Chapter 4: Status of Compliance with Water Quality Criteria in the Everglades Protection Area and Tributary Waters

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Summary

According to State of Florida Surface Water Quality Standards, Section 62-302.200 (28) F.A.C., water quality standards shall mean standards composed of designated present and future most beneficial uses (classification of waters), the numerical and narrative criteria applied to the specific water uses or classification, the Florida antidegradation policy, and the moderating provisions contained in this Rule and in F.A.C. Rule 62-4, adopted pursuant to Chapter 403, F.S. All waters of the Everglades Protection Area are classified as Class III that have the designated uses of recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Water quality criteria shall mean elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports the present and future most beneficial uses (Section 62-302.200(27) F.A.C.). Based on the foregoing definitions, this chapter focuses on the extent to which waters discharged into the Everglades Protection Area (EPA), as well as interior waters, currently meet or do not meet the water quality criteria specified in Section 62-302.530 F.A.C.

The data used in this Report were retrieved from the District's water quality database. They were then divided into a **baseline period** (October 1, 1978 through September 30, 1988) and into individual **recent water years** (1990 through 1998) to determine if any changes in water quality were evident during the 1990s when compared to the baseline period.

For this analysis the EPA was divided into four regions: Loxahatchee National Wildlife Refuge, Water Conservation Area 2, Water Conservation Area 3, and Everglades National Park. In each region, water quality sampling stations were classified as sources of stormwater **inflow or interior** sites. Data sets were created for each water quality constituent sampled at inflow structures and interior sites during the baseline period and in recent water years.

The overall status of compliance with water quality criteria in the Everglades Protection Area as of April 1998 was determined by 1) performing an analysis of excursions of constituents with Class III numeric criteria, and also for pesticides, excursions of aquatic invertebrate toxicity limits; 2) using notched box and whisker plots to define changes in constituent levels in WY90-98 compared to the baseline period; and 3) documenting changes in TP and TN loads and changes in other constituent concentrations between the EPA regions compared to the baseline period.

Excursion analysis. The following definitions of excursion categories were developed to rank the severity of excursions from water quality criteria in the EPA:

Excursion Category	Class III Waters	Pesticides	TP
Category A	> 5% excursions	Class III criterion and/or toxicity levels exceeded	> 50 ppb
Category B	up to 5% excursions	>Practical Quantitation Limit	≥ 10 ppb
Category C	> Method Detection Limit but no excursions	≤Practical Quantitation Limit	< 10 ppb

Dissolved oxygen was placed in **Category A** because of the high excursion percent in all EPA regions at both the inflow and interior sites. Specific conductance was assigned to **Category A** at all inflow sources and in the Refuge rim canal, and to **Category B** at all interior sites. Alkalinity and pH were placed in **Category A** in the interior marshes of the Refuge. Unionized ammonia, pH and turbidity were assigned to **Category B** in the inflows to the Refuge, in the Refuge rim canal, and at the inflow and interior sites in WCA-2, WCA-3 and the Park. TP was placed in **Category A** in all EPA regions except for the Park and interior marshes of the Refuge, where it was placed in **Category B**. Four pesticides were assigned to **Category A**. Endosulfan was detected above its numeric criterion seven times and the toxicity limits for aquatic invertebrates were exceeded one time each by chlorpyrifos ethyl, ethion and parathion methyl.

Significant trends. In the recent water years the inflow flow-weighted mean TP concentrations to the Refuge, WCA-2 and WCA-3 have generally been lower than the baseline period, but remain above 50 ppb most of the time. The Refuge and WCA-3 sites also showed TP improvement trends. At the inflow structures to the Refuge, significant improvement trends were also found for specific conductance and alkalinity as compared to the baseline period. There were no significant trends in the rim canal. At the interior sites, an improvement trend for iron existed, but there was a worsening trend for dissolved oxygen. No pattern of change could be seen in TP for interior sites in WCA-2. At the WCA-2 inflow structures, TN and total iron had improvement trends while only total iron showed an improvement trend at the interior sites. At WCA-3 inflow sites there were no significant trends, but turbidity, TN and total iron each had improvement trends at interior sites. The Park had improvement trends in TP and TN at the inflow structures, but no significant trends at any interior sites.

Load and concentration changes in the EPA. The changes in 1) TP and TN loads and in median concentrations and 2) in median concentrations or values of the other constituents that had excursions were analyzed following the direction of water flow from north to south through the EPA. When comparing the TP loads discharged into the EPA between the baseline and recent water years, it appears that the Refuge is the only region to have received a higher load in recent water years even with the benefit of the Everglades Nutrient Removal Project and recent declines in TP concentration. For inflows to WCA-2 and WCA-3, TP concentrations and loads differ relatively little from the baseline period, while average TP loads into the Park since WY90 show a greater relative reduction spurred (in part) by decreases in TP concentration for WY95-98. In contrast, TN loads have increased slightly in WCA-3 and the Park in the recent water years. As expected, TP and TN loads show that Refuge and conservation areas continue to retain TP and TN as the water flows to the south. TP and TN median concentrations in WCA-2 and WCA-3 also indicate the assimilation capacity of the marshes.

The calculated unionized ammonia concentration at the Refuge interior marsh sites is 100 times lower than the calculated concentration of the inflow, due to the large decrease in pH that exists between the inflows and the rain-driven waters of the interior marsh. Specific conductance has shown some large decreases in the Refuge, WCA-2 and inflows to WCA-3. The Park has had specific conductance increases at both the inflows and interior sites. There are no trends in the EPA for dissolved oxygen or pH. Refuge pH is a natural condition that is significantly lower than the other marshes of the EPA. Alkalinity has consistently decreased between the baseline period and recent water years in each region and also between regions in both periods. Turbidities are higher in the recent water years in inflows to the Refuge and WCA-2. The Refuge rim canal reflects the higher inflow turbidity with some decrease due to particulate settling in the canal. The marsh site turbidity range of 1 to 2 NTU most likely reflects a natural condition.

Anticipated improvements. The positive changes in water quality within the EPA are just beginning. There have been reductions in TP entering the EPA from the Everglades Agricultural Area (EAA) through implementation of Best Management Practices. The Everglades Nutrient Removal Project demonstrated the effectiveness of STA technology by retaining an average of 81% of the inflow TP load from WY95 through WY98. This retention reduced the total TP load discharged to the Refuge by an average of 15% over the same time period. The District's Everglades Stormwater Program, required by the Act, will be further improving water quality in the drainage basins of all the remaining structures that discharge into the EPA, through monitoring and regulatory action programs.

The STAs will have the biggest impact on reducing TP and, to a lesser extent, TN. There will also be water quality improvements in specific conductance, turbidity and unionized ammonia in the EAA waters treated in the STAs. It is also expected that low dissolved oxygen concentrations in the waters from the EAA canals will be improved when passed through the STAs. The relationship between excessive nutrients, alteration of natural aquatic plant, microbial and animal communities, and dissolved oxygen levels lower than natural background conditions is reasonably well understood and is being further documented by ongoing District research efforts. The continuous dissolved oxygen data from nutrient gradient studies in the Refuge and WCA-2 (presented in this chapter) indicate how the marsh systems may respond as nutrient levels continue to be lowered by BMPs and STAs.

Recommendations for modifying Class III criteria. While many of the water quality problems are substantive and require the specific restoration programs discussed in other chapters of this Report, some of the problems evidenced by excursions can be rectified by adopting more appropriate water quality criteria. Specifically, dissolved oxygen in unimpacted waters of the EPA, and alkalinity and pH in Refuge marshes have excursions in natural areas with no apparent disturbance. Evidence is presented indicating that the criteria for these three water quality constituents are not representative of natural conditions, *i.e.* inappropriate criteria are being used to define as excursions what are naturally occurring variations in water quality.

Introduction

Purpose of This Chapter

The purpose of this chapter is to evaluate the extent to which waters in the Everglades Protection Area (EPA) and tributary waters are not in compliance with the water quality criteria specified in the State of Florida Class III Criteria for Surface Water Quality (Section 62-302.530, F.A.C.), and to determine if any water quality improvement trends are evident during the 1990s when compared with the 10-year baseline period from October 1, 1978 through September 30, 1988. To accomplish this purpose the following tasks were performed:

- Previous Everglades Protection Area water quality studies and EPA and Everglades Agricultural Area (EAA) data analysis reports were summarized.
- The Everglades Protection Area was divided into four regions, (Loxahatchee National Wildlife Refuge, Water Conservation Area 2, Water Conservation Area 3 and Everglades National Park) to evaluate water quality data (**Figure 4-1**).
- Water quality sampling stations were classified in each region as being either sources of stormwater runoff, (structures that discharge into each region) or interior sites (marshes, interior canals and structures that convey water within or from each region) to enable water quality data to be evaluated as inputs or outputs (**Appendix 4-1**).
- Data sets were created for each water quality constituent sampled at inflow structures and interior sites in each region from October 1, 1978 through September 30, 1988 (baseline period) and for individual water years 1990 through 1998 (recent water years); each data set summarized the number of samples, basic statistical parameters of the data as well as the number and percentage of excursions for constituents having numerical criteria.
- Excursions from Class III criteria were summarized for the baseline period and compared with excursion data from each recent water year.
- Notched box and whisker plots were developed for water quality constituents that had excursions from Class III limits to determine if water quality conditions were getting better, remaining the same or getting worse.
- The projected combined inflows to Stormwater Treatment Area 3-4 are presented to emphasize the need to construct this facility to achieve the TP reduction goals of the Everglades Construction Project and the Everglades Forever Act.
- Changes in TP and TN flow-weighted mean concentrations and loads were evaluated from points of discharge into each region of the EPA (**Figure 4-1**).
- TP loads and flow-weighted mean concentrations were calculated for stations G136, C139DFC and L3BRS in the C139 Basin for water years 1995 through 1998 in support of the C139 Basin load limitation program.
- Water quality constituents and pesticides were ranked by “category of concern” for each of the four regions of the Everglades Protection Area.
- Modifications to the existing criterion for dissolved oxygen in specific areas in the Everglades Protection Area and to the pH and alkalinity criteria in the Loxahatchee National Wildlife Refuge were recommended because natural background conditions in these areas have exceeded the existing criteria continuously or on a seasonal basis.

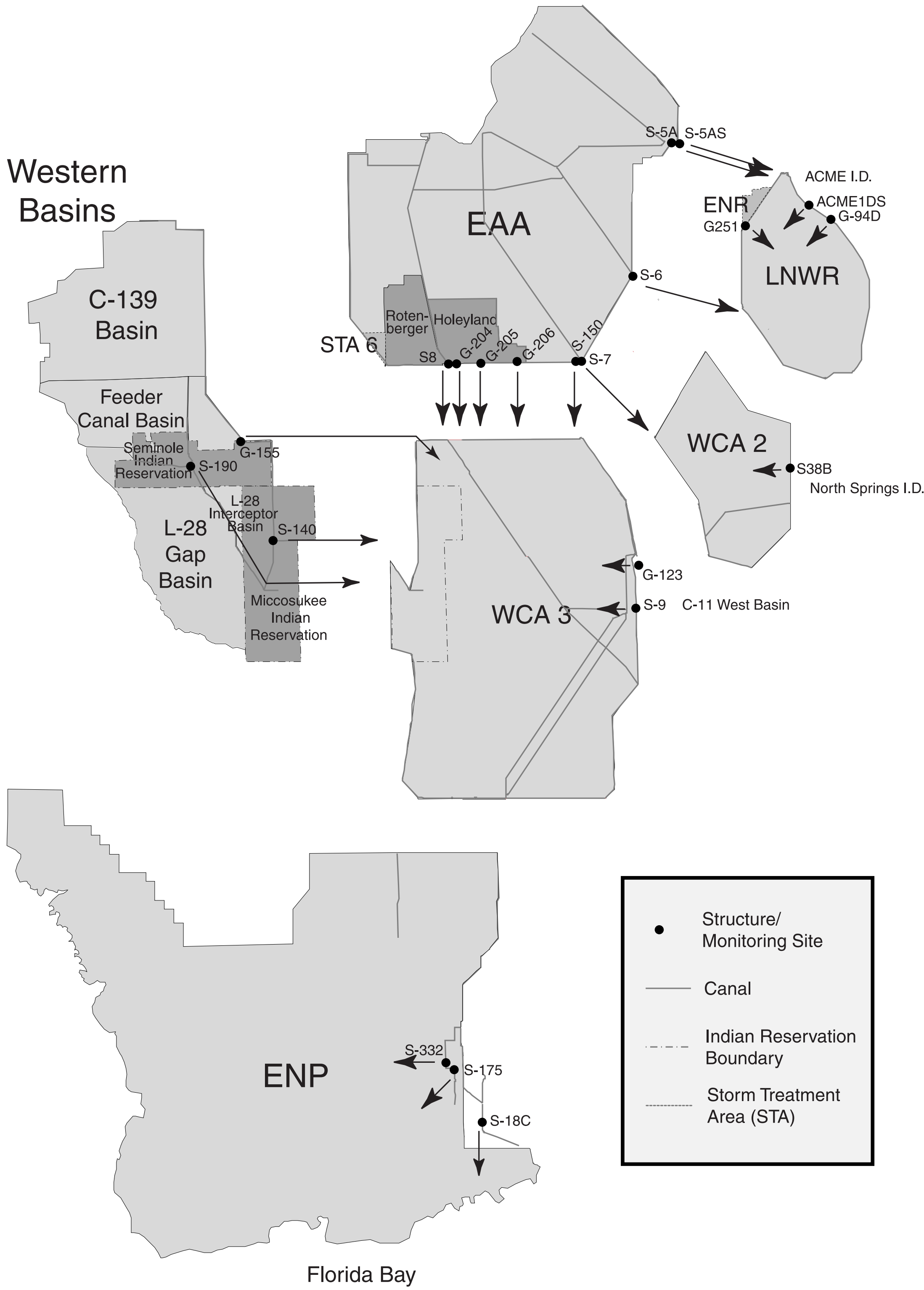


Figure 4-1. Location of basins and structures that discharge into the EPA.

Summary of Previous Water Quality Studies

The Everglades ecosystem is believed to have developed under low P loads entering the system through direct rainfall (Davis, 1994; **Chapter 3**). Approximately 196 metric tons per year of P were assumed to have been delivered to the Water Conservation Areas (WCAs) and Everglades National Park (Park) by atmospheric fallout (Davis, 1994). As a result of agricultural activities and water management practices that began in the early 1900s, P loads, as well as other constituents (i.e., nitrogen, mercury, trace metals, etc.) entering the WCAs, have increased significantly (Scheidt et. al., 1987; Belanger et. al., 1989; Walker, 1991; Davis, 1994; Moustafa, 1998).

Kolipinski and Higer (1968) performed one of the earliest water quality studies in south Florida. This study identified effects of water quantity and quality on biological communities in the Park. Sampling was performed at 21 monitoring sites at (approximately) monthly intervals. Water quality data presented in the report were collected from 1958 through 1968. Median concentrations measured during this study were lower than reported for 95 percent of natural waters in the United States. Further, the authors concluded that, based on five parameters of interest (nitrate, sulfate, calcium, total dissolved solids, and iron), the waters of the Park were not polluted. Concentrations of nitrates and orthophosphates measured within the Park ranged from <0.1 to 79 mg/L and from <0.01 to 35 mg/L, respectively.

A permanent water quality monitoring program was implemented by the United States Geological Survey (USGS) in July 1972 to evaluate the quality of water flowing to the Park (Waller and Earle, 1975). A baseline study of water quality was completed by June 1974. This study measured the chemical composition of surface waters and bottom sediments at 25 stations located from Lake Okeechobee to Taylor Slough. In addition, bulk precipitation samples were collected at three monitoring sites.

Data collected from this study indicated that most measured constituents were higher within the agricultural area than in the WCAs (Waller and Earle, 1975). The authors concluded that the area under investigation in the Everglades was a sink for nutrients, trace metals and pesticides. In addition, Waller and Earle (1975) observed that water quality entering the Park was of a better quality than that entering the water conservation areas. They attributed these observed improvements in water quality to ". . . certain physical, chemical and biological processes, which alter or remove constituents in the water as it flows southward."

The most prevalent form of nitrogen observed in the study area was organic nitrogen (Waller and Earle, 1975) suggesting that the area was highly productive because of the contribution of organic nitrogen from terrestrial and aquatic plants. Spatially, nitrogen concentrations varied throughout the study area (**Figure 4-2**). Typically, higher nitrogen concentrations were observed in areas with extensive agricultural activity. Water conservation areas exhibited relatively lower nitrogen concentrations due to their distance from agricultural areas. Uptake by the biota and adsorption by sediments were believed to be processes controlling nitrogen concentrations in the WCAs (Waller and Earle, 1975). In addition, nitrogen concentrations throughout the study area were observed to vary as a function of rainfall and freshwater flow.

A similar spatial distribution was observed for P, with the northern portion of the study area (**Figure 4-3**) exhibiting the highest TP concentrations. High concentrations in the northwestern portion of the study area were attributed to P rich clays, while agricultural input was considered the major source in the northeastern section (Waller and Earle, 1975). Rapid uptake by vegetation and adsorption by sediments

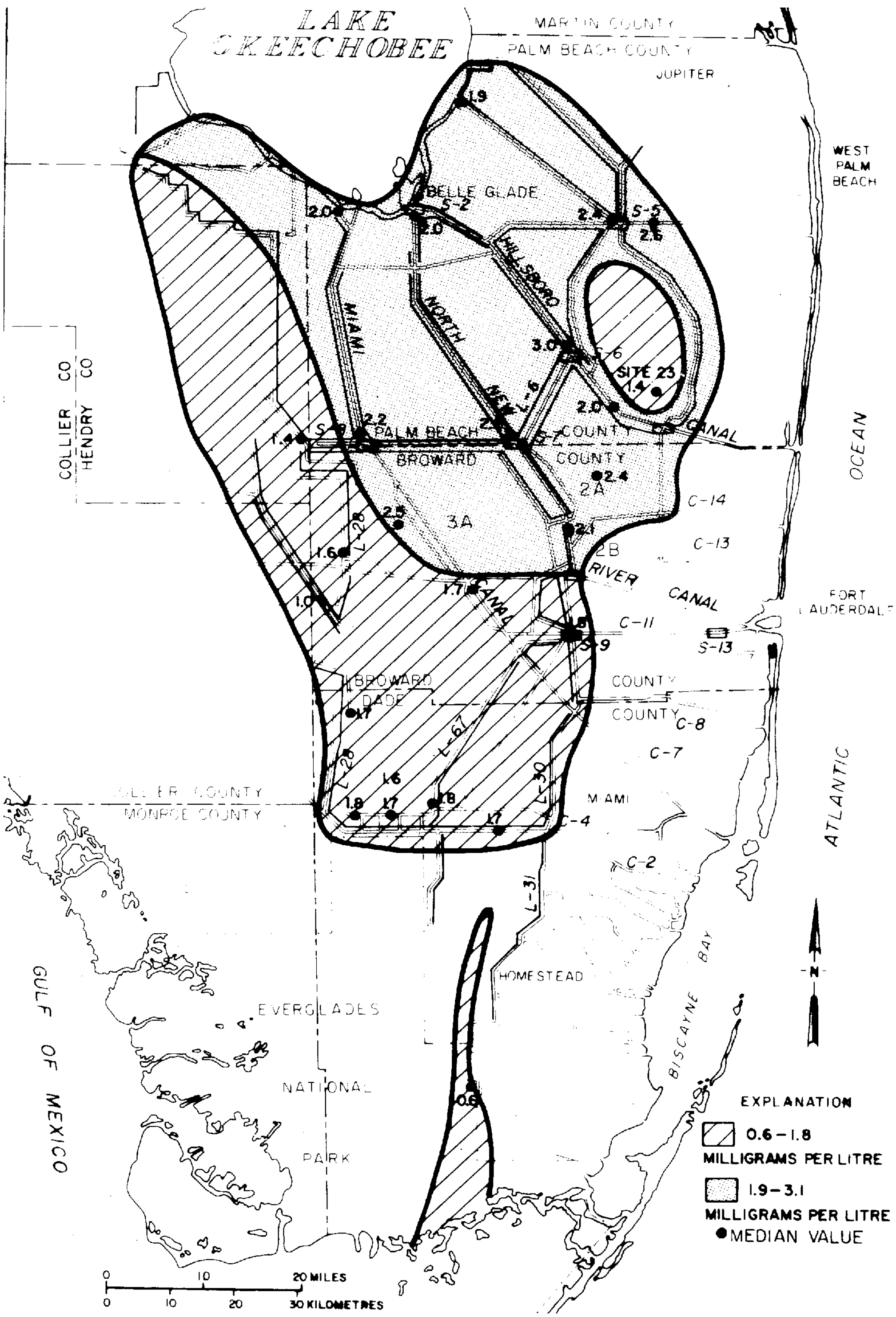


Figure 4-2. Median TN concentrations from July 1972 through June 1974 (Waller and Earle, 1975).

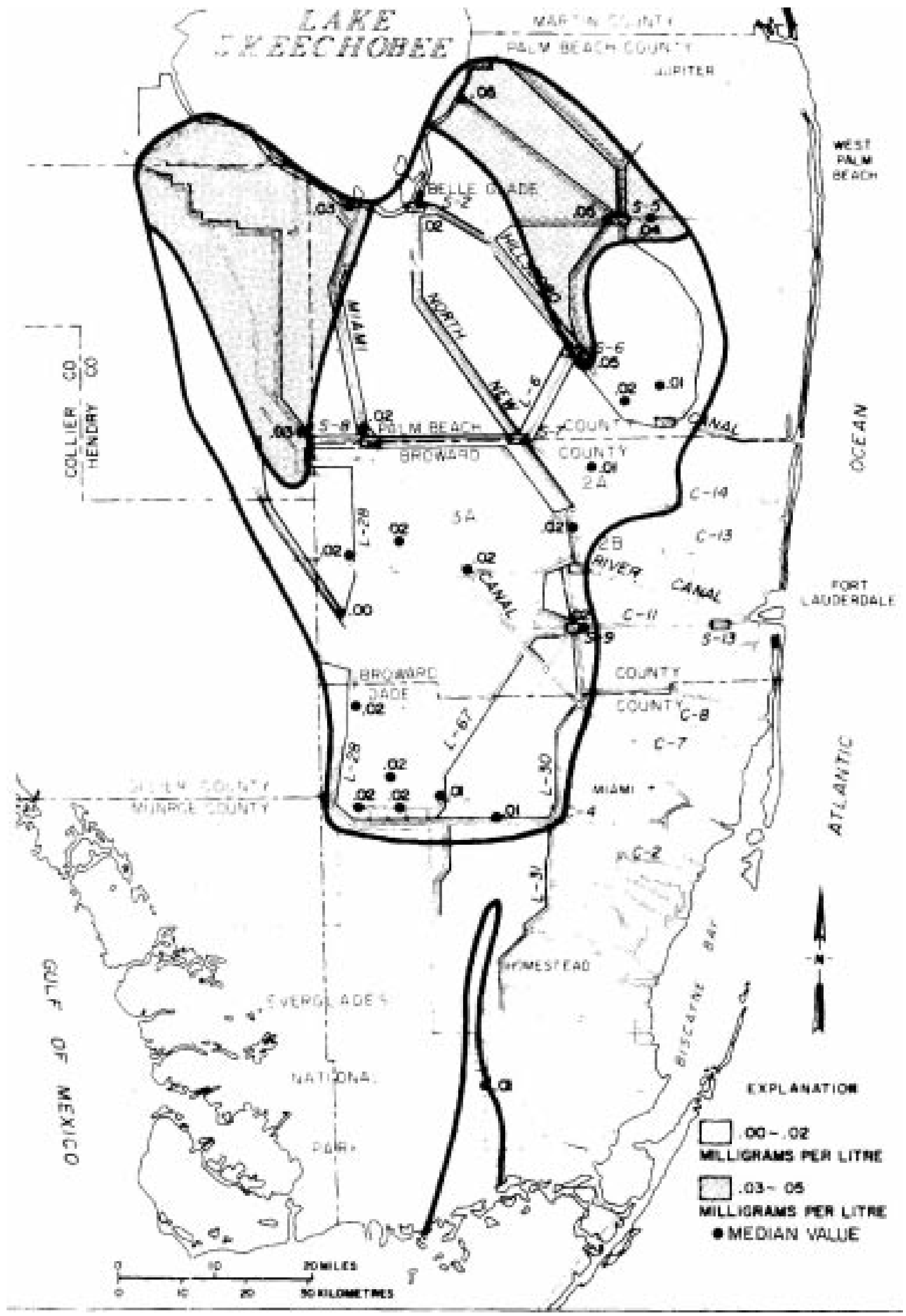


Figure 4-3. Median TP concentrations from July 1972 through June 1974 (Waller and Earle, 1975).

resulted in significantly lower P concentrations in the southern portion of the study area (**Figure 4-3**). TP concentrations measured during the two-year study exhibited similar seasonal trends as those observed for nitrogen (Waller and Earle, 1975).

By the end of the 1970's, water quality standards were being developed to assure that water entering the Park would not cause ecological damage or deterioration to its environment. A control chart theory was employed to statistically derive water quality standards from water quality data collected from 1970 through 1978 at two canal sites immediately north of the Park (Rosendahl and Rose, 1979).

Scheidt et. al. (1987) summarized the characteristics of the water quality entering the Park from 1984 through 1986. The water quality data were compiled from the bimonthly monitoring performed by the District at 16 monitoring sites and compared to the adopted water quality standards for the Park. The most frequent violations of the Park water quality standards were for dissolved oxygen and pH. Other violations of notable concern were turbidity, iron and conductivity (Scheidt et. al., 1987). Violations of the nutrient standards (e.g., ammonia and orthophosphate) were more isolated than for the other parameters.

Natural nutrient levels in the interior marshes of the Park were described as being extremely low (Flora and Rosendahl, 1982; Waller, 1982; Scheidt et. al., 1987). Typical orthophosphate and nitrate concentrations in the freshwater marshes were 0.004 mg/L (or 4 ppb) and 0.010 mg/L (or 10 ppb), respectively (Scheidt et. al., 1987; Belanger et. al., 1989). By comparison, orthophosphate concentrations from Lake Okeechobee and the Everglades Agricultural Area (EAA) were 10 to 35 times higher than those observed in the Park (**Figure 4-4a**). Nitrate concentrations for these two regions were up to 216 times higher than in the Park (**Figure 4-4b**). These higher nutrient concentrations from the EAA are believed to have resulted in increased nutrient levels observed in the WCAs (Mattraw et. al., 1987; Scheidt et. al., 1987; Belanger et. al., 1989).

Because of the concern that these increased nutrient concentrations could adversely impact the Park, controlled nutrient dosing studies were performed over an 18-month period to evaluate the effects of nutrient inputs on periphyton and macrophyte community compositions (Scheidt et. al., 1987). These studies indicated that a four- to six-fold increases in nutrient concentrations can result in the disappearance of the dominant periphyton mats and change the macrophyte community composition (Scheidt et. al., 1987). These observed changes were attributed to increased orthophosphate and, to a lesser degree, nitrate concentrations (Scheidt, 1988). **Chapter 3** of this Report contains a thorough discussion of nutrient effects on Everglades vegetation.

Based on water quality and periphyton samples collected along a nutrient-rich gradient in the northern Everglades, McCormick and O'Dell (1996) observed a strong correlation of periphyton taxonomic change with increased P concentrations within marshes. At canal stations, periphyton changes were significantly correlated with nitrogen and iron in addition to P. Controlled enrichment studies provided evidence that periphyton changes along the nutrient-rich gradient resulted from increased P concentrations (McCormick and O'Dell, 1996).

Further investigations into the observed increase in nutrient concentrations were performed by Walker (1991). Using the seasonal Kendall test, trend analyses were performed on water quality data collected at inflows to the Park. These analyses examined 20 water quality components in samples collected from 1977 to 1989 at structures discharging into Shark River Slough (S-12A, S-12B, S-12C, S-12D, and S-333), and from 1982 to 1989 at S-332 and S-18C, the structures discharging into Taylor Slough

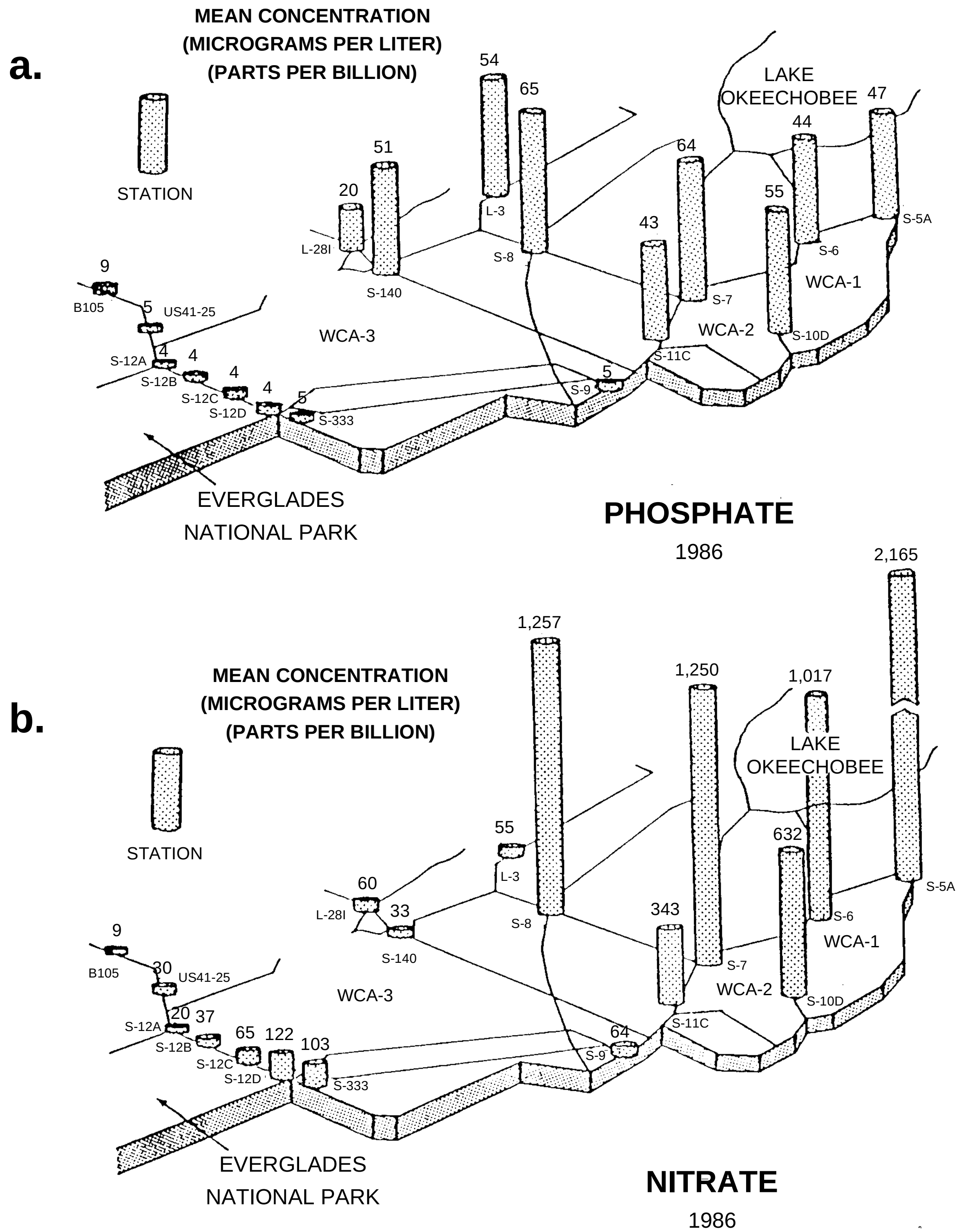


Figure 4-4. **a.** Mean annual dissolved orthophosphate (as P) and **b.** dissolved nitrate (as N) concentrations at outflow structures throughout the Everglades system. Nutrient concentrations are based on samples collected twice per month by the District for the 1986 monitoring year (Scheidt et. al., 1987).

and the Coastal Basins. Based on these trend analyses, Walker concluded that nutrient concentrations entering the Park had increased significantly.

TP concentrations exhibited significant increases from 1977 to 1989 at eight of the nine stations examined. When the water quality data were adjusted for variations in antecedent rainfall and water surface variations, significant increases in TP concentrations were reduced to seven monitoring stations (Walker, 1991). P increases at these seven monitoring stations were estimated to be from 4 to 21 percent per year. Several monitoring stations also exhibited significant increases in nitrate+nitrite concentrations over the period of record (Walker, 1991). In general, nitrate+nitrite concentrations increased from 12 to 22 percent per year.

Walker (1991) also observed a decreasing trend from 1977 to 1989 in nitrogen to P (N/P) ratios, ranging from 7 to 15 percent per year, at seven of nine monitoring stations. Based on these analyses, Walker concluded that increases in P concentrations and decreases in N/P ratios were symptomatic of eutrophication. These apparent nutrient trends could not be explained by hydrologic factors (antecedent rainfall, water elevation, flow, or season). Finally, Walker stated that trends in water quality components other than nutrients occurred less frequently and were of less importance from a water quality management perspective.

A Vollenweider-type model was developed by Moustafa (1998) to estimate load reduction efficiency of Stormwater Treatment Areas (STAs) and evaluate management alternatives to be considered in the Everglades restoration effort. The model was tested at two wetland sites located in south Florida and subsequently used to simulate several management alternatives and predict results from external P loads. The level of agreement between model simulations and observed data indicated that the model was an effective tool for predicting ecosystem responses to reduced P loads and long-term P levels. The results also indicated that lower P levels in the EPA were dependent on reduced P loads from the Everglades Agricultural Area (EAA). Rainfall did not have a significant impact on lowering P concentrations in the marshes.

In the northern part of WCA-2A (on approximately 80 km^2), Moustafa (1998) also simulated the impact(s) of treated and untreated runoff from the EAA. Untreated runoff would result in average concentrations of TP in WCA-2A reaching 20 ppb within a period of five years. Conversely, a 25 percent removal of the P load would result in P concentrations averaging approximately 10 ppb. Further, the elimination of all loading to the WCAs would result in P concentrations less than 10 ppb.

In addition to apparent nutrient enrichment in south Florida, mercury has also become a major concern in the Everglades ecosystems (see **Chapter 7**). Mercury concentrations in game fish from the Everglades were reported to be among the highest in the world. In the late 1980s, statewide sampling of large mouth bass revealed that 50 to 70 percent of lakes in Florida contained elevated mercury concentrations. Average mercury concentrations measured in the Florida largemouth bass ranged from 0.5 to 1.5 mg/kg (ppm). However, average mercury concentrations in largemouth bass found in the Everglades exceeded 1.5 ppm. The sources and factors contributing to the elevated mercury concentrations observed in the Everglades are not clearly understood (Strober et. al., 1996).

Studies have revealed that, in contrast to P, elevated mercury concentrations are typically found in marshes and not canals (Strober et. al., 1996; Bates et. al., 1997; Hurley et. al., 1997). Reduced flows and stagnation within canals result in increased methylated mercury concentrations (Hurley et. al., 1997). In addition, recent studies indicate that mercury speciation has strong seasonal and spatial patterns (Hurley et. al., 1997).

Everglades Program Management Plan

After the enactment of the Everglades Forever Act (Act) in 1994, the Florida Department of Environmental Protection (DEP) and the South Florida Water Management District (District) organized the Act's requirements into the Everglades Program Management Plan. This plan was first issued in November 1994, and is updated annually (SFWMD/FDEP, 1997). The plan consists of seven major elements containing a total of 56 projects. The Research and Monitoring (RAM) element contains 13 projects of which RAM-1, RAM-3, RAM-4 and RAM-9 address water quality issues in the Everglades Protection Area (EPA) and tributary waters (See **Chapter 1**).

1995 EPA water quality report

The RAM-1 project, entitled "Description of Water Quality in the EPA and Tributary Waters", was accomplished through a District contract to Limno-Tech, Inc. (LTI) in August 1994 to address this requirement of the Act. Water quality data from the District's water quality database for the period October 1, 1979 through September 30, 1993 were used as the basis for LTI's analysis. A total of 121 water quality parameters were examined at 455 stations. Included in this analysis were data from stations located outside of the EPA, (select stations representing canals, structures and the Holey Land within the Everglades Agricultural Area (EAA), as well as select stations in Collier County). The primary objective of the analysis was to summarize and characterize these data and compare them to Florida's Class III Criteria for Surface Water Quality (Section 62-302.530 F.A.C.). The results, presented in LTI's final report titled "Data Analysis in Support of the Everglades Forever Act," were submitted to the District on September 15, 1995 (LTI, 1995). The LTI contract was expanded in November 1995 to analyze data from the period March 1, 1978 through September 30, 1979 (which includes the baseline year March 1, 1978 to March 1, 1979) for the Outstanding Florida Waters (OFW) designations of the Everglades National Park and the Loxahatchee National Wildlife Refuge. This expanded analysis was completed in June 21, 1996 and appended to the original report as Section 5.0., Supplemental Water Quality Analysis and Processing plus Appendices F through I (LTI, 1996).

1996 EPA water quality report

In support of the RAM-3 project, District staff prepared a report titled "Evaluation of Water Quality Criteria in the Everglades Protection Area" (Bechtel et al., 1996). This report evaluated in greater detail the water quality criteria excursions identified in the RAM-1 project and determined whether causes of criteria excursions could be identified and, if so, whether the excursions were the result of natural processes or human activities.

Excursions vs. violations of water quality criteria

The term "**excursion**," as used in both the RAM-1 and RAM-3 reports and in this chapter, denotes a constituent concentration in a surface water quality sample that is of potential concern based on a comparison with its Class III criterion. An "excursion" indicates some uncertainty in the interpretation of whether a water quality criteria has been violated. For an excursion to be considered a violation by DEP, it must undergo additional scrutiny in the following areas:

- Natural background conditions for constituents such as pH, specific conductance and dissolved oxygen need to be examined before a definitive comparison to the appropriate criteria can be made.
- Calculated criteria for such constituents as un-ionized ammonia and trace metals must have the appropriate temperature, pH or hardness data available from the same sample.
- Quality Assurance/Quality Control (QA/QC) procedures for sample collection and sample analysis must be performed before comparisons with criteria are made.
- Comparisons of historic and recent data where different criteria were in effect may bias conclusions regarding excursion percentages.

Without an assessment of such information, a definitive conclusion regarding violations of criteria cannot be drawn.

Other water quality evaluations in the Everglades region

A review and evaluation of existing EAA canal data (RAM-4, Evaluation of Water Quality Standards and Classification of Everglades Agricultural Area Canals) was prepared by DEP in the form of a draft report (Gilbert and Feldman, 1995). In this report the EAA was divided into separate basins named after the pump station providing drainage for that basin (C139, S2, S3, S5A, S6, S7 and S8). Only stations identified as canal or pump stations were analyzed. This analysis included data provided by the District from water years 1979 through 1993. The primary objectives were to compare each water quality measurement to its corresponding State of Florida Class III criterion, and to develop a ratio of total number of observations to the number of excursions. Also, statistical summaries were presented for each evaluated parameter by station. Where the number of samples was sufficiently large, parameters were categorized into excursion categories based on percent excursion **(Appendix 4-2)**. Due to large percent excursions, dissolved oxygen was consistently of high concern within EAA canals (**Table 4-1**). In addition, dissolved oxygen excursions were common (52.4-81.4%) at all pump stations. Unionized ammonia was of a moderate to high concern within all basins except C139. However, 13 of the 21 canals evaluated had either no un-ionized ammonia data, or too few samples for a conclusive analysis; therefore the level of concern may be potentially higher than was presented. Specific conductance excursions were frequently (28.0-49.2%) observed at the S2, S5A and S6 pump stations. Moderately frequent excursions (5.3-19.3%) were observed at the S3, S352 and S7 pump stations, while rare excursions (0.8%) occurred at the S8 pump station. In general the rate of specific conductance excursions within canals tended to follow those of the corresponding pump stations, i.e. most canals in the S5A basin had high, to extremely high, excursion rates. Turbidity and total suspended solids were also identified as parameters of moderate to high concern at several pump stations and canals.

Table 4-1. Range of dissolved oxygen excursions for major canals. Canals were grouped by basin.

Basin	Percent Dissolved Oxygen Excursions
C139	39.7
S2	80.0-100
S3	33.0-91.2
S5A	50.2-87.3
S6	74.9-80.0
S7	61.4-90.4
S8	39.5-93.2

Gilbert and Feldman (1995) performed a numeric analysis on organic compounds (herbicides and pesticides) at the S2, S3, S5A, S6, S7 and S8 pump stations in a similar manner as other water quality constituents. Results from this analysis did not identify excursions for compounds with existing numeric criterion. Since specific numeric criteria were lacking for a number of detected herbicides and pesticides, the percent of values above the detection limit for those constituents was used as the method of identifying compounds that may merit additional scrutiny. Compounds were categorized into excursion categories based on the percent of values detected **(Appendix 4-2)**. Only atrazine and ametryn were consistently of moderate to high concern within all the basins. Bromacil was infrequently detected in all basins.

