initially classified as concerns within the Refuge rim canal based on WY2003 data only, although the minimum sample size of 28 was not met. Therefore, the excursion analyses were based on a longer, five-year period of record that identified both total iron and turbidity as minimal concerns in the Refuge rim canal. Conductivity and NH_3 were classified as potential concerns for WCA-2 inflows. Conductivity, pH, alkalinity, and NH_3 were categorized as minimal concerns for several EPA regions due to infrequent and localized excursions. Fifteen pesticides were detected between December 2001 and September 2002. Of these pesticides, atrazine, chlorpyrifos ethyl, and diazinon were classified as concerns.

WATER YEAR 2004 RESULTS

Water Year 2004 (WY2004) (May 1, 2003 through April 30, 2004) data for water quality variables with Class III numeric criteria are summarized by region and monitoring station in Appendix 2A-1 and Appendix 2A-2, respectively. Comparisons of WY2004 water quality data with applicable Class III water quality criteria resulted in excursions for six identified water quality variables. These excursions were localized to specific areas of the EPA, with the exception of DO, which exhibited excursions in all regions. Alkalinity and conductivity were classified as a concern for the Refuge interior (**Table 2A-2**). Because DO is now 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 (WY2000–WY2004) for all areas. DO was categorized as a concern for the Refuge interior, WCA-2 inflows, WCA-2 interior, and WCA-3 interior. Additionally, DO was categorized as a potential concern for Refuge inflows, Park inflows, and WCA-3 outflows. Specific conductance was classified as a concern for WCA-2 inflows and interior, and a potential concern for Refuge inflows and rim canal sites (**Table 2A-2**). Additionally, specific conductance, pH, and NH_3 were categorized as minimal concerns for several EPA regions due to infrequent and localized excursions. Water quality variables that were classified as minimal concerns will not be discussed further in this chapter. Twelve pesticides, or breakdown products, were detected between September 2002–2003. Of these pesticides, only atrazine was classified as a concern. No other variables exceeded state water quality criteria during WY2004, and therefore are not discussed in this chapter.

Excursion frequencies and categories for variables with any recorded excursions in the last five water years (WY2000–WY2004) are summarized for three time periods (WY1978–WY2002, WY2003, and WY2004) to evaluate the presence of any temporal trends (**Table 2A-3**). Excursion categories for all periods are based on the methodology previously described in this chapter (**Table 2A-1**). Additionally, excursion frequencies and categories for individual monitoring stations are summarized in Appendix 2A-2. Excursion frequencies for WY2004 were generally within the range of the historical periods for most water quality variables, with the exceptions of increased specific conductance excursion rates for WCA-2 inflows and interior stations, and decreased specific conductance excursion rates in Refuge inflows. Water quality variables categorized as concerns or potential concerns for WY2004 are reviewed in greater detail below. The review includes discussions concerning the environmental significance associated with the observed excursions, potential causes of the excursions, and any actions taken to resolve the associated concerns, including evaluation of the applicable criteria and natural background conditions within the EPA.

Table 2A-2. Summary of water quality data and excursions from applicable criteria in the EPA for WY2004. Only water quality variables with excursions in the given region and class are listed. Excursion categories of concern, potential concern, and minimal concern are denoted by "C," "PC," and "MC," respectively. Excursion categories with parentheses indicate a localized exceedance rate greater then the regional (area and class) classification; that is, one or more stations exhibited higher exceedance rates between WY2000–WY2004 than the WY2003 regional aggregate. Summary statistics for dissolved oxygen (DO) were calculated based on annual station averages[1].

Area	Class	Variable	Units	Class III Criteria	N	Mean	Std. Deviation	Min	Max	Excursion	
										%±90% C.I.	Category
Refuge	Inflow	DO	mg/L	SSAC[1]	4	4.12	1.77	1.70	5.59	25.0 ± 35.6	C/PC[3]
		Specific Conductance	µmhos/cm	≤ 1275[2]	134	1061	223	450	1429	11.2 ± 4.5	PC
	Interior	Alkalinity	mg/L	≥ 20	213	97	79	6	288	19.7 ± 4.5	C
		DO	mg/L	SSAC[1]	23	3.14	1.27	0.80	5.01	34.8 ± 16.3	C/C[3]
		pH	units	≥ 6.0,≤8.5	244	6.87	0.38	5.58	7.73	2.9 ± 1.8	MC (C)
	Outflow	pH	units	≥ 6.0,≤8.5	65	7.70	0.32	7.08	8.62	3.1 ± 3.5	MC
		Specific Conductance	µmhos/cm	≤ 1275[2]	65	866	241	390	1314	4.6 ± 4.3	MC
	Rim	Specific Conductance	µmhos/cm	≤ 1275[2]	24	1093	191	776	1432	16.7 ± 12.5	PC/PC
WCA-2	Inflow	DO	mg/L	SSAC[1]	9	4.34	1.78	1.73	6.73	33.3 ± 25.8	C/C[3]
		pH	units	≥ 6.0,≤8.5	166	7.55	0.28	6.74	8.62	1.2 ± 1.4	MC
		Specific Conductance	µmhos/cm	≤ 1275[2]	165	1101	214	443	1425	27.9 ± 5.7	C
		NH_3	mg/L	≤ 0.02	100	0.005	0.010	0.0001	0.064	6.0 ± 3.9	MC (C)
	Interior	DO	mg/L	SSAC[1]	18	2.58	1.25	0.92	4.99	61.1 ± 18.9	C/C[3]
		Specific Conductance	µmhos/cm	≤ 1275[2]	267	985	294	479	2707	14.2 ± 3.5	C
WCA-3	Inflow	DO	mg/L	SSAC1	14	4.66	1.15	2.90	6.30	14.3 ± 15.4	PC/C[3]
		Specific Conductance	µmhos/cm	≤ 1275[2]	411	729	195	106	1315	0.7 ± 0.7	MC
		NH_3	mg/L	≤0.02	213	0.002	0.003	0.0001	0.036	0.5 ± 0.8	MC
	Interior	DO	mg/L	SSAC[1]	23	2.35	0.94	0.97	3.89	52.2 ± 17.1	C/C
	Outflow	DO	mg/L	SSAC[1]	9	3.65	0.92	2.63	5.45	11.1 ± 17.2	PC/PC[3]
Park	Inflow	DO	mg/L	SSAC[1]	11	3.65	0.95	2.03	5.45	18.2 ± 19.1	PC/PC[3]
		Specific Conductance	µmhos/cm	≤ 1275[2]	290	459	269	190	4425	0.3 ± 0.6	MC
	Interior	DO	mg/L	SSAC[1]	9	5.26	2.39	2.27	9.27	11.1 ± 17.2	PC/MC[3]
		Specific Conductance	µmhos/cm	≤ 1275[2]	101	461	154	198	1405	1.0 ± 1.6	MC

1. The Everglades DO site-specific alternative criterion (SSAC) is based on a mathematical equation that models the sinusoidal diel cycle and seaonal variability of DO in the Everglades, and is assessed as an annual average by station. The SSAC is discussed in the *Dissolved Oygen* section of this chapter.

2. Specific conductance shall not be increased 50 percent above background or 1,275 µmhos/cm, whichever is greater. Assessment present in this report is based only on the 1,275 µmhos/cm component of the criterion.

3. Insufficient sample size to apply binomial hypothesis test to only WY2003 data; analysis was based on a five-year period of record from WY2000–WY2004.

Table 2A-3. Summary of excursions from Class III criteria in the EPA for WY2004, WY2003, and historical data (WY1978–WY2002). An entry of "—" indicates that there were no samples collected for the parameter during the given period of record.