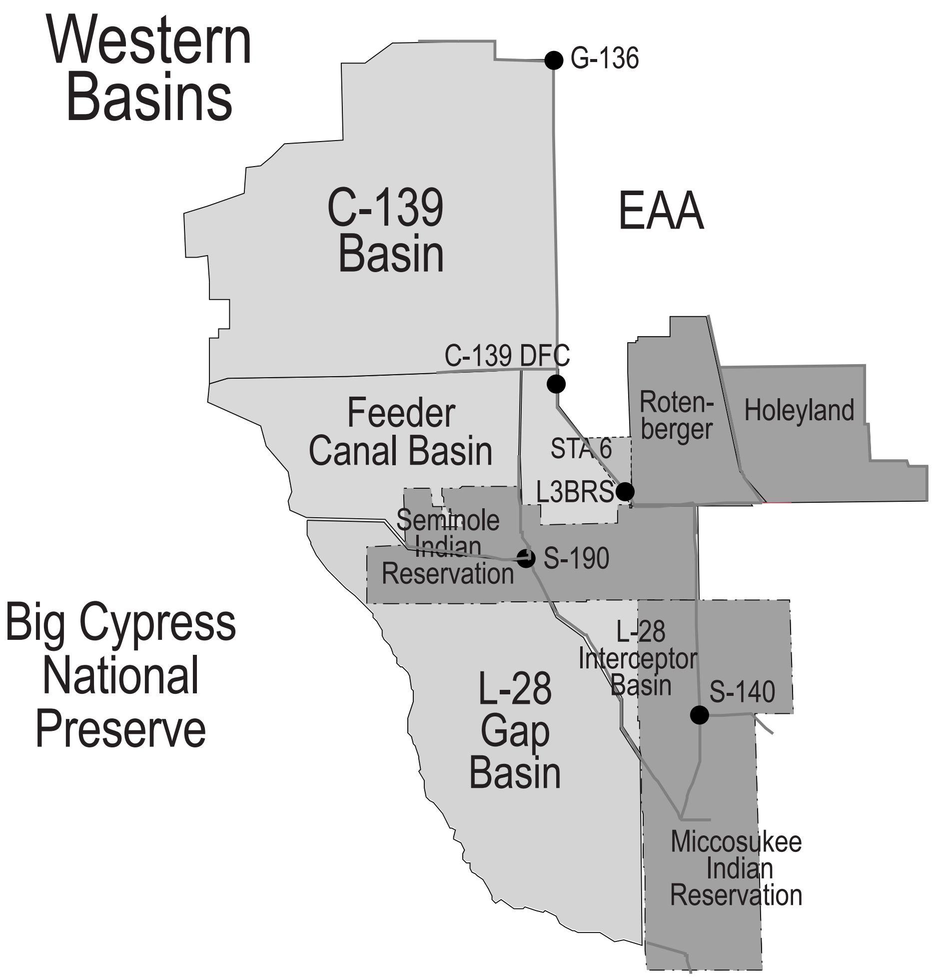


Figure 4-5. Location of key water quality monitoring stations in the western basins.

RAM-9 describes the development and implementation of the ongoing C139 Basin Water Quality Monitoring Program. This program is collecting data to: confirm historic loads and flows used in the design of STA 5; provide, for structure G136, the flow and nutrient concentration data entering the EAA from the northeast corner of the C139 Basin; and provide water quality and flow data from monitoring sites C139DFC (in the L2 Canal) and L3BRS (in the L3 Canal) to the Everglades Regulatory Program in order to determine compliance with a C139 Basin TP load limitation (**Figure 4-5)**. As of the writing of this report, the procedures for applying the Best Management Practices Regulatory Program (Chapter 40E-63, F.A.C.) to the most appropriate historical C139 Basin data are being developed. When completed, the procedures will specify which data set and sampling collection methods will be used to establish the annual hydrologically adjusted TP load limit for the C139 Basin. The results of the C139 Basin water quality monitoring program for TP and flow from WY96 to July 1998 are presented for monitoring stations G136, C139DFC and L3BRS in **Figures 4-6**, **4-7** and **4-8**, respectively.

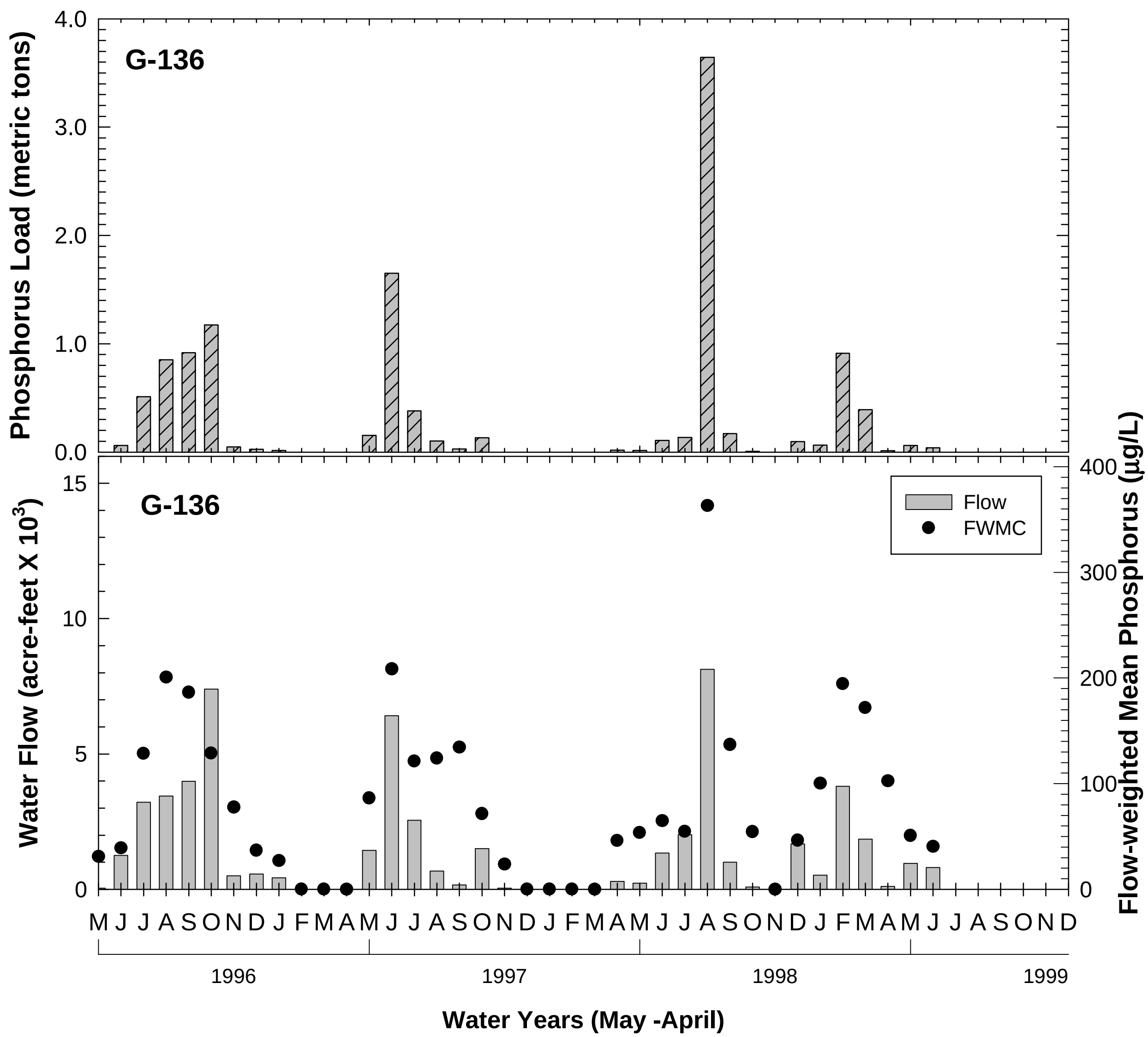


Figure 4-6. Monthly TP loads, flows and flow-weighted mean P concentrations at G-136 from WY96 through WY98.

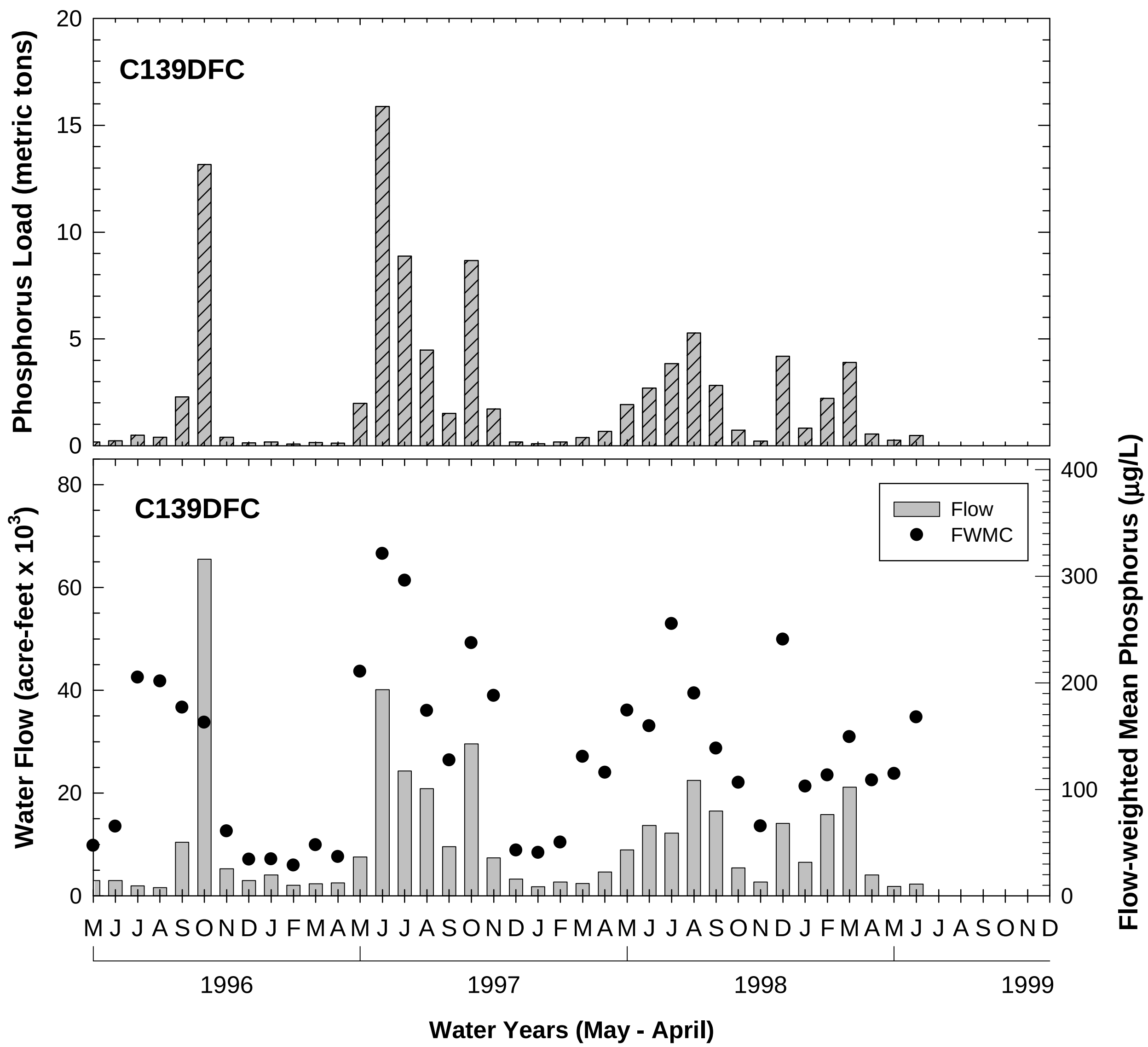


Figure 4-7. Monthly TP loads, flows and flow-weighted mean P concentrations at C139DFC from WY96 through WY98.

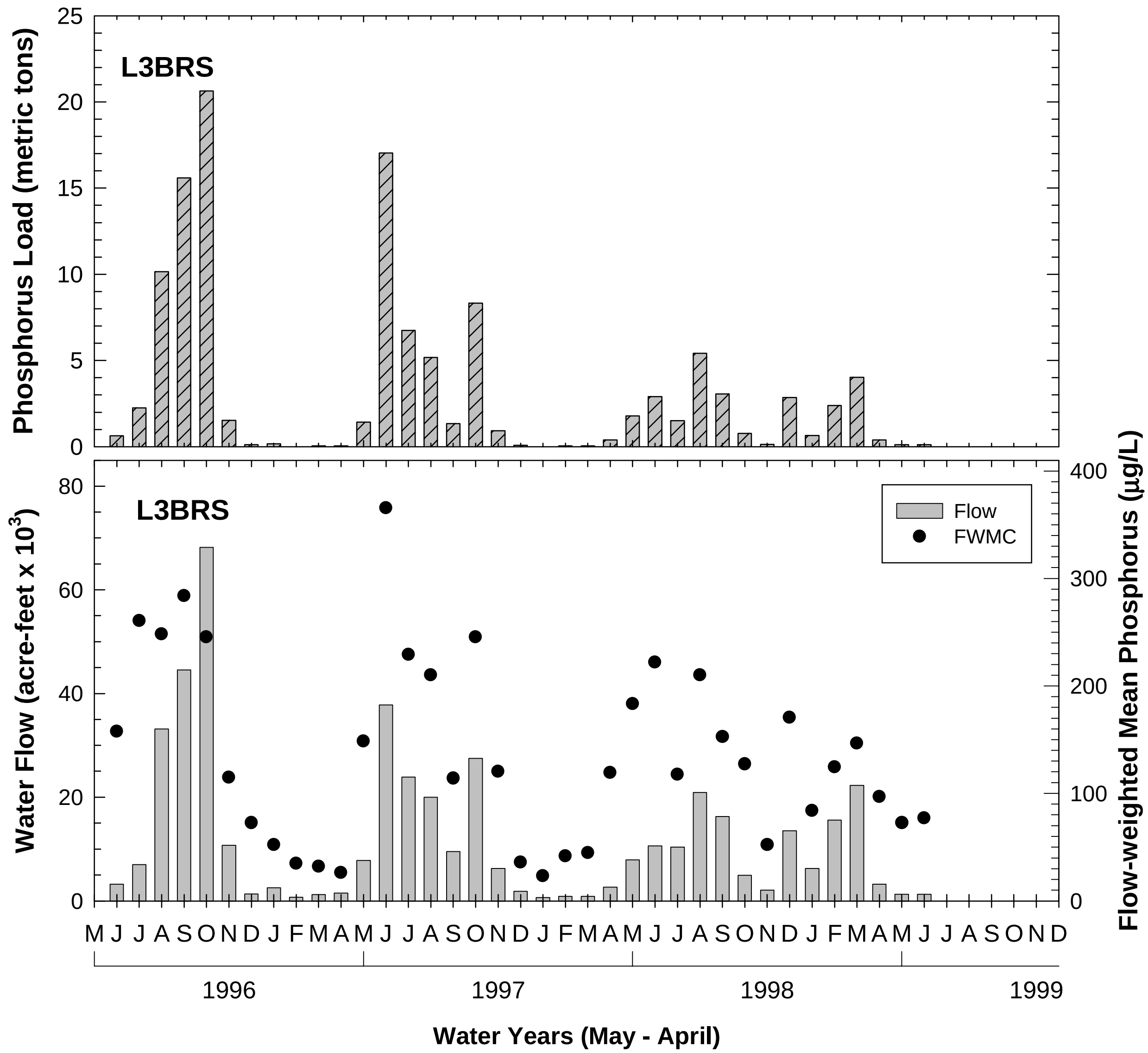


Figure 4-8. Monthly TP loads, flows and flow-weighted mean P concentrations at L3BRS from WY96 WY98.

Methods

A regional synoptic approach was selected as the most appropriate method to present an overview of the status of compliance with water quality criteria in the Everglades Protection Area and tributary waters. The EPA was divided into four regions: the **Loxahatchee National Wildlife Refuge**, **Water Conservation Area 2**, **Water Conservation Area 3** and **Everglades National Park**. Due to the voluminous data utilized in the preparation of this chapter, the consolidation of water quality data on a regional basis provides for analysis over time, but limits spatial analysis within each region. There is an ability to discern spatial differences from region to region because the large majority of inflow and pollutants enter the northern one-third of the Everglades Protection Area, and the net water flow is from north to south. The location of the inflows to the EPA are identified by structure name in **Figure 4-1**.

<u>Water quality data sources</u>

The large majority of the water quality data evaluated in this chapter was retrieved from the South Florida Water Management District's water quality database. Before data is entered into the database, the District follows strict Quality Assurance/Quality Control (QA/QC) procedures approved by the Florida Department of Environmental Protection (DEP) for both data collection and analytical methods. These methods are documented in the District's Comprehensive Quality Assurance Plan #870166G which is annually reviewed, updated and approved by DEP. Contract laboratories used by the District must also have their comprehensive plans approved by DEP.

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 and the southwestern part of the Loxahatchee National Wildlife Refuge were obtained from the Everglades Research Database. Graphs depicting these nutrient gradients are presented in **Chapter 3**. The flow and nutrient data used to calculate inputs to Florida Bay from the Everglades National Park presented in this chapter were obtained from Louisiana State University through a contract with the Everglades Systems Research Division. All other flow data were retrieved from the District's hydrologic database DBHYDRO.

<u>Inflow and interior water quality sampling stations</u>

Water quality sampling stations in each region were divided into **inflow sources** and **interior sites** to analyze each region for compliance with Class III criteria. It was necessary to add to the inflow stations identified in **Figure 4-1** those interior structures that convey water from one region to another within the EPA. Thus, the S10 structures were added as inflow sources to Water Conservation Area 2, the S11 structures as inflow sources to Water Conservation Area 3, and the S12 structures plus S333 as inflow sources to the Everglades National Park. These sets of inflow structures are shown in **Figure 4-9**. The interior sites of each region consist of marsh and canal stations in addition to those structures that convey water within or from each region.

In contrast to the other regions, the Loxahatchee National Wildlife Refuge was divided into three components for analysis, (inflow sources, rim canal stations and interior marsh sites) to account for inflows being conveyed in rim canals that border the east and west refuge levees into discharge structures in the south levee. Rim canal water intrudes into the interior marsh about one to two kilometers, depending on marsh water depth, and has a detrimental effect on water quality in the intrusion zone. **Chapter 3** provides a summary of water quality conditions in both the intrusion zone and interior marsh. Water quality

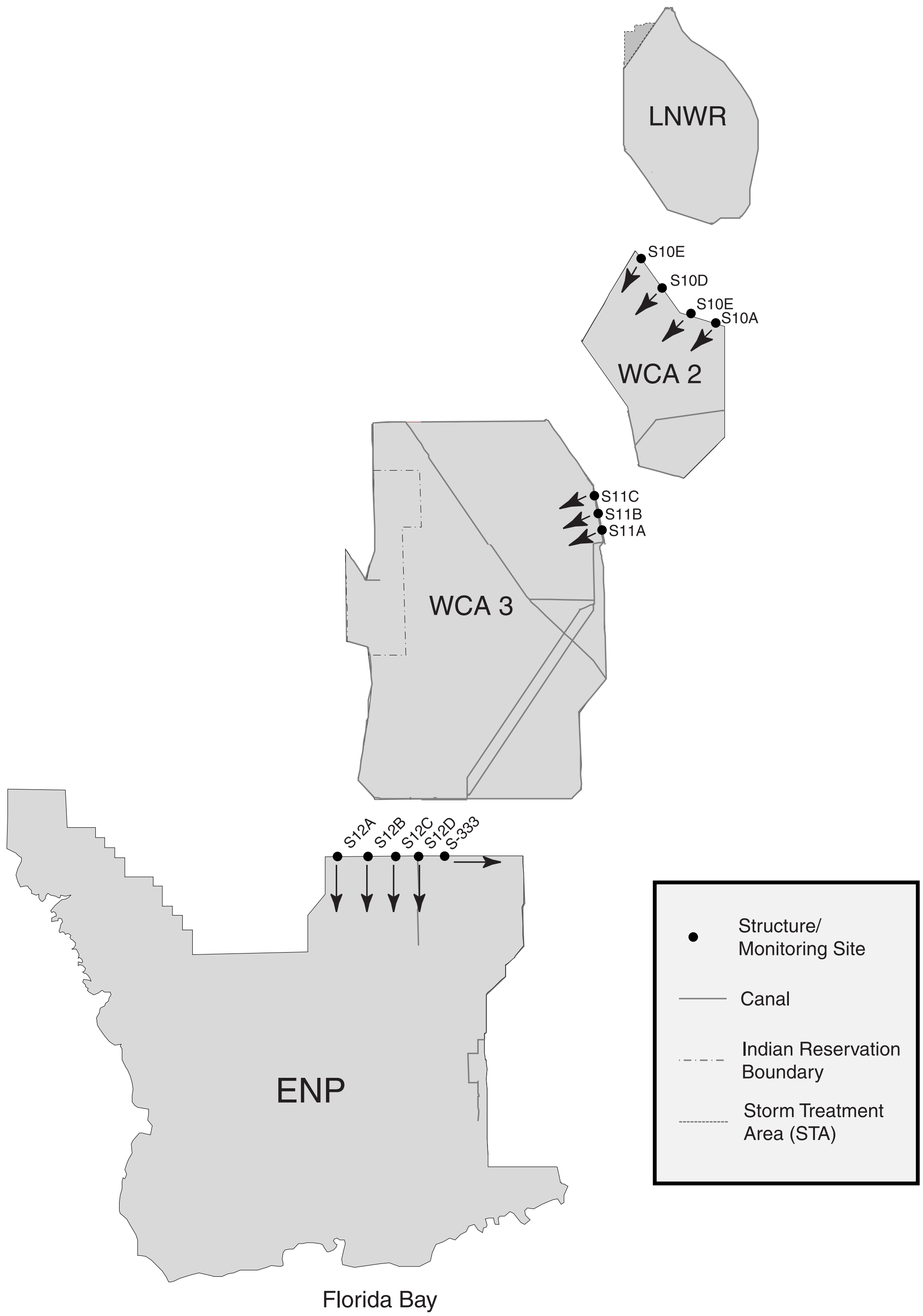


Figure 4-9. Location of S10, S11 and S12 structures in the EPA.

conditions in the interior marsh are rainfall-driven, thereby creating a softwater system that is uniquely different from the conservation areas and Everglades National Park. The water quality sampling stations that were combined to create all the inflow sources, all interior sites, and the rim canal stations in the Loxahatchee National Wildlife Refuge (for both the baseline and recent water years) are identified in **Appendix 4-1** and depicted in **Appendix 4-3**.

Data analysis periods

Water quality data from monitoring stations within the Everglades Protection Area (EPA) were grouped into a ten-year **baseline period** from October 1, 1978 through September 30, 1988 and into annual data sets for **recent water years** 1990 through 1998 (May 1 to April 30 each year). Since there were seven months between the end of the baseline period and the beginning of the 1989 water year (October 1988 to April 1989), this period was designated as a **transition period**. The data from the transition period were not used in any analyses because of its seven-month time period, but the excursions that occurred during the transition period are tabulated in **Appendix 4-4**. The baseline period is the same as that used to determine baseline rainfall for the Everglades Agricultural Area TP load reduction program and baseline flow for the average annual flow increase to the EPA from the Everglades Construction Project. Additionally, the water year from May 1 through April 30 conforms to the period used to determine annual compliance with the TP load reduction in the Everglades Agricultural Area. The recent water years were substantially wetter than the baseline period with respect to rainfall, flows and water levels. Some of the apparent improvements in water quality, especially at interior sites, discussed later in this chapter may be related to hydrologic effects rather than water quality improvement projects such as BMPs.

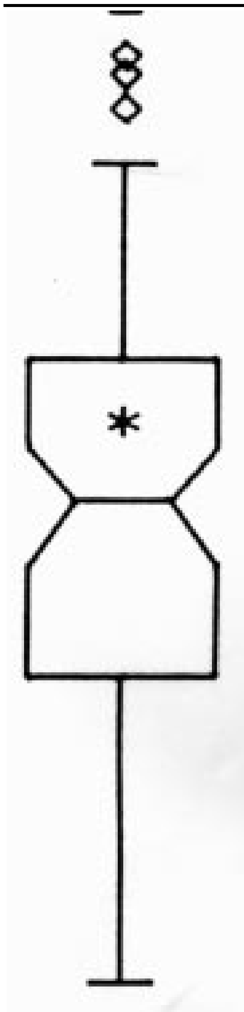
Evaluation methods

To evaluate compliance of each region for the baseline period and water years 1990 through 1998, constituent concentrations were compared to their respective Class III numerical criteria. If a constituent concentration exceeded the numeric criteria, an **excursion** was recorded. The total number of excursions and the percent of excursions for inflow sources and interior sites were compiled and then compared between the four regions for each time period.

Data summaries in the form of notched box and whisker plots were created for each constituent that exceeded its numerical criterion in the inflow sources and at the interior sites for each region and time period. A notched box and whisker plot summarizes selected statistical properties of the data set for a constituent. Notched box and whisker plots can be used to test for statistical significance between data sets, to detect changes in constituent concentration variability over time and to determine if trends exist. The notched box and whisker plot used in this chapter is described in **Table 4-2** (McGill, et al., 1978).

TP and TN loads and flow-weighted means were calculated for the regional inflow sources for comparison over time, and between regions, because no narrative criteria for nutrients currently exist. The TP and TN loads and flow-weighted mean concentrations were calculated using the job control files presented in **Appendix 4-7** and the Fortran code presented in **Appendix 4-8**. Notched box and whisker plots of TP and TN concentrations were also created for the inflow sources and interior sites for comparison between regions.

Table 4-2. Description of the notched box and whisker plot used in this chapter.



Square represents data greater than 4 standard deviations above the median.

Diamond represents data greater than 2 standard deviations above the median.

Upper whisker is maximum data value or highest value not outside +2 standard deviations.

Top of box is the 75th percentile (Q75).

Asterisk is mean concentration. An open circle (O) in the notched box plot represents flow-weighted mean concentrations of TP and TN at inflow structures.

Notch represents the 95% confidence interval for the median.

Bottom of box is the 25th percentile (Q25).

Lower whisker is minimum data value or lowest value not outside -2 standard deviations.

1. Notches surrounding the medians provide a measure of the significance of differences between notched box plots. If the notches about two medians do not overlap, the medians are significantly different at about a 95% confidence level.

2. At times the variability in a data set may be quite high. When highly variable data are presented in a notched box and whisker plot, the width of the notch may be greater than the 25th or 75th percentile. When this occurs the box plot appears as if it is folded from the end of the notch back toward the median. This is done automatically by the statistics program to save space within the figure being presented (see **Figure 4-18** as an example).

3. This report uses an open circle (o) in the notched box plot to represent flow-weighted mean concentrations of TP and TN at inflow structures (see **Figure 4-15a** as an example).

The un-ionized portion of dissolved ammonia measured in a water sample was calculated and compared to the ≤0.02 mg/L criterion only if temperature and pH had been recorded for that sample. The equations used to calculate the un-ionized ammonia concentration are presented below.

Notched box and whisker plots were created for the trace metals cadmium, copper, lead and zinc since they had excursions in the base period and water years 1990 through 1998. The most recent trace metal calculated criteria were used for evaluating data from the baseline period and water years 1990 through 1998, even if the criteria had changed over time.

Calculated criteria for trace metals and un-ionized ammonia were derived from the following equations (Chapter 62-302.530 F.A.C.):

Cadmium: $$\mathrm{Cd} \le e^{(0.7852[\ln H] - 3.49)} \quad (2.1)$$

Chromium (trivalent): $$\mathrm{CrIII} \le e^{(0.819[\ln H] + 1.561)} \quad (2.2)$$

Copper: $$\mathrm{Cu} \le e^{(0.8545[\ln \mathrm{H}] - 1.465)} \quad (2.3)$$

Lead: $$\mathrm{Pb} \le e^{(1.273[\ln \mathrm{H}] - 4.705)} \quad (2.4)$$

Nickel $$\mathrm{Ni} \le e^{(0.846[\ln \mathrm{H}] + 1.1645)} \quad (2.5)$$

Zinc $$\mathrm{Zn} \le e^{(0.8473[\ln \mathrm{H}] - 0.7614)} \quad (2.6)$$

Unionized Ammonia $$\mathrm{pKa} = 0.0918 + (2729.92/(273.2 + \text{temp in } C°)) \quad (2.7)$$

$$\text{Fraction of unionized ammonia} = 1/(10^{\mathrm{pKa} - \mathrm{pH}} + 1) \quad (2.8)$$

$$\mathrm{NH}_X = (\mathrm{NH}_4)/(1 - \text{Fraction}) \quad (2.9)$$

$$\mathrm{NH}_3 \text{ as N} = \mathrm{NH}_X - \mathrm{NH}_4 \quad (2.10)$$

$$\mathrm{NH}_3 = \mathrm{NH}_3 \text{ as N} \times 17/14 \quad (2.11)$$

When comparing the calculated criteria with trace metal concentrations, only water samples that had hardness determined from the same sample as the trace metal were used, i.e. no extrapolations to samples without hardness data were made. When reviewing the cadmium, copper, lead and zinc data used in the draft version of this report, it was noticed that at almost all stations, greater than 50% of the data were below the MDL, thus skewing the trace metal notched box and whisker plots presented. In this final version of the report only trace metal data greater than the MDL were used to construct the notched box and whisker plots.

A second change made in this report was to calculate the criteria for each trace metal using the annual maximum and minimum hardness data associated with that data set. The calculated maximum and minimum criteria were plotted on the notched box and whisker plots. If a notched box and whisker plot was below the minimum criteria line, no excursions occurred. Those notched box and whisker plots that extend above the minimum criteria line indicate that some of the trace metal concentrations measured could fall above the calculated criteria. If the notched box and whisker plot was located above the maximum criteria line, then all concentrations for that period exceeded the calculated criterion. With the exception of the trace metal data, all other data in this chapter that were below the MDL were assigned the MDL value for calculation and graphical purposes.

Pesticides

The number of pesticide detections at monitoring sites in the EPA and in tributary waters from 1992 through 1997 were grouped by region. At this point in time, surface water samples are not being collected at interior sites, but sediment samples are collected on an annual basis in the conservation areas.

Excursion analysis for Class III constituents and pesticides

Three categories were developed to rank water quality constituents, including pH and pesticides, that had excursions in the EPA (**Table 4-3**). These categories provide a ranking system for the severity of excursions to aid in decision making.

The District recognizes that there is no numeric standard for TP at this time. However, in order to provide a framework for analysis, the District has divided TP data into the same three excursion categories as the other water quality constituents. For TP, **Category A** is >50 ppb, **Category B** is ≥10 ppb and **Category C** is <10 ppb. This approach is consistent with the Settlement Agreement (1991), which requires the District's STAs to achieve a long-term TP average of 50 ppb, and also requires long-term TP averages of approximately 10 ppb in the Refuge and Park.

This analysis may be modified in future years once the nutrient threshold research is completed and a nutrient criterion for TP is established. Furthermore, current scientific data from WCA-2 suggests that TP levels between 10 and 20 ppb may cause changes in flora and fauna (see **Chapter 3**). Nevertheless, the current objectives of the Act require the District to achieve 50 ppb, which is based upon the calculated performance of STAs. It is anticipated that the nutrient threshold research projects will provide additional evidence that the threshold is well below 50 ppb (**Table 4-3**).

Table 4-3. Definitions of three excursion categories regarding water quality constituents that had excursions in the EPA.

Excursion Category	Class III Waters	Pesticides	TP
Category A	Greater than 5% excursions	Class III criterion and/or aquatic invertebrate toxicity level exceeded	>50 ppb
Category B	Up to 5% excursions	Greater than Practical Quantitation Limit (PQL)	≥10 ppb
Category C	Greater than MDL but no excursions	Less than or equal to PQL	<10 ppb

Analysis of Water Quality in the Everglades Protection Area

Excursions from Class III Criteria

Water quality constituent concentrations measured in the EPA during the **baseline period** (Oct. 1, 1978 through Sept. 30, 1988) were summarized as ten-year averages and in the recent water years (May 1, 1990 through April 30, 1998) they were summarized annually. Each data set was then compared with Class III water quality criteria pursuant to Chapter 62-302.530 F.A.C. Of the numerous parameters analyzed (n=~109) in the EPA, numeric standards for Class III exist for the following fifteen parameters:

- Total Alkalinity
- Dissolved Oxygen
- Specific Conductance
- pH
- Total Coliform Bacteria
- Total Silver
- Total Beryllium
- Total Cadmium
- Total Copper
- Total Iron
- Total Lead
- Total Selenium
- Total Zinc
- Turbidity
- Un-ionized Ammonia

TP and TN currently have no numeric criteria. However, pursuant to Chapter 62-302.530(48)(b) F.A.C.: "In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora and fauna." Presently, research is being conducted to provide evidence to be used by the Florida Environmental Regulatory Commission in establishing a numerical criterion for TP that will meet the "imbalance" criterion in the EPA. Under the Everglades Forever Act (Act), a default criterion of 10 ppb will apply in the EPA if no numeric criterion is adopted by DEP by December 31, 2003. In contrast, a numeric criterion for TN is not required by the Act. Present evidence suggests that areas of the EPA are sensitive primarily to changes in P. See **Chapter 3** for details on the TP research and P limitation of ecosystem function.

In addition, an interim criterion of 50 ppb has been established for Stormwater Treatment Areas (STAs) discharging into the EPA. In the absence of an established numeric criterion for TP, the **10 ppb** default and the **50 ppb** interim criteria were used to evaluate current TP concentrations in discharges into the Everglades Protection Area.

Observed excursions from Class III numeric criteria for the four regions in the EPA are summarized in **Tables 4-4** through **4-7**. A comparison of observed excursions listed by each water year is provided in **Appendix 4-4**.

Loxahatchee National Wildlife Refuge

Excursions from Class III numeric criteria in the Loxahatchee National Wildlife Refuge (Refuge) were compared for both the baseline period and recent water years. Of the fifteen water quality parameters listed above, dissolved oxygen, specific conductance and pH had consistent excursions from the Class III criteria during both the baseline period and recent water years (**Table 4-4**). These excursions were observed at inflow structures, interior marsh stations, and rim canal stations.

The frequency of excursions for dissolved oxygen measurements has increased during recent water years compared with the baseline period. The highest increase in the frequency of dissolved oxygen excursions from the baseline period to the recent water years was observed at the interior marsh stations (**Table 4-4**).

The relative number of excursions from the state standard for specific conductance has decreased during the recent water years compared with the baseline period (**Table 4-4**). This observed decrease suggests that more dilute water flowed through the Refuge during the recent water years because of greater rainfall.

No consistent comparison could be made for pH excursions at the three segments of the Refuge. At inflow structures and rim canal stations, the relative number of pH excursions increased by less than 1 percent during recent water years (**Table 4-4**). Interior marsh stations, in contrast, had approximately 16 percent less excursions from the acceptable pH range during the recent water years compared to the baseline period (**Table 4-4**).

Total alkalinity excursions were only observed at interior marsh stations in the Refuge. Overall, the relative number of excursions increased from 30 percent during the baseline period to 45 percent for recent water years (**Table 4-4**).

Turbidity measurements during the recent water years exhibited a slight increase (1 to 2 percent) compared to the baseline period (**Table 4-4**). The relative number of un-ionized ammonia concentrations above the Class III criteria decreased from the baseline period (**Table 4-4**).A similar trend was observed for iron and lead. No comparison could be made for total coliform bacteria, silver, beryllium, or selenium because these parameters were not measured during the baseline period.

The distribution of TP concentrations in samples collected in the Refuge over time is presented in **Figure 4-10**. At the inflow structures, 47 to 81 percent of TP concentrations measured were greater than 50 ppb during the recent water years. Approximately 19 to 52 percent of TP concentrations measured during the recent water years were between 10 and 50 ppb while less than 2.5 percent of TP concentrations measured at the inflow structures were less than 10 ppb. During the baseline period 76 percent of samples collected at inflow structures had concentrations in excess of 50 ppb. Approximately 23 percent of samples collected had TP concentrations between 10 and 50 ppb and 1 percent were lower than 10 ppb.

Table 4-4. Summary of excursions from Class III Criteria in the Loxahatchee National Wildlife Refuge

	Baseline Period (10/01/1978 - 09/30/1988)			Water Years (May 1 - April 30) 1990 - 1998		
Parameters	No. of Samples	No. of Excursions	% Excursions	No. of Samples	No. of Excursions	% Excursions
Into Structures						
Total Alkalinity	914	0	0.0	738	0	0.0
Dissolved Oxygen	569	440	77.3	868	686	79.0
Specific Conductance	551	254	46.1	882	170	19.3
pH < 6.0	561	0	0.0	868	6	0.7
pH > 8.5	561	1	0.2	868	4	0.5
Total Coliform Bacteria	ND	ND	ND	134	1	0.7
Total Silver	ND	ND	ND	16	11	68.8
Total Beryllium	ND	ND	ND	15	7	46.7
Total Cadmium	31	0	0.0	90	0	0.0
Total Copper	28	0	0.0	88	0	0.0
Total Iron	54	2	3.7	302	10	3.3
Total Lead	31	1	3.2	89	0	0.0
Total Selenium	ND	ND	ND	16	1	6.3
Total Zinc	31	0	0.0	88	0	0.0
Turbidity	911	14	1.5	707	23	3.3
Un-ionized Ammonia	1078	29	2.7	1634	6	0.4
Interior Stations						
Total Alkalinity	304	91	29.9	564	253	44.9
Dissolved Oxygen	71	28	39.4	567	419	73.9
Specific Conductance	105	3	2.9	603	1	0.2
pH < 6.0	214	54	25.2	571	54	9.5
pH > 8.5	214	0	0.0	571	1	0.2
Total Coliform Bacteria	ND	ND	ND	25	0	0.0
Total Silver	ND	ND	ND	ND	ND	ND
Total Beryllium	ND	ND	ND	ND	ND	ND
Total Cadmium	ND	ND	ND	211	0	0.0
Total Copper	ND	ND	ND	212	0	0.0
Total Iron	97	0	0.0	587	0	0.0
Total Lead	ND	ND	ND	208	0	0.0
Total Selenium	ND	ND	ND	ND	ND	ND
Total Zinc	ND	ND	ND	211	0	0.0
Turbidity	174	0	0.0	549	0	0.0
Un-ionized Ammonia	313	0	0.0	39	0	0.0
Rim Canal Stations						
Total Alkalinity	511	0	0.0	677	0	0.0
Dissolved Oxygen	529	320	60.5	733	547	74.6
Specific Conductance	526	147	27.9	744	69	9.3
pH < 6.0	520	1	0.2	726	1	0.1
pH > 8.5	520	0	0.0	726	0	0.0
Total Coliform Bacteria	ND	ND	ND	93	5	5.4
Total Silver	ND	ND	ND	18	14	77.8
Total Beryllium	ND	ND	ND	18	6	33.3
Total Cadmium	15	0	0.0	96	0	0.0
Total Copper	15	0	0.0	96	0	0.0
Total Iron	53	0	0.0	344	3	0.9
Total Lead	14	0	0.0	95	0	0.0
Total Selenium	ND	ND	ND	18	0	0.0
Total Zinc	15	0	0.0	96	0	0.0
Turbidity	503	4	0.8	667	9	1.3
Un-ionized Ammonia	986	8	0.8	1134	2	0.2

The rim canal stations generally reflected the TP distribution of the inflows (**Figure 4-10**). The distribution of TP concentrations during the baseline period can be summarized as being 60.1 percent of samples greater than 50 ppb; 39.7 percent between 10 and 50 ppb; and 0.2 percent of samples collected being less than 10 ppb. Samples from recent water years with concentrations greater than 50 ppb ranged from 42 to 77% while samples having levels between 10 and 50 ppb ranged from 23 to 58%. Only WY95 had samples with TP concentrations less than 10 ppb (**Figure 4-10**).

The distribution of TP in the interior marshes of the Refuge was quite different from the inflow structures and rim canal stations. Few TP concentrations measured during the recent water years were greater than 50 ppb (**Figure 4-10**). The majority of TP concentrations measured at marsh stations in recent water years were less than 10 ppb. During the baseline period, TP levels were frequently below 50 ppb with most samples having concentrations between 10 and 50 ppb (**Figure 4-10**).