Area	Class	Parameter	1978-2002		2003		2004	
			Number of Excursions	Percent Excursions	Number of Excursions	Percent Excursions	Number of Excursions	Percent Excursions
Refuge	Inflow	DO	21 (126)	16.7 (C)	1 (4)	25.0 (C*)	1 (4)	25.0 (C*/PC*)
		pH	13 (2459)	0.5 (MC)	0 (131)	0.0 (NC)	0 (134)	0.0 (NC)
		Specific Conductance	616 (2472)	24.9 (C)	8 (131)	6.1 (MC)	15 (134)	11.2 (PC)
		Total Iron	20 (524)	3.8 (MC)	0 (8)	0.0 (NC*)	0 (8)	0.0 (NC*/MC)
		Total Silver	3 (35)	8.6 (MC)	--	--	--	--
		Turbidity	62 (1986)	3.1 (MC)	0 (77)	0.0 (NC)	0 (80)	0.0 (MC)
		NH_3	39 (2019)	1.9 (MC)	0 (77)	0.0 (NC)	0 (78)	0.0 (NC)
	Interior	Alkalinity	482 (1910)	25.2 (C)	44 (213)	20.7 (C)	42 (213)	19.7 (C)
		DO	51 (176)	29.0 (C)	7 (23)	30.4 (C*)	8 (23)	34.8 (C*/C)
		pH	215 (1962)	11.0 (C)	3 (231)	1.3 (MC)	7 (244)	2.9 (MC)
		Specific Conductance	9 (1877)	0.5 (MC)	0 (231)	0.0 (NC)	0 (244)	0.0 (NC)
		Total Copper	3 (283)	1.1 (MC)	--	--	--	--
		NH_3	3 (1447)	0.2 (MC)	0 (203)	0.0 (NC)	0 (223)	0.0 (C)
	Outflow	DO	35 (100)	35.0 (C)	0 (6)	0.0 (NC*)	0 (6)	0.0 (NC*)
		pH	3 (1157)	0.3 (MC)	0 (71)	0.0 (NC)	2 (65)	3.1 (MC)
		Specific Conductance	152 (1180)	12.9 (C)	0 (71)	0.0 (NC)	3 (65)	4.6 (MC)
		Turbidity	11 (1146)	1.0 (MC)	0 (69)	0.0 (MC)	0 (65)	0.0 (NC)
		NH_3	12 (1128)	1.1 (MC)	0 (70)	0.0 (NC)	0 (65)	0.0 (NC)
	Rim	Specific Conductance	103 (706)	14.6 (C)	0 (22)	0.0 (NC*)	4 (24)	16.7 (PC*/PC)
		Turbidity	11 (414)	2.7 (MC)	--	--	--	--
WCA-2	Inflow	DO	40 (121)	33.1 (C)	1 (8)	12.5 (PC*)	3 (9)	33.3 (C*/C)
		pH	6 (1558)	0.4 (MC)	0 (147)	0.0 (NC)	2 (166)	1.2 (MC)
		Specific Conductance	258 (1583)	16.3 (C)	16 (147)	10.9 (PC)	46 (165)	27.9 (C)
		Turbidity	15 (1288)	1.2 (MC)	0 (84)	0.0 (NC)	0 (80)	0.0 (NC)
		NH_3	51 (1443)	3.5 (MC)	10 (105)	9.5 (PC)	6 (100)	6.0 (MC)
	Interior	DO	95 (221)	43.0 (C)	9 (18)	50.0 (C*)	11 (18)	61.1 (C*/C)
		pH	21 (3542)	0.6 (MC)	0 (280)	0.0 (NC)	0 (268)	0.0 (NC)
		Specific Conductance	310 (3486)	8.9 (PC)	58 (280)	20.7 (C)	38 (267)	14.2 (C)
		NH_3	12 (2912)	0.4 (MC)	0 (257)	0.0 (NC)	0 (226)	0.0 (NC)
	Outflow	DO	26 (109)	23.9 (C)	0 (5)	0.0 (NC*)	0 (5)	0.0 (NC*)
		pH	6 (1431)	0.4 (MC)	1 (63)	1.6 (MC)	0 (82)	0.0 (NC)
		Specific Conductance	26 (1443)	1.8 (MC)	1 (63)	1.6 (MC)	0 (82)	0.0 (NC)
		NH_3	6 (1416)	0.4 (MC)	0 (63)	0.0 (NC)	0 (79)	0.0 (NC)

Table 2A-3. Continued.

WCA-3	**Inflow**	DO	94 (301)	31.2 (C)	0 (16)	0.0 (NC*)	2 (14)	14.3 (PC*/C)
		pH	30 (4442)	0.7 (MC)	5 (328)	1.5 (MC)	0 (412)	0.0 (NC)
		Specific Conductance	64 (4493)	1.4 (MC)	2 (327)	0.6 (MC)	3 (411)	0.7 (MC)
		Total Beryllium	4 (19)	21.1 (C)	0 (3)	0.0 (NC*)	--	--
		Total Iron	8 (890)	0.9 (MC)	0 (69)	0.0 (NC)	0 (56)	0.0 (NC)
		Turbidity	55 (3894)	1.4 (MC)	1 (168)	0.6 (MC)	0 (185)	0.0 (NC)
		NH_3	9 (3917)	0.2 (MC)	1 (204)	0.5 (MC)	1 (213)	0.5 (MC)
	Interior	Alkalinity	4 (1874)	0.2 (MC)	0 (295)	0.0 (NC)	0 (321)	0.0 (NC)
		DO	26 (108)	24.1 (C)	13 (23)	56.5 (C*)	12 (23)	52.2 (C*/C)
	Outflow	DO	34 (175)	19.4 (C)	2 (11)	18.2 (PC*)	1 (9)	11.1 (PC*/PC)
		pH	44 (3846)	1.1 (MC)	0 (203)	0.0 (NC)	0 (216)	0.0 (NC)
		Turbidity	3 (2990)	0.1 (MC)	0 (171)	0.0 (NC)	0 (177)	0.0 (NC)
		NH_3	6 (2920)	0.2 (MC)	0 (164)	0.0 (NC)	0 (180)	0.0 (NC)
Park	**Inflow**	DO	23 (182)	12.6 (PC)	2 (11)	18.2 (PC*)	2 (11)	18.2 (PC*/PC)
		pH	54 (4457)	1.2 (MC)	0 (291)	0.0 (NC)	0 (319)	0.0 (NC)
		Specific Conductance	0 (4528)	0.0 (NC)	0 (291)	0.0 (NC)	1 (290)	0.3 (MC)
		Total Lead	4 (1182)	0.3 (MC)	--	--	--	--
		Turbidity	3 (3433)	0.1 (MC)	0 (187)	0.0 (NC)	0 (201)	0.0 (NC)
		NH_3	20 (3378)	0.6 (MC)	0 (181)	0.0 (NC)	0 (205)	0.0 (NC)
	Interior	DO	2 (159)	1.3 (MC)	0 (9)	0.0 (NC*)	1 (9)	11.1 (PC*/MC)
		pH	21 (1360)	1.5 (MC)	1 (80)	1.3 (MC)	0 (101)	0.0 (NC)
		Specific Conductance	21 (1478)	1.4 (MC)	0 (80)	0.0 (NC)	1 (101)	1.0 (MC)
		Total Copper	6 (1239)	0.5 (MC)	--	--	--	--
		Total Iron	113 (1300)	8.7 (PC)	--	--	--	--
		Total Lead	5 (1261)	0.4 (MC)	--	--	--	--
		NH_3	21 (1295)	1.6 (MC)	0 (79)	0.0 (NC)	0 (100)	0.0 (NC)

Note: For the "Number of Excursions" columns, the number in front of the parentheses specifies the number of excursions, while the number inside the parentheses specifies the number of samples collected. Excursion categories of concern, potential concern, and minimal concern are denoted by "C," "PC," and "MC," respectively, and are provided within parentheses in the "Percent Excursions" columns. 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.

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 dissolved oxygen (DO) in an aquatic environment is an important indicator of that environment's quality. Due to oxygen's importance to life, it is essential to understand the processes that influence DO concentrations in the Everglades. 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 a sufficient levels of DO to support a variety of aquatic life.

In the Everglades open-water slough communities, where light penetration is high, high photosynthetic rates by periphyton and submerged aquatic vegetation (P/SAV) result in increasing oxygen concentrations during daylight hours (Belanger and Platko, 1986; McCormick et al., 1997). At night, respiration and sediment oxygen demand (SOD) reduce oxygen concentrations. Under natural conditions, oxygen production exceeds respiration during the photoperiod, allowing the accumulation of an oxygen reserve, which prevents concentrations from decreasing to extremely low levels at night (< 1.0 to 2.0 milligrams per liter, or mg/L). Cultural eutrophication results in increased productivity in the system and an increased accumulation of organic matter in the sediments. The breakdown of this organic matter increases the SOD, which results in oxygen declines throughout the diel cycle. Additionally, nutrient enrichment in the Everglades dramatically reduces the native P/SAV community and increases emergent aquatic vegetation coverage (Rutchey and Vilchek, 1994; McCormick et al., 1998; Payne et al., 1999, 2000, and 2001b). Emergent aquatic vegetation contributes little oxygen to the water column while also shading P/SAV and resulting in further reductions in DO production within the water column.

An SSAC for DO in the EPA was adopted by the FDEP on January 26, 2004 and was subsequently approved by USEPA as a revision to Florida water quality standards. Because a single value criterion does not adequately account for the wide-ranging natural daily (diel) fluctuations observed in the marsh, 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. 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:

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

Where:

DOL_i is the lower limit for the i^{th} annual DO measurement in mg/L
t_i is the sample collection time in minutes (EST) since midnight of the i^{th} annual DO
C_i is the water temperature associated with the i^{th} annual DO measurement in °C

To fully account for seasonal and annual variability in marsh DO concentrations, ambient assessment with the SSAC is based on a comparison between the annual average of multiple (e.g., monthly) DO measurements made throughout the year, 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 to be compared to the annual average of all DOL_i determinations for that year. DO excursion results for individual stations are provided in Appendix 2A-3.

Because DO is now 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 (WY2000–WY2004) for all areas. DO was categorized as a concern for the Refuge interior, WCA-2 inflows, WCA-2 interior, and WCA-3 interior. Additionally, DO was categorized as a potential concern for Refuge and Park inflows, and WCA-3 outflows.

Stations that failed to meet the SSAC were generally influenced either by altered hydrogeomorphic conditions caused by the construction of the canals and operation of the water control structures, or by nutrient enrichment. Similar to the results reported in the 2001–2004 Everglades Consolidated Reports (Weaver et al., 2001–2003; Weaver and Payne, 2004), several of the water control structures (inflow and outflow sites) failed the SSAC test during WY2004. This pattern of non-compliance is likely due to a combination of 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 are commonly mixed with canal surface waters during pumping events. These sediments typically increase oxygen demand within the water column, and subsequently result in reduced 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” (Chapter 62-302.800, F.A.C.), and should be addressed separately. The second group of stations failing the SSAC consists of interior marsh stations known to be biologically impaired as a result of phosphorus enrichment (e.g., E1, F1, Z1, and 3AW05). Conditions at these stations are expected to remain impaired until phosphorus concentrations in the surface water and sediment are reduced, and the biological communities recover. Continuing efforts to research and potentially accelerate the biological recovery of these areas is reported on in Chapter 2C of the *2005 South Florida Environmental Report – Volume I* (2005 SFER).