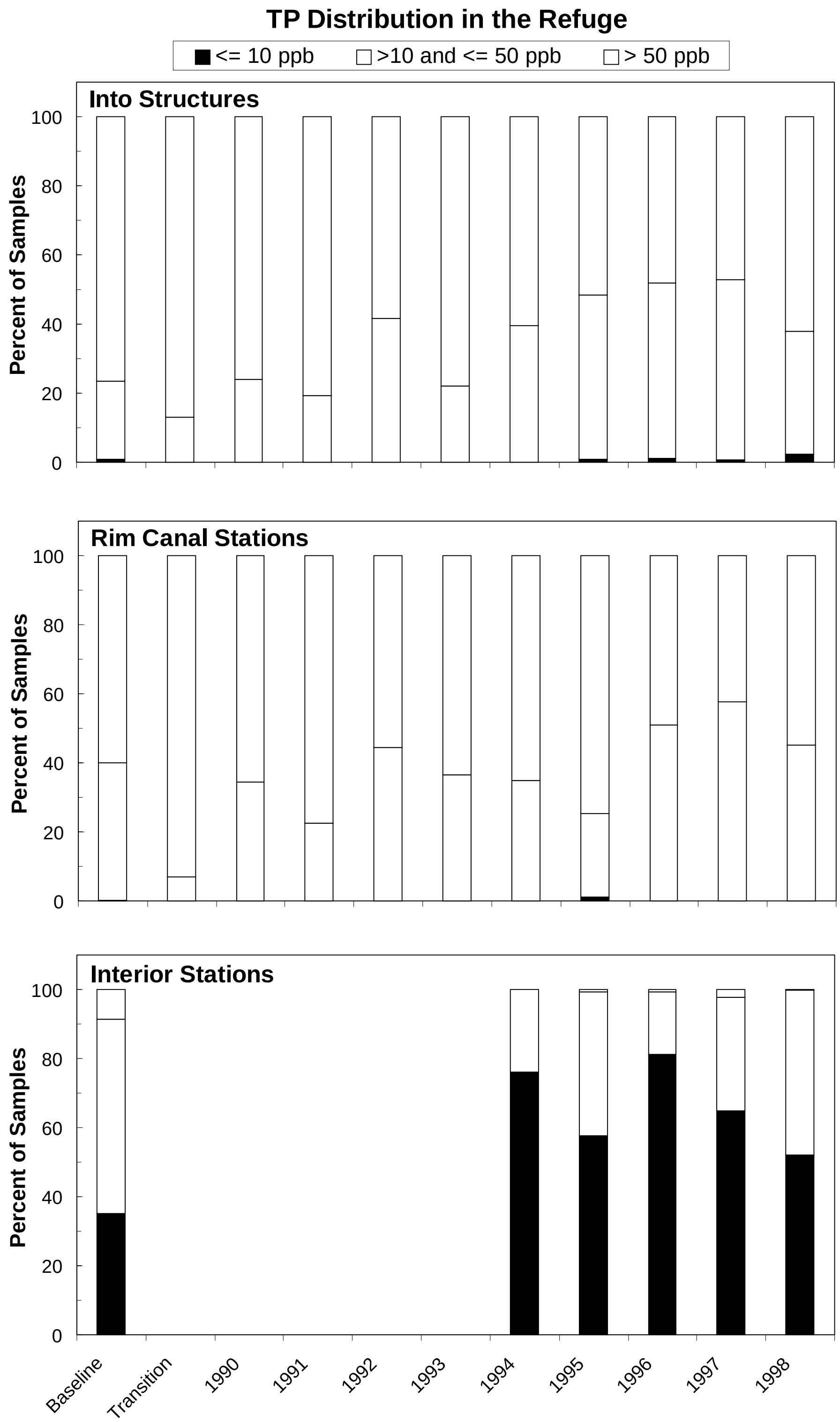


Figure 4-10. The distribution of mean annual TP concentrations for the Refuge at into structures, rim canal stations and interior stations from the baseline study period to WY98.

Water Conservation Area 2

Both inflow structures and interior marsh stations of Water Conservation Area 2 (WCA-2) exhibited the same excursion trend for dissolved oxygen and specific conductance levels as discussed for the Refuge (**Table 4-5**). In addition, the relative number of pH excursions generally decreased from the baseline period to recent water years (**Table 4-5**).

Fewer excursions were observed for un-ionized ammonia levels measured during the recent water years compared to the baseline period (**Table 4-5**). Turbidity levels exhibited the same amount of excursions for both periods. Iron and cadmium levels measured during the recent water years had less than 2 percent excursions compared with no excursions reported for the baseline period (**Table 4-5**).

Table 4-5. Summary of excursions from Class III Criteria in Water Conservation Area 2.

	Baseline Period (10/01/1978 - 09/30/1988)			Water Years (May 1 - April 30) 1990 - 1998		
Parameters	No. of Samples	No. of Excursions	% Excursions	No. of Samples	No. of Excursions	% Excursions
Into Structures						
Total Alkalinity	592	0	0.0	488	0	0.0
Dissolved Oxygen	414	280	67.6	514	376	73.2
Specific Conductance	413	132	32.0	520	29	5.6
pH < 6.0	403	1	0.2	508	2	0.4
pH > 8.5	403	1	0.2	508	0	0.0
Total Coliform Bacteria	ND	ND	ND	ND	ND	ND
Total Silver	ND	ND	ND	ND	ND	ND
Total Beryllium	ND	ND	ND	ND	ND	ND
Total Cadmium	21	0	0.0	54	0	0.0
Total Copper	20	0	0.0	54	1	1.9
Total Iron	52	0	0.0	133	0	0.0
Total Lead	20	0	0.0	54	0	0.0
Total Selenium	ND	ND	ND	ND	ND	ND
Total Zinc	21	0	0.0	54	0	0.0
Turbidity	585	5	0.9	487	5	1.0
Un-ionized Ammonia	798	6	0.8	923	1	0.1
Interior Stations						
Total Alkalinity	1527	1	0.1	916	0	0.0
Dissolved Oxygen	1169	765	65.4	895	650	72.6
Specific Conductance	1229	96	7.8	918	6	0.7
pH < 6.0	1278	10	0.8	899	7	0.8
pH > 8.5	1278	3	0.2	899	1	0.1
Total Coliform Bacteria	ND	ND	ND	ND	ND	ND
Total Silver	ND	ND	ND	ND	ND	ND
Total Beryllium	ND	ND	ND	ND	ND	ND
Total Cadmium	59	0	0.0	111	1	0.9
Total Copper	59	0	0.0	111	0	0.0
Total Iron	197	0	0.0	469	0	0.0
Total Lead	53	0	0.0	111	0	0.0
Total Selenium	ND	ND	ND	ND	ND	ND
Total Zinc	59	0	0.0	111	1	0.9
Turbidity	1288	3	0.2	915	2	0.2
Un-ionized Ammonia	2422	10	0.4	1142	1	0.1

The TP distribution of WCA-2 is presented in **Figure 4-11**. An average of 66 percent of TP concentrations measured during the recent water years at the inflow structures were greater than 50 ppb. These compare well with the baseline period during which approximately 65 percent of the samples collected exhibited TP concentrations greater than 50 ppb. TP concentrations measured at the inflow structures ranged from 10 to 50 ppb and constituted from 18 to 58 percent (or an average of 34 percent) of the samples collected during the recent water years. This average percent is consistent with that observed during the 10-year baseline period. TP levels less than 10 ppb were only observed in WY96 and WY98.

During both the baseline period and recent water years, the majority (greater than 50 percent) of TP concentrations at the interior marsh stations were observed between 10 and 50 ppb (**Figure 4-11**). In contrast, less than 22 percent of samples collected during both periods at the marsh stations had TP concentrations greater than 50 ppb (**Figure 4-11**).

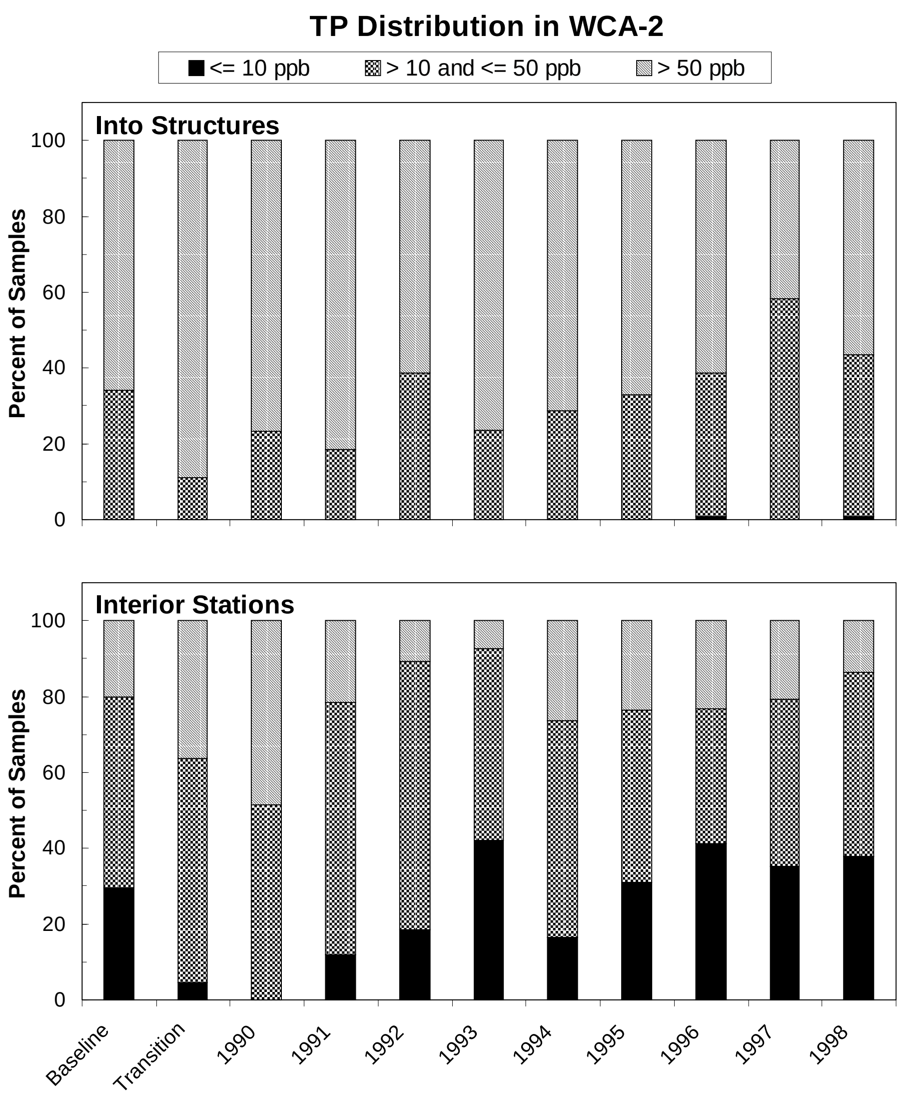


Figure 4-11. The distribution of mean annual TP concentrations for WCA-2 at Into Structures and Interior Stations from the baseline study period to WY98

Water Conservation Area 3

During the baseline period, excursions from the Class III criteria at inflow structures to WCA-3 were observed for nine constituents. Dissolved oxygen had the most frequent excursions at both the into structures and interior marsh stations (**Table 4-6**). The second highest excursions at Into Structures during the baseline period were observed for specific conductance and turbidity. Trace metals, pH, and un-ionized ammonia had a less than 2 percent occurrence of excursions from Class III criteria at either the inflow structures or interior marsh stations during the baseline period.

A small increase in the frequency of excursions was observed for dissolved oxygen throughout the WCA-3 during the recent water years. Interior marsh stations exhibited a slightly greater increase than observed at into structures. A slight increase in the number excursions for pH levels less than 6.0 was also

Table 4-6. Summary of excursions from Class III Criteria in Water Conservation Area 3.

	Baseline Period (10/01/1978 - 09/30/1988)			Water Years (May 1 - April 30) 1990 - 1998		
Parameters	No. of Samples	No. of Excursions	% Excursions	No. of Samples	No. of Excursions	% Excursions
Into Structures						
Total Alkalinity	1456	0	0.0	1217	0	0.0
Dissolved Oxygen	1271	849	66.8	1501	1059	70.6
Specific Conductance	1273	53	4.2	1518	2	0.1
pH < 6.0	1249	0	0.0	1498	20	1.3
pH > 8.5	1249	2	0.2	1498	1	0.1
Total Coliform Bacteria	ND	ND	ND	ND	ND	ND
Total Silver	ND	ND	ND	16	12	75.0
Total Beryllium	ND	ND	ND	16	7	43.8
Total Cadmium	93	0	0.0	151	0	0.0
Total Copper	87	1	1.1	151	2	1.3
Total Iron	172	2	1.2	310	4	1.3
Total Lead	88	1	1.1	150	0	0.0
Total Selenium	ND	ND	ND	16	0	0.0
Total Zinc	93	1	1.1	151	0	0.0
Turbidity	1443	41	2.8	1339	11	0.8
Un-ionized Ammonia	2458	3	0.1	2500	1	0.0
Interior Stations						
Total Alkalinity	1795	0	0.0	2005	0	0.0
Dissolved Oxygen	1327	941	70.9	2626	2003	76.3
Specific Conductance	1491	5	0.3	2683	0	0.0
pH < 6.0	1604	0	0.0	2593	28	1.1
pH > 8.5	1604	2	0.1	2593	13	0.5
Total Coliform Bacteria	ND	ND	ND	ND	ND	ND
Total Silver	ND	ND	ND	ND	ND	ND
Total Beryllium	ND	ND	ND	ND	ND	ND
Total Cadmium	206	2	1.0	669	2	0.3
Total Copper	209	0	0.0	665	0	0.0
Total Iron	529	9	1.7	1607	4	0.2
Total Lead	204	0	0.0	667	2	0.3
Total Selenium	ND	ND	ND	ND	ND	ND
Total Zinc	204	3	1.5	668	1	0.1
Turbidity	1555	2	0.1	1995	3	0.2
Un-ionized Ammonia	2989	1	0.0	2450	2	0.1

observed in both areas of the WCA-3. The remaining parameters (i.e., trace metals, turbidity, specific conductance, and un-ionized ammonia) exhibited a decrease in the frequency of concentrations within acceptable Class III criteria for water samples collected during the recent water years.

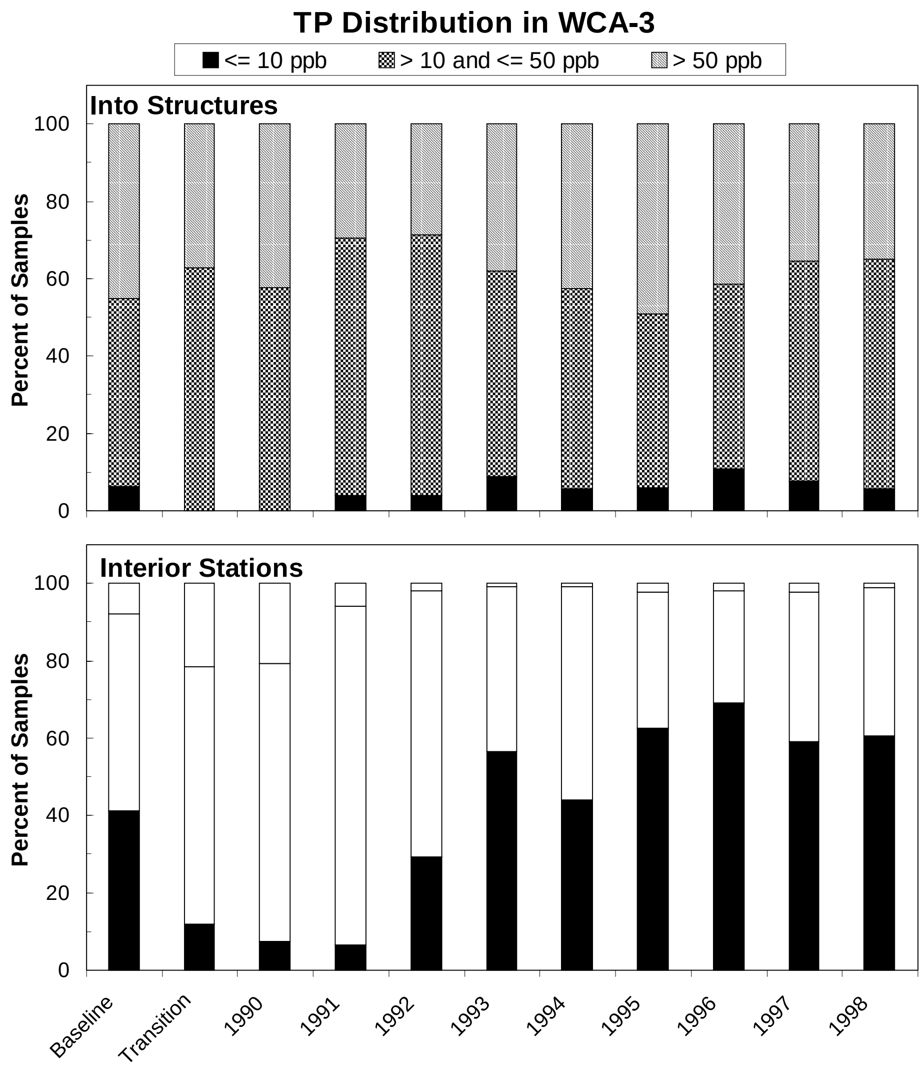


Figure 4-12. The distribution of mean annual TP concentrations for WCA-3 at Into Structures and Interior Stations from the baseline study period to WY98

Greater than 50 percent of water samples collected during the baseline period and recent water years at both the inflow and marsh sites in WCA-3 had TP concentrations between 10 and 50 ppb (**Figure 4-12**). During the baseline period, approximately 45 percent of samples collected at inflow structures had TP concentrations greater than 50 ppb. The frequency of water samples collected during recent water years at inflow structures to WCA-3 with TP concentrations greater than 50 ppb has decreased to an average of 38 percent. This trend is also depicted in **Figure 4-12**. Approximately 6 percent of TP samples collected at both inflow and marsh sites in WCA-3 during both the baseline and recent water years had concentrations less than 10 ppb. These data document a positive direction in TP concentrations for WCA-3 inflows, but also indicated that far greater decreases are needed to get the vast majority of values substantially less than the 50 ppb interim criterion.

At the interior marsh stations, approximately 40 percent of the samples collected during both the baseline period and recent water years had TP concentrations less than 10 ppb. Samples having TP concentrations greater than 50 ppb comprised less than 8 percent during the baseline period and less than 5 percent during recent water years (**Figure 4-12**).

Everglades National Park

Dissolved oxygen levels measured at inflow structures and interior marsh stations in the Park during the baseline period and recent water years exhibited the greatest excursions from Class III criteria (**Table 4-7**). Four trace metals (cadmium, copper, iron and zinc) measured during the baseline period at Into Structures had concentrations greater than their respective Class III criteria. Of these trace metals, cadmium had the highest excursions. In addition to dissolved oxygen, iron concentrations measured at the interior marsh stations during the baseline period exhibited excursions from Class III criteria (**Table 4-7**).

During recent water years, Inflow Structures for the Park have exhibited slightly higher percent excursions for dissolved oxygen, pH (above 8.5 and below 6.0) and un-ionized ammonia compared to the baseline period (**Table 4-7**). With the exception of total lead, percent excursions of trace metal concentrations were lower during the recent water years.

Table 4-7. Summary of excursions from Class III Criteria in the Everglades National Park.

	Baseline Period			Water Years (May 1 - April 30)		
	(10/01/1978 - 09/30/1988)			1990 - 1998		
Parameters	No. of Samples	No. of Excursions	% Excursions	No. of Samples	No. of Excursions	% Excursions
Into Structures						
Total Alkalinity	1338	1	0.1	1502	0	0.0
Dissolved Oxygen	1293	900	69.6	2113	1488	70.4
Specific Conductance	1294	0	0.0	2143	0	0.0
pH < 6.0	1278	0	0.0	2087	28	1.3
pH > 8.5	1278	1	0.1	2087	19	0.9
Total Coliform Bacteria	ND	ND	ND	ND	ND	ND
Total Silver	ND	ND	ND	ND	ND	ND
Total Beryllium	ND	ND	ND	ND	ND	ND
Total Cadmium	298	9	3.0	746	1	0.1
Total Copper	307	1	0.3	740	0	0.0
Total Iron	559	3	0.5	1322	4	0.3
Total Lead	302	0	0.0	746	3	0.4
Total Selenium	ND	ND	ND	ND	ND	ND
Total Zinc	299	3	1.0	746	1	0.1
Turbidity	1321	0	0.0	1502	0	0.0
Un-ionized Ammonia	2538	0	0.0	2620	6	0.2
Interior Stations						
Total Alkalinity	274	0	0.1	736	0	0.0
Dissolved Oxygen	274	136	49.6	717	297	41.4
Specific Conductance	274	11	0.0	710	9	0.0
pH < 6.0	205	1	0.0	659	6	1.3
pH > 8.5	205	0	0.1	659	11	0.9
Total Coliform Bacteria	ND	ND	ND	ND	ND	ND
Total Silver	ND	ND	ND	ND	ND	ND
Total Beryllium	ND	ND	ND	ND	ND	ND
Total Cadmium	244	1	3.0	739	1	0.1
Total Copper	244	1	0.3	720	2	0.0
Total Iron	274	22	0.5	737	65	0.3
Total Lead	244	1	0.0	739	3	0.4
Total Selenium	ND	ND	ND	ND	ND	ND
Total Zinc	244	0	1.0	739	0	0.1
Turbidity	274	2	0.0	720	2	0.0
Un-ionized Ammonia	408	5	0.0	1170	12	0.2

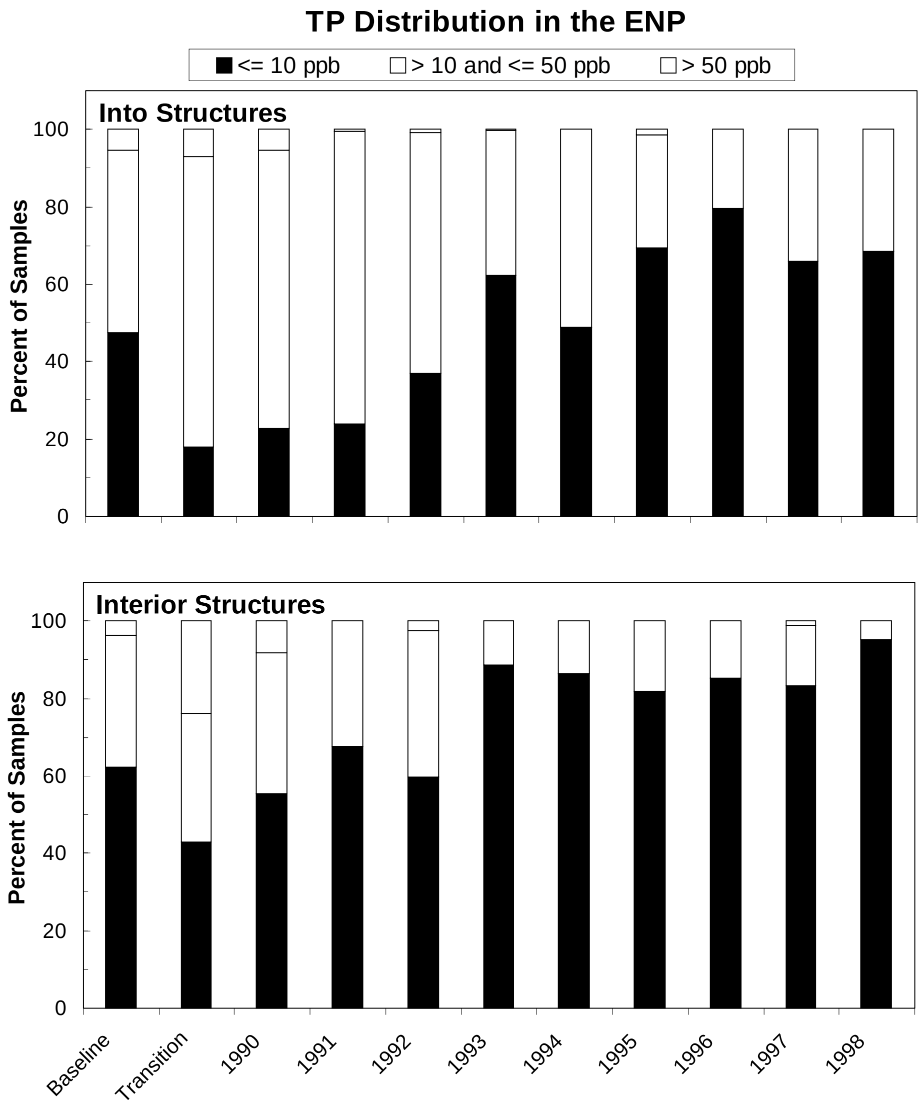


Figure 4-13. The distribution of mean annual TP concentrations for WCA-3 at Into Structures and interior stations from the baseline study period to WY98

Interior marsh stations exhibited a large increase in the number of dissolved oxygen excursions during the recent water years as compared to the baseline period, although the excursion rate increased only 0.8% (**Table 4-7**). In addition total lead and un-ionized ammonia exhibited very small increases in percent excursions during the recent water years.

Less than 1.5 percent of TP concentrations measured in the Park (including inflow and interior stations) during the recent water years were greater than 50 ppb (**Figure 4-13**). The percent of samples collected in the Park during the baseline period with TP concentrations exceeding 50 ppb was slightly higher compared to recent water years.

The majority of TP concentrations measured at interior stations in the Park during both the baseline and recent water years were equal to or less than 10 ppb (**Figure 4-13**). A slightly higher percent of concentrations at or less than 10 ppb was measured during the current water years at these interior marsh stations. It should be noted that many TP concentrations at interior stations in the Park are near or below the District's MDL of 4 ppb.

During the baseline line study, the relative number of TP concentrations measured at inflow structures to the Park were equally divided between those at or less than 10 ppb and those between 10 and 50 ppb. However, during recent water years, approximately 53 percent of TP concentrations were less than or equal to 10 ppb.

Temporal and Spatial Changes of Constituents with Excursions from Class III Criteria

Loxahatchee National Wildlife Refuge

The Refuge has two unique features that distinguish it from the other conservation areas and the Park. It was created by surrounding much of the area covered by the Hillsboro Lakes Marsh with a dike (Parker, 1984, Figure 2). This marsh was situated within the lowest elevation contour in the northern Everglades and received drainage from the northwest and northeast (Brooks, 1984, Figure 21; Parker, 1984, Figure 3). Since the marsh had a longer hydroperiod than the other wet prairie marshes in the area, it developed a floating leaf and submerged aquatic species slough community that created a unique peat, commonly called **Loxahatchee peat** (Goodrick, 1984). This peat is different from that derived from typical wet prairie vegetation and is reflected in water that is naturally acidic, low in dissolved minerals and poorly buffered, i.e. low in alkalinity (Cohen and Spackman, 1984, Swift and Nicholas, 1987).

The second unique feature of the Refuge is that stormwater inflows from pump stations are directed into a rim canal three to four meters deep, running along the inside of the levee, thereby reducing the sheet flow across the marshes. This is characteristic of many areas in the water conservation areas and the Park. A peripheral marsh containing cattail has developed along the boundary between the rim canal and the interior marsh in response to the high nutrient concentrations in stormwater discharged into the rim canal. During low water periods, water pumped into the Refuge flows south in the rim canals to the S10 and S39 structures and does not penetrate far into the peripheral marsh due to slightly higher interior ground level elevations. As water levels in the rim canal rise with increased inflow, rim canal water can flow further into the marsh (Swift and Nicholas, 1987). However, the most interior marsh areas are essentially isolated from rim canal water, and the water quality in these marshes is considered to be rain-driven. See **Chapter 3** for analysis of data collected on transects through the peripheral marsh.

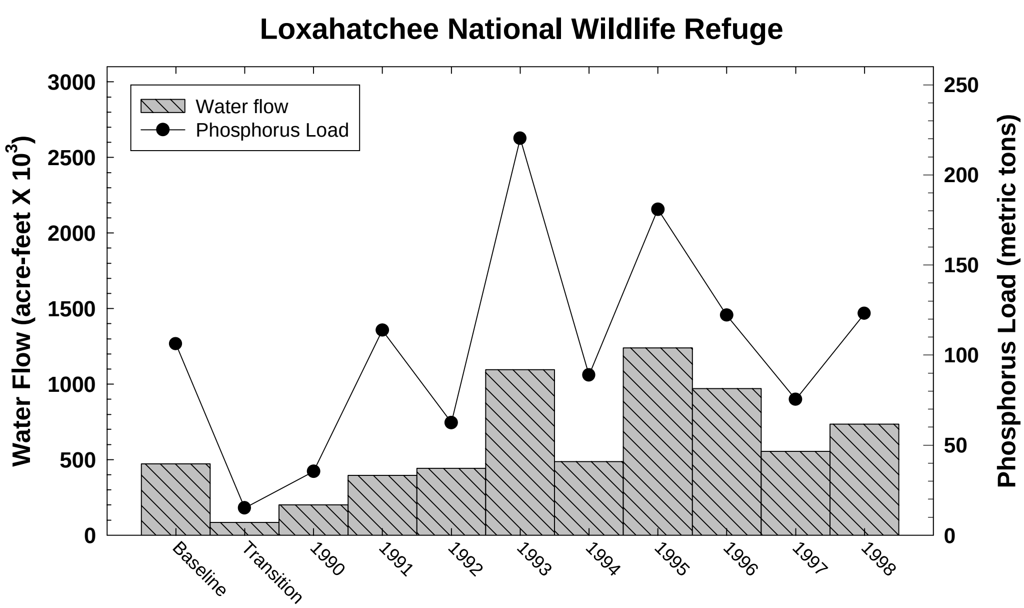


Figure 4-14. Annual flows and P loads to the Refuge from the baseline period through WY98.

Total phosphorus. TP loads discharged into the Refuge for the baseline period and in recent water years are presented in **Figure 4-14**. Loads tend to vary with flow, although the highest load in 1993 was not associated with the highest flow in 1995. In comparison to the baseline period load of 106 metric tons, loads in WY90 to WY98 varied from 35 to 220 metric tons. Notched box and whisker plots of TP data from the inflow sources indicate that, compared to the baseline median concentration of 95.5 ppb, statistically significant lower TP concentrations occurred in WY92 and WY94 through WY98 **(Figure 4-15a)**. Water year 1997 had the lowest median of 26 ppb. Flow-weighted mean TP concentrations of all the inflows to the Refuge are represented as open circles in **Figure 4-15a**. Only WY91 and a greater flow-weighted mean TP concentration than the baseline period. Because the rim canal receives the inflows, rim canal TP concentrations closely track the inflow concentration data in magnitude and over time **(Figure 4-15b)**. The interior marsh sites in the Refuge were not sampled from August 1983 through November

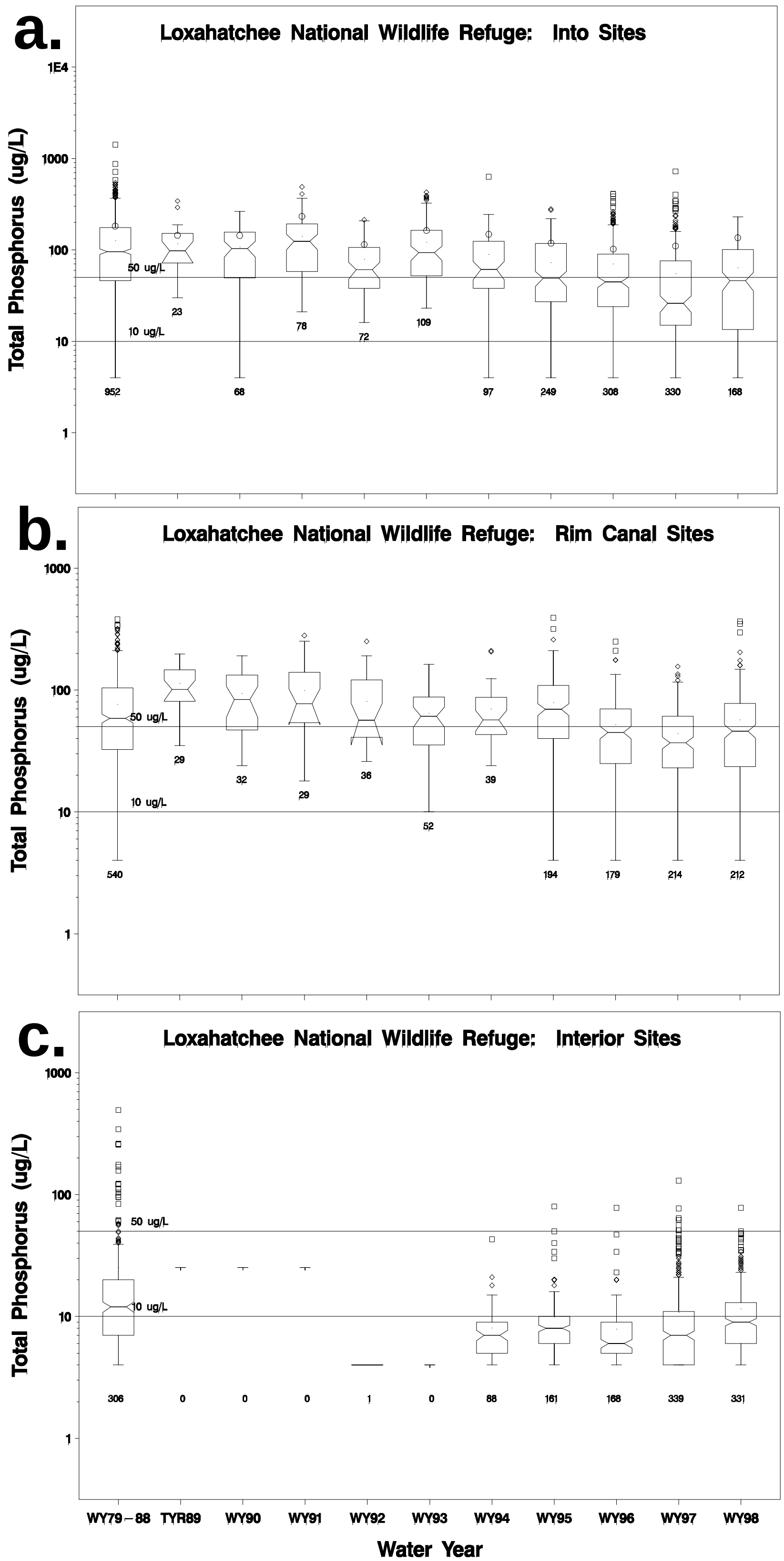


Figure 4-15. Notched box and whisker plots of TP data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

1993. The TP concentration from the 14 interior marsh sites (shown in **Figure 4-15c)** for WY94 through WY98 represent a stable condition in which the medians ranged from 6 to 9 ppb.

Updates of these data are presented in the District's "Water Quality Conditions Quarterly Report" as required by the Settlement Agreement (1991). The Settlement Agreement provides equations for calculating interim and long-term TP concentrations based on water depth measurements at three gaging stations within the Refuge. The TP results from monthly sampling at 14 interior marsh stations are summarized as a geometric mean, and compared to the calculated concentrations. Results are reported to the Settlement Agreement Technical Oversight Committee.

The Everglades Nutrient Removal (ENR) Project began treating water diverted from the flow to the S5A pump station in August 1994. **Table 4-8** presents the surface water inflow TP loads retained within the ENR for Water Years 1995 through 1998. The four-year average retention was 81%. The amount of TP retained within the ENR reduced the TP loads discharged to the Refuge by an average of 15% per year thereby demonstrating the effectiveness of STA technology (**Table 4-9**, **Chapter 6**).

Table 4-8. TP loads (metric tons) retained in the ENR Project for WY 95-98

WY	ENR Inflow Load	ENR Outflow Load	Inflow Load Retained	% Inflow Load Retained
1995	15.5	2.7	12.8	82.6
1996	24.5	5.1	19.4	79.2
1997	14.0	2.7	11.3	80.7
1998	11.3	2.1	9.2	81.4

Table 4-9. Effect of ENR on TP loads (metric tons) discharged into Refuge for WY95-98.

	1995	1996	1997	1998
Load discharged from S5A to Refuge	111.6	79.4	40.5	77.2
Load diverted into ENR	15.5	24.5	14.0	11.3
Load discharged from ENR to Refuge	2.7	5.1	2.7	2.1
Inflow load retained in ENR	12.8	19.4	11.3	9.2
% Inflow load retained in ENR	82.6	79.2	80.7	81.4
Total load discharged into Refuge	114.3	84.5	43.2	79.3
Load that would have been discharged into Refuge through S5A without ENR	127.1	103.9	54.5	88.5
% Load Reduction in Refuge due to ENR	10.1	18.7	20.7	10.4

Total nitrogen. TN loads discharged into the Refuge for the baseline period and in recent water years are presented in **Figure 4-16**. TN loads also vary with flow and appear to have increased since 1992. The TN loads for WY93 through WY98 have varied about the baseline period load of 3504 metric tons. Notched box and whisker plots of TN concentration data from the inflow sources indicate that the baseline period median concentration of 4.3 mg/L is significantly greater than the median concentrations in recent water years, which ranged from 2.1 to 3.0 mg/L (**Figure 4-17a**). The rim canal baseline period median concentration was significantly greater than the median concentrations in WY90, WY91, WY93 and WY96 (**Figure 4-17b**). The interior site TN data is rather sparse but the median concentrations of the data collected in WY95 and WY96, 1.2 and 1.0 mg/L, respectively, were significantly lower than the baseline period median of 2.4 mg/L (**Figure 4-17c**).

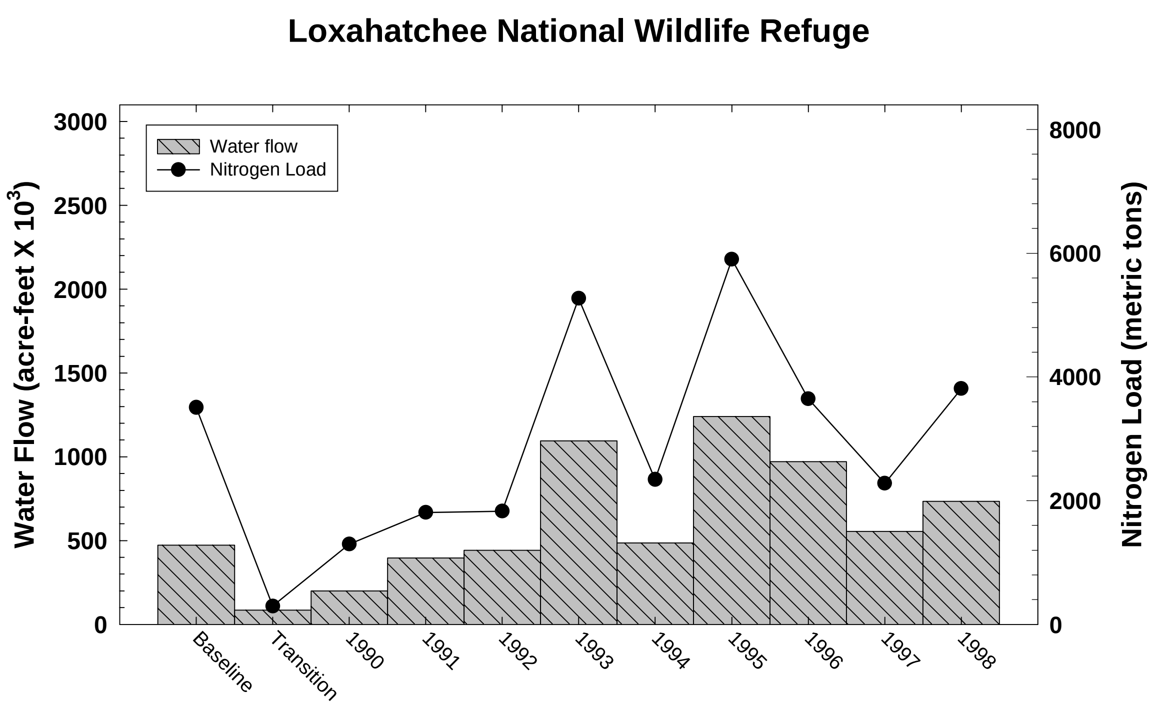


Figure 4-16. Annual flows and nitrogen loads to the Refuge from the baseline period through WY98.

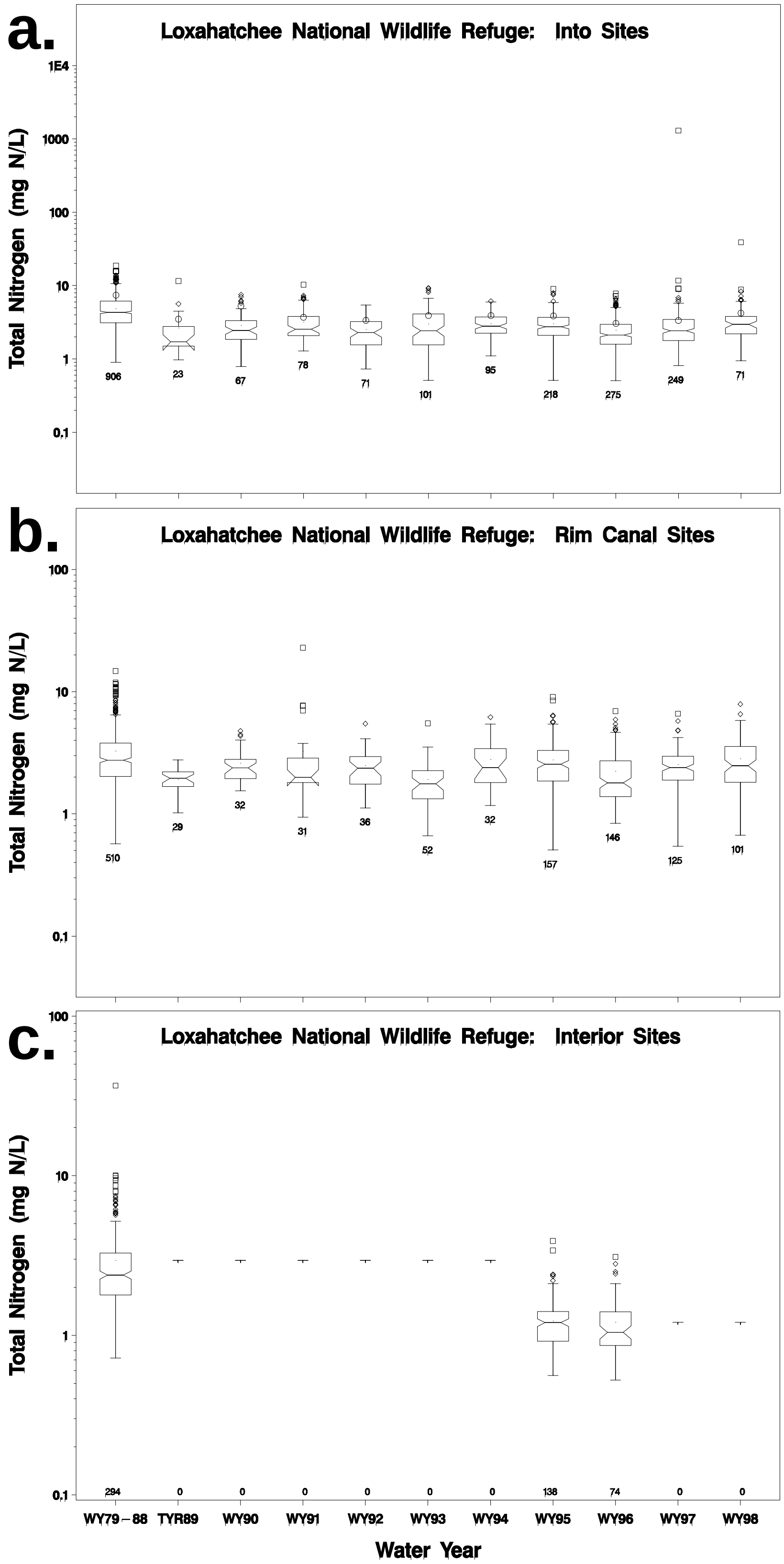


Figure 4-17. Notched box and whisker plots of TN data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Un-ionized ammonia. The un-ionized portion of the amount of dissolved ammonia in water is important to track because toxic conditions can occur when the temperature and pH of the water are above certain levels. The toxic concentration for un-ionized ammonia in Class III waters is ≤0.02 mg/L. Except for WY94, median un-ionized ammonia concentrations in inflows to the Refuge have been significantly lower than the baseline period concentration of 0.0036 mg/L. There is no trend in the data from the individual water years, but there have been no excursions above the 0.02 mg/L criterion since WY94 (**Figure 4-18a)**. Median un-ionized ammonia concentrations in the rim canal were lower than the inflow concentrations in the baseline period and all water years except 1998. Only WY94 had excursions since the baseline period (**Figure 4-18b)**. The few un-ionized ammonia data collected in the Refuge interior marshes were an order of magnitude lower in concentration compared to the rim canal data (**Figure 4-18c)**.

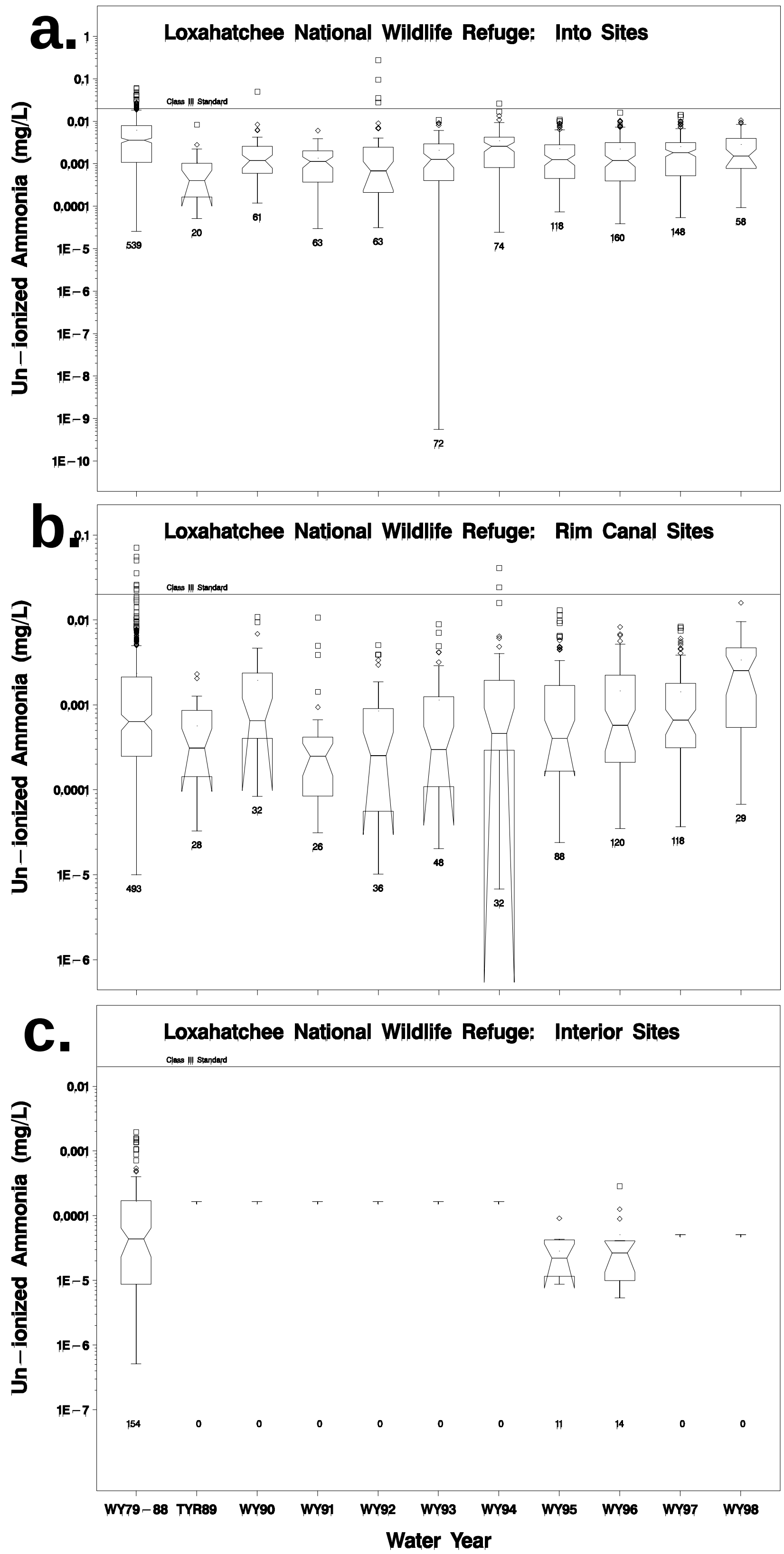
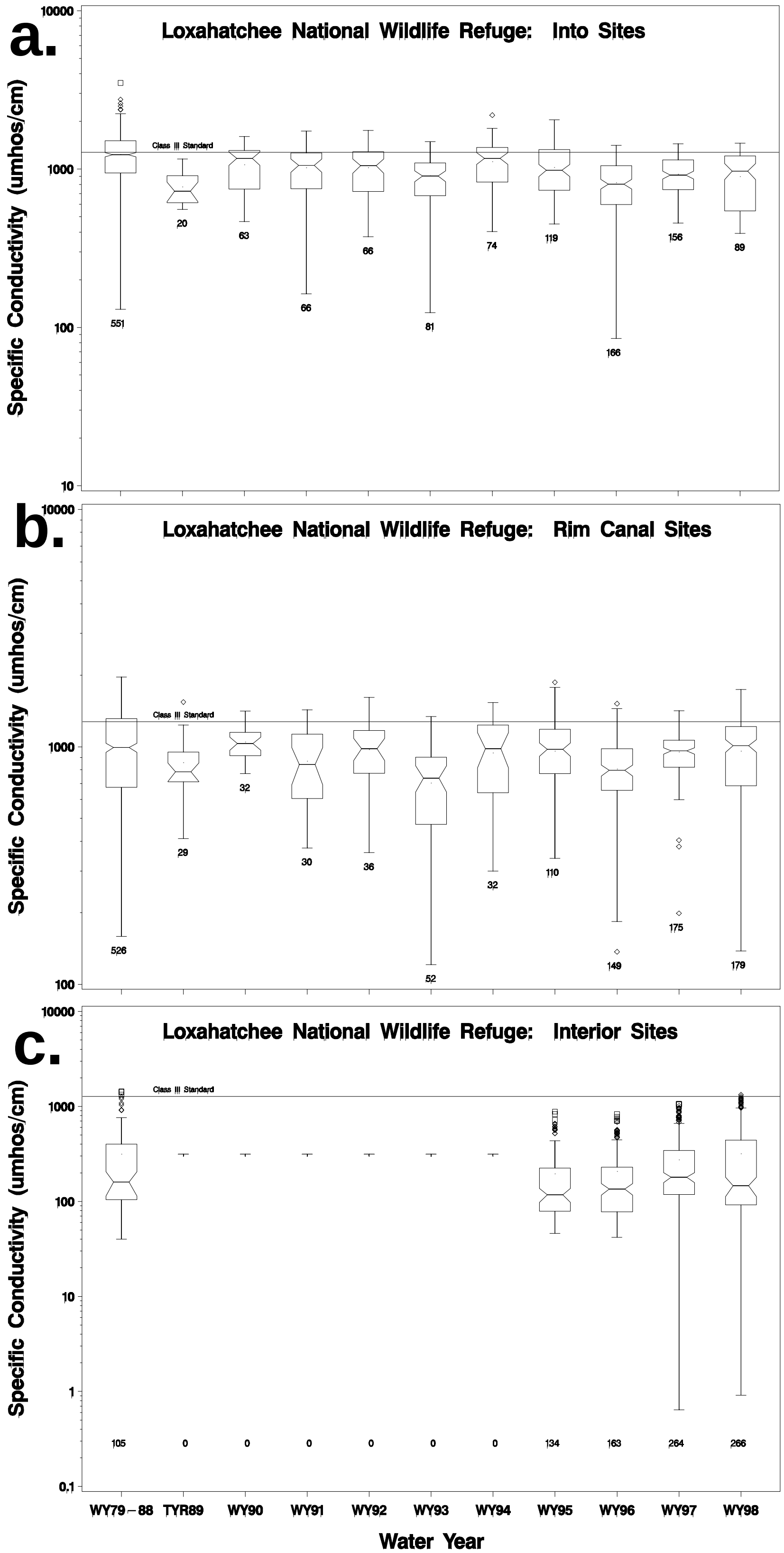


Figure 4-18. Notched box and whisker plots of un-ionized ammonia data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.



Specific conductance. The specific conductance of the inflows to the Refuge show an improving trend relative to the baseline period. With the exception of WY90 and WY94, the other water years had significantly lower median values than the baseline period median of 1234 µmhos/cm. However, problems still exist since excursions have occurred every year (**Figure 4-19a)**. The rim canal sites have the same year-to-year variation in median values as do the inflows, but the rim canal medians are all lower than the inflow medians with the exception of WY98. The baseline median of 992 µmhos/cm for the rim canal stations was significantly lower than the median value of the inflows (**Figure 4-19b)**. The median specific conductance at the interior marsh sites are significantly lower than the rim canal median concentrations. There are, however, events in which high conductance water can flow from the rim canal far enough into the marsh to cause an excursion, as was the case in WY98 (**Figure 4-19c)**.

Figure 4-19. Notched box and whisker plots of specific conductance data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Dissolved oxygen. The majority of dissolved oxygen measurements at all Refuge stations have been consistently less than the 5.0 mg/L criterion (**Figures 4-20a, b and c)**. There are no long-term trends evident in the data. As part of the P enrichment research being conducted in the southwestern part of the Refuge by the District's Everglades Research Division, continuous dissolved oxygen data were collected on a weekly basis along established transects. See **Chapter 3** for a detailed discussion of this work. The data from transect stations Z1 to Z4 were collected between June 5 and June 12, 1997. The data are presented as frequencies of occurrence of hourly averaged values for the week, placed in dissolved oxygen intervals of <2, >2 and <4, and >4 mg/L (**Figures 4-21a, b, c, and d)**. The inverse relationship between decreasing nutrient concentrations along the transect and the amount of time per day dissolved oxygen concentrations are less than 2 mg/L is evident because dissolved oxygen levels improve in marshes with lower nutrient concentrations.

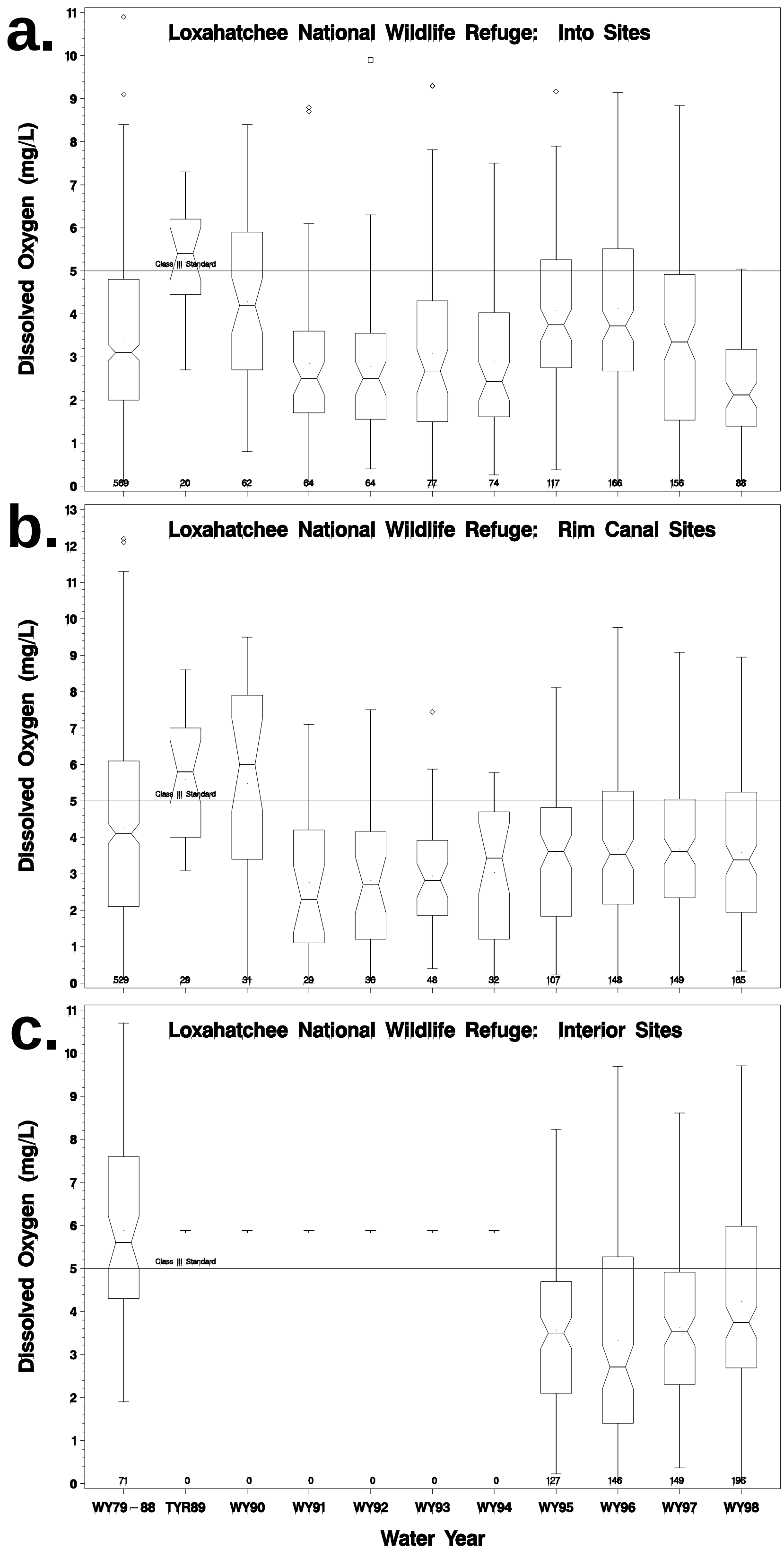


Figure 4-20. Notched box and whisker plots of dissolved oxygen data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

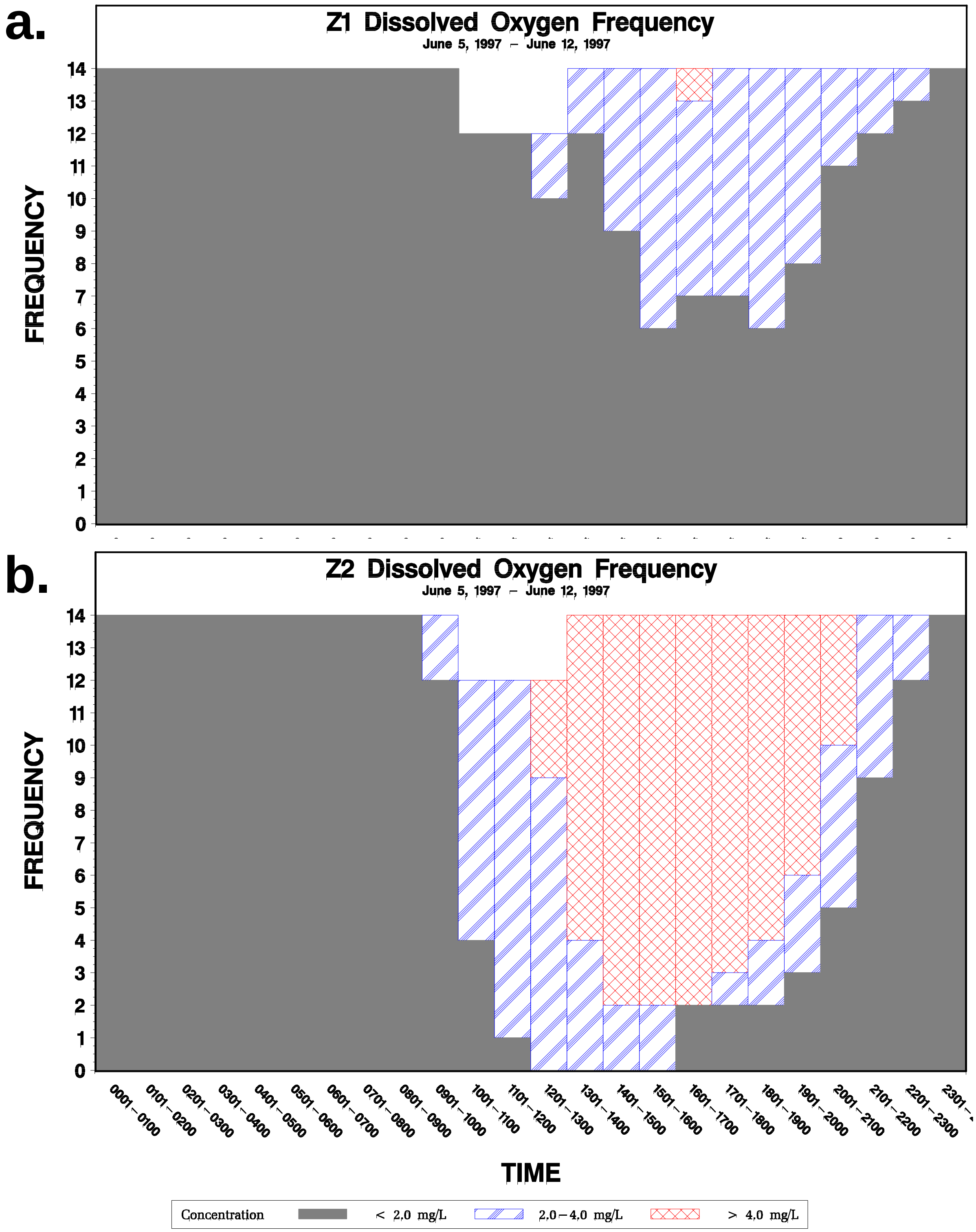


Figure 4-21. Frequencies of occurrence of hourly averaged dissolved oxygen concentrations at four stations on the Z transect, a nutrient gradient in the Refuge.

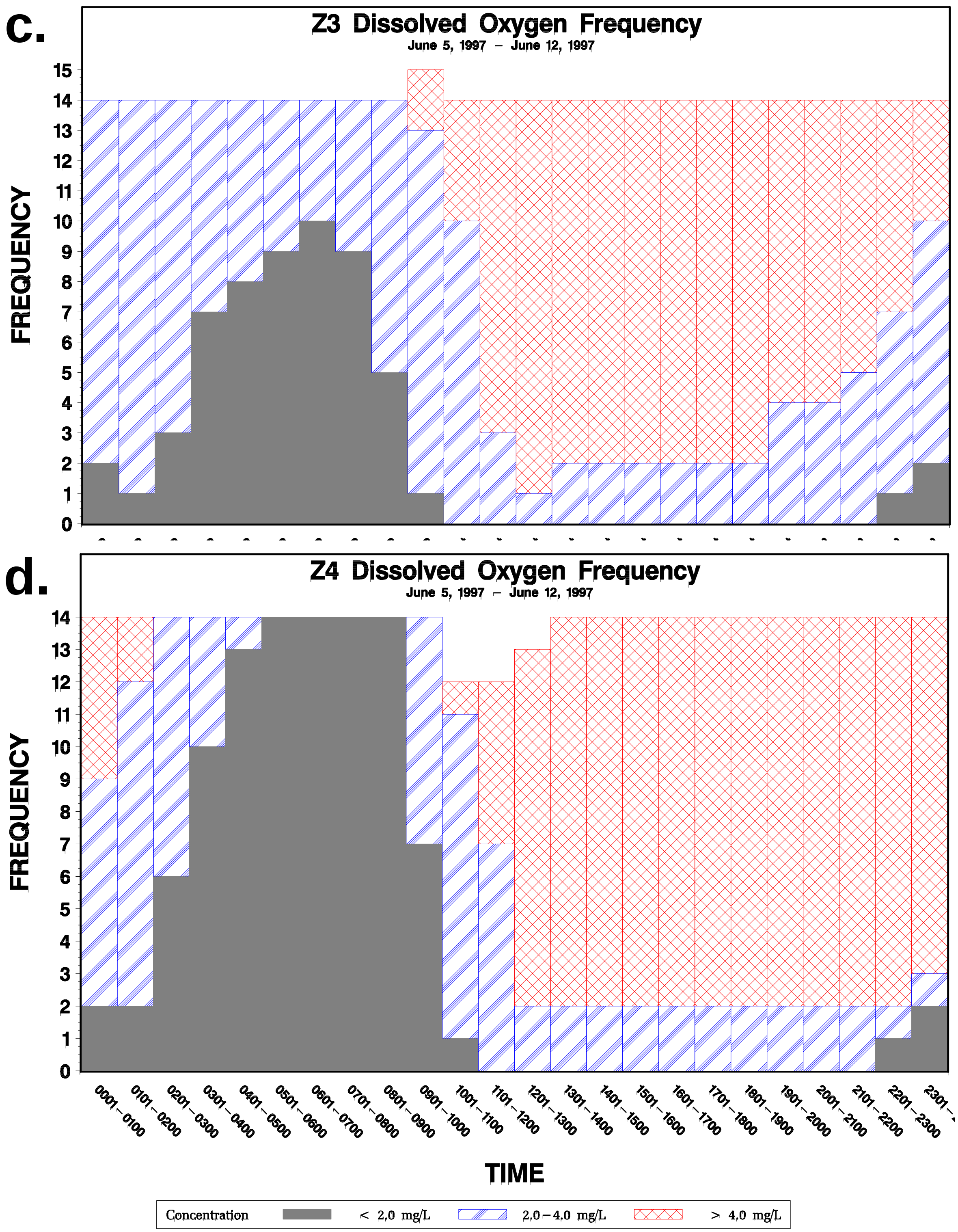
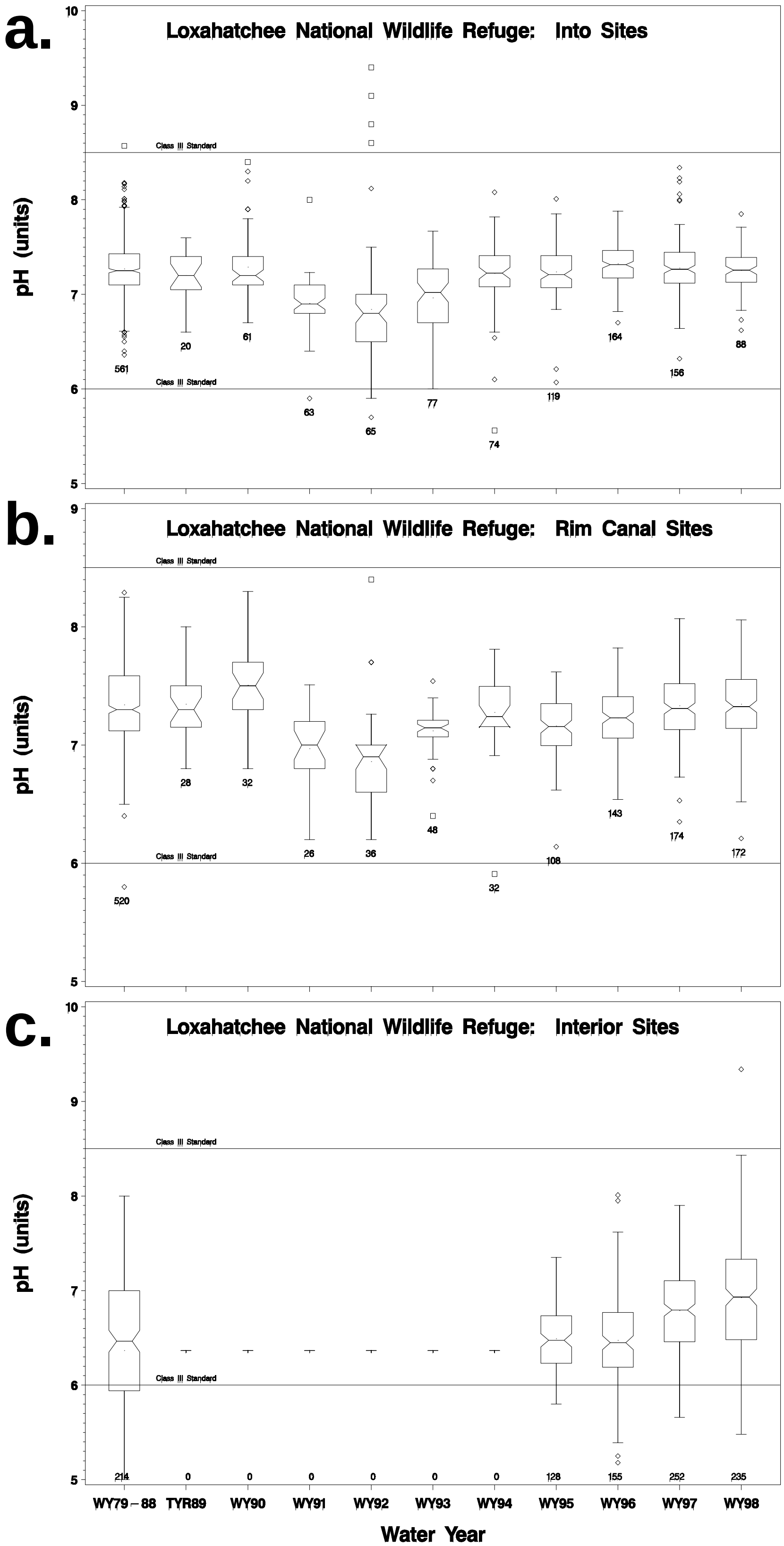


Figure 4-21. (continued) Frequencies of occurrence of hourly averaged dissolved oxygen concentrations at four stations on the Z transect, a nutrient gradient in the Refuge.



pH. The pH of the inflows to the Refuge have been relatively consistent over time with median pH values fluctuating between 7.2 and 7.3 except for WY91, WY92 and WY93 (**Figure 4-22a)**. We do not have an explanation for the lower pH that occurred in these years. There have been no excursions above the 8.5 pH limit since WY92 and no excursions below the 6.0 pH limit since WY94. The pH of the rim canal has been a little more variable than the inflows, ranging from 7.1 to 7.5 exclusive of WY91 and WY92. There have been no pH excursions greater than 8.5 and only two excursions less than pH 6.0. The same decrease in pH in WY91 to WY93 occurred in the rim canal (**Figure 4-22b)**. As a naturally acidic system, the median pH of the interior Refuge marsh has typically ranged from 6.4 to 6.5, with many individual measurements being less than 6.0 (**Figure 4-22c)**. The increase in median pH to 6.8 in WY97 and to 6.9 in WY98 may be due to the construction of the diversion structure in the northern end of the Refuge for Stormwater Treatment Areas (STA) 1-West and 1-East. In WY98 there was a single pH excursion of 9.3.

Figure 4-22. Notched box and whisker plots of pH data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Alkalinity. The median alkalinity concentrations in the inflows to the Refuge have been declining relative to the baseline period median of 279 mg/L. With the exception of WY90 and WY94, the other water year medians are significantly lower than the baseline period median (**Figure 4-23a)**. This trend is considered to be a water quality improvement. In contrast to the inflows, alkalinity in the rim canal has remained relatively stable. Some water years have had median concentrations significantly higher than the baseline period median, while in other water years the median concentrations have been significantly lower (**Figure 4-23b)**. As with pH, the alkalinity increase in the interior marsh in WY97 and WY98 may be due to construction of the STA 1W and 1E diversion works. The median alkalinity concentration in WY97 was significantly greater than the previous two water years. Interestingly, the distribution of the alkalinity data in WY98 is remarkably similar to the baseline period (**Figure 4-23c)**. This indicates that marsh alkalinity could have decreased during the years that were not sampled.

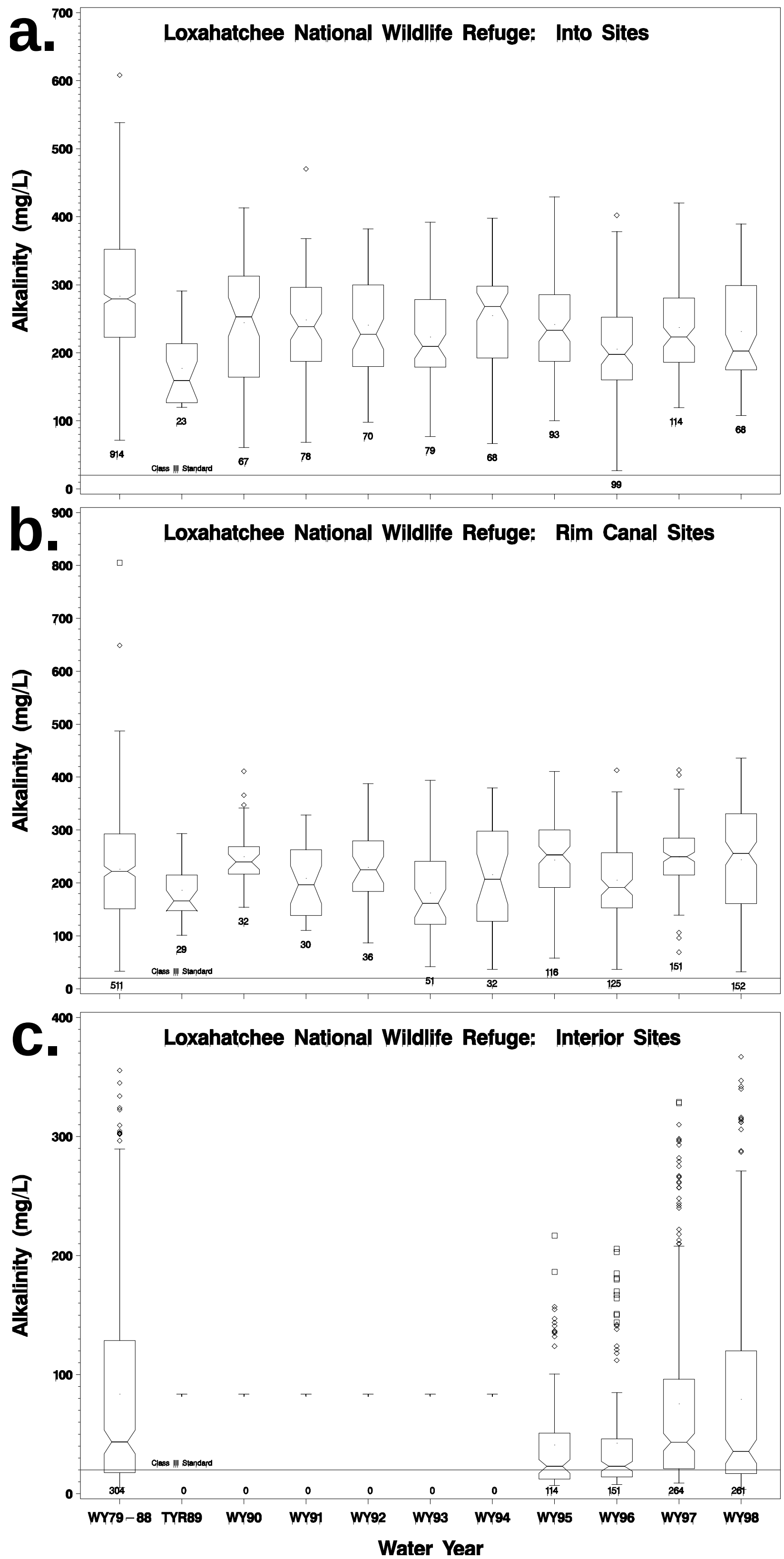


Figure 4-23. Notched box and whisker plots of alkalinity data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Turbidity. The median turbidity values in the inflows to the Refuge have varied from 2.6 to 5.0 from WY90 to 98. Several of these water years have had median turbidity values significantly greater than the baseline period. Except for WY98, there has been at least one excursion above the 29 NTU criterion (**Figure 4-24a)**. The variation of turbidity values from year-to-year in the rim canal generally follow the same variation pattern of the inflow turbidity. However, the median values in the rim canal are somewhat lower and there are less excursions in the rim canal due to particulate settling (**Figure 4-24b)**.

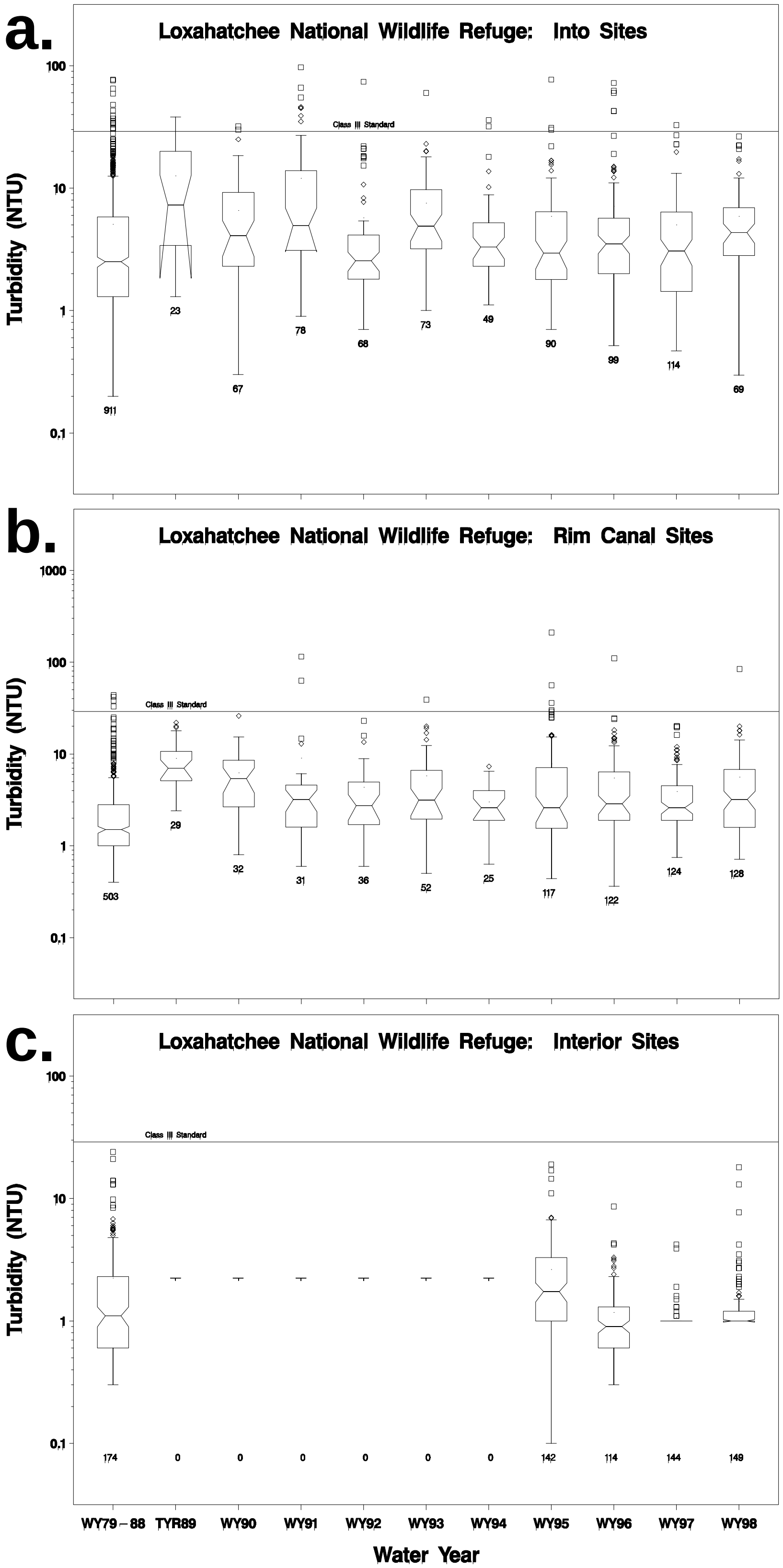


Figure 4-24. Notched box and whisker plots of turbidity data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Water Conservation Area 2

Total phosphorus. TP loads discharged into Water Conservation Area 2 (WCA-2) for the baseline period and in recent water years are presented in **Figure 4-25**. The variation in the magnitude of the annual load is closely correlated with flow. The baseline period load was 86 metric tons, in comparison to loads ranging from 10 metric tons in WY90, to 174 metric tons in WY93. Notched box and whisker plots of TP concentration data from the inflow sources show a declining trend in median TP concentrations from WY91 through WY98 (**Figure 4-26a)**, but only the median TP concentration of 45 ppb in WY97 was significantly lower than the median TP concentration of 62 ppb in the baseline period. The TP data for the interior sites do not show the trend seen in the inflows, but the median TP concentrations at the interior sites are all significantly lower than the corresponding inflow median TP concentration for the baseline period and each water year except 1990 (**Figure 4-26b)**. A number of individual samples collected at interior sites immediately downstream from the S10 structures continue to have concentrations greater than 100 ppb. See **Chapter 3** for a detailed discussion of the nutrient gradient in WCA-2.

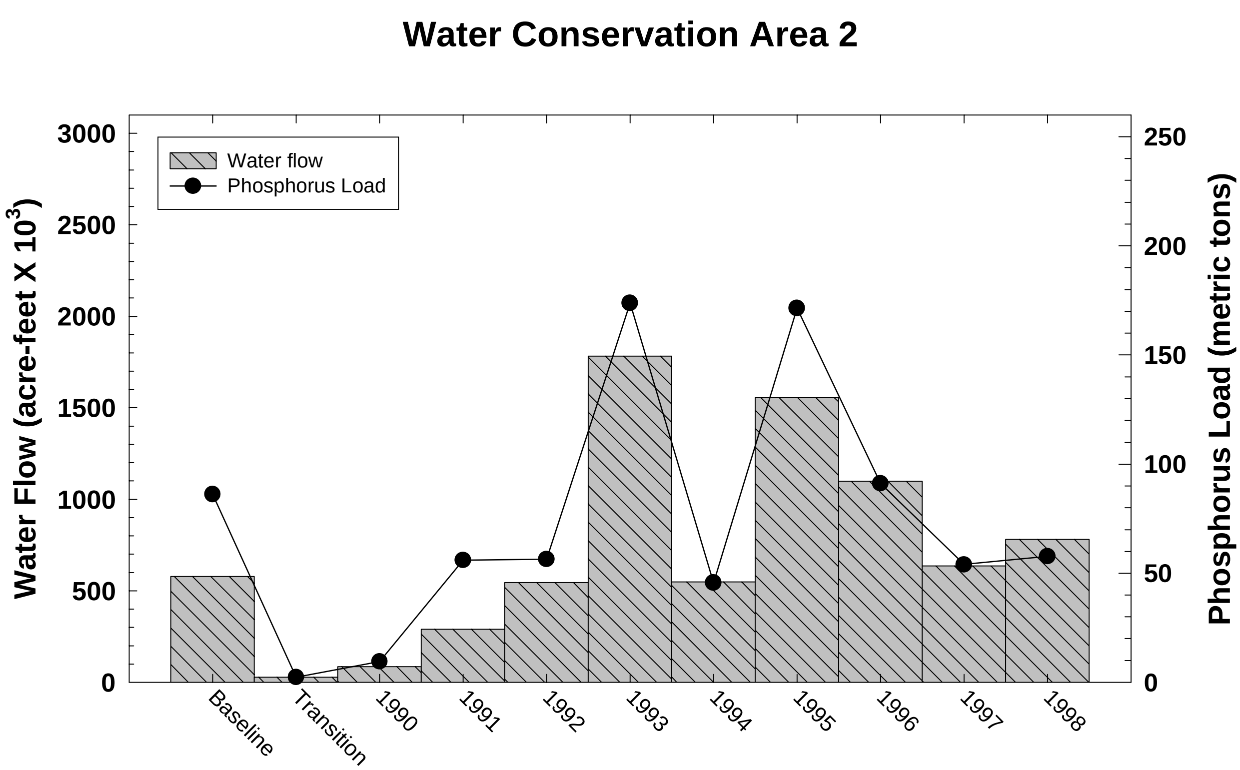


Figure 4-25. Annual flows and P loads to Water Conservation Area 2 from the baseline period through WY98.