It should be noted that the excursion categories assigned to 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 minimal concerns for unimpacted areas of the Park and WCA-2, a potential concern for WCA-3, and a concern for the Refuge. DO exceedances within the unimpacted Refuge marsh were localized in two areas. Between WY2000–WY2004, a total of seven exceedances were recorded among sites X3, X4, and Y4 on the west central side of the Refuge. Additionally, during the same period, four exceedances occurred in the southern portion of the Refuge at site LOX16. The cause of these existences is uncertain, although nutrient enrichment does not appear to be a major factor. Five-year average geometric mean total phosphorus (TP) concentrations were less than or equal 10 micrograms per liter (µg/L) at all four sites (1-sided t-test: $p = 0.07–1.0$).

ALKALINITY AND pH

Alkalinity is a measure of water's acid neutralization capacity and provides a measure of the water's buffering capacity. In most surface water bodies, the buffering capacity is primarily the result of the equilibrium between carbon dioxide 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) that are influenced by canal inflows 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 mg of calcium carbonate per liter ($CaCO_3$/L).

The pH value is defined as the negative $\log_{(\text{base }10)}$ of the hydrogen (H^+) ion activity. In low ionic-strength freshwaters, the activity of the H^+ ion is approximately equal to the concentration of H^+ ions. Because pH is based on a log scale, each pH unit change represents a ten-fold change in the concentration of H^+ ions (acidity). For example, a solution at a pH of 3.0 is 10 times more acidic than one at a pH of 4.0. Most living organisms, especially aquatic life, function best in a pH range of 6.0–9.0, although individual species have specific ideal ranges. For instance, most fish fail to spawn if conditions are below a pH of 5.0, and many species die if conditions are below a pH of 4.0. Amphibians also are particularly sensitive to extreme pH levels as well as drastic pH changes. Some amphibian declines have been attributed to declining pH (Wyman, 1990). Additionally, the pH of water affects the toxicity and solubility of other substances (e.g., ammonia, aluminum, cadmium, and iron). The current Class III criterion for pH specifies that this parameter shall not be lowered below 6.0 units, or raised above 8.5 units in predominately fresh waters.

There are a number of interrelationships between pH, photosynthesis, and CO_2 in water. When CO_2 enters fresh water, small amounts of carbonic acid are formed, which then dissociate into H^+ and CO_3^{2-} ions, thereby resulting in a lowering of pH. Because photosynthesis and respiration alter CO_2 concentration in the water, these processes exert an influence on pH. During the day, while photosynthetic processes are consuming CO_2, the concentration of carbonic acid declines and pH rises. The addition of CO_2 by respiration at night reverses the reactions and lowers pH. In poorly buffered systems (low alkalinity), the daily changes in pH can be dramatic.

Given the regulating effect of alkalinity on pH, these two variables are evaluated together in this section. Excursions of state Class III water quality criteria for both variables have historically occurred in the interior of the Refuge (Bechtel et al., 1999 and 2000; Weaver et al., 2001, 2002 and 2003; Weaver and Payne, 2004). As in previous years, alkalinity was designated as a concern for the interior of the Refuge for WY2004, due to an excursion rate of 19.7 ± 4.5 percent. As stated above, the low alkalinity values in the Refuge are primarily attributed to hydrology. Although pH was not identified as either a concern or potential concern for any area based on regional assessments, localized high exceedance rates (7 to 44 percent) were recorded at several interior Refuge stations for the five-year period from WY2000–WY2004. This resulted in pH being classified as a concern for stations LOX5, LOX8, LOX11, and LOX13, and classified as a potential concern for stations LOX14 and LOX16.

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 soft-water conditions within the interior. The dichotomy of the soft-water interior and the hard-water 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). 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 are due to 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.

Excursions for pH are closely linked to the naturally low alkalinities within the Refuge's interior marsh. Given that the buffering capacity within the interior is low, small changes in the production or consumption of CO_2 by marsh biota or absorbance of CO_2 from the atmosphere produce significant changes in pH. All recent excursions (WY2000–WY2004) from the pH criterion have occurred at alkalinities below 40 mg $CaCO_3$/L, which is consistent with patterns noted for previous periods (Weaver et al., 2001; Weaver and Payne, 2004). Additionally, the greatest variability in pH has occurred at alkalinities of less than 100 mg $CaCO_3$/L (**Figure 2A-6**). Such fluctuations in pH at low alkalinities in areas free of discharges are typically caused by changes in CO_2 concentrations due to natural processes of photosynthesis and respiration within the environment. 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.

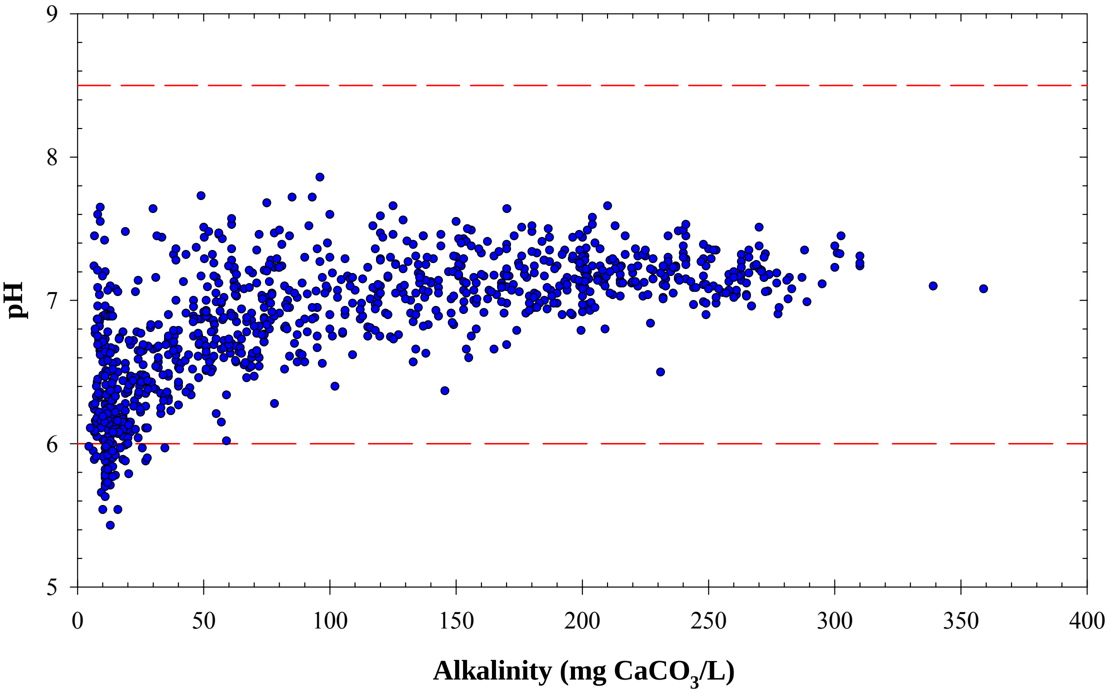

Figure 2A-6. Relationship between pH variability and alkalinity within the interior marsh of the Refuge from WY2000–WY2004. PH variability is highest at low alkalinity levels (50 mg $CaCO_3$/L). Dashed horizontal lines show the lower (6.0) and upper (8.5) Class III pH criteria.

SPECIFIC CONDUCTANCE

Specific conductance (conductivity) is a measure of water's ability to conduct an electrical current, and is an indirect measure of the total concentration of ionized substances (e.g., Ca^{2+}, Mg^{2+}, Na^+, Cl^-, HCO_3^-, and SO_4^{2-}) in the water. Conductivity will vary with the number and type of these ions in solution. 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 example, 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 meant to preserve natural background conditions and protect aquatic organisms from stressful ion concentrations. Since background conductivities are low within the EPA, excursions were calculated using the 1,275-µmhos/cm criterion (Weaver et al., 2001 and 2002).

For WY2004, conductivity was categorized as a concern for WCA-2 interior and inflow stations and a potential concern for Refuge inflows. The WY2004 exceedance frequency (27.9 ± 5.7 percent) for WCA-2 inflows was significantly elevated above both WY2003 (10.9 ± 4.2 percent), and the WY1978–WY2002 historical period (16.1 ± 1.5 percent). Conversely, the WY2004 exceedance frequency (11.2 ± 4.5 percent) in Refuge inflows was lower than the historical period (24.9 ± 1.4 percent). A majority (34 out of 46) of the exceedances into WCA-2 occurred at the G-335 structure. Overall, most of the conductivity excursions (69) occurred either at water control structures or within canals. Previous ECRs explained that the elevated conductivity levels at water control structures and stations near canal inflows were probably linked to groundwater intrusion into canal surface waters (Weaver et al., 2001; 2002). This groundwater intrusion can occur due to seepage into canals, via pumping station operation (which can pull additional groundwater into the surface water), and as a result of agricultural dewatering practices. The FDEP intends to continue its evaluation of conductivity in the EPA and Everglades Agricultural Area (EAA) canals.

As reported in the 2004 Everglades Consolidated Report, an unusually high number of specific conductance exceedances during WY2003 at WCA-2 interior stations distant from inflows (F2, F3, F4, F5, CA215, and CA29). Furthermore, WY2003 specific conductivity levels recorded at several of these stations, particularly F1, were well above the previously recorded values (**Figure 2A-7**). During WY2004, specific conductivity levels at most these sites returned to prior baseline conditions, except at sites F1, F2, and F3 (**Figure 2A-7**). Although several values above previous baseline conditions were recorded at sites F2 and F3, the annual WY2004 median concentrations at the two sites were not significantly different from the WY1995–WY2002 period (Mann-Whitney: p = 0.24–0.45). Conversely, median conductivities at site F1 remained above WY1995–WY2002 levels (Mann-Whitney: p = 0.015). The elevated conductivities at sites F1, F2, and F3 are likely the result of a variety of factors. Like the previous water year, many of the exceedances at these sites occurred during the dry season when no flows were recorded through the upstream structures (S-10A, S-10C, and S-10D). During this period, the exceedances 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). In addition to the dry season, exceedances were also recorded during the wet season. There were discharges through the S-10 structures during a portion of the wet season, which may have contributed to the exceedances, although conductivity levels in the discharge waters were typically lower than that at site F1.

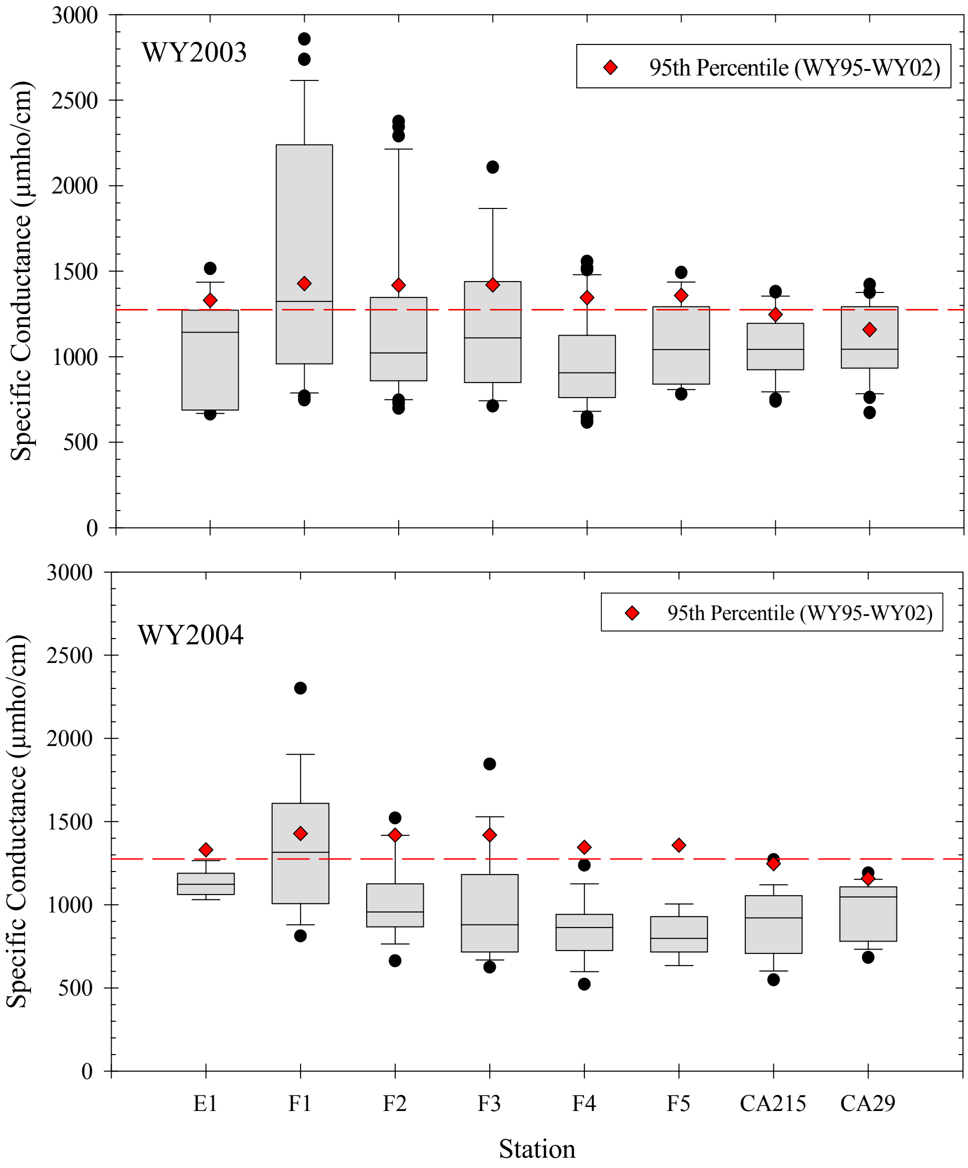

Figure 2A-7. Boxplots of WY2003 and WY2004 specific conductance versus 95th percentile for WY1995–WY2002 specific conductance results at WCA-2 interior marsh stations with WY2003 excursions. The top and bottom boxplots summarizes WY2003 and WY2004 results, respectively. Whiskers indicate 10th and 90th percentiles. The 25th and 75th percentiles are shown by the bottom and top of each box, respectively. Station medians are shown as solid horizontal lines through each box. Black circles indicate WY2003 and WY2004 results beyond the 10th or 90th percentile. Red diamond symbols indicate the 95th percentile for all previous water years (WY1995–WY2002), and provide a measure of site-specific background conditions. The horizontal red dashed line depicts 1,275 µmhos/cm.

In addition to the exceedances along the F1 transect in WCA-2, a relatively high number (15) of exceedances were recorded at interior sites (CA27 and CA28) on the northwestern side of WCA-2. Conductivity levels have increased at the two interior sites over the past three years, with the most dramatic increases at CA28, which is downstream of STA-2 discharges (**Figure 2A-8**). Treated water from STA-2, which is conveyed through the G-335 structure, is discharged into WCA-2 through a degraded levee near site CA28. It is likely that high conductivity water is now being conveyed to northwestern and western WCA-2 through STA-2 discharges. This conclusion is supported by the fact, as stated above, that frequent specific conductance exceedances have been recorded for G-335 discharges water[5].

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[5] STA-2 began flow through operations on August 9, 2001 (during WY2002).

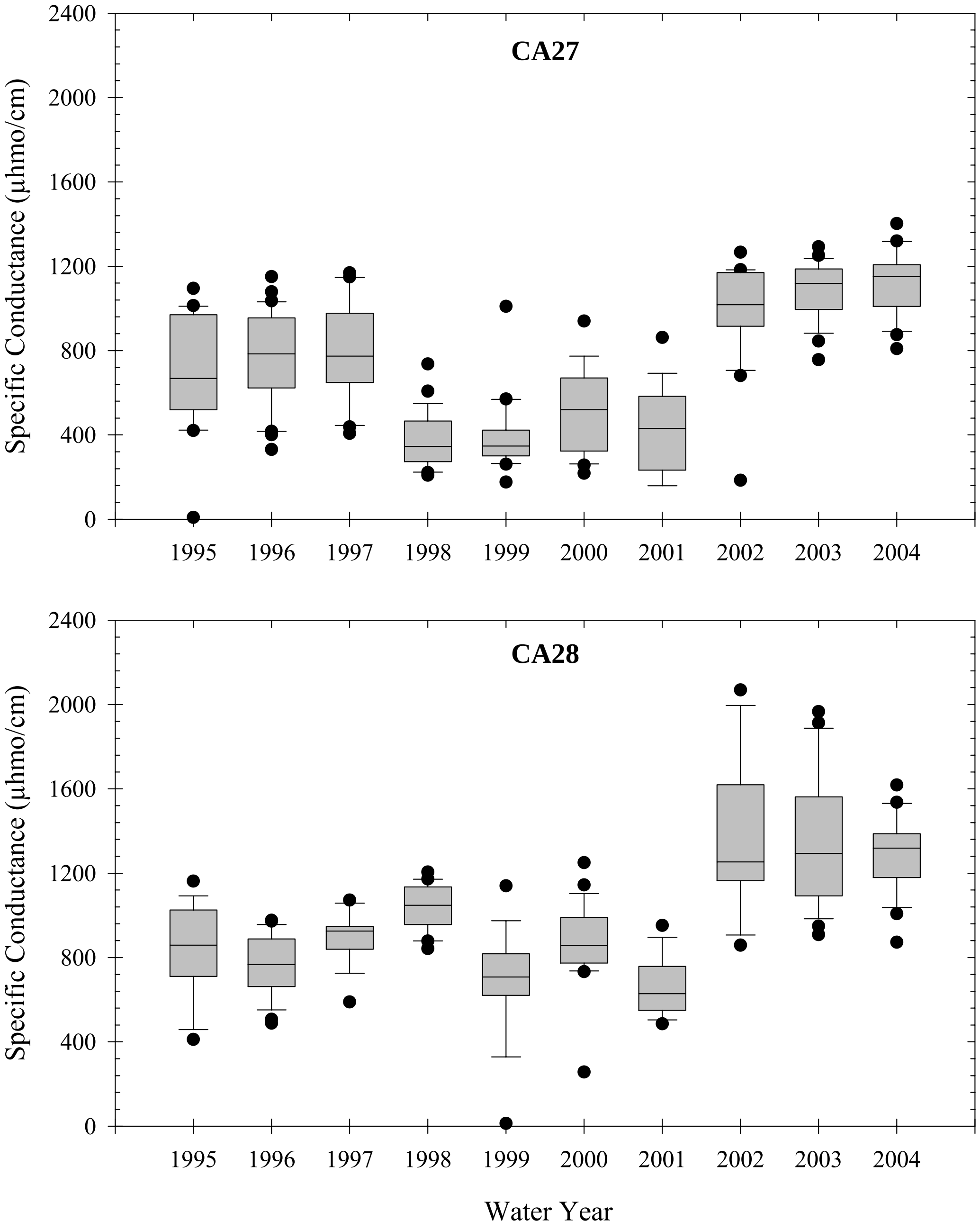

Figure 2A-8. Boxplots of annual specific conductance results for WCA-2 interior monitoring sites CA27 (top) and CA28 (bottom). Whiskers indicate 10th and 90th percentiles. The 25th and 75th percentiles are shown by the bottom and top of each box, respectively. Station medians are shown as solid horizontal lines through each box. Black circles indicate results beyond the 10th or 90th percentile.