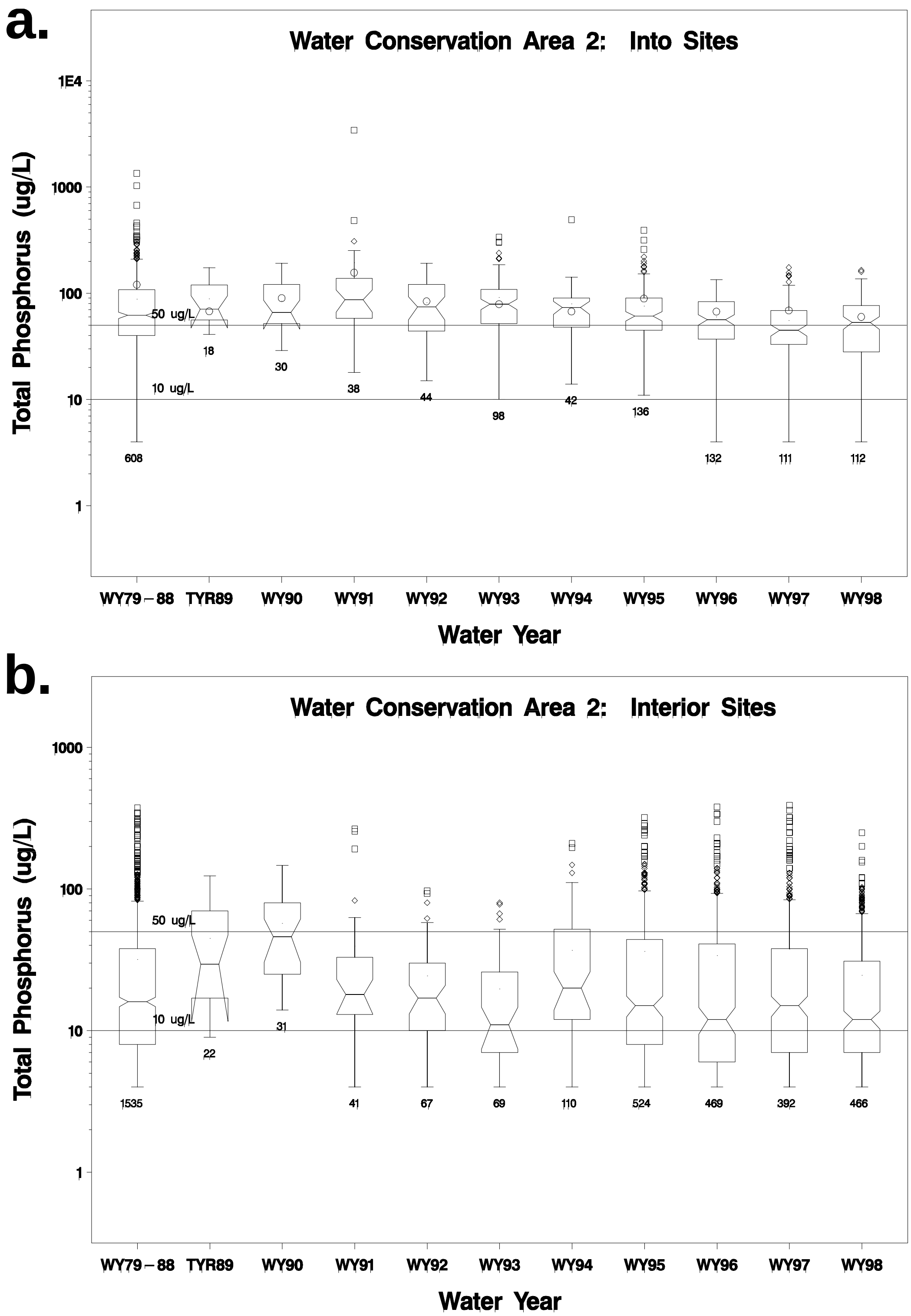


Figure 4-26. Notched box and whisker plots of TP data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Total nitrogen. TN loads discharged into WCA-2 are presented in **Figure 4-27**. As with TP, the magnitude of the TN loads is driven by the amount of flow. The baseline period TN load was 3009 metric tons. The TN loads have varied from 264 metric tons in WY90 to 5243 metric tons in WY95. Notched box and whisker plots of TN data from the inflow sources have remained relatively stable in the recent water years. The TN median concentrations in the recent water years are all significantly lower than the baseline period median concentration of 3.3 mg/L (**Figure 4-28a)**. The TN data from the interior sites also remained relatively stable in the recent water years with the TN median concentrations for these years all being significantly lower than the baseline period concentration of 2.4 mg/L (**Figure 4-28b)**. The baseline period TN median concentration, and all median concentrations at the interior sites in the recent water years, were significantly lower than the corresponding inflow TN median concentrations.

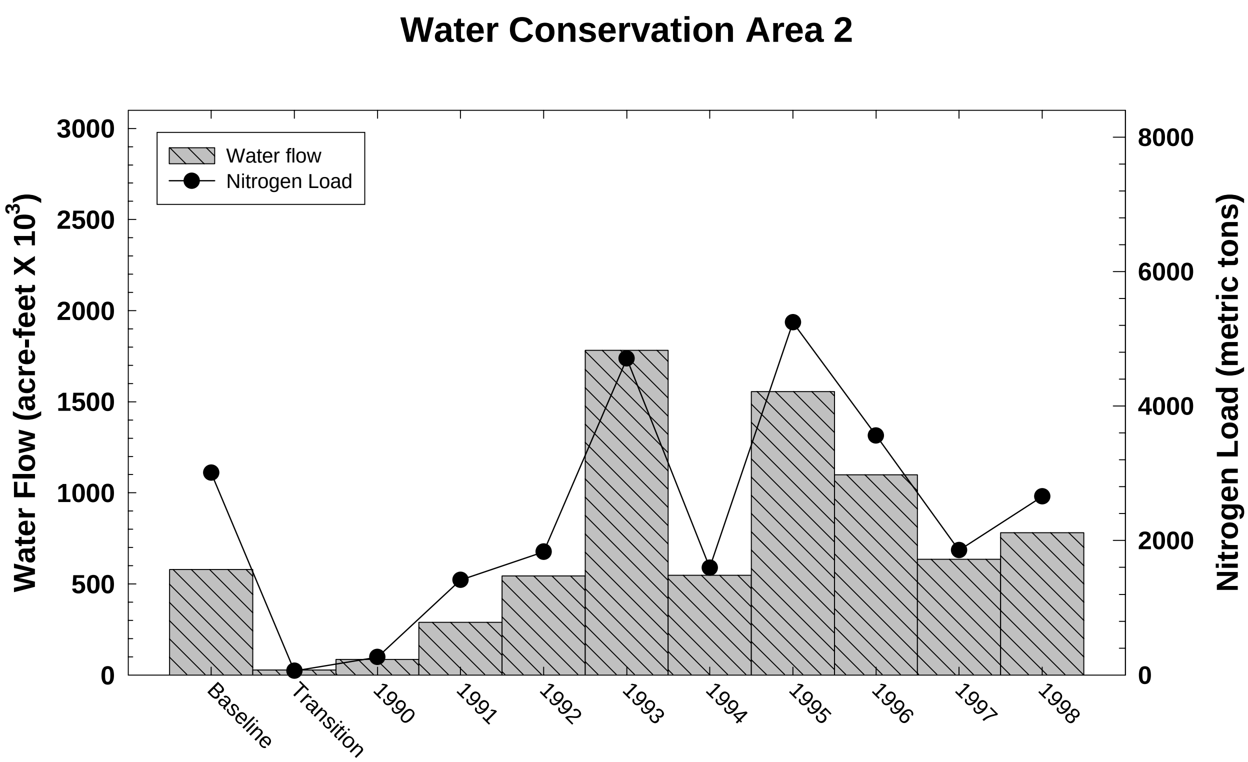


Figure 4-27. Annual flows and nitrogen loads to Water Conservation Area 2 from the baseline period through WY98.

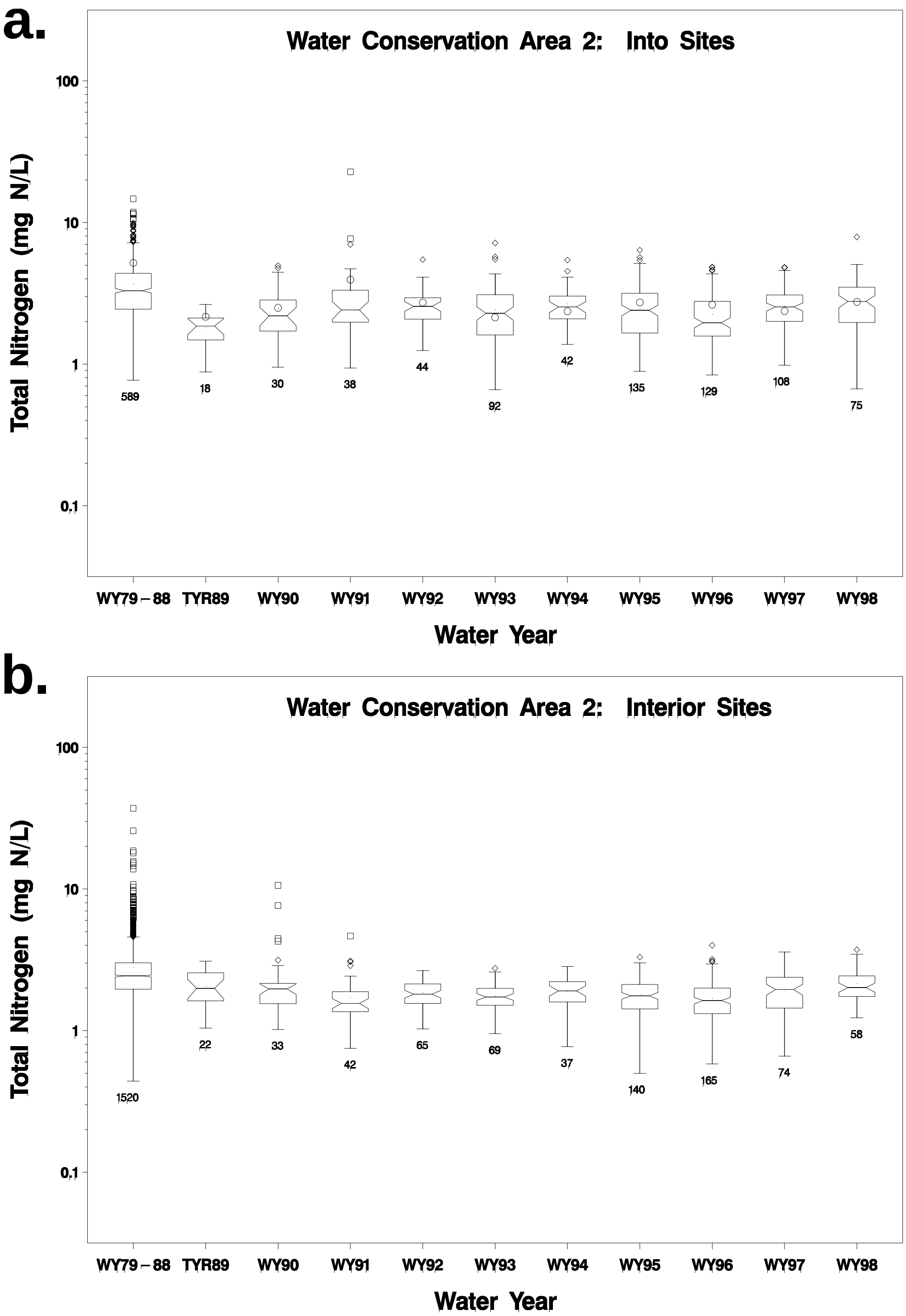


Figure 4-28. Notched box and whisker plots of TN data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Un-ionized ammonia. Un-ionized ammonia has been detected above the 0.02 mg/L criterion only once since the baseline period in the inflows to WCA-2. The median un-ionized ammonia concentrations indicate an increasing trend in the recent water years (**Figure 4-29a)**. The pH of the inflows show a similar increase from WY92 through WY98 (**Figure 4-33a)** and, as pH is a variable used to calculate the un-ionized ammonia concentration, it appears the observed un-ionized ammonia trend is pH driven (**Table 4-4)**. The un-ionized ammonia data from the interior sites also indicates an increasing trend in the median concentrations from WY92 to WY97 (**Figure 4-29b),** although the concentrations are three to five times lower than the inflow concentrations. The corresponding pH data presented in **Figure 4-33b)** show the same increase from WY92 to WY98. The un-ionized ammonia excursion at an interior site in WY98 (0.08 mg/L) is associated with a pH of 9.5. This value appears to be an outlier when compared with the other WCA-2 marsh pH data.

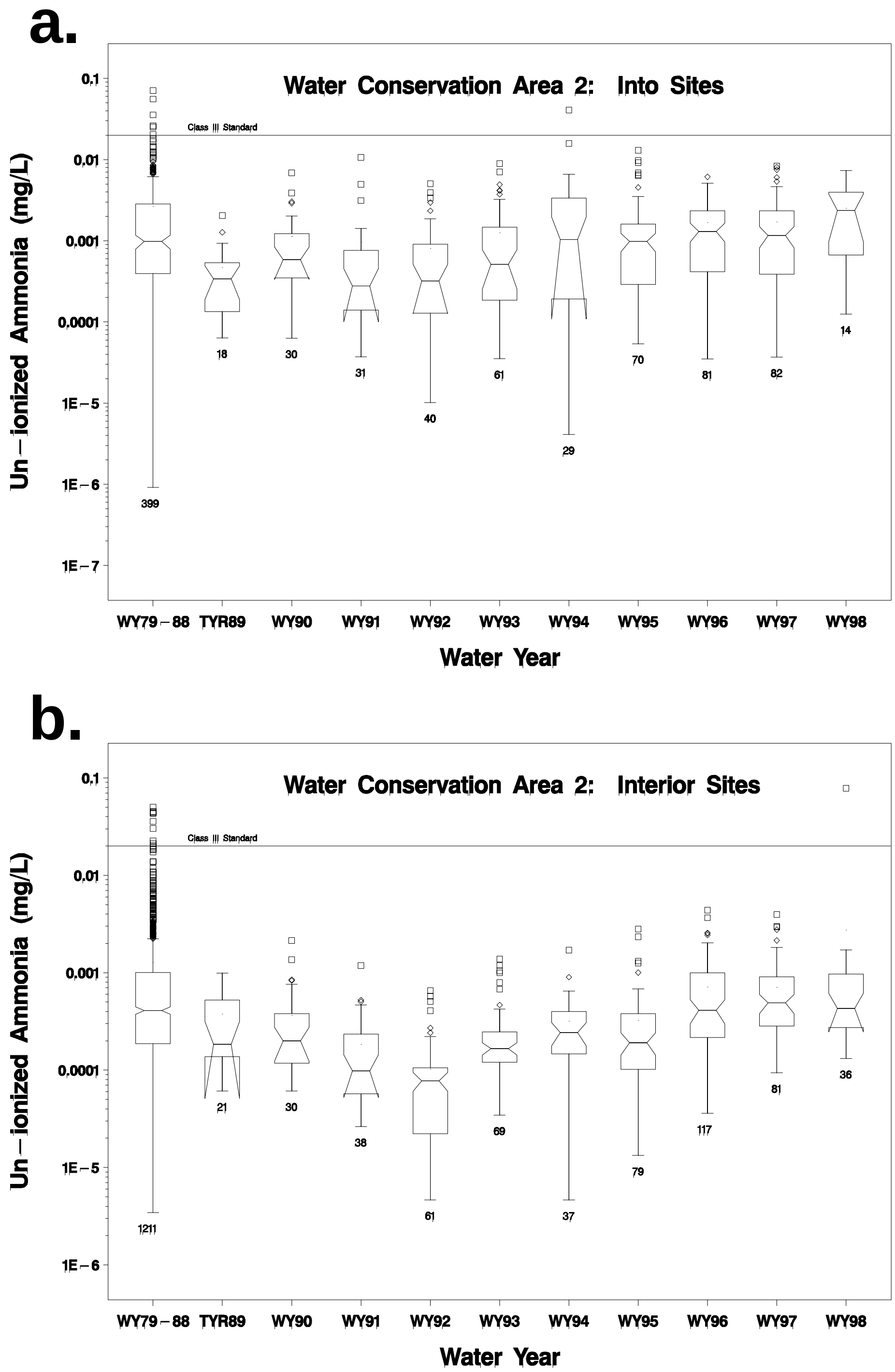


Figure 4-29. Notched box and whisker plots of un-ionized ammonia data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

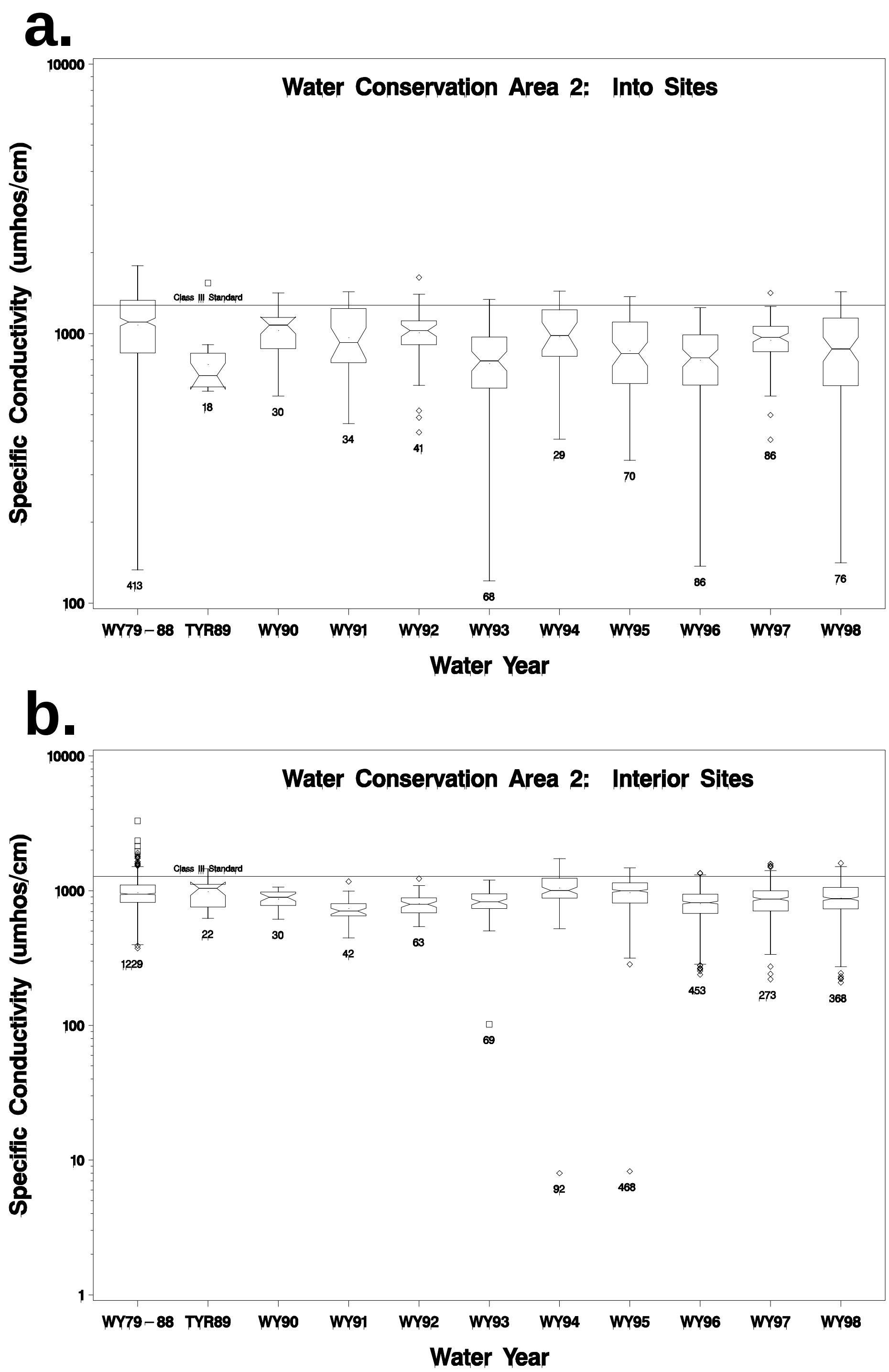


Figure 4-30. Notched box and whisker plots of specific conductance data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Specific conductance. The specific conductance at the inflow sites to WCA-2 (**Figure 4-30a)** is closely correlated with the year-to-year variation in the rim canal specific conductance data (**Figure 4-19b)**. The maximum specific conductance values of the water entering WCA-2 exceeded the criterion of 1275 µmhos/cm in the baseline period and in eight of the nine water years. Specific conductance median values of the interior waters were significantly lower than the inflow medians in the baseline period and in four of the nine water years (**Figure 4-30b)**.

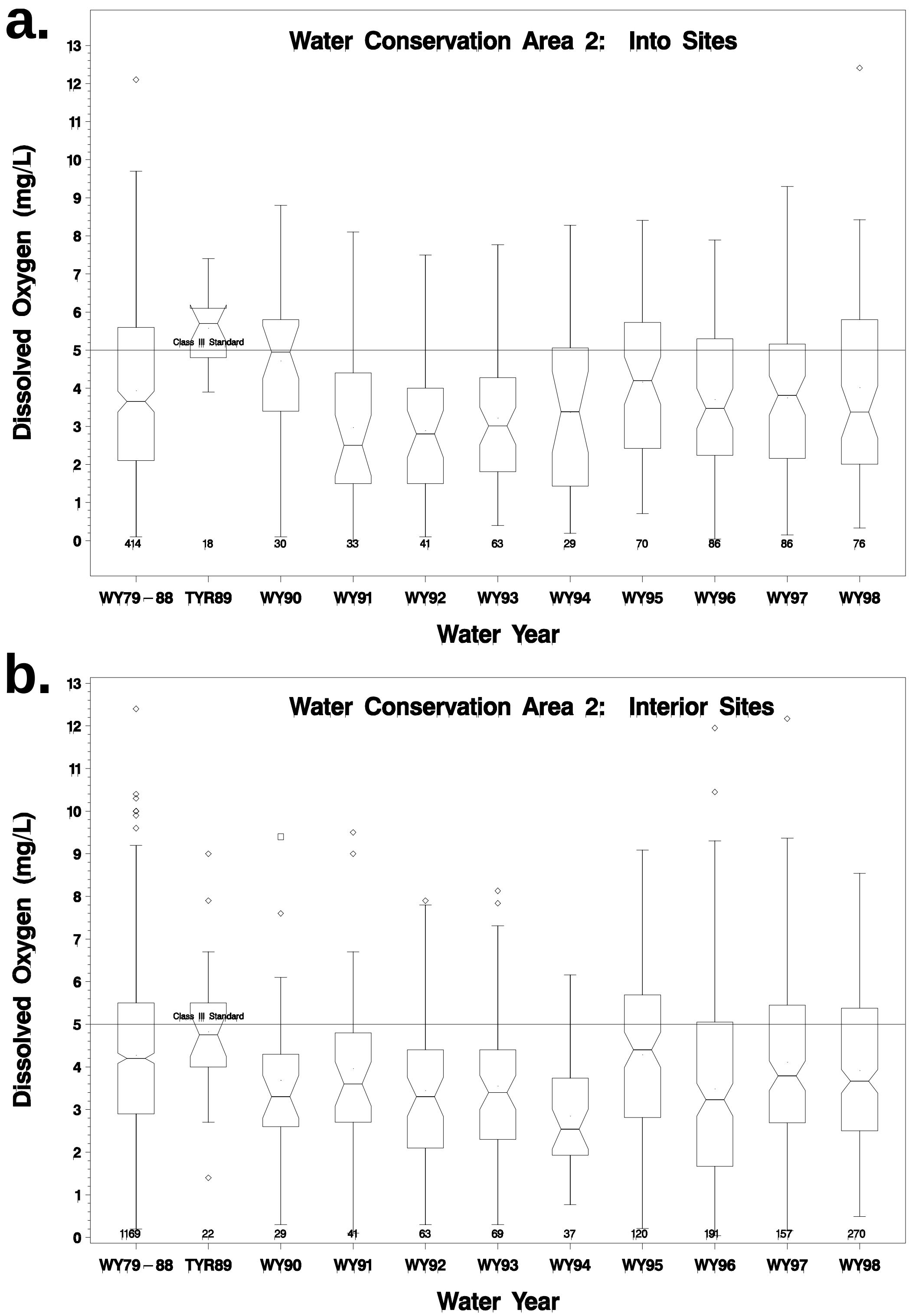


Figure 4-31. Notched box and whisker plots of dissolved oxygen data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Dissolved oxygen. The large majority of the water discharged into WCA-2 and the water at the interior sites is less than the 5.0 mg/L criterion (**Figures 4-31a and b)**. The diel nature of dissolved oxygen concentrations in the northern part of WCA-2 is presented in **Figures 4-32a, b, c, d and e**. This data was collected along the F transect as part of the Everglades Research Division's P enrichment research (McCormick, et al., 1996). **Chapter 3** also provides a discussion of this work. The dissolved oxygen data were analyzed in the same way as the data from the Z transect in the Refuge. Sites F1 to F5 are on a north to south gradient of declining nutrient concentrations and corresponding aquatic plant communities that transition from dense cattails (F1) to sawgrass prairies and open water sloughs (F5). The continuous dissolved oxygen data were collected between October 27 and October 31, 1997. Site F1 had dissolved oxygen concentrations less than 2 mg/L except in late afternoon for a few hours while, at the other end of the gradient, site F5 did not have any dissolved oxygen concentrations less than 2 mg/L. Although Site F4 is further south than F3, it had a greater frequency of dissolved oxygen concentrations less than 2 mg/L. Ground water has periodically been observed to rise and mix with surface water at the F4 site and other sites in the northern part of WCA-2. Ground water effects on surface water dissolved oxygen concentrations and specific conductance will be addressed in 1999 Everglades Interim Report.

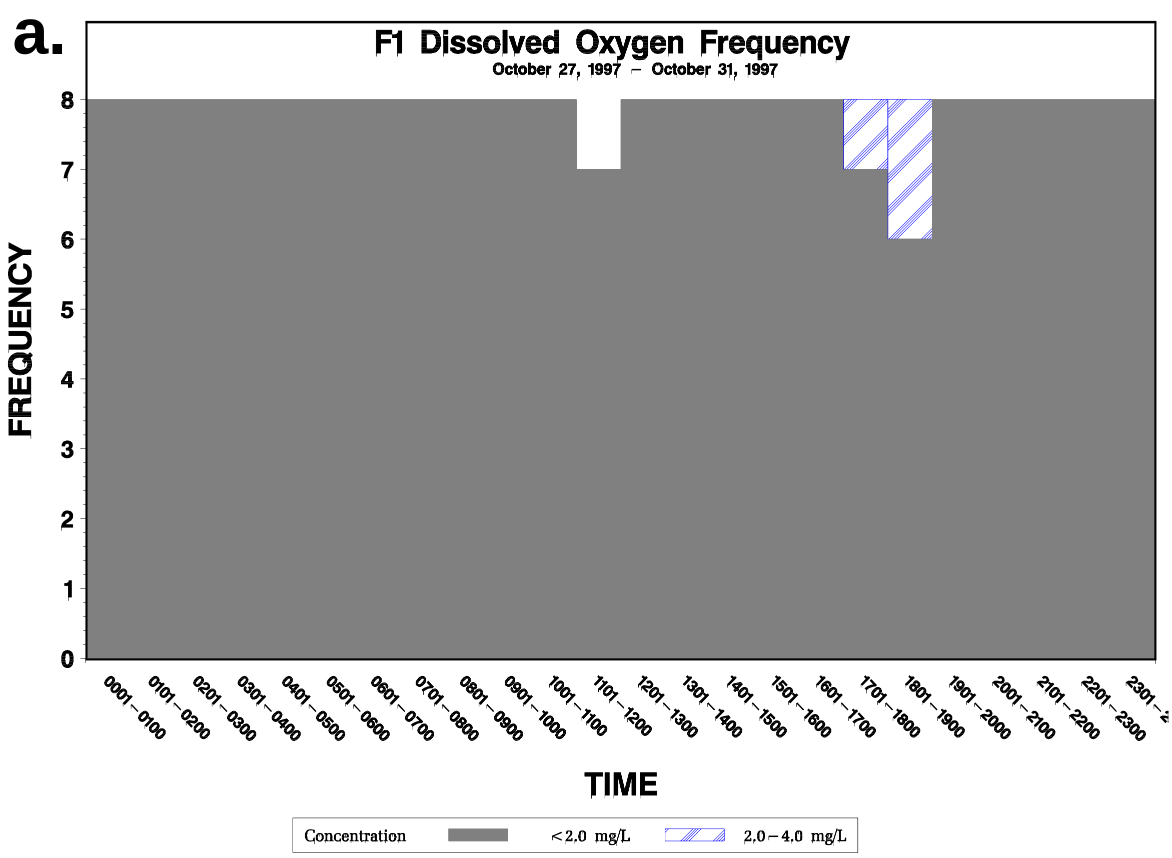


Figure 4-32. Frequencies of occurrence of hourly averaged dissolved oxygen concentrations at five stations on the F transect, a nutrient gradient in WCA-2.

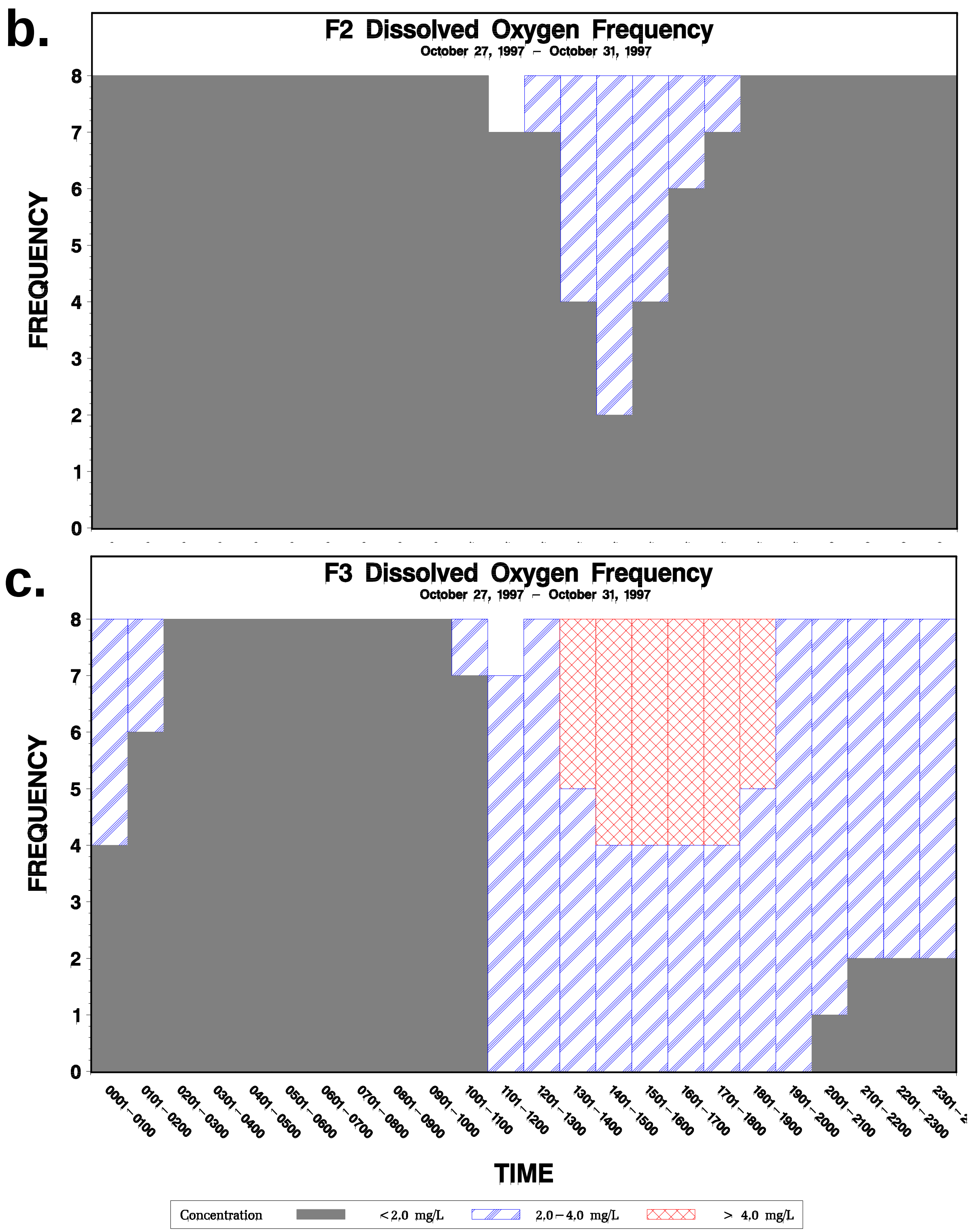


Figure 4-32. (continued) Frequencies of occurrence of hourly averaged dissolved oxygen concentrations at five stations on the F transect, a nutrient gradient in WCA-2.

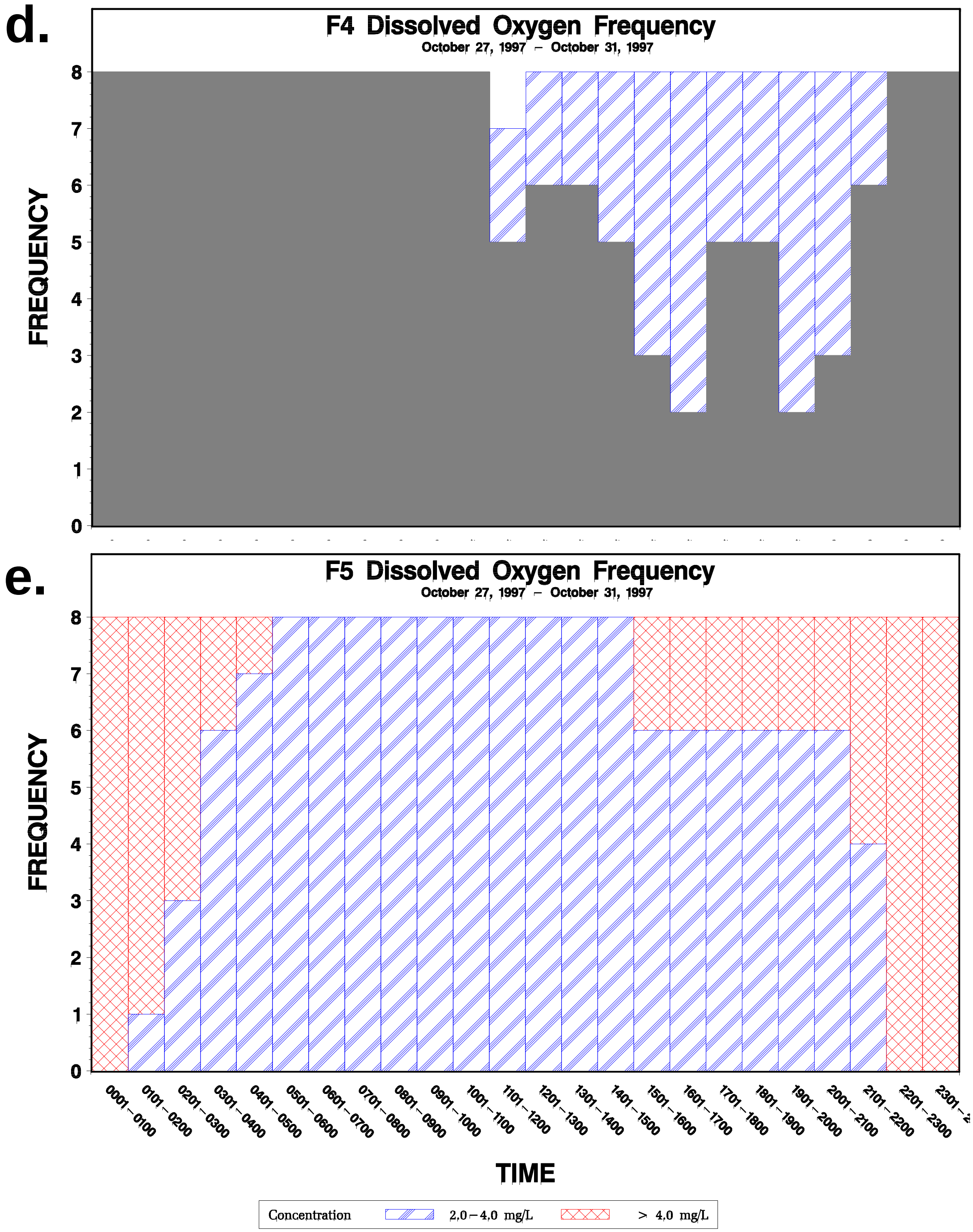


Figure 4-32. (continued) Frequencies of occurrence of hourly averaged dissolved oxygen concentrations at five stations on the F transect, a nutrient gradient in WCA-2.

pH. The same pattern of pH decreasing from WY90 to WY92, and then increasing from WY93 to WY98, in the Refuge was observed in the inflows to WCA-2 and at the interior marsh waters (**Figure 4-33 a and b)**. There have been no excursions above the 8.5 pH criterion since the baseline period and no excursions below the pH 6.0 criterion since WY94 at the inflow sites. The WY98 pH excursion mentioned previously as being the cause of the un-ionized ammonia excursion at an interior site was the only pH excursion since the baseline period. There have been no excursions below the pH 6.0 criterion since WY95.