REFUGE INTERIOR SPECIFIC CONDUCTANCE

As stated above, the Refuge is naturally a rainfall-dominated system with surface water exhibiting a low mineral or ion content. In fact, the periphyton community within the Refuge shows a response to ion concentrations, such as alkalinity, chloride, and calcium. In interior regions of the Refuge with low mineral content (i.e., low conductivity), the periphyton assemblage is comprised primarily of numerous species of desmids and filamentous green algae, which form a thin, hairy green to brown coating (sweater) on plant stems. As mineral content increases in oligotrophic areas nearer the rim canal, the periphyton community becomes dominated by calcareous blue-green algae (particularly *Scytonema* and *Schizothrix*) with numerous diatoms that form a thick cream to yellowish-brown mat with calcite crystals; that is, the community shifts to one more like the hardwater portions of WCA-2 and WCA-3 (Payne et al., 2001a). Given this characteristic the current specific conductance standard may not be fully protective of the area. Chapter 6 of the 2005 SFER – Volume I provides additional information on the influence of water mineral content (conductivity) on periphyton community structure and summarizes recent research results.

Although the current standard may not be fully protective, changes or trends in major ions can be tracked over time insure the water body is not being degraded. Overall, specific conductance levels within the interior (LOX3–LOX16) of the Refuge show neither a trend since inception (WY1995) of the current monitoring program, nor an increase relative to a baseline period from WY1979–WY1984 (**Figure 2A-9**)[6]. However, the variability of specific conductance measurements has increased during several recent years (i.e., 2001, 2003, and 2004), but not when compared to baseline years. Because the spatial variability among sites may obscure annual patterns across the entire marsh, annual specific conductance at individual monitoring stations was also evaluated. The result of this evaluation is presented as a series of boxplots in Appendix 2A-4. Most stations exhibited no trend. However, LOX10 and several Refuge transect stations (X3, Z3, X4, Y4, and Z4) exhibited a pattern of increasing specific conductance between WY1998–WY2000[7], and WY2002 followed by a decrease in WY2002 and subsequent increase for WY2003 for sites Z3, X4, Y4, Z4, and LOX10. While specific conductance at most the aforementioned sites decreased during WY2004, the levels at site X3 remained elevated. It should be noted that the transect sites have a limited baseline period, and it is uncertain whether the lower conductivities observed during the early monitoring years (i.e., WY1997 and WY1998) represent background conditions.

Higher conductivity canal water is conveyed to the Refuge via waters discharged to the L-7 and L-40 rim canal. These canal waters will either overflow into the Refuge interior when canal stages exceed the levee height or will bypass the marsh and be discharged to WCA-2A through the S-10 structures. The degree to which high conductivity waters permeate the Refuge depends

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[6] The baseline period was selected to be consistent with the one used to establish existing ambient Outstanding Florida Waters baseline conditions for phosphorus in the federal Settlement Agreement. Analytical methods between the two periods may not be completely comparable. Specific conductance was analyzed in the laboratory during the baseline period; while contemporary (WY1995–WY2004) measurements are conducted in the field.

[7] The elevated conductivities first occurred at sites nearest the rim canal (X3 and Z3). Increases were not evident at more distant sites until WY1999 or even WY2000 for site Z4.

on the head differential between the rim canal and marsh stages, which are influenced by both the volume of water discharged to the rim canal, and rainfall to the marsh. The interannual conductivity variability may be partially explained by the influence of rainfall (**Figure 2A-10**), although the management of canal and Refuge stages is an important and often overriding factor. During below average rainfall years (e.g., WY2001, WY2003, and WY2004), there is a tendency for Refuge marsh conductivity to rise (**Figures 2A-9** and **2A-10**). Conversely, conductivity tends to be lower during high rainfall years (e.g., WY1995).

The FDEP and the District will continue to evaluate specific conductance conditions in the Refuge. This evaluation will include further analysis of the observed trends to determine if the recent increases are due to increased inflow of high conductivity water, increased groundwater influence, or highly variable climatic conditions. Also included will be an assessment of regulatory options designed to acknowledge the natural low ion content of the water, which may be achieved through an SSAC, revised standard, or definition of background conditions. Results of these evaluations will be reported in future South Florida Environmental Reports.

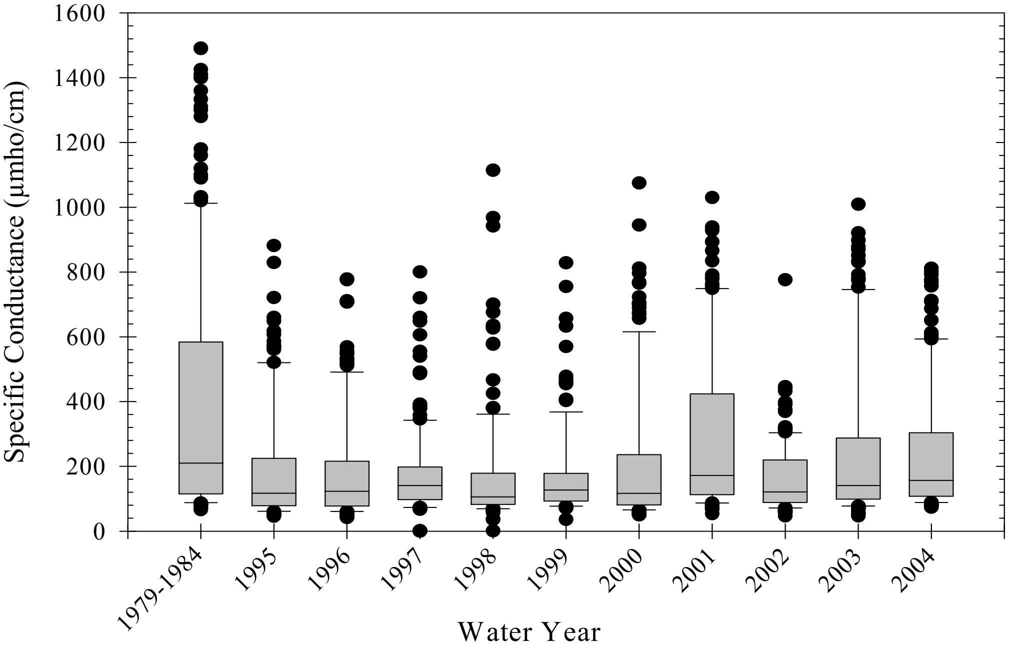


Figure 2A-9. Boxplots for WY1995-WY2004 specific conductance results for the current Refuge interior monitoring network (LOX3–LOX16) and interior baseline conditions from WY1979–WY1984. Whiskers indicate 10th and 90th percentiles. The 25th and 75th percentiles are shown by the bottom and top of each box, respectively. Station medians are shown as solid horizontal lines through each box. Black circles indicate results beyond the 10th or 90th percentile.

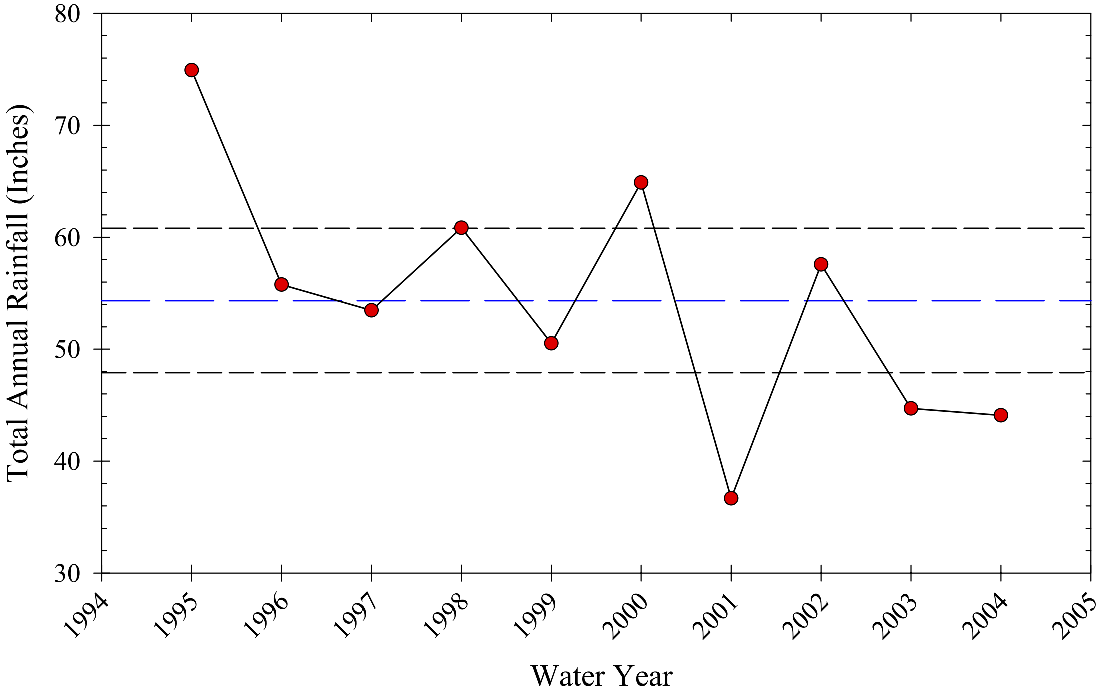


Figure 2A-10. Total annual rainfall for WCA-1 from WY1995–WY2004. The blue and black dashed lines are the 10-year average annual total rainfall and 90-percent confidence interval (90% C.I.) of the average, respectively.