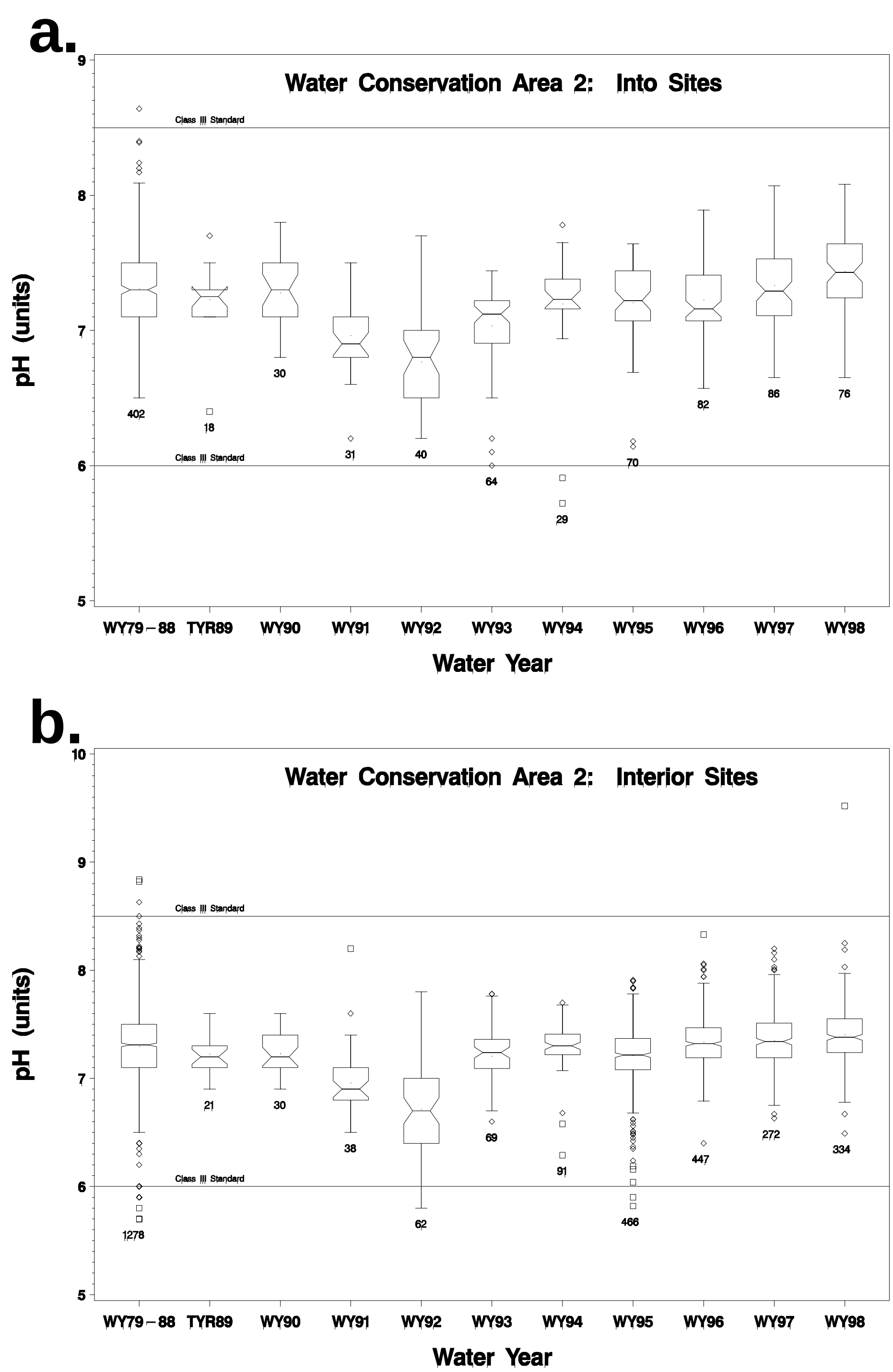


Figure 4-33. Notched box and whisker plots of pH data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

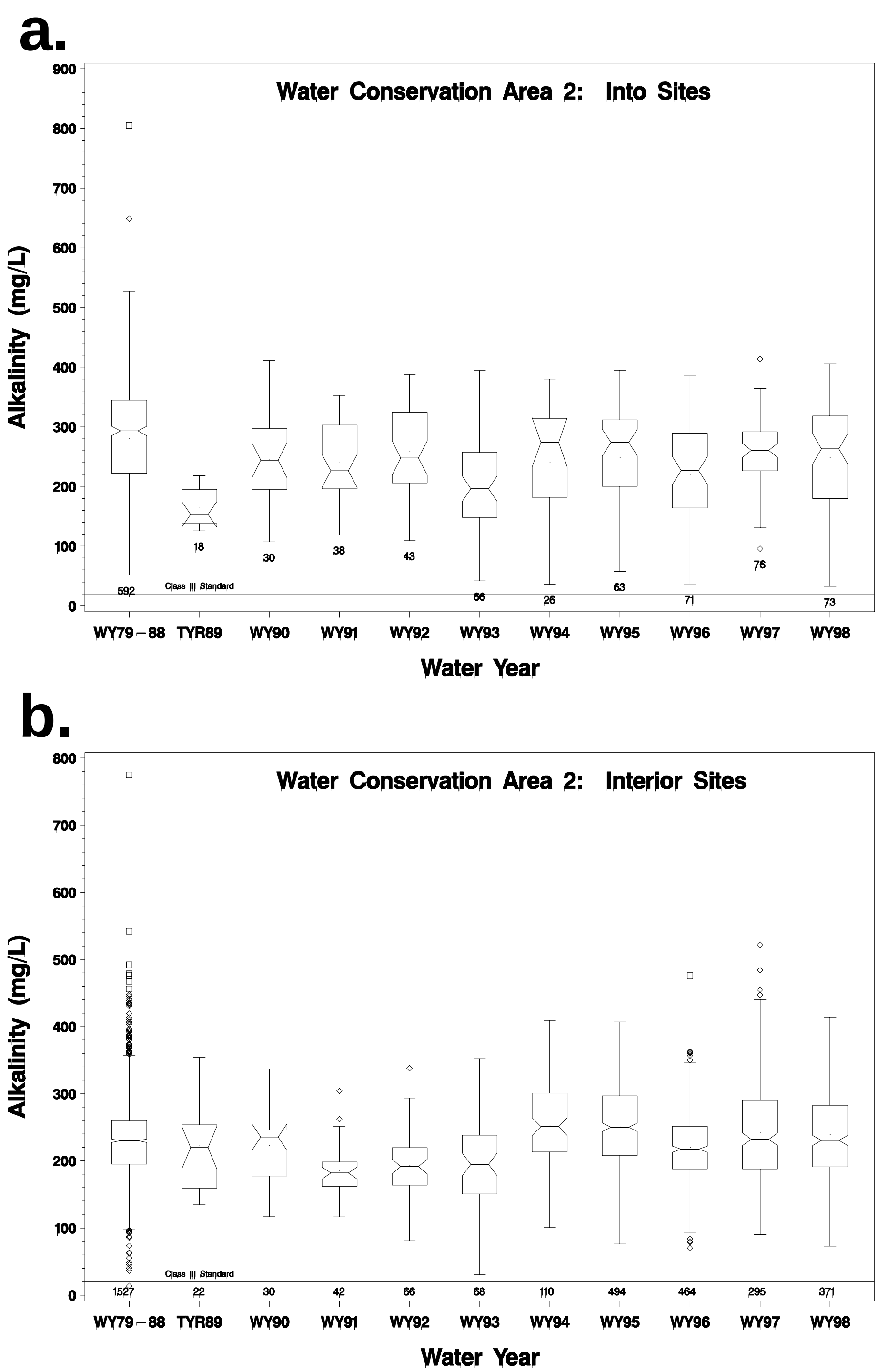


Figure 4-34. Notched box and whisker plots of alkalinity data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Alkalinity. The median alkalinity concentrations at the inflow sites were slightly higher than the median concentrations for the baseline period and in the recent water years. One excursion below the 20 mg/L criterion occurred during the baseline period at an interior marsh site (**Figure 4-34a and b)**. There does not appear to be a correlation between alkalinity and pH at the inflow sites, but the changes in both pH and alkalinity from year-to-year at interior sites track rather closely except for WY92.

Turbidity. The median turbidity values at the inflow sites have shown a significant decrease from 5.4 NTU in WY90 to 2.4 NTU in WY98. However, WY98 is not significantly different from the baseline value of 2.2 NTU (**Figure 4-35a)**. The interior sites baseline median turbidity value of 1.1 was not significantly different from the WY98 value of 1.0 (**Figure 4-35b**). Although there are some significant differences between certain years, the last six water years have an average median of 0.9 NTU.

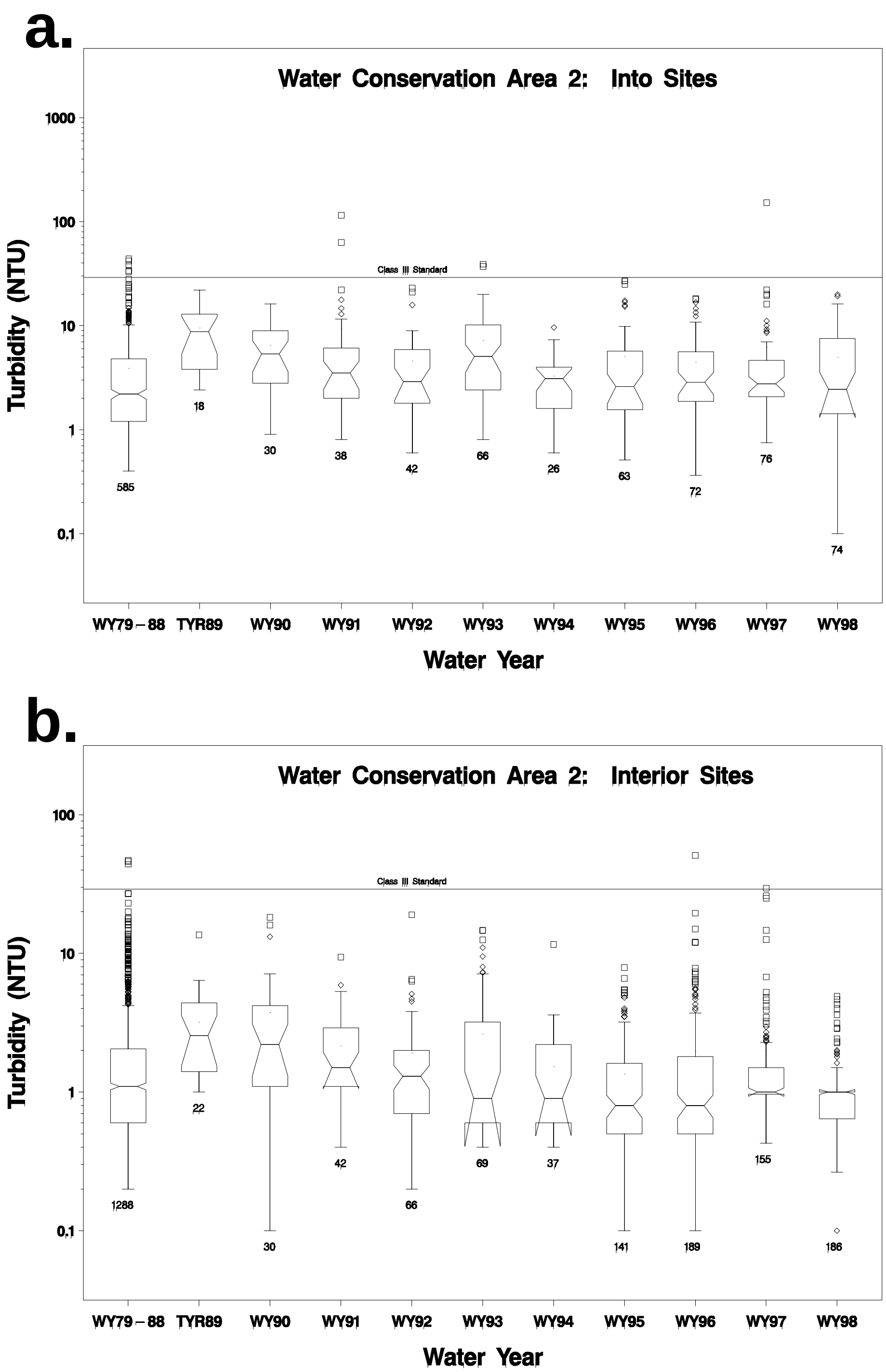


Figure 4-35. Notched box and whisker plots of pH data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Water Conservation Area 3

Total phosphorus. TP loads discharged into Water Conservation Area 3 (WCA-3) for the baseline period and in the recent water years are presented in **Figure 4-36**. The baseline period was 103 metric tons in comparison to loads ranging from 46 metric tons in WY90 to 235 metric tons in WY95. Notched box and whisker plots of TP concentration data from all the current sources show that the median concentrations in WY91 to WY93 were significantly lower than the baseline median concentration, but the increased medians in WY94 to WY97 were not significantly different. In WY98 the median was significantly lower than the baseline median, but not significantly different than the two previous water years **Figure 4-37a)**. The data for the interior sites show a dramatic decrease in median TP concentration from 29 ppb in WY90 to 6 ppb WY96. However, the median concentration increased significantly in WY97 and WY98 to 8 ppb **(Figure 4-37b)**.

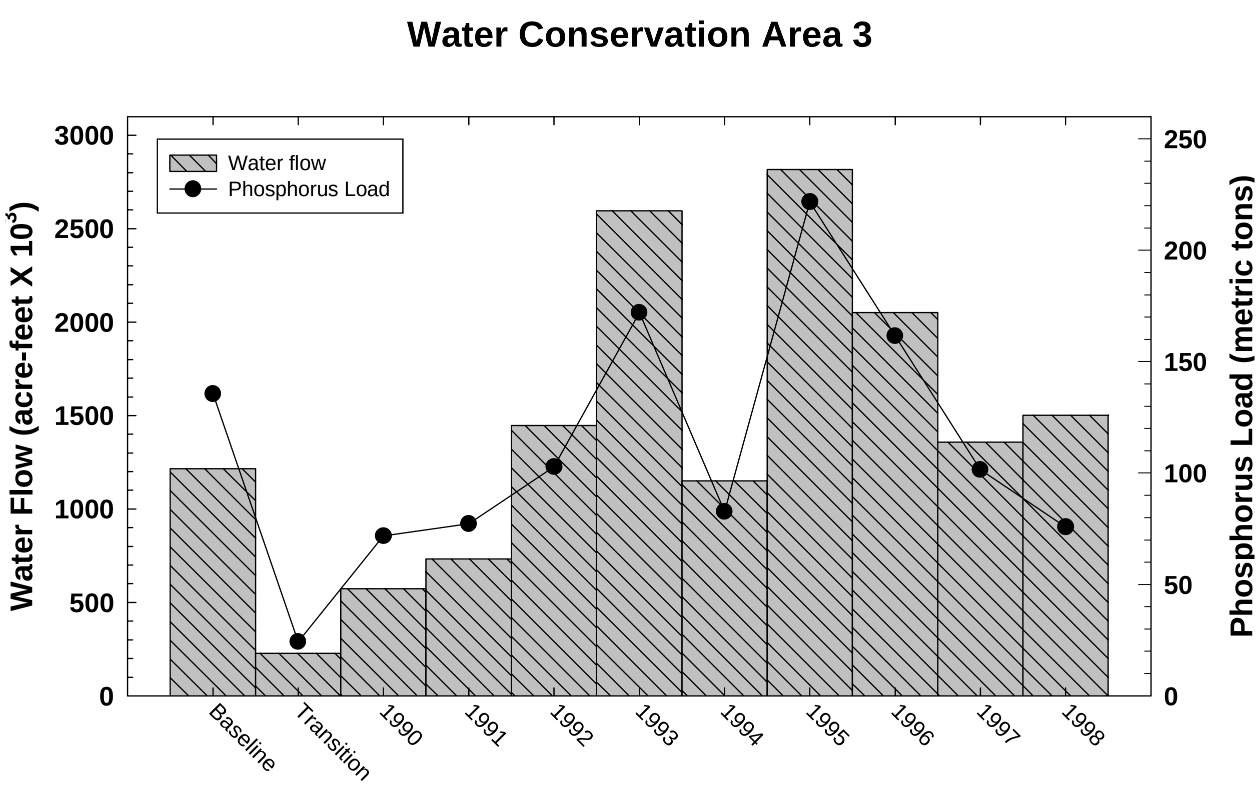


Figure 4-36. Annual flows and P loads to Water Conservation Area 3 from the baseline period through WY98.

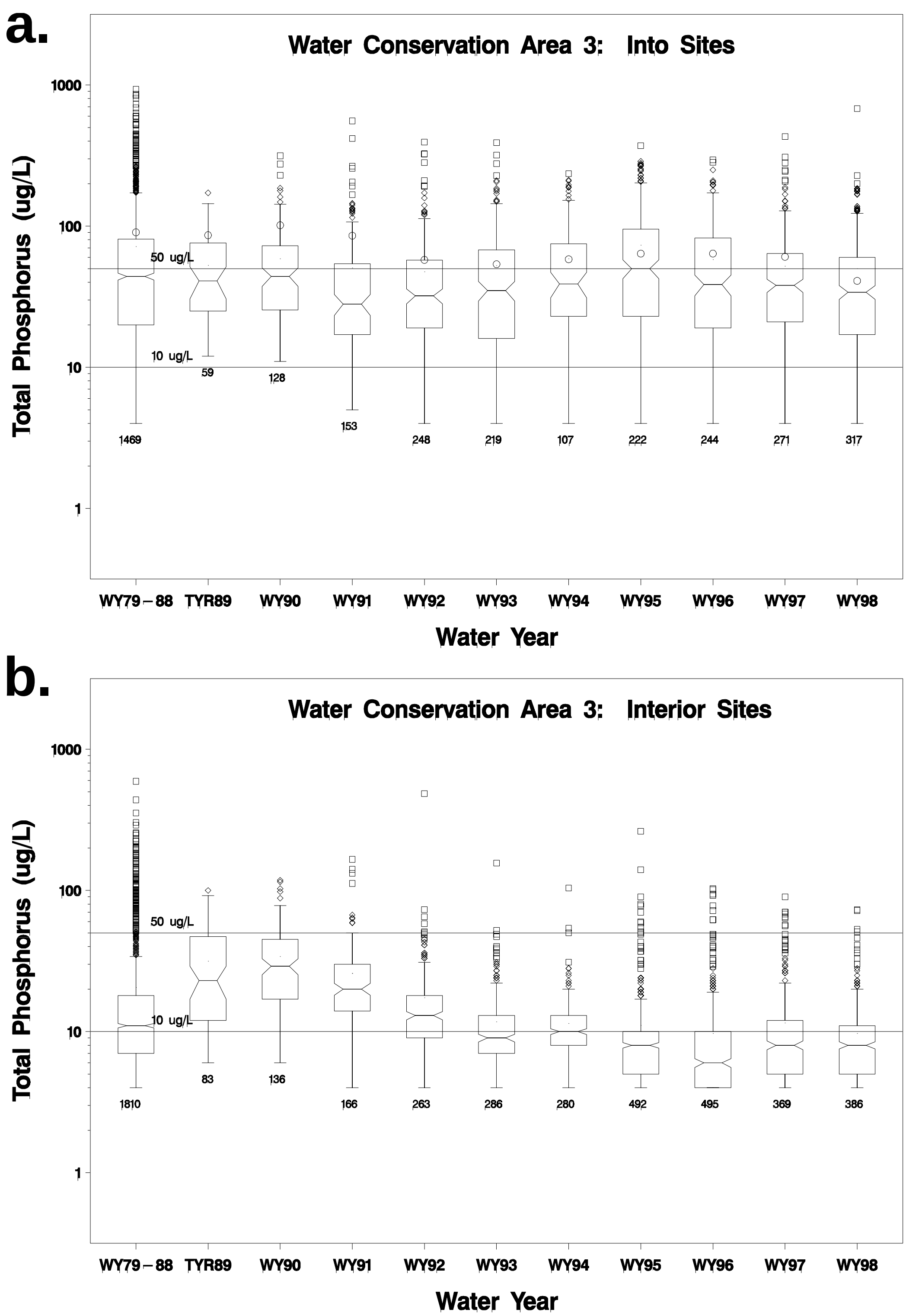


Figure 4-37. Notched box and whisker plots of TP data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Everglades Agricultural Area Runoff to be Treated in STA-3/4. Of the total TP loads shown in **Figure 4-36**, the amount contributed from the S7, S150, S8 and G200 sources is designed to be treated in STA-3/4 (**Figure 4-1**). The Everglades Forever Act, (373.4592 (4) (d) 5., F.S.) requires that "The construction of STA-3/4 shall not be commenced until 90 days after the interim report has been submitted to the governor and the Legislature." This requirement provides time for a mid-course review and evaluation of data generated since the Act was passed (see **Chapter 1** for a more detailed discussion). STA-3/4 is the largest of the STAs, and is designed to treat the combined Everglades Agricultural Area (EAA) runoff from S7, S150, G200 and S8 (minus G88 and G606 flows). A question periodically asked is whether TP concentrations have declined enough from implementation of Best Management Practices in the EAA to render STA-3/4 non-essential to the achievement of long-term compliance with water quality standards.

The amount of TP in the combined flows from the above mentioned EAA sources from October 1978 through June 1998 has been evaluated by Walker (1998). The summary of flow-weighted TP concentrations in the combined flows for this period indicate a tendency towards lower concentrations since 1989 **(Figure 4-38**). The TP concentration data in **Figures 4-39** and **4-40** also show a decline in the proportion of samples with concentration values greater than 100 ppb and a corresponding increase in samples with lower TP levels. In spite of this modest improvement it should be noted that, as of June 1998, approximately 80% of the combined inflows from the four structures had TP concentrations greater than 50 ppb. It is this 80% of the combined EAA runoff that will be treated to less than 50 ppb by STA-3/4. While the long-term standard for TP remains to be set by the Environmental Regulation Commission, existing research suggests that the standard will be well below 50 ppb. These findings clearly demonstrate that the fundamental need for constructing STA-3/4 as a water quality management system remains.

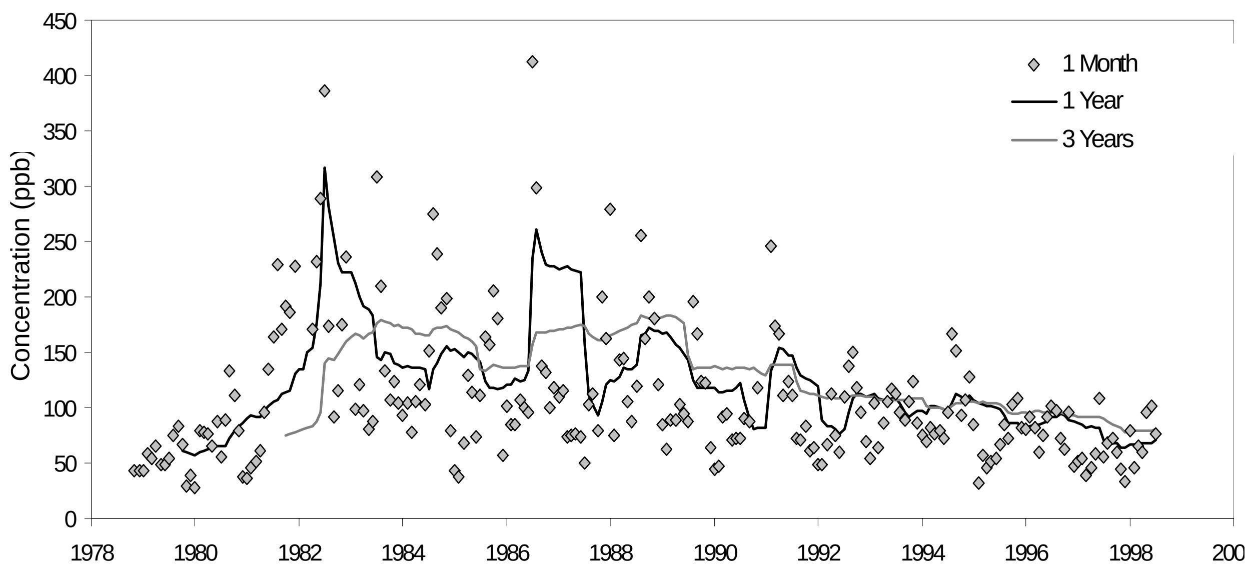


Figure 4-38. TP concentrations in combined EAA Flows through S7, S150, S8 and G200. (From Walker, 1998)

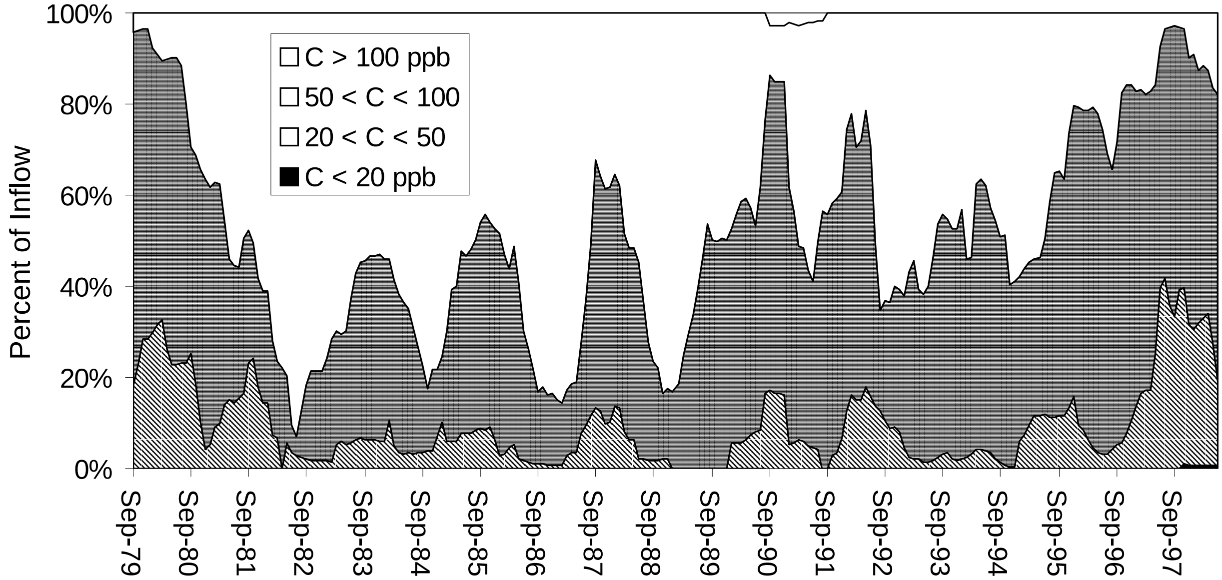


Figure 4-39. Percent of four TP concentration intervals in the combined EAA flows (12-month moving averages. (From Walker, 1998)

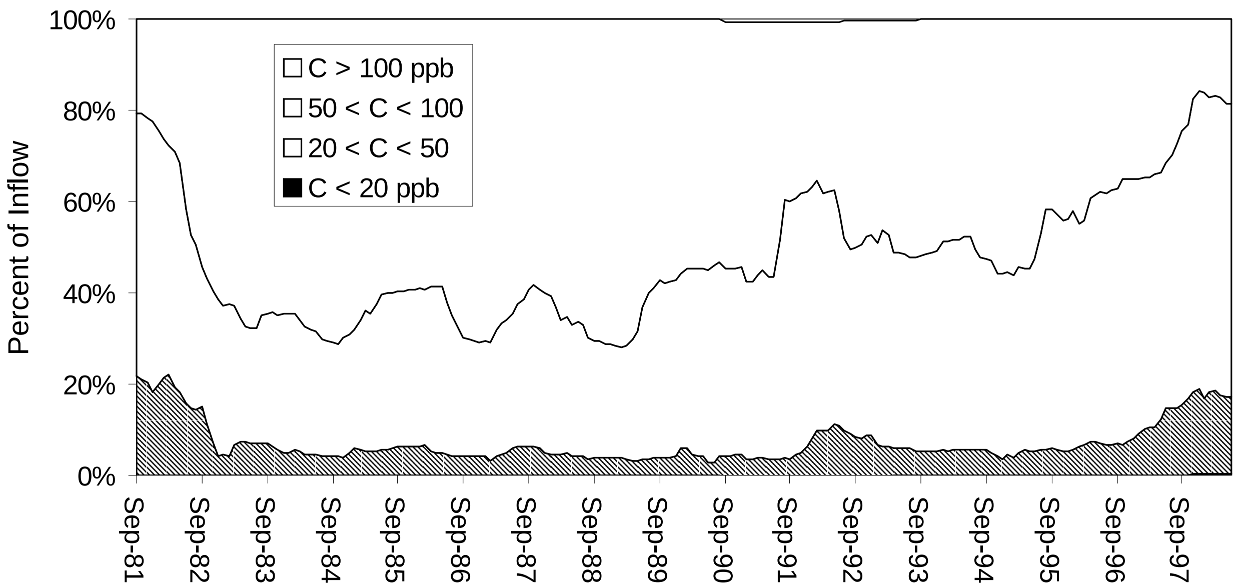


Figure 4-40. Percent of four TP concentration intervals in the combined EAA flows (3-year moving averages. (From Walker, 1998)

Total nitrogen. TN loads discharged into WCA-3 are presented in **Figure 4-41**. The baseline period load was 3300 metric tons. The TN loads varied from 1600 metric tons in WY90 to 7550 metric tons in WY95. Notched box and whisker plots of median TN concentration data from the inflow sources indicate that the concentrations in the recent water years were all significantly lower than the baseline period median concentration of 2.2 mg/L (**Figure 4-42a**). There has been a steady increase in the median TN concentration from 1.5 mg/L in WY90 to 1.9 mg/L in WY98. The median concentrations in WY97 andWY98 were significantly higher than the WY90 median concentration. The median TN concentration data from the interior sites were also all significantly lower than the baseline period median TN concentration. In contrast to the inflow source data, the median concentrations in the interior sites have steadily declined from 1.5 mg/L in WY90 to 1.2 mg/L in WY98. The median concentrations from WY95 to WY98 are significantly lower than WY90 (**Figure 4-42b**).

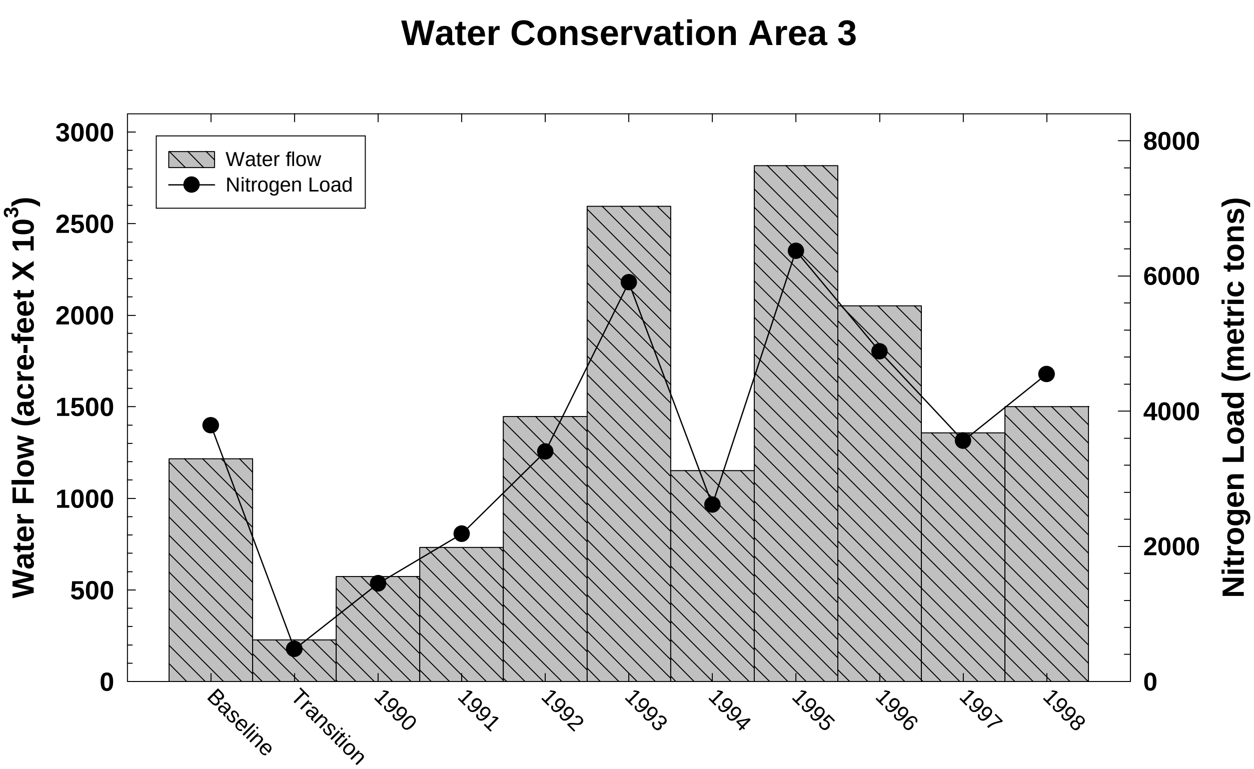


Figure 4-41. Annual flows and nitrogen loads to Water Conservation Area 3 from the baseline period through WY98.

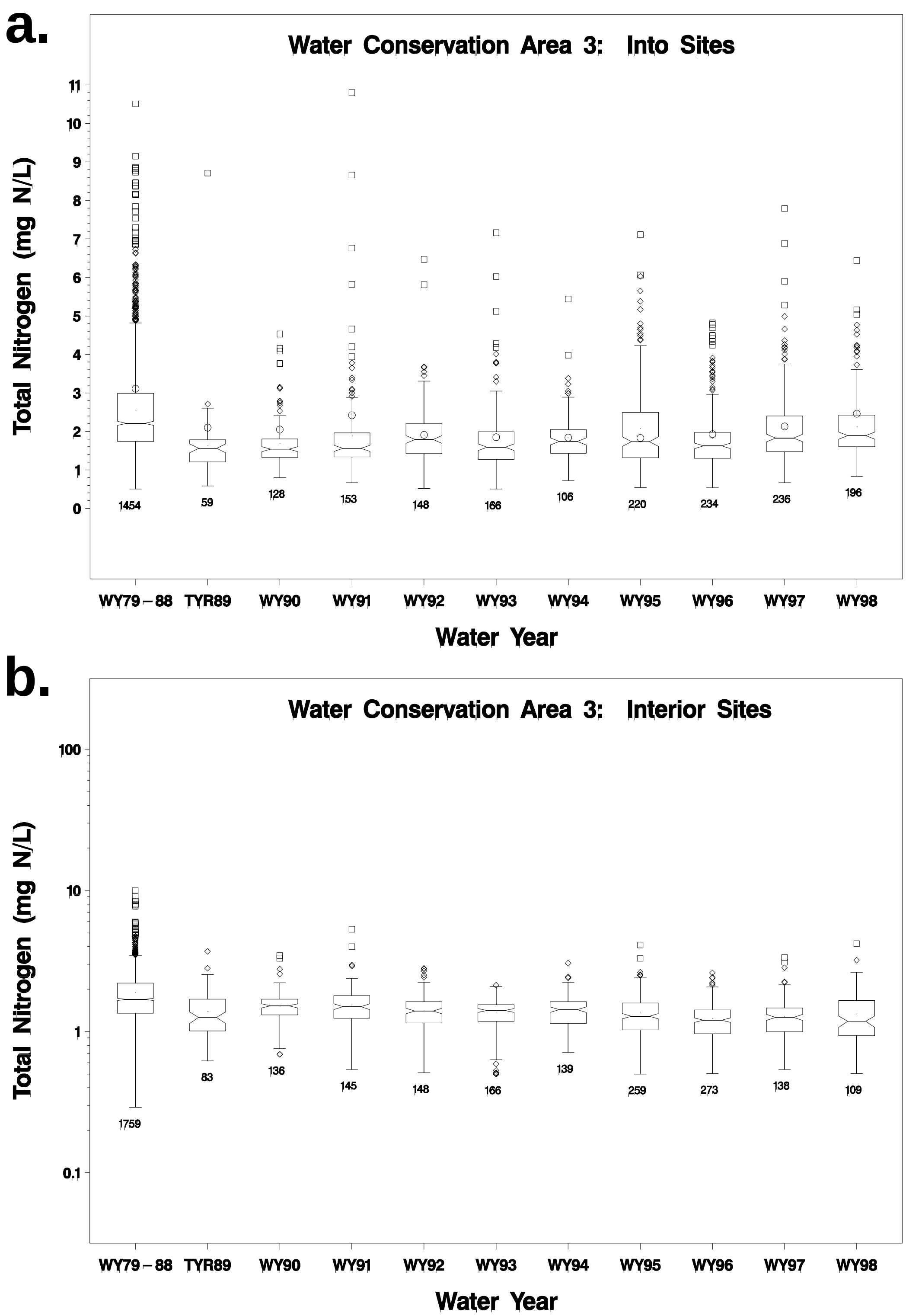


Figure 4-42. Notched box and whisker plots of nitrogen data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Un-ionized ammonia. Un-ionized ammonia has been detected above the 0.02 mg/L criterion since the baseline period once in 1998 at an inflow site (**Figure 4-43a**). As with the un-ionized ammonia data in WCA-2, the minimum median concentration in WY92 corresponds with a minimum pH. Other than the decreasing and increasing median concentrations before and after the WY92 minimum median concentration, there were no significant longer-term trends. The interior sites also show a decreasing and increasing change in median concentrations around WY92 (**Figure 4-43b**). The median concentrations in WY96, WY97 and WY98 were significantly higher than the baseline period median concentration. There was one excursion since the baseline period above the 0.02 mg/L criterion in WY91.

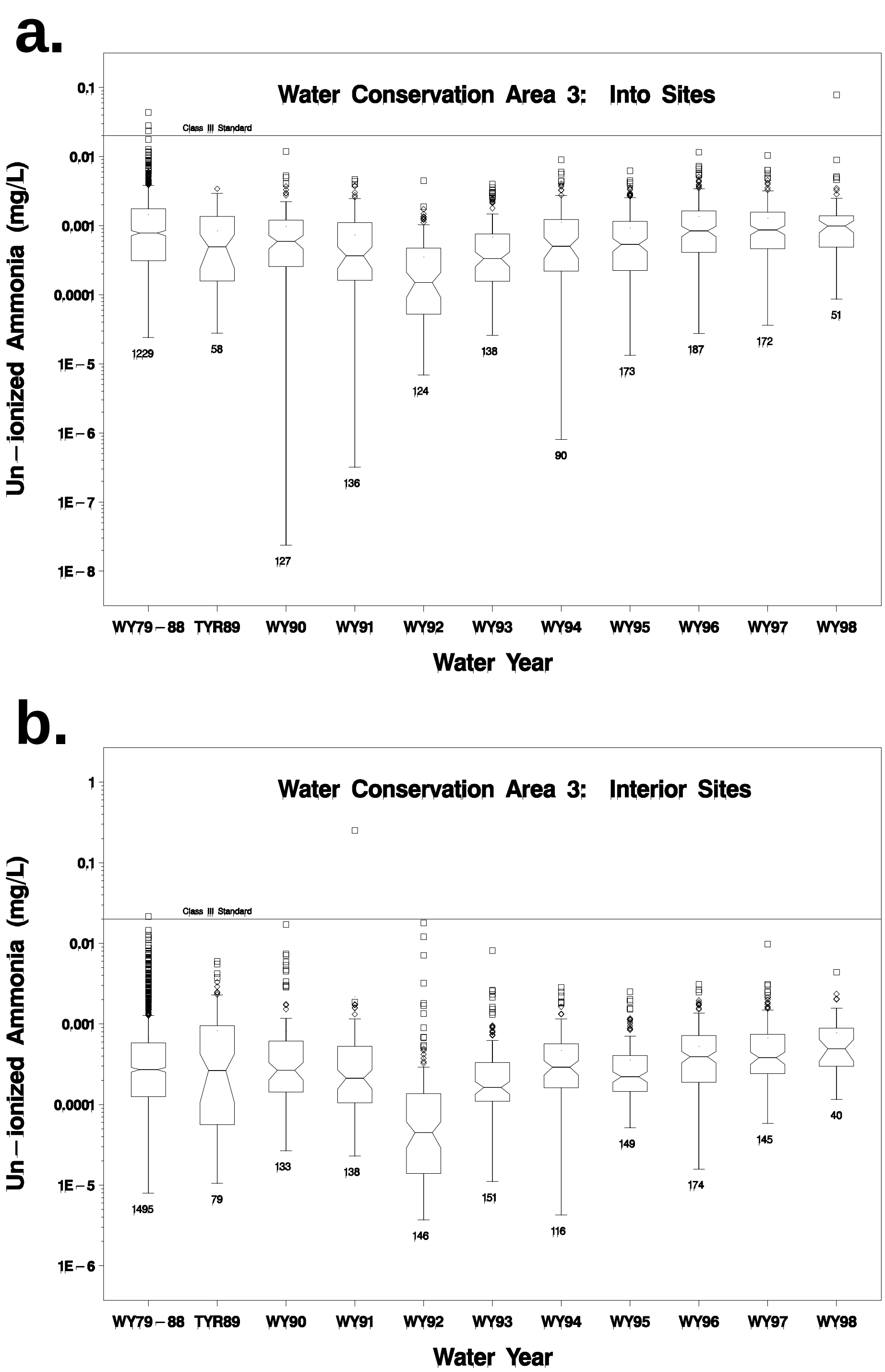


Figure 4-43. Notched box and whisker plots of un-ionized ammonia data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Specific conductance. The specific conductance at the inflow sites to WCA-3 has been significantly lower in all water years since the baseline period. There have been no excursions above the 1275 µmho/cm criterion since WY91 (**Figure 4-44a**). The median specific conductance values were relatively stable in the recent water years. Specific conductance at the interior sites was both significantly less than and greater than the baseline median value of 523 µmhos/cm in the recent water years, but there were no long-term trends (**Figure 4-44b**). There have been no excursions since the baseline period.

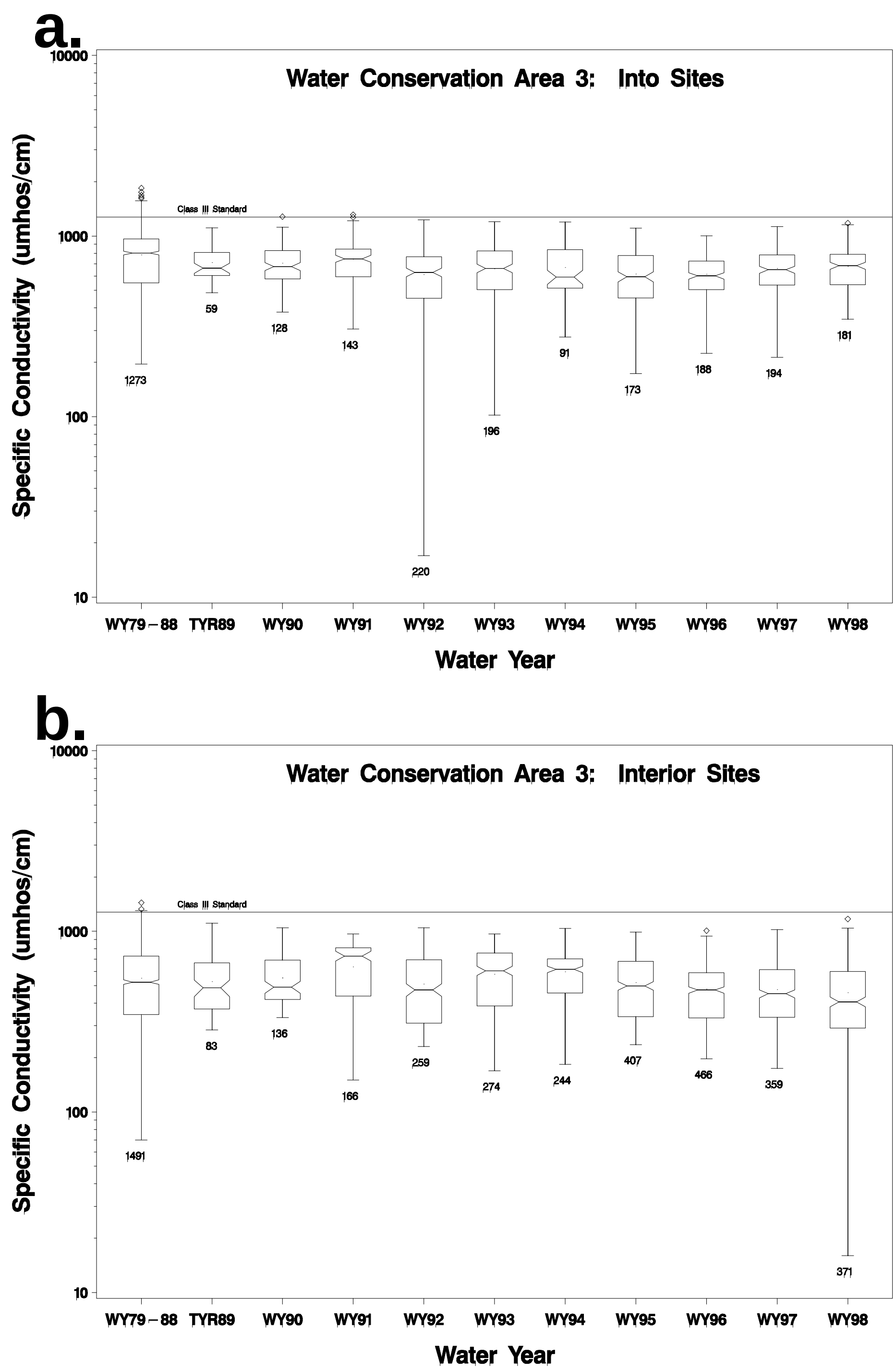


Figure 4-44. Notched box and whisker plots of specific conductance data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

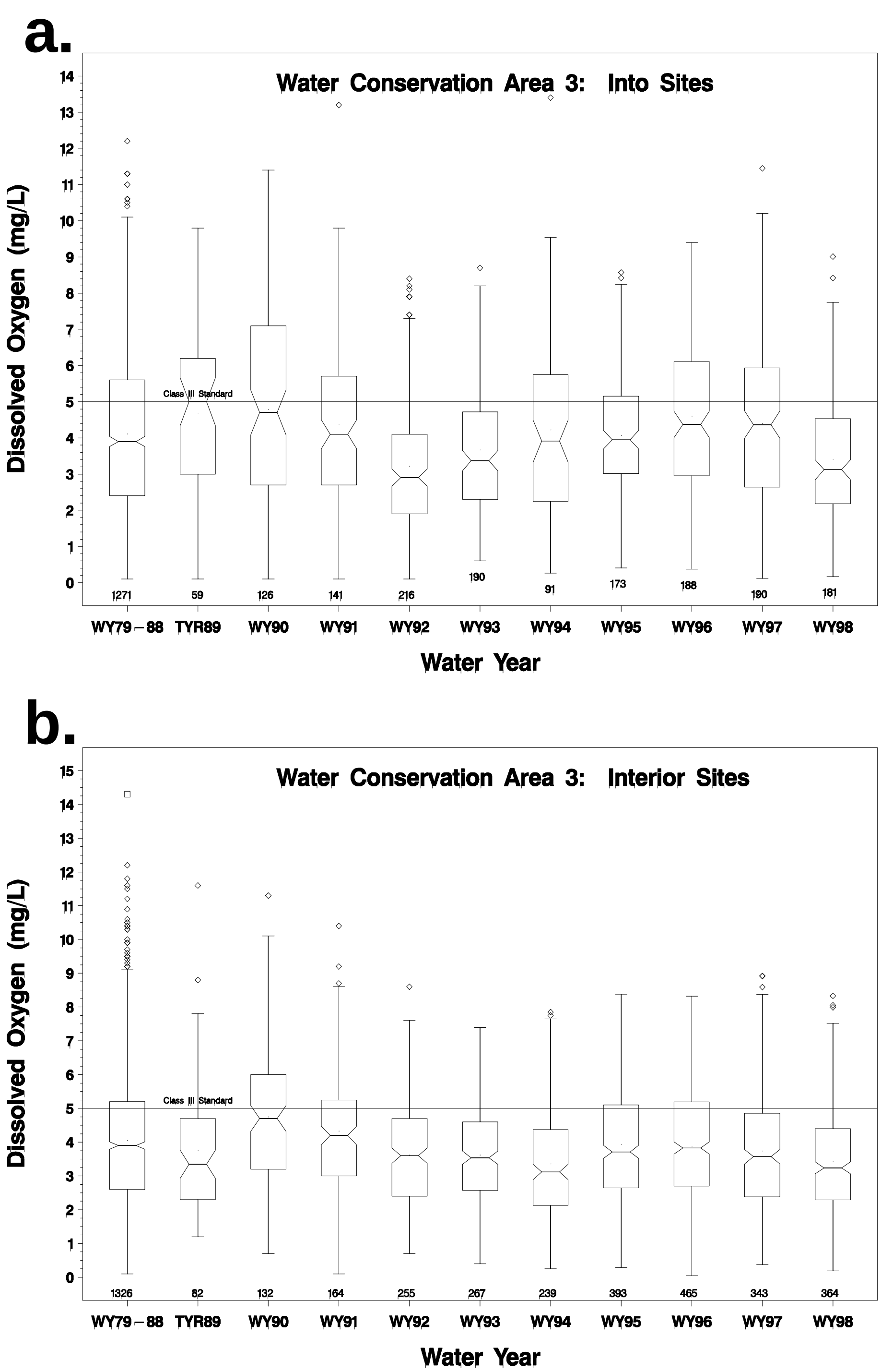


Figure 4-45. Notched box and whisker plots of dissolved oxygen data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Dissolved oxygen. Greater than 50% of the water discharged into WCA-3 and more than 75% of the water at the interior sites is less than the 5.0 mg/L criterion for dissolved oxygen (**Figures 4-45a and b**). Median dissolved oxygen concentrations have been both significantly less than and greater than the baseline period median concentration of 3.9, but no long-term trend exists at either the inflow or interior sites.

pH. As was observed in the Refuge and WCA-2, pH in WCA-3 decreases from WY90 to WY92 and then increases **(Figures 4-46a and b)**. No long-term trends exist and the median pH at both the inflow and interior sites in WY98, 7.23 and 7.21 respectively, are not significantly different from the baseline median pH values.

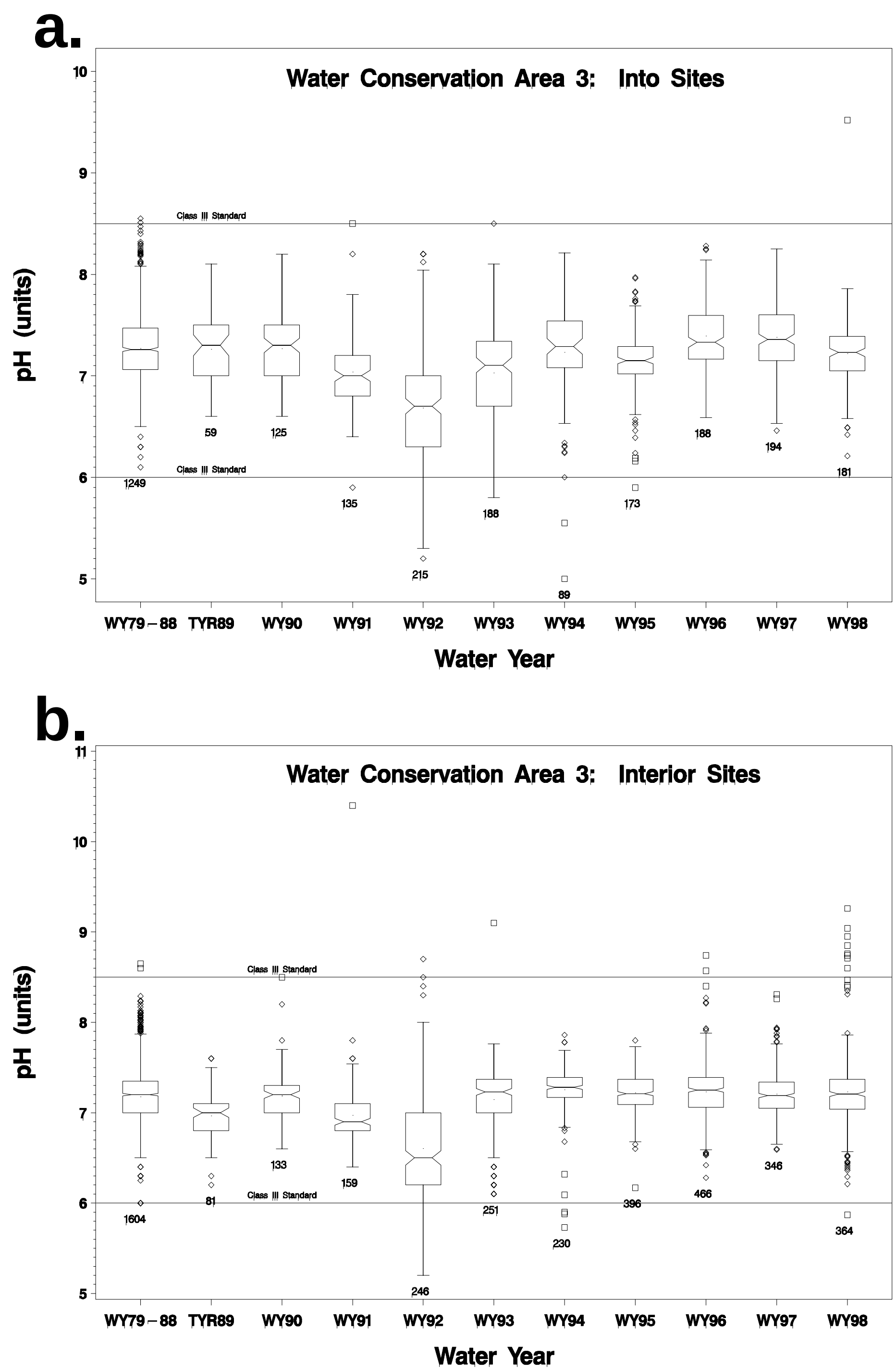


Figure 4-46. Notched box and whisker plots of pH data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Alkalinity. The median alkalinity concentrations at the inflow sites during the baseline period and in the recent water years were significantly higher than the median concentrations at the interior sites for these same periods, with the exception of WY91 (**Figures 4-47a and b**). At the inflow sites, the median concentrations were significantly lower than the baseline period from WY90 to WY96. At the interior sites only WY96 through WY98 had significantly lower median concentrations than the baseline period.

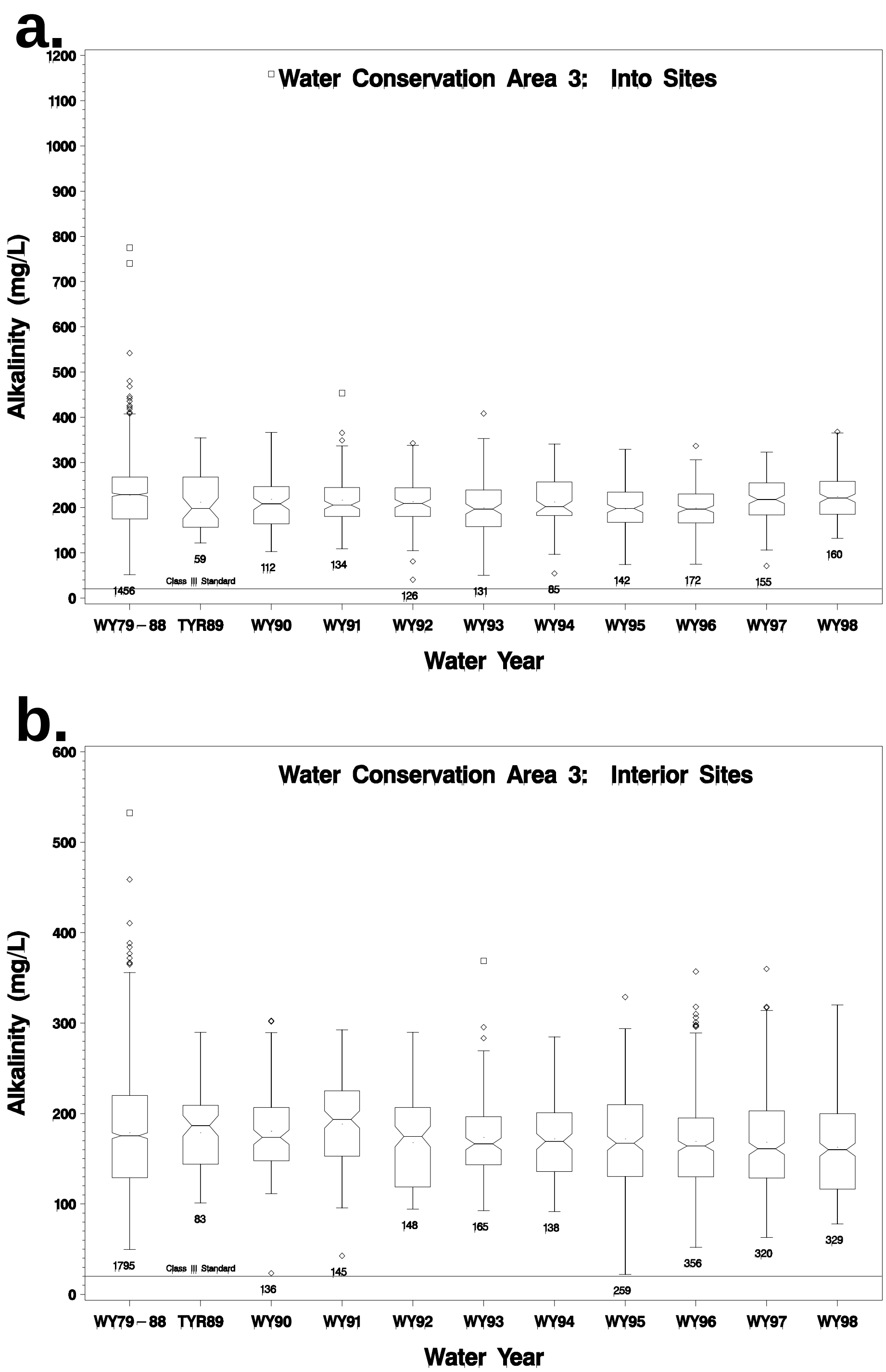


Figure 4-47. Notched box and whisker plots of alkalinity data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Turbidity. The median turbidity values at the inflow sites have been both significantly higher and lower than the baseline period, but there has been no long-term trend. There have been 10 excursions above the 29 NTU criterion since the baseline period (**Figure 4-48a**). At the interior sites, median turbidity values are less than the inflow medians but the data are more variable (**Figure 4-48b**). There have been three excursions since the baseline period. The median turbidity value of 2.4 NTU in WY90 was significantly greater than the baseline period. Thereafter there was a significant decreasing trend through WY96 to 0.79 NTU. The median values in WY97 and WY98 were not significantly different from the baseline period.

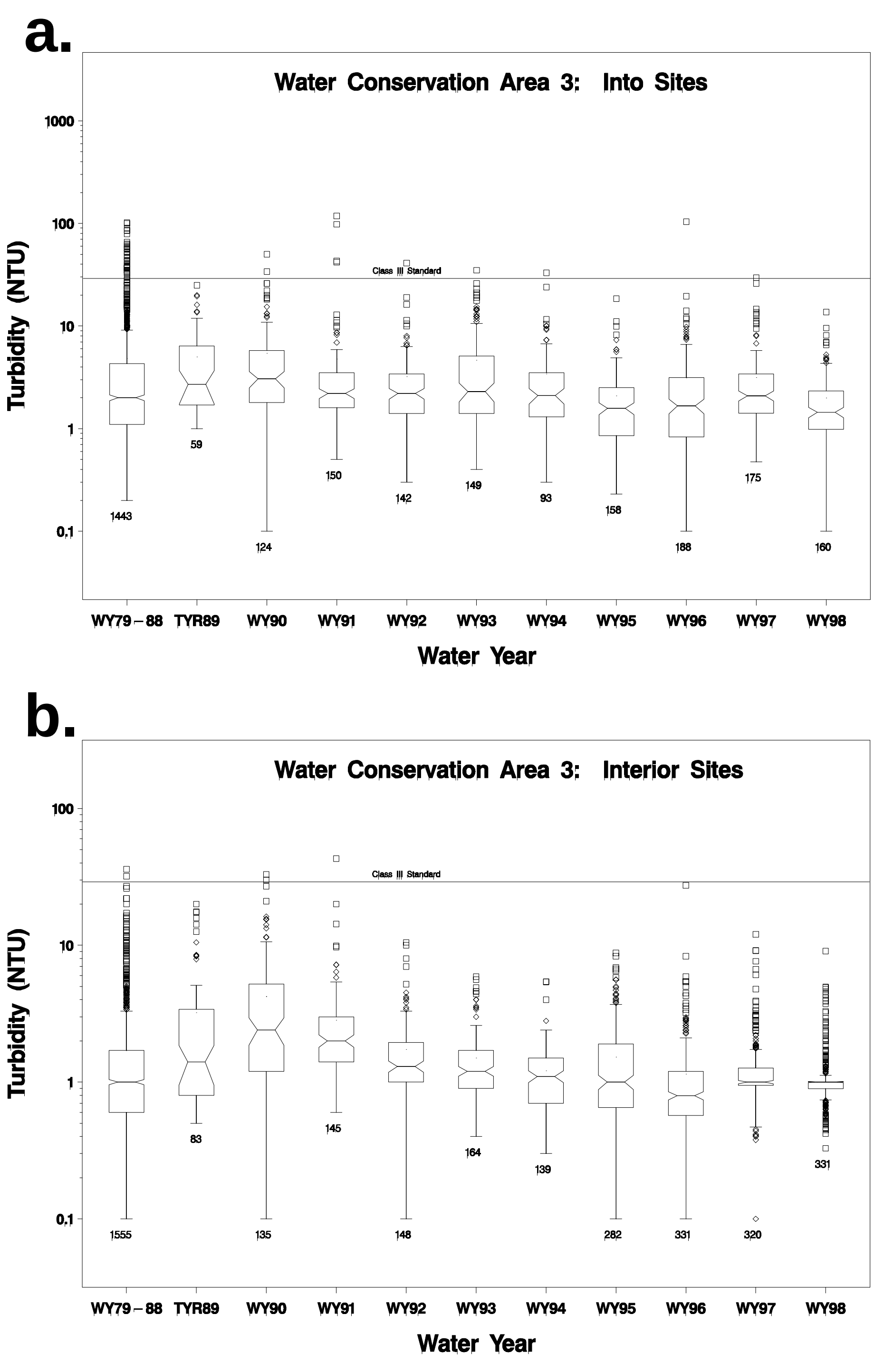


Figure 4-48. Notched box and whisker plots of turbidity data collected within Water Conservation Area 3 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Everglades National Park

Total phosphorus. TP loads discharged into the Everglades National Park (Park) for the baseline period and in the recent water years are presented in **Figure 4-49**. In contrast to the Refuge, WCA-2 and WCA-3, the loads at the Park inflow sites do not change as dramatically with flow. However, a comparison of **Figures 4-49** and **4-50** does support the finding that higher TP concentrations were associated with periods of low flow during and after the 1989-1990 drought. In comparison to the baseline period load of 15 metric tons, loads in the recent water years varied from 4.4 metric tons in WY90 to 21.5 metric tons in WY95. The total load during this nine-year period was 108 metric tons and the average per year was 12 metric tons. Notched box and whisker plots of TP concentration data from the inflow sources show that the median concentrations in WY90 and WY91 were significantly higher than the baseline period. A decreasing trend in median concentrations from 19 ppb in WY90 to 5 ppb in WY96 is evident. The medians in WY97 and WY98 were 7 ppb (**Figure 4-50a**). The baseline median of the interior sites was 7 ppb. The median TP concentrations at the interior sites have decreased from 8 ppb in WY92 to the MDL of 4 ppb or lower in WY96 through WY98. All TP Values less than the MDL were assigned a value of 4 ppb for statistical and graphical purposes in this report, thereby providing a conservative estimate of low TP concentrations. These last three water years are significantly lower than the baseline period (**Figure 4-50b**).

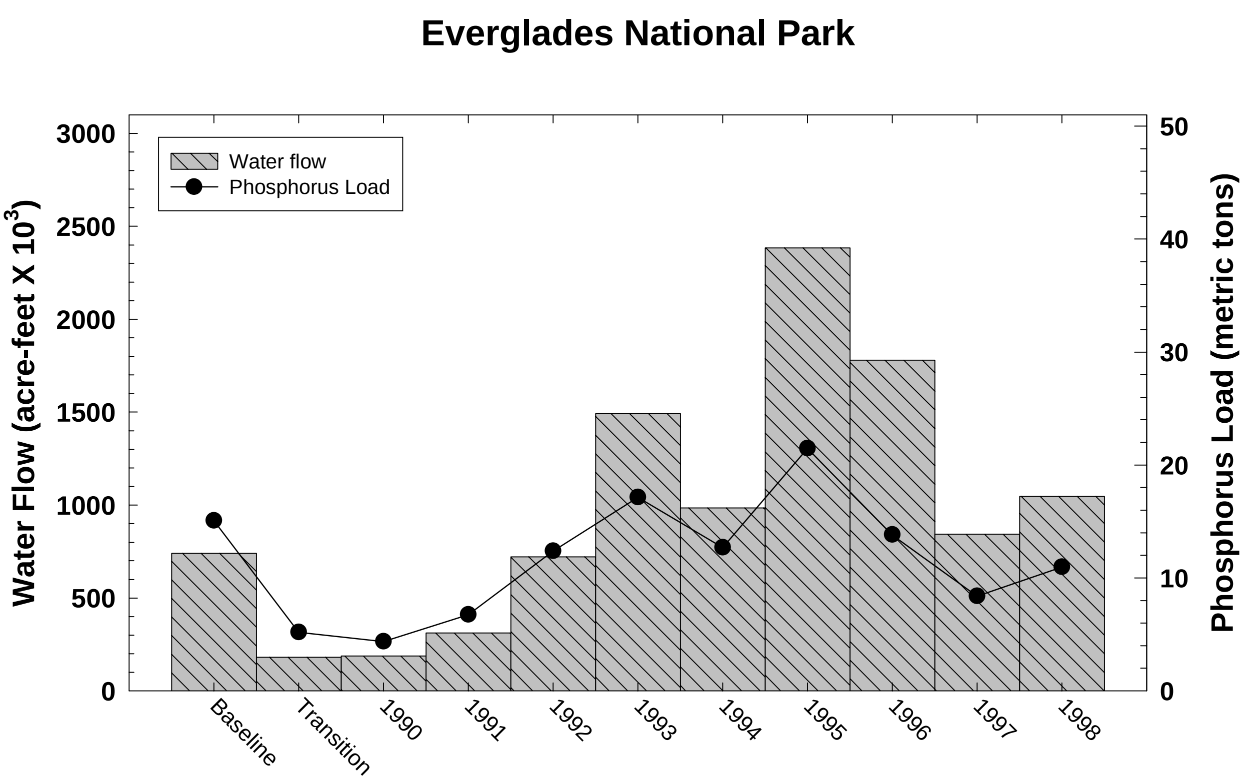


Figure 4-49. Annual flows and TP loads to Everglades National Park from the baseline period through WY98. Note that the scale used for P load is 0-50 rather than 0-250 used for other areas in the Everglades Protection Area.

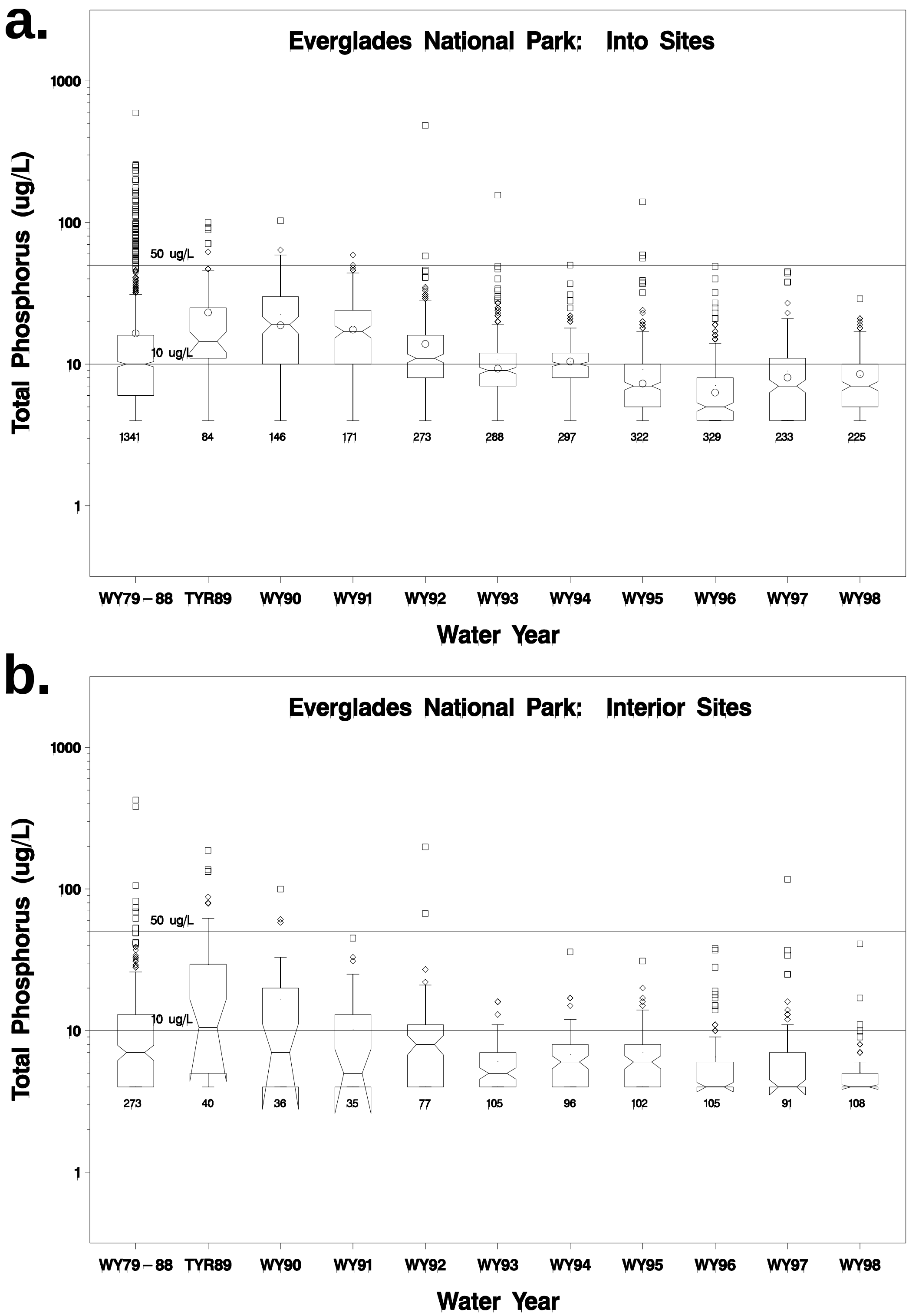


Figure 4-50. Notched box and whisker plots of TP data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

As required by the Settlement Agreement (1991), the District's "Water Quality Conditions Quarterly Report" provides an update of TP concentrations discharged into the Park through Shark River Slough and Taylor Slough. Shark River Slough has both interim and long-term TP discharge limits calculated from equations that vary with inflow through the S12 structures and S333. Taylor Slough, which receives inflow from S332 and S175, and the Coastal Basins, which receive inflow from S18C, have a fixed TP limit of 11 ppb. The TP data from biweekly sampling at each structure are converted into 12-month moving, flow-weighted, mean concentrations, and compared to the calculated limits. Results are reported to the Settlement Agreement Technical Oversight Committee, composed of signatory agencies to the Settlement Agreement (1991).

Total nitrogen. TN loads discharged into the Park for the baseline period and in the recent water years are presented in **Figure 4-51**. The baseline period load was 1525 metric tons, while the loads varied from 266 metric tons in WY90 to 3562 metric tons in WY95. The total load during this nine-year period was 14,900 metric tons and the average per year was 1656 metric tons. Notched box and whisker plots of TN concentration data from the inflow sources indicate that the median TN concentrations were significantly lower than the baseline median concentration of 1.5 mg/L. The median concentrations in WY95 to WY98 were significantly lower than WY90 **(Figure 4-52a)**. The TN median concentrations at the interior sites in recent water years essentially varied about the baseline period median of 1.32 mg/L, with no significant differences (**Figure 4-52b)**.

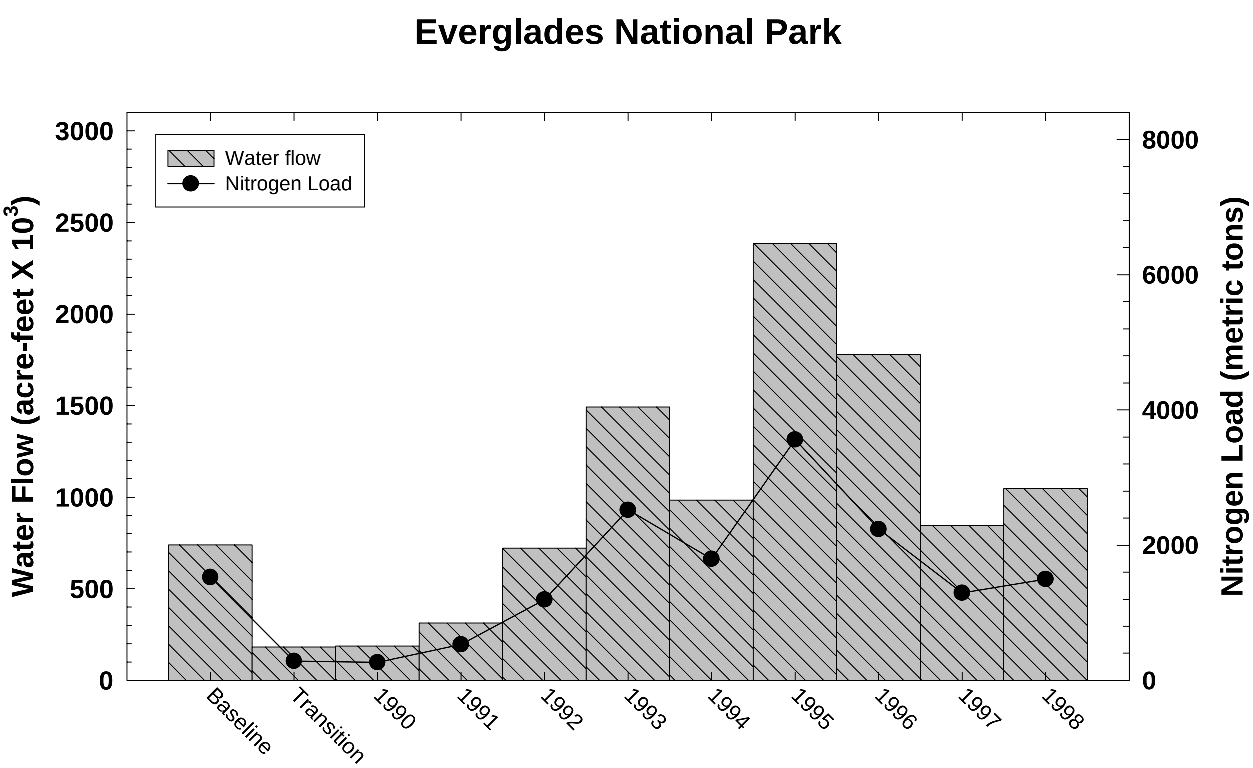


Figure 4-51. Annual flows and nitrogen loads to Everglades National Park from the baseline period through WY98.

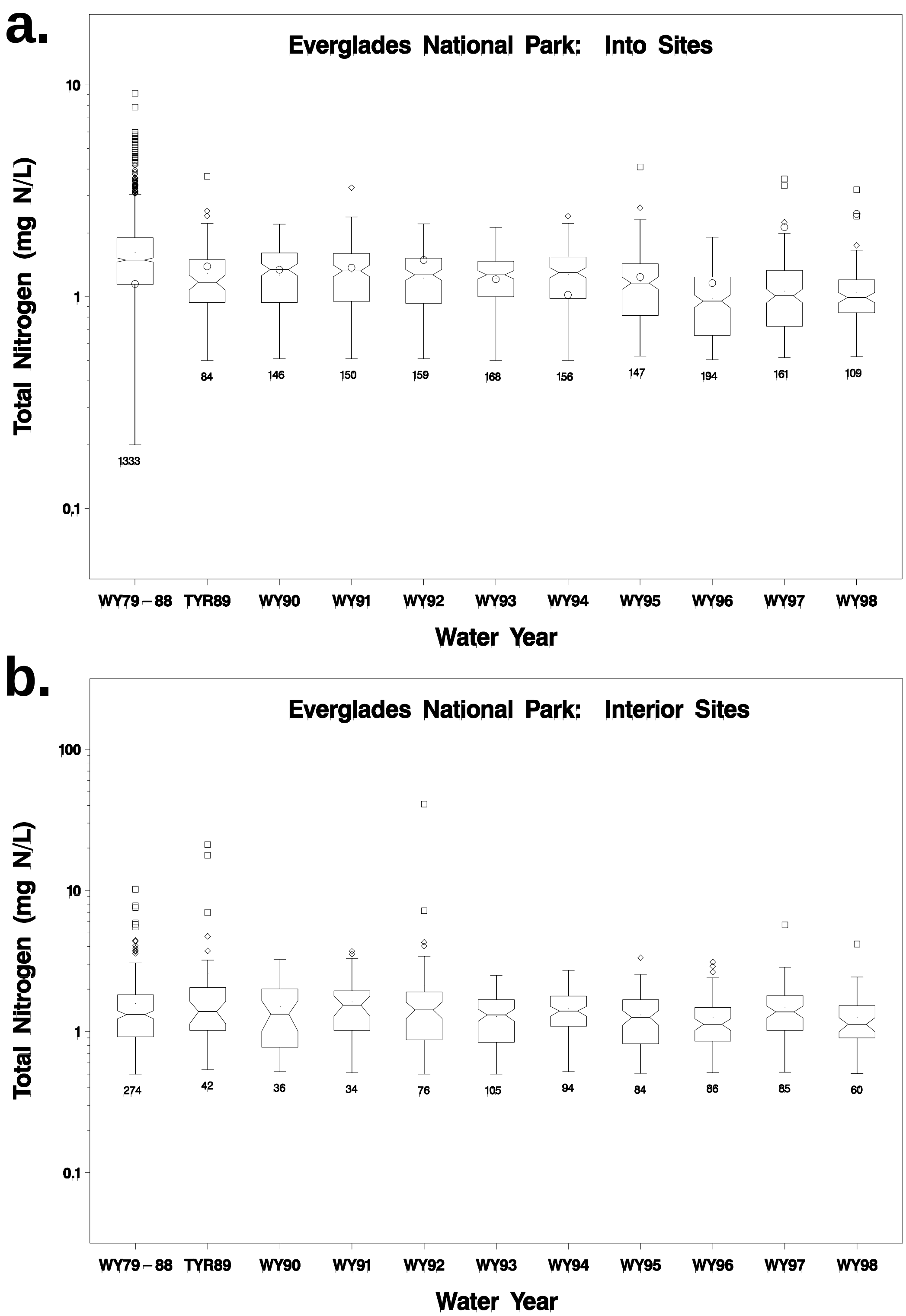


Figure 4-52. Notched box and whisker plots of nitrogen data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

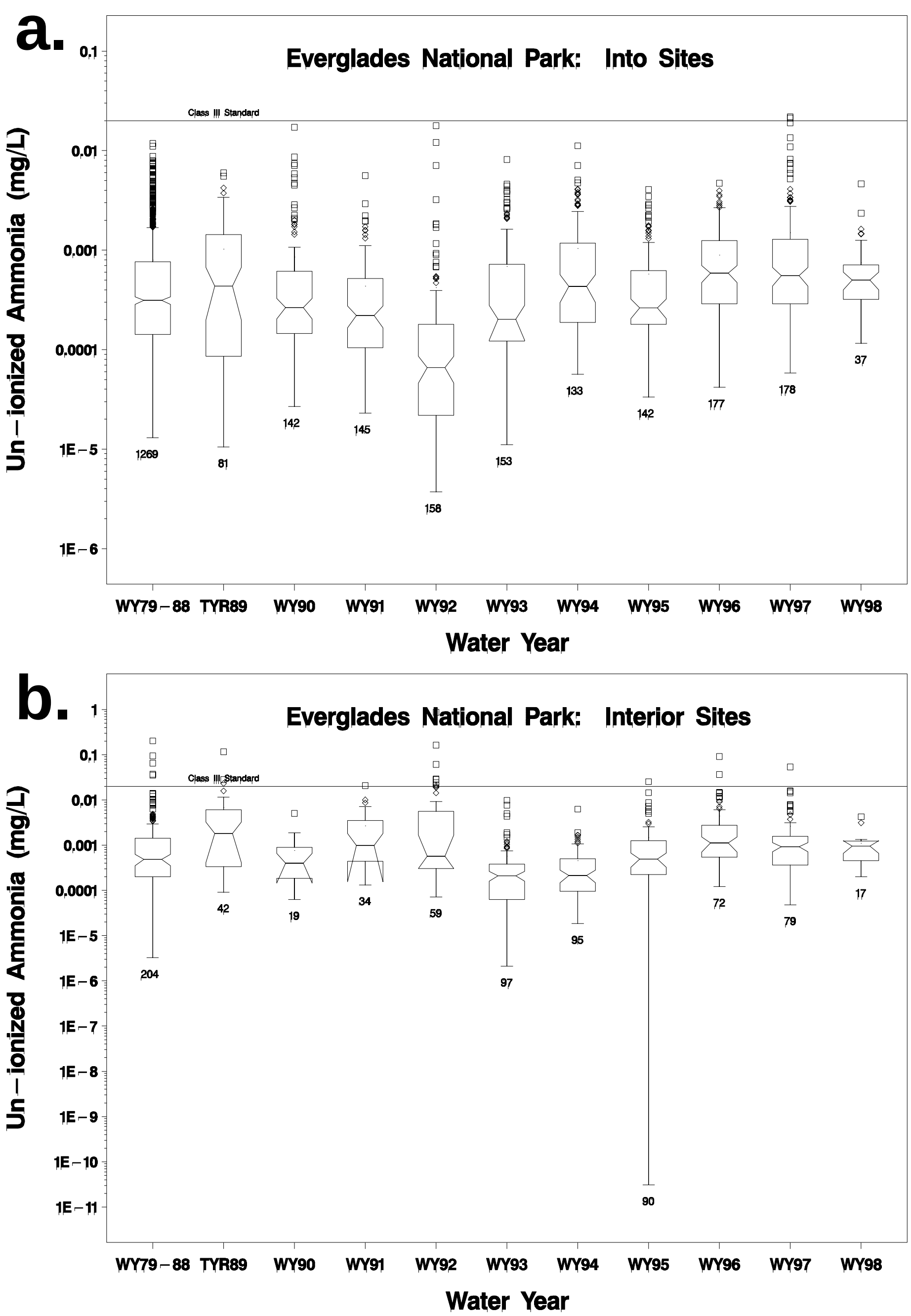


Figure 4-53. Notched box and whisker plots of un-ionized ammonia data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Un-ionized ammonia. As was observed in WCA-2 and WCA-3, a minimum median un-ionized ammonia concentration occurred in WY92 in the Park inflows, which corresponded with a minimum inflow pH **(Figures 4-53a and 2-56a)**. The baseline period median concentration was 0.0003 mg/L, compared with significantly greater median concentrations in WY96 through WY98 that appear not to be influenced by varying pH values. One excursion with a calculated concentration of 0.022 mg/L occurred in WY97. In contrast to the inflow data, the interior sites had minimum median un-ionized ammonia concentrations in WY93 and WY94 that corresponded to the lowest annual median pH values observed **(Figures 4-53b and 2-56b)**. The median concentrations at the interior sites in WY96 through WY98 were also significantly greater than the baseline period of 0.0005 mg/L. With the exception of WY94, the interior site median concentrations were higher than the inflow median concentrations. In addition, the number of excursions increased from five in the baseline period, to 12 in recent water years. These observations correlate with higher median pH values at the interior sites than at the inflow sites except in WY93 and WY94.