UN-IONIZED AMMONIA

Un-ionized ammonia (NH_3) is a colorless gas with a pungent odor that is very soluble in water at low pH. Ammonia can serve as an important source of nitrogen for plant life, but is toxic to aquatic life when present in excess. In the aquatic environment, ammonia is very soluble and is readily hydrolyzed to form ammonium (NH_4^+) ions as shown in the following reaction:

$$NH_3 + H_2O = NH_4^+ + OH^-$$

The NH_4^+ ions produced as a result of the hydrolysis are not toxic to aquatic life. However, even though ammonia is highly soluble in water, the hydrolysis is not complete and some portion of the total ammonia remains in the toxic unionized (NH_3) form. The equilibrium established between the unionized (NH_3) and ionized (NH_4^+) forms of ammonia is a function of temperature and pH. As can be seen in the above equation, increases in pH (increased levels of OH^- ions) as well as temperature forces the reaction to the left resulting in increasing levels of NH_3. For example, in fresh water at 25°C, an increase in pH from 7.0 to 8.0 results in an increase in the percent of NH_3 in the un-ionized form from 0.5 to 5.4 percent. At a pH of 9.0, more than one-third (36 percent) of the total dissolved ammonia (i.e., the concentration of ammonia measured in the water column, $NH_3 + NH_4^+$) is in the un-ionized form. The resulting NH_3 is able to diffuse across cell membranes more readily and is acutely toxic to aquatic life at relatively low concentrations.

Ammonia 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 NH_3 necessary to become toxic is highly variable, because the toxic effect of NH_3 is affected by temperature, pH, DO concentrations, CO_2 concentrations, previous acclimation to NH_3, and the presence of other toxic compounds. High external, NH_3 concentrations reduce or reverse diffusion gradients used by organisms to excrete excess NH_3. This excess NH_3 can accumulate in the organism, resulting in altered metabolism, loss of equilibrium, hyperexcitability, increased respiratory activity and oxygen uptake, and increased heart rate. Even slightly elevated concentrations of NH_3 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 NH_3 can result in convulsions, coma, and even death.

The current state Class III water quality criterion for NH_3 is $\leq$ 0.02 mg/L. NH_3 is calculated from pH, temperature, and total dissolved NH_3 measurements from the same sample. During WY2004, seven calculated NH_3 values above 0.02 mg/L were recorded. Based on the aggregated regional analysis, NH_3 was categorized as a minimal concern for WCA-2 inflows; however, all WCA-2 WY2004 exceedances were localized at two inflow stations (E0 and F0). Furthermore, NH_3 was categorized as a localized concern for E0 and F0, based on an analysis of WY2000–WY2004 data.

The localization of NH_3 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-2A 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 level of NH_3 excursion at sites E0 and F0 were likely related to the stagnant (i.e., low DO), low-water conditions in the spreader canal during WY2002–WY2004. 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 NH_3 excursion episodes occurring following periods of no flow (**Figure 2A-11**).

As discussed in the 2003 and 2004 Everglades 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, then 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 to nitrite and nitrate, the ammonia accumulates (concentration increases) within the canal.

The elevated total dissolved ammonia levels continue to be the proximal cause of the E0 and F0 NH_3 excursions (**Figure 2A-12**), which is expected if the cause were related to the release of NH_3 under low-flow or stagnant conditions, as described above. For WY2004, the median total dissolved NH_3 concentrations at sites E0 and F0 were 0.72 and 0.63 mg/L, respectively. Furthermore, during the entire monitoring record (WY1994–WY2004) at these two stations, elevated total dissolved NH_3 concentrations were the proximal cause of all 57 excursions of NH_3 within the WCA-2 spreader canal. The phenomenon of periodically elevated total dissolved NH_3 concentrations is apparently isolated to the spreader canal, and has not contributed to excursions in the marsh adjacent to the spreader canal. From WY1994–WY2004, the total dissolved NH_3 concentrations at the marsh transect stations E1 and F1 (1.8–2.2 km) downstream of the spreader canal have been significantly lower (Kruskal-Wallis; $p < 0.0001$; median = 0.041–0.054 mg/L) than concentrations observed at stations E0 or F0 (median = 0.25–0.37 mg/L).

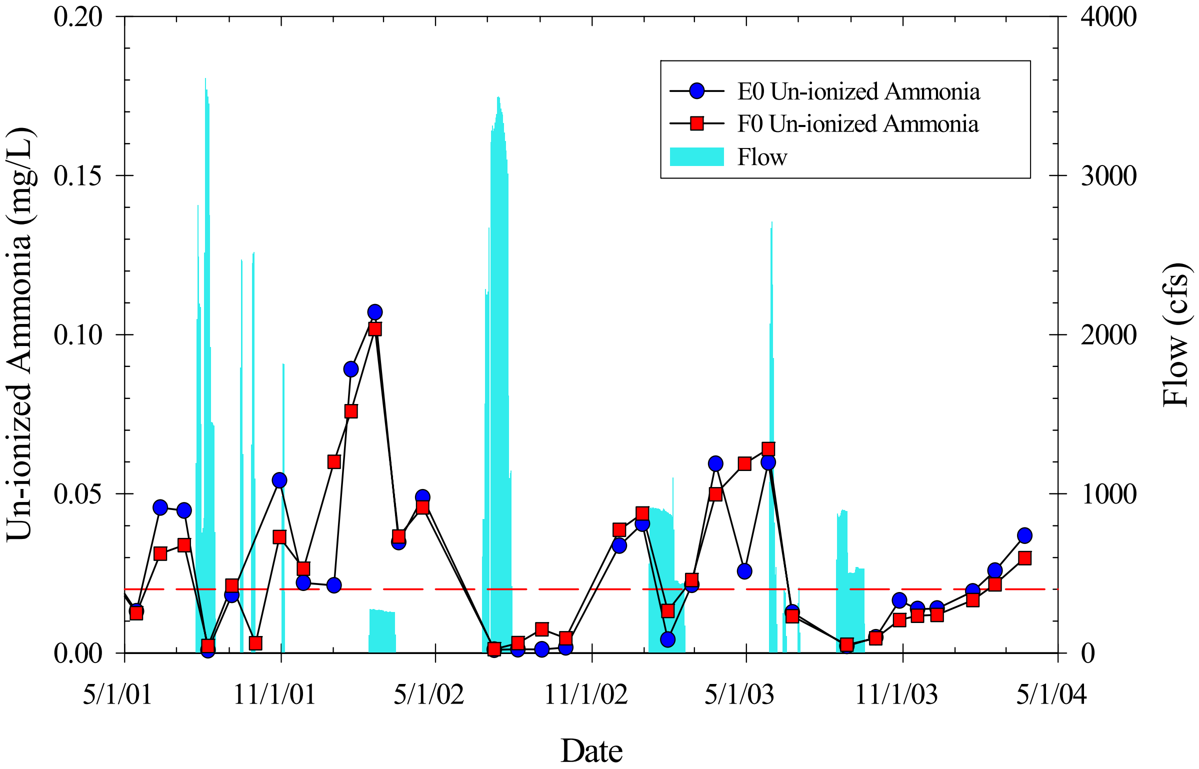
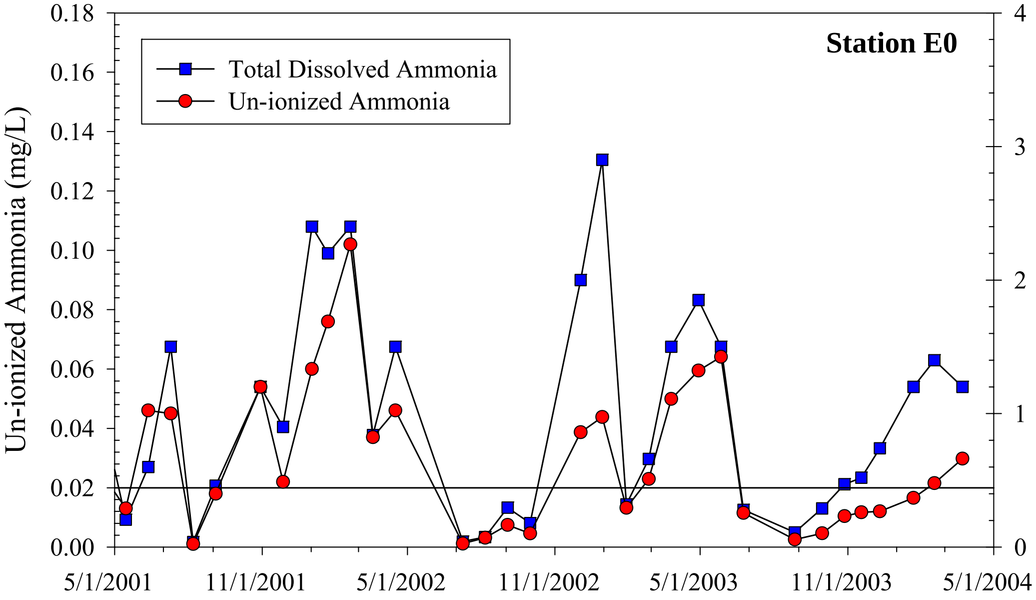


Figure 2A-11. Total average daily inflow volume through the S-10A, S-10C, and S-10D structures, and calculated NH_3 concentrations for sites E0 and F0 from WY2002–WY2004. Horizontal red dashed line is the Class III NH_3 criterion (0.02 mg/L).



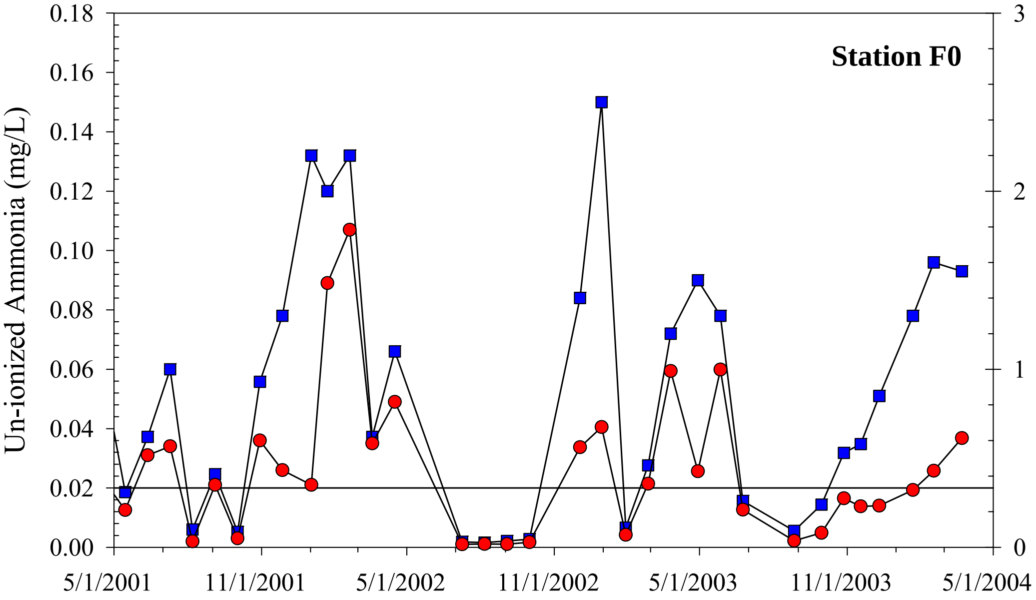


Figure 2A-12. Total dissolved ammonia concentrations and calculated NH_3 values for sites E0 (top) and F0 (bottom) during WY2002–WY2004. Horizontal solid black line is the Class III NH_3 criterion (0.02 mg/L).

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 2B of the 2005 SFER – Volume I and previous ECRs (Atkeson and Parks, 2002; Atkeson and Axelrad, 2003). 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 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 2A-7** for WY2004, WY2003, and WY1978–WY2002, based on arithmetic mean and median values.

Given that one of the primary sources of sulfate entering the EPA is stormwater runoff from the EAA, sulfate concentrations in the inflow and interior marsh generally follow trends similar to those observed for total phosphorus and total nitrogen; 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, similar to those identified for nutrient levels (**Figure 2A-13**). 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 of the area in the rim canal and is discharged to WCA-2 through the S-10 structures. Due to this hydrologic characteristic, the Refuge interior has remained relatively uninfluenced by the inflow of sulfate-rich water. However, the 2004 Everglades Consolidated Report noted elevated sulfate concentrations during WY2003 within the interior of the Refuge. These elevated WY2003 concentrations (median = 11 mg/L) returned to historic levels (3.3 mg/L) during WY2004 (median = 3.7 mg/L). Among the EPA marsh areas, the interior of WCA-2 exhibits the highest sulfate concentrations, and is the area most affected by EAA runoff, with a WY2004 median concentration of 35 mg/L. Sulfate concentrations at stations in the interior of WCA-3 have also been elevated by inputs of sulfate-enriched runoff, though this is not readily apparent in WY2004, given the median sulfate concentration of 2.3 mg/L. As demonstrated in the 1995, 1996, and 1999 USEPA Regional Environmental Monitoring and Program (REMAP) 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 2A-13**). The highest WY2004 sulfate concentrations within the WCA-3 interior were observed in the marsh near the Miami Canal in the northwestern part of the area at station CA36 (median = 30 mg/L). Concentrations decreased through the marsh, following the southerly flow of water. The lowest median sulfate concentration observed during WY2004 at sites in the WCA-3 marsh (median < 0.10 mg/L) was observed at station CA315, the most southerly sampling location in WCA-3.

Table 2A-7. Summary of sulfate concentrations (mg/L) in the EPA for WY2004, WY2003, and WY1978–WY2002.

Region	Class	Period	N	Arithmetic Mean	Std. Deviation	Median	Min.	Max.
Refuge	Inflow	1978–2002	776	58	44	50	<0.1	461
		2003	60	58	20	54	19	105
		2004	60	73	24	73	8.3	123
	Rim	1978–2002	562	53	27	48	2	140
		2003	22	52	10	50	38	73
		2004	24	79	28	78	39	120
	Interior	1978–2002	1924	15	70	3.3	<0.1	2900
		2003	212	20	22	11	<0.1	76
		2004	223	15	24	3.7	<0.1	110
	Outflow	1978–2002	339	48	48	40	1	571
		2003	27	52	22	50	11	93
		2004	24	47	27	39	8	98
WCA-2	Inflow	1978–2002	650	51	43	45	6	644
		2003	76	51	18	52	16	93
		2004	68	64	22	62	15	106
	Interior	1978–2002	3060	45	27	42	0	370
		2003	245	40	89	32	6	1400
		2004	215	36	24	32	6	121
	Outflow	1978–2002	360	36	27	31	2	224
		2003	19	31	11	32	14	54
		2004	20	36	17	35	10	73
WCA-3	Inflow	1978–2002	1009	26	26	18	0.5	286
		2003	71	19	14	13	1.2	54
		2004	66	18	16	10	0.8	73
	Interior	1978–2002	1729	11	15	5.7	<0.1	262
		2003	296	7.5	11	3.8	<0.1	83
		2004	320	5.9	9.1	2.3	<0.1	45
	Outflow	1978–2002	520	13	17	8.9	<0.1	113
		2003	45	3.4	6.5	0.1	<0.1	32
		2004	40	3.3	5.5	0.1	<0.1	17
Park	Inflow	1978–2002	492	13	17	8.5	<0.1	113
		2003	43	3.3	4.6	2.0	<0.1	23
		2004	41	3.8	5.1	0.8	<0.1	16
	Interior	1978–2002	1373	6.8	19	3.0	<0.1	403
		2003	79	3.7	13.7	1.0	<0.1	120
		2004	96	2.3	2.8	1.0	<0.1	11

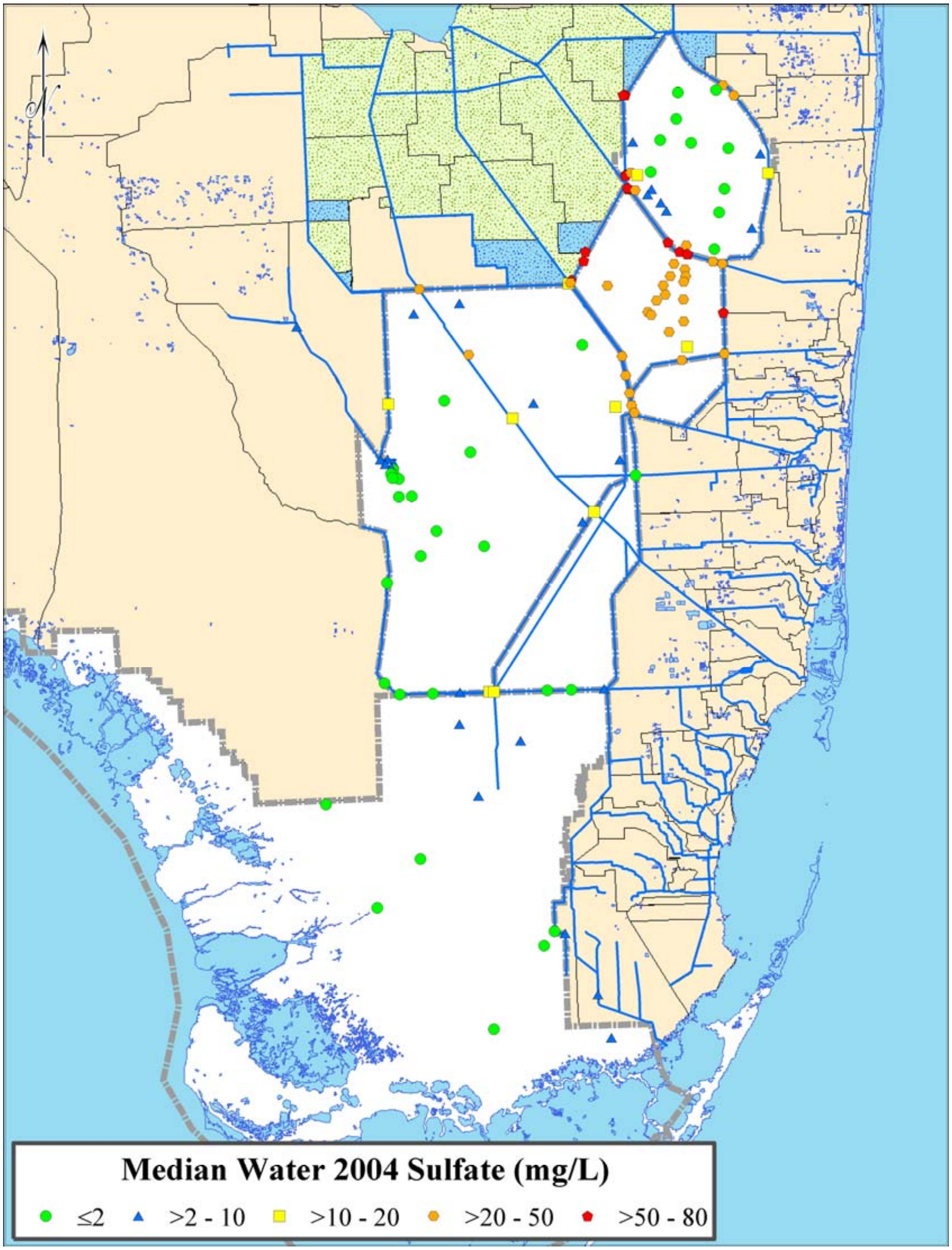


Figure 2A-13. Summary of median WY2004 sulfate concentrations (mg/L) at stations across the EPA. Median sulfate concentrations are classified utilizing four levels as follows: ≤ 2 mg/L, 2–10 mg/L, 10-20 mg/L, 20–50 mg/L, and > 50–80 mg/L.

PESTICIDES

The SFWMD has maintained a pesticide monitoring program in South Florida since 1984. The pesticide monitoring network includes sites designated in the ENP 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 2A-14**). The sites were grouped by basin for analysis.

Surface water concentrations of pesticides are regulated under criteria established in Chapter 62-302, F.A.C. Chemical-specific numeric criteria for a number of pesticides and herbicides (e.g., DDT, 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 the 2001 Everglades Consolidated Report (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."

The *2005 SFER – Volume I* analyzes data collected during pesticide monitoring events conducted between September 2002–2003. 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. Variables 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, known to be reasonably below levels that result in adverse biologic effects, but may result in a problem at some future date, or in interaction with other compounds. The "no concern" category was used to designate pesticides that were not detected at sites within a given area.

Twelve pesticides or breakdown products were detected between September 2002–2003 (**Table 2A-8**). Only atrazine was classified as a concern. A total of six atrazine exceedances (guidance concentration = 1.8 µg/L) were recorded at the inflows to the Refuge, WCA-2, and WCA-3. Atrazine was also detected in 86 samples across all EPA areas. On March 26, 2003 atrazine exceedance were recorded at the S-5A (5.9 µg/L), G-310 (4.8 µg/L, and G-251 (2.8 µg/L) structures, which ultimately deliver water to the Refuge.[8] An atrazine exceedance was recorded in the WCA-3 inflow structure S-8 (4.6 µg/L) on March 11, 2003. Exceedances

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[8] The S-5A structure does not typically discharge water directly into the Refuge. Discharges from S-5A are treated within STA-1W, and discharged to the Refuge rim canal via the G-251 and G-310 structures.

occurred at the S-6[9] (5.0 µg/L) and S-38B (2.1 µg/L) WCA-2 inflow structures on March 12, 2003 and May 14, 2003, respectively.

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[9] S-6 discharges do not flow directly into WCA-2. S-6 discharges are treated by STA-2, and discharged to WCA-2A via the G-335 structure.

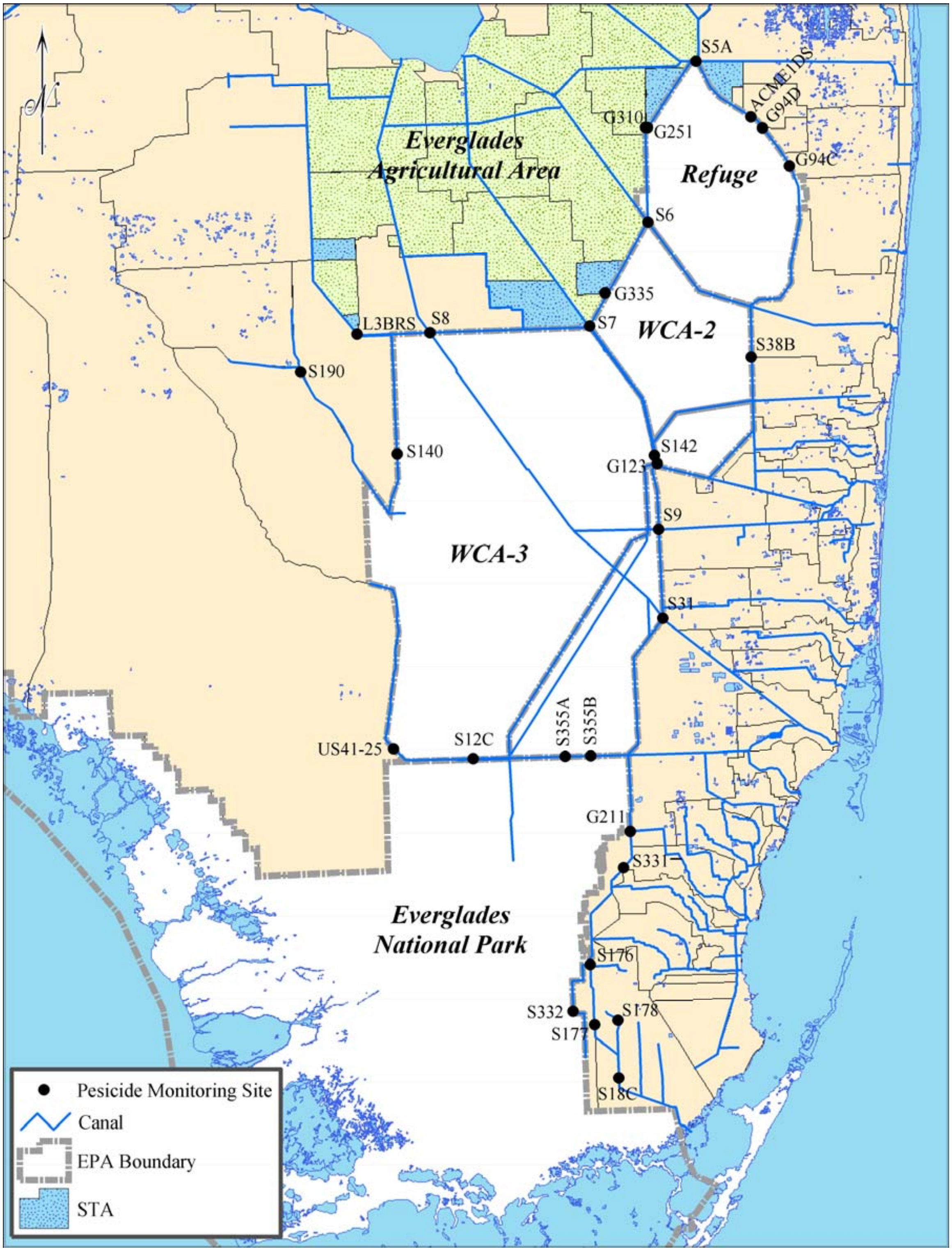

Figure 2A-14. SFWMD pesticide monitoring sites in the EPA.

Table 2A-8. Pesticide detections and exceedance categories in the EPA inflows, canals, and structures between September 2002–2003. 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.

Variable	Refuge[1]	WCA-2[2]	WCA-3[3]	Park[4]	C-111[5]
Ametryn	PC (29:30)	PC (12:14)	PC (12:32)	(0:24)	(0:16)
Atrazine	C (30:30)	C (13:14)	C (20:32)	PC (14:19)	PC (9:12)
Atrazine Desethyl	PC (17:24)	PC (8:10)	PC (7:28)	PC (1:20)	PC (1:16)
Atrazine Desisopropyl	PC (8:14)	PC (3:8)	PC (3:21)	(0:14)	(0:12)
Bromacil	(0:15)	(0:14)	PC (3:32)	(0:24)	(0:16)
Dichlorophenoxy Acetic Acid, 2,4- (2-4-D)	(0:12)	PC (1:12)	(0:32)	PC (1:24)	PC (2:16)
Diuron	(0:15)	(0:14)	PC (1:32)	(0:24)	(0:16)
Endosulfan (alpha +beta)	(0:16)	(0:8)	(0:32)	(0:24)	PC (2:16)
Endosulfan Sulfate	(0:15)	(0:14)	(0:32)	PC (2:24)	PC (5:16)
Hexazinone	PC (4:15)	PC (2:14)	PC (1:32)	(0:24)	(0:16)
Norflurazon	(0:15)	(0:14)	PC (9:32)	(0:24)	(0:16)
Simazine	PC (5:15)	PC (2:14)	PC (6:32)	(0:24)	(0:16)

1. ACME1DS, G-251, G-94D, G-310, and S-5A (via STA-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 forms were detected, but are combined in the total, and are considered as a single constituent.

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