Specific conductance. Specific conductance at the inflow sites to the Park had a baseline period value of 472 µmhos/cm. The range of values in recent water years was from 458 µmhos/cm in WY98 to 578 µmhos/cm in WY94. The data indicate there have been no specific conductance excursions in inflows to the Park **(Figure 4-54a)**. The median specific conductance at the interior sites for the baseline period was 460 µmhos/cm, with median values ranging from 442 µmhos/cm in WY96, to 603 µmhos/cm in WY90. There have been a number of excursions at interior site P35, possibly due to upwelling of groundwater, and one at site EP in WY97, where salinity intrusion from Florida Bay occurs during dry periods **(Figure 4-54b)**.

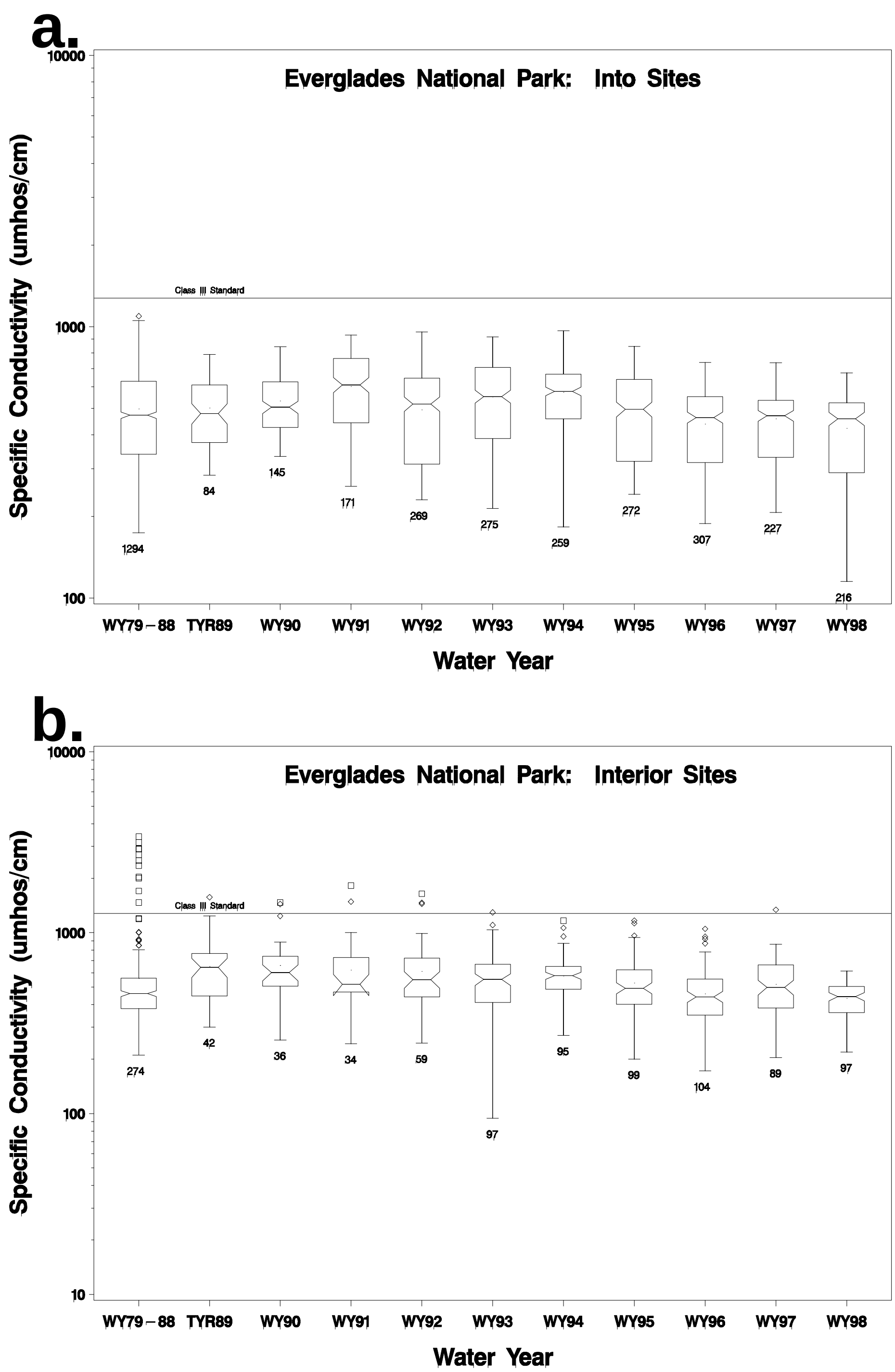


Figure 4-54. Notched box and whisker plots of specific conductance data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Dissolved oxygen. The large majority of the water discharged into the Park is less than the 5.0 mg/L criterion **(Figure 4-55a)**. The median dissolved oxygen concentration for the baseline period was 3.9 mg/L. The median concentration was 5.0 mg/L in WY90, decreased to 3.1 in WY94, increased to 4.5 mg/L in WY97, and then decreased again to 3.4 in WY98. The median dissolved oxygen concentrations in WY95 through WY97 were significantly higher than the baseline median, whereas the WY98 median concentration was significantly lower than the baseline median. In contrast to the inflow data, the interior dissolved oxygen concentrations have been significantly better since WY92 except in WY97 **(Figure 4-55b)**. The interior sites had the highest median concentrations in WY93 and WY95. The median concentrations decreased significantly in WY96 through WY98. The dissolved oxygen data in WY98 were very similar to the data from the baseline period and WY90. At present, we do not have an explanation for the cyclical nature of either the inflow or the interior dissolved oxygen data. This cyclic pattern also can be observed in the Refuge (**Figure 4-20**), WCA-2 (**Figure 4-31**) and WCA-3 (**Figure 4-45**). We plan to address the causes for this cyclical pattern in next year's report.

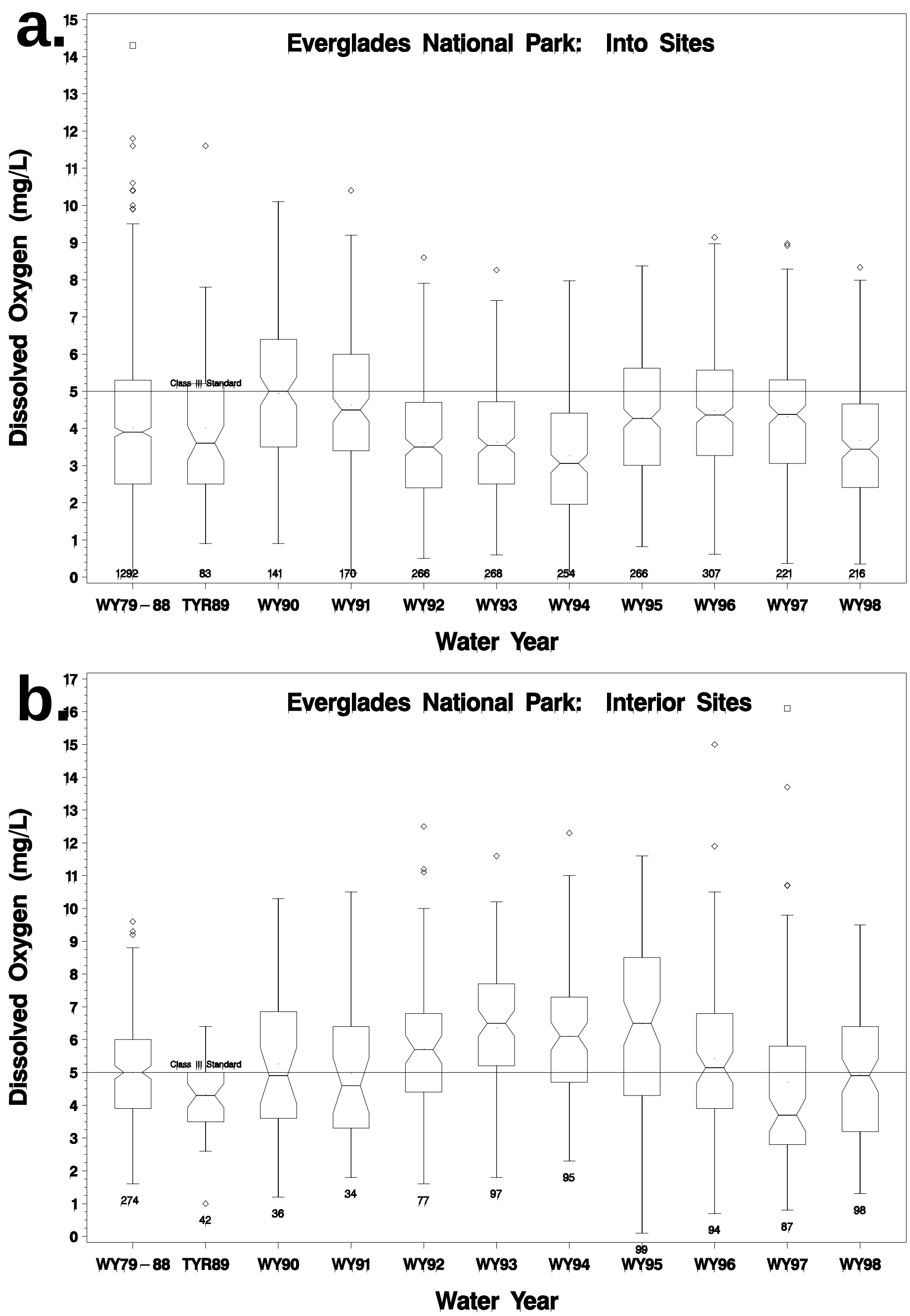


Figure 4-55. Notched box and whisker plots of dissolved oxygen data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

pH. As mentioned in the discussion of un-ionized ammonia data, the pH of the inflows to the Park in WY92 was significantly lower (pH 6.6) than the baseline period (pH of 7.2) and any other water year **(Figure 4-56a)**. In comparison to the baseline period, pH in WY91 was also significantly lower. From WY93 through WY98 the system seems to have shifted several tenths of a pH unit higher. The median values during this period ranged from 7.32 in WY95 and WY96, to 7.22 in WY98. The median pH values of the inflows from WY94 through WY97 were significantly higher than the baseline period. Excursions of both the upper and lower pH criteria occurred in the inflows. The median pH of the Park interior waters was significantly greater than the median pH of the inflows except for WY93 and WY94 during which the medians decreased to 7.1 and 7.0, respectively **(Figure 4-56b)**. The remainder of the water year pH medians ranged from 7.5 to 7.7. The baseline period median pH was 7.5. There have also been excursions of both the upper and lower pH criteria in the interior waters.

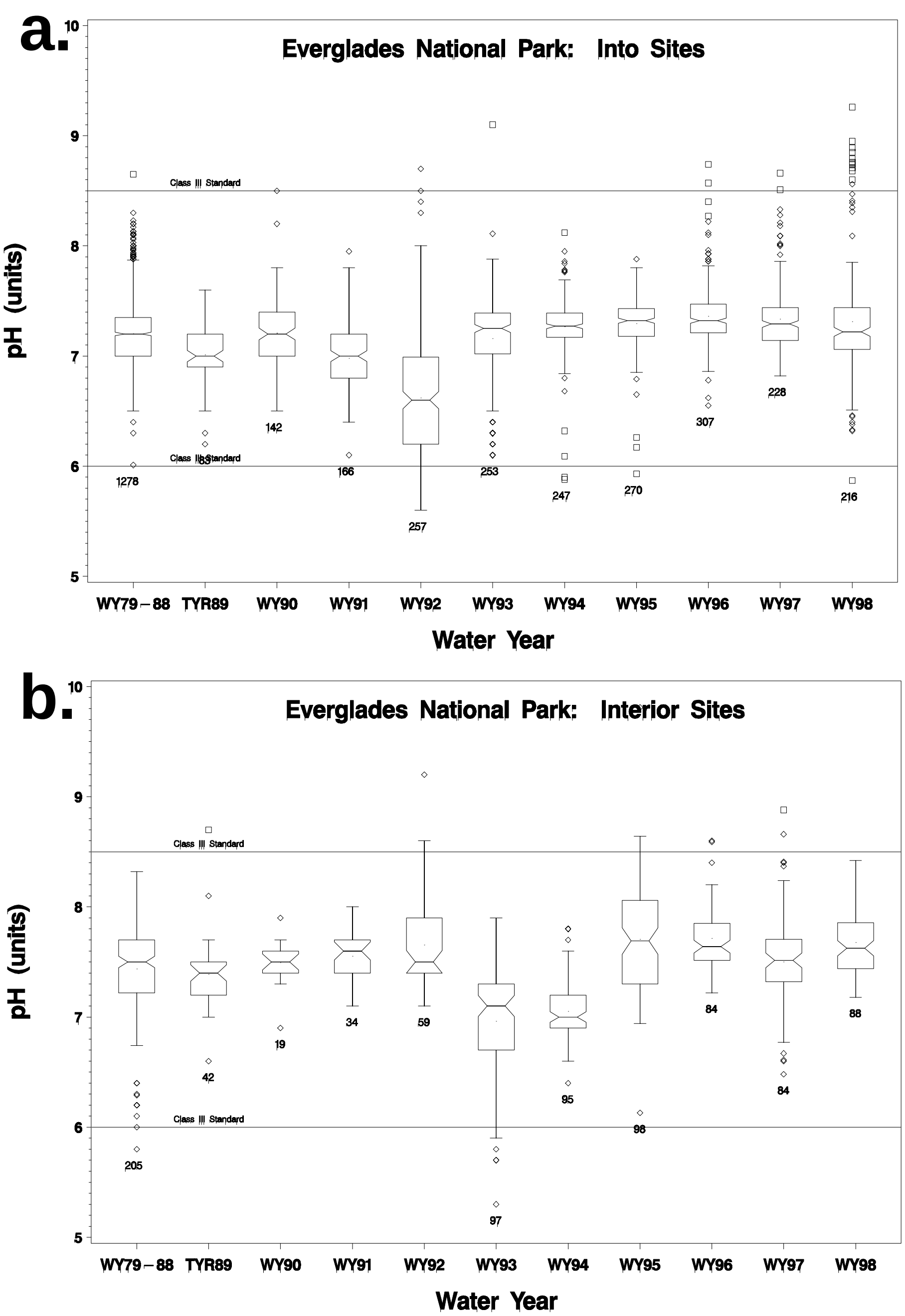


Figure 4-56. Notched box and whisker plots of pH data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

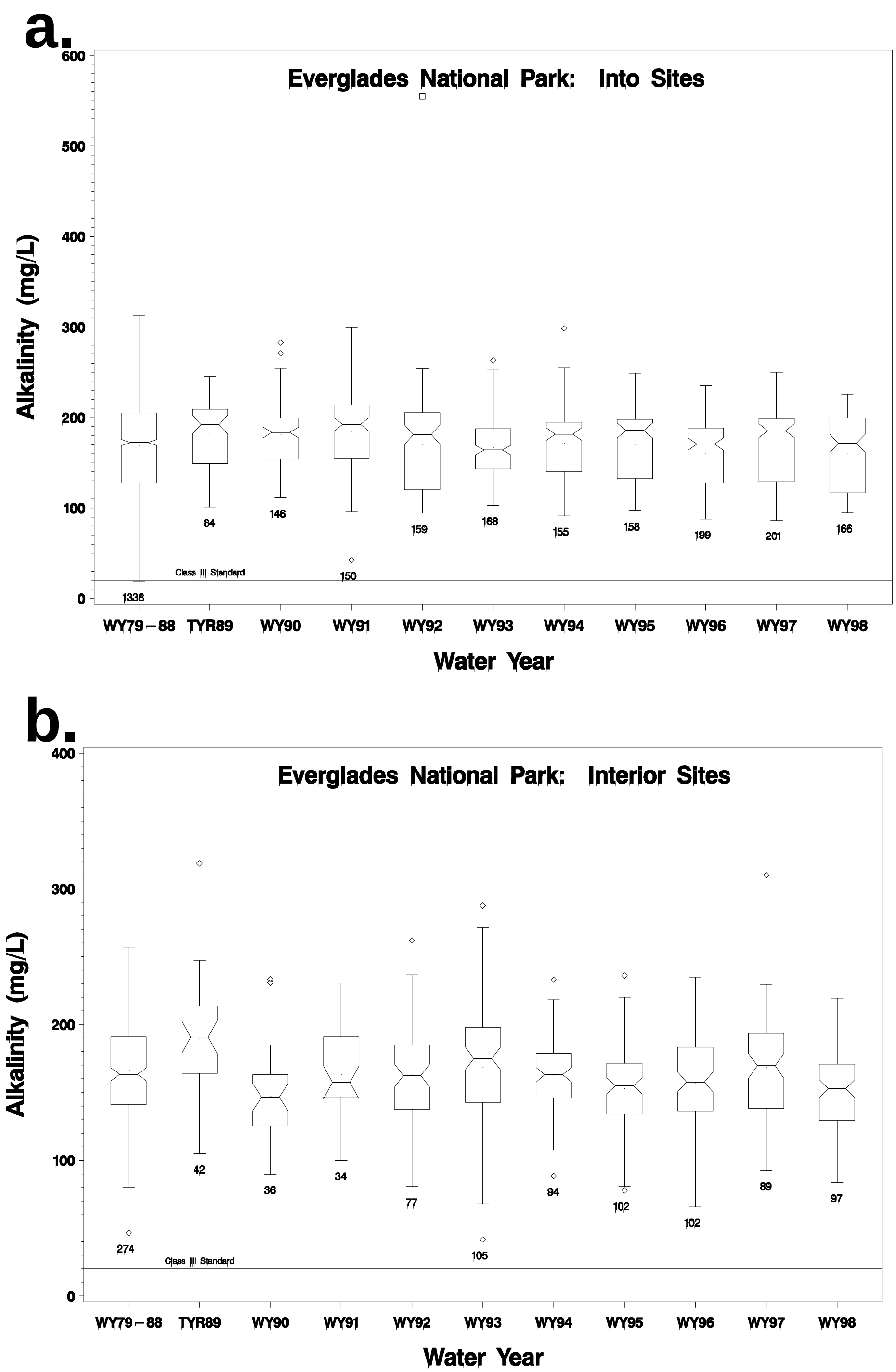


Figure 4-57. Notched box and whisker plots of alkalinity data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Alkalinity. The median alkalinity concentrations in the waters discharged into the Park have shown little variation around the baseline median concentration of 172 mg/L. In recent water years, the median concentrations ranged from 171 to 192 mg/L. There have been no excursions of the alkalinity criterion of <20 mg/L since one incident during the baseline period **(Figure 4-57a)**. The interior site median alkalinity concentrations are lower than the inflow median concentrations. The baseline period median of the interior waters was significantly lower than the median of the inflows. In addition, in four of the nine water years the interior site median concentrations were significantly lower than the corresponding inflow median concentrations **(Figure 4-57b)**. We currently do not have an explanation for this observation.

Turbidity. Turbidity is very low in both the inflows and at the interior sites within the Park. The median turbidity value of the inflows during the baseline period was 1.0 NTU and the range of turbidity values in the recent water years was from 2.0 to 0.9 NTU **(Figure 4-58a)**. No turbidity excursions have been observed at the inflow sites. The median turbidity value for the baseline period at the interior sites was 1.5 NTU. Although this value was significantly higher than the baseline period inflow median, there were no significant differences between the inflow and interior site data in any of the water years. The range of turbidity values at the interior sites in recent water years was from 2.3 to 0.8 NTU. Five excursions of the 29 NTU criterion occurred at interior sites after the baseline period during which two excursions occurred **(Figure 4-58b)**.

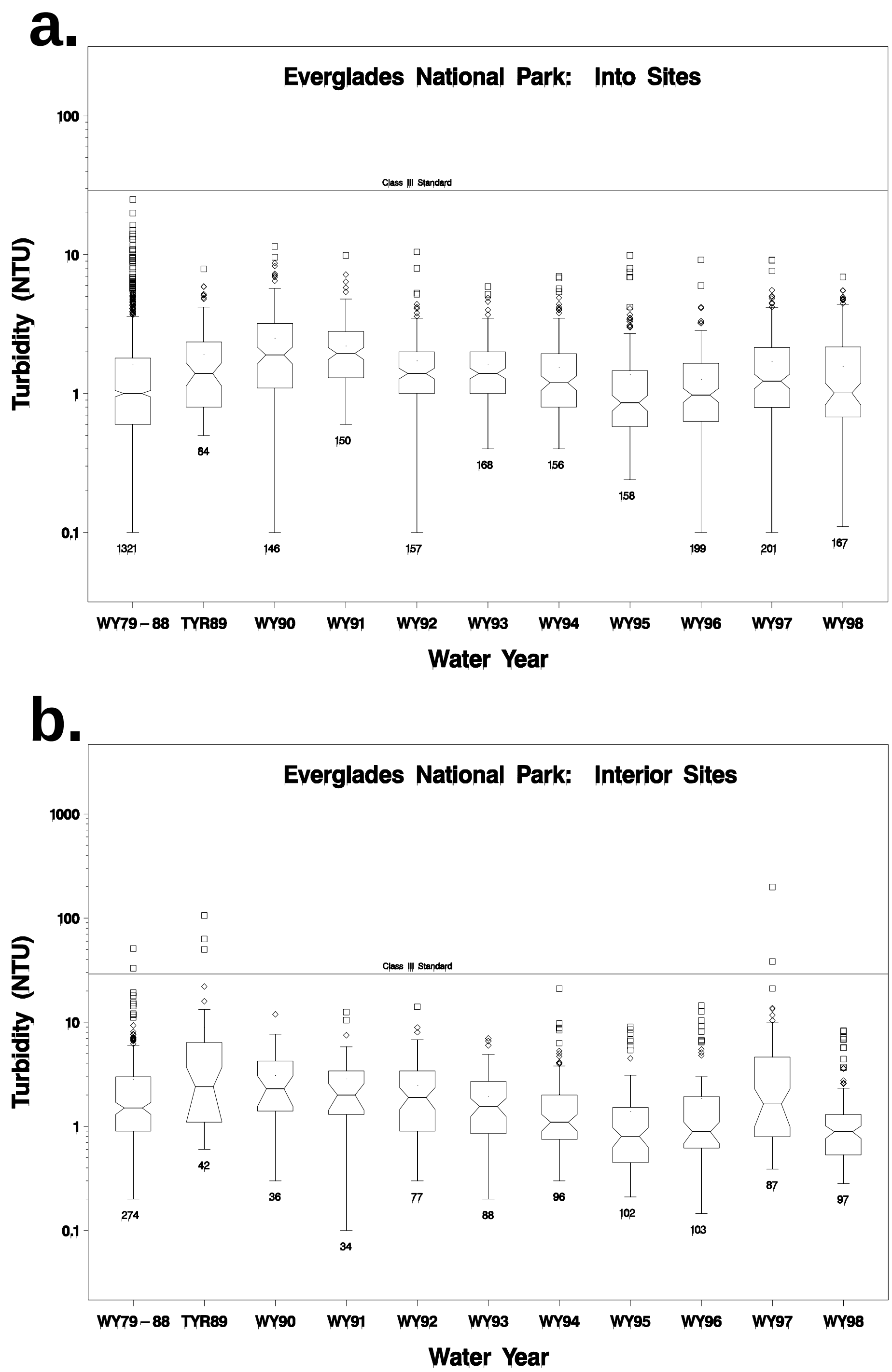


Figure 4-58. Notched box and whisker plots of turbidity data collected within Everglades National Park at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Nutrient Inputs to Florida Bay from the Park

Nutrient inputs to Florida Bay, which is a part of the Everglades Protection Area, are of ecological concern. Changes that have been observed in the ecology of Florida Bay during the past decade include the mortality of seagrasses and the occurrence of algal blooms in the water column, which are common symptoms of excessive nutrient inputs. While it is commonly thought that the primary cause of Florida Bay's ecological changes is the long-term increase in the Bay's salinity that resulted from diversion of fresh water away from Florida Bay (via canals north and east of the Park), nutrient loading may also be contributing to the Bay's problems. Nutrients enter the Bay from wet and dry atmospheric deposition, the Florida Keys, the Gulf of Mexico, and the Park. The major Florida Bay restoration plan currently being implemented is to increase fresh water flow through the Park to the Bay. Thus, a perception is that increased fresh water flow will carry with it more nutrients and negatively affect efforts to restore the Bay.

A large interagency effort, including both state and federal agencies, is under way to assess the environmental history and status of Florida Bay, and understand effects of changing water management on the Bay (Armentano, et al., 1997). This effort includes water quality monitoring and studies of fresh water flow into the Bay, the exchange of Bay water with the Gulf of Mexico, and the Atlantic Ocean, and the rates at which nutrients enter, exit and cycle within the Bay. Studies are also underway to determine the effect of changing fresh water flow and salinity on nutrient availability, seagrass die-off, and algal blooms.

Some interim results from this interagency scientific effort are presented here. Since 1996, the District has worked with the USGS and Everglades National Park, as well as funded university scientists, to measure the flow of water, nitrogen and P into Florida Bay through Taylor River, one of the main creeks that flows from Taylor Slough in the Park, into the Bay. In 1997 water and nutrient inputs to the Bay from McCormick Creek to the west of Taylor River and Trout Creek to the east of Taylor River were also measured. Because there are many other fresh water sources from the Everglades, including other creeks, surface sheet-flow, and possibly ground water flow, the nutrient loads calculated from three creeks provide only an estimate of the effect of increasing water flow on nutrient loading to the Bay. Data collected at the mouth of Taylor River during six sampling periods are presented in **Table 4-10**. During each sampling period, water samples were collected every three hours for ten days. Nutrient samples were analyzed by the Southeastern Environmental Research Program Laboratory at Florida International University, Miami, Florida.

Table 4-10. Mean water discharge and flow-weighted mean inorganic and total nutrient concentrations collected at the mouth of Taylor River. (Rudnick et al, 1998)

	Jan-96	May-96	Aug-96	Nov-96	Jan-97	May-97
Water flow (m3/s)	0.61	-0.52	0.56	0.84	0.65	0.08
Nitrate+nitrite N (µg/L)	14	13.5	30.5	10.5	45.5	36.8
Ammonium N (µg/L)	38.4	85.7	41.8	15.7	61.6	28
TN (µg/L)	845	824	1188	859	701	665
SRP (µg/L)	<4	<4	<4	<4	<4	<4
TP (µg/L)	13.2	14.9	13.3	9.6	13.3	42.6
TOC (µg/L)	12,400	10,000	16,700	14,200	13,300	15,200

Fresh water discharges and salinity concentrations fluctuated seasonally in Taylor River. Discharges into Florida Bay were high during the wet season, with peak flows of about one-half million cubic meters of water per day (about 400 acre-feet) during June 1997 (**Figure 4-59**). A rapid decrease in salinity reflected this seasonal inflow. During the wet season, salinity was near zero. However, from the start of the dry season in November through May, salinity increased steadily. In May 1997 salinity was about 30 parts per thousand, but with the start of summer rains again decreased quickly to near zero (**Figure 4-59**).

P and nitrogen concentrations also followed seasonal patterns, but the patterns for these two important nutrients differed. P concentrations were highest during the dry season, with TP concentrations sometimes exceeding 30 µg/L (**Figure 4-59**). During the times when P concentrations were high, there was almost no water flowing in Taylor River or there was reverse flow (Bay water flowing into the wetland). Salinity levels were near that of seawater. These high P concentrations probably reflect the decomposition of organic matter in the mangrove forest near Florida Bay, and do not indicate P enrichment from upland EPA water. When water from the Park flowed into the Bay during the wet season, P concentrations decreased to flow-weighted mean concentrations of about 13 µg/L during the wet seasons of 1996 and 1997.

Unlike P, nitrogen concentrations were highest during the wet season and lowest during the dry season. This indicates that a likely nitrogen source of Taylor River is not only local decomposition, but also the upstream waters of the Park. With increasing fresh water flow, increased inputs of nitrogen to Florida Bay occurred (**Figure 4-59**).

A preliminary estimate of total nutrient loads to Florida Bay from the Park can be made using the measurements of Taylor River, McCormick Creek, and Trout Creek. Assuming that other creeks that flow into Florida Bay have similar nutrient concentrations as these three creeks, creeks contributed about 2.8 metric tons of TP and about 230 metric tons of total N to the Bay in 1997. These estimates are net exports to the Bay, i.e. they take into account any periods of nutrient import from the Bay to the wetlands caused by wind or tide reversing flow in the creeks.

The 2.8 metric ton TP input is probably insignificant to the Bay because it is far less than P inputs from other sources, including the Florida Keys and atmospheric deposition (each with inputs of about 40 metric tons per year, as estimated by Rudnick et al, 1998). However, the 230 metric ton total N input from Park creeks is probably significant to the Bay, being similar in magnitude to N inputs from the Keys and atmospheric deposition (about 200 and 800 metric tons per year, respectively, as estimated by Rudnick et al., 1998). Atmospheric deposition estimates were based on measurements of Hendry et al., (1981) in the Florida Keys. Nutrient inputs to Florida Bay from the Gulf of Mexico, which includes some of the nutrients that passed through Shark Slough, may greatly exceed all other inputs to Florida Bay. At this time, nutrient inputs from the Gulf cannot be accurately estimated. Measuring these inputs is a high priority of the interagency Florida Bay science program.

Based on these preliminary results, it appears unlikely that increasing fresh water flow to Florida Bay as a restoration strategy will significantly affect the input of P to Florida Bay. However, it does appear that nitrogen inputs to the Bay will increase with increased fresh water flow. The consequences of nitrogen inputs are not certain. Much of Florida Bay already has high concentrations of nitrogen and it is not likely to be affected by any further increase. These areas are generally much more sensitive to P inputs. However, in western Florida Bay and in adjacent ocean waters, both N and P concentrations are low. Increased N

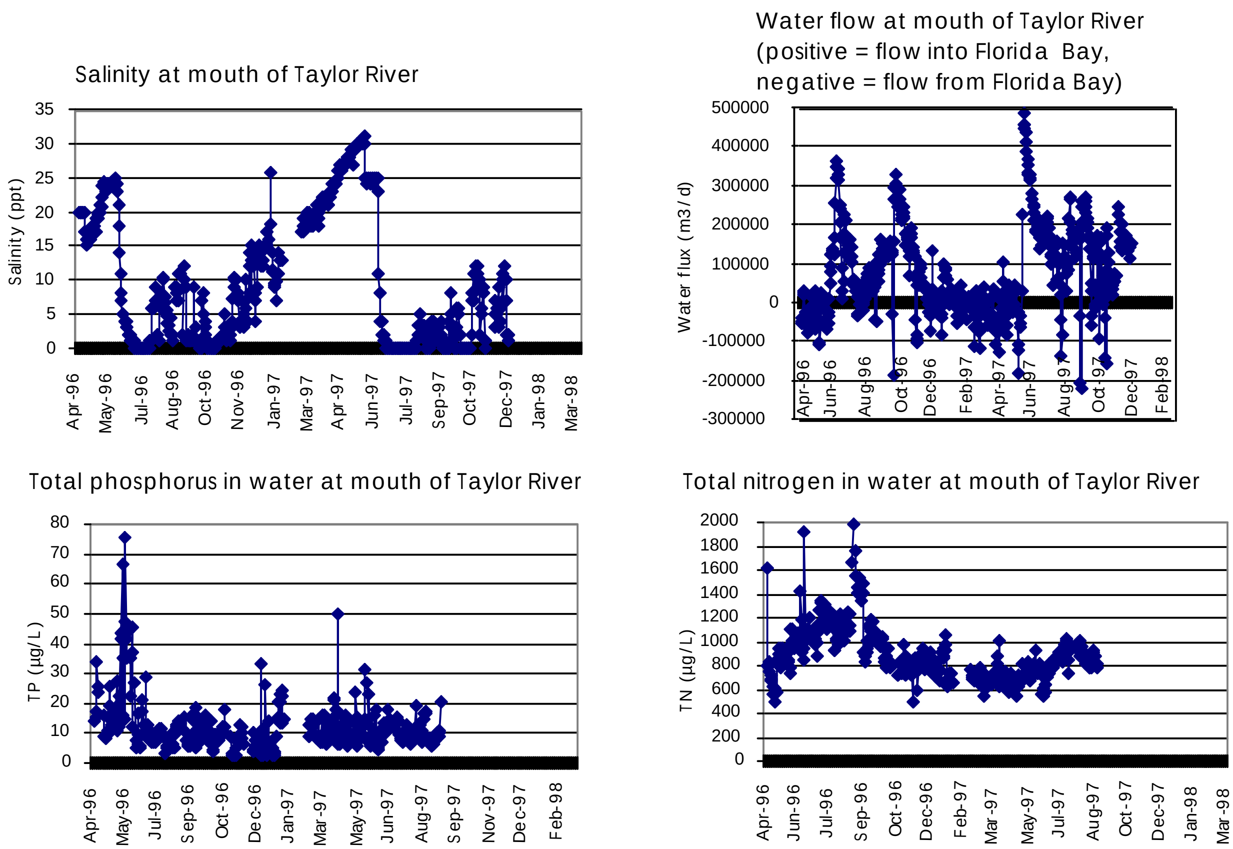


Figure 4-59. Salinity (**a**), water flow (**b**), TP (**c**) and TN (**d**) in water at the mouth of Taylor River. Positive values of water flow indicate flow into Florida Bay. Negative values of water flow indicate flow from Florida Bay (Rudnick et al, 1998).

inputs to these regions could stimulate productivity, including the production of algal blooms. At this time, however, it is premature to conclude that efforts to restore Florida Bay by increasing fresh water flow will cause any harm to any part of the Bay or adjacent waters.

Spatial and Temporal Trends of Trace Metals in the EPA

Over the past 18 years, trace metal sampling in the EPA was performed on a quarterly basis. Trace metal data collected during this period were divided into the baseline period and the recent water years, as has the other water quality constituent data, for the purpose of discussing spatial and temporal variations in concentration. The five (5) trace metals that will be discussed in this section are: total cadmium, total copper, total iron, total lead, total zinc.

Notched-box and whisker plots for the five trace metals are provided as **Figures 4-60** through **4-79**. For those trace metals whose Class III criteria are calculated based on hardness, lines representing the Class III criteria calculated from the lowest and highest hardness concentrations for each monitoring period are provided on each plot. As explained in the **Methods** section, only trace metal concentrations greater than the detection limit were used to create the notched-box and whisker plots.

Analytic changes explain some trace metal fluctuations

In June 1995, which is in WY96, the water quality monitoring laboratory at the District began analyzing cadmium, copper, and zinc using inductively coupled plasma (ICP) spectrophotometers (Struve, 1998). This procedure allows for the simultaneous analyses of metals, and has lower detection capabilities for some trace metals, *e.g.* zinc, than heated graphite furnace (HGA) atomic absorption spectroscopy previously used by the laboratory. However, ICP is a less sensitive method than HGA for cadmium and copper. Therefore, slight changes in cadmium, copper and zinc concentrations beginning WY96 may have resulted from changes in analytical techniques rather than anthropogenic sources.

Human activities explain other trace metal fluctuations

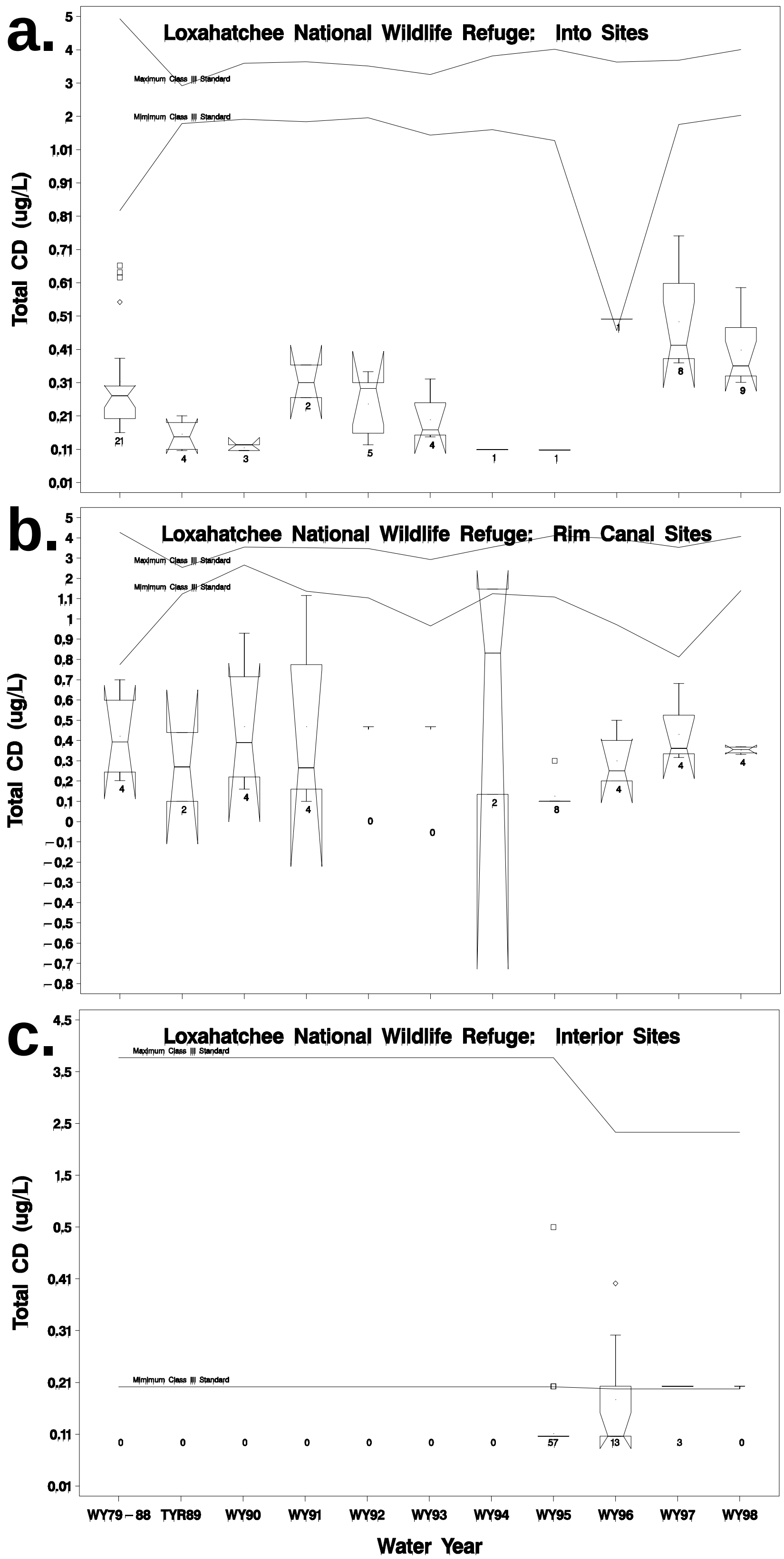
Small quantities of the above trace metals occur naturally in air, water and soil. Anthropogenic activity, however, can increase the concentration of these metals above their natural concentrations. Cadmium levels in soil and surface water can be increased through the application of phosphate fertilizers or sewage sludge (Forstner and Wittman, 1983). One of the largest sources of cadmium release to the environment is through the burning of fossil fuels (i.e., coal or oil) or incineration of municipal waste (Forstner and Wittman, 1983).

Copper is widely used as a fungicide because it can disrupt important microbial processes such as nutrient cycling by inhibiting mineralization of nitrogen and P (Salomons and Forstner, 1984). The use of copper-based fungicides and algicides can increase copper concentrations in the aquatic system. Another source of copper is through the burning of fossil fuels (Salomons and Forstner, 1984) or incineration of municipal wastes (CRC, 1998).

Iron is the second most abundant metal in the Earth's crust. Elevated concentrations of iron found in surface waters are usually associated with industrial activity. However, iron can readily be leached from soils as a function of pH and redox potential.

Industrial activity and fossil fuel emission are the most common sources for elevated lead concentrations in the environment. Mining and smelting operations can introduce lead into the aquatic environment through runoff or atmospheric deposition (Forstner and Wittman, 1983; Salomons and Forstner, 1984). Until recently, lead arsenate has been used as an insecticide. Its use has been eliminated in favor of less harmful organic compounds. However, the largest source of lead in the environment is the burning of fossil fuels.

Zinc is one of the most widely used metals in the world. It can be found in products ranging from batteries to soap. Sources of zinc to the environment are domestic and industrial effluents, atmospheric fallout, and agricultural activity.



Loxahatchee National Wildlife Refuge

Cadmium. Median cadmium concentrations measured at inflow structures to the Refuge during the recent water years ranged from 0.1 µg/L in WY95 to 0.5 µg/L in WY96 (**Figure 4-60a**). No significant changes in cadmium concentrations were observed from the baseline period, whose median concentration was 0.3 µg/L. Slightly higher median concentrations were observed for WY96 through WY98. The apparent increase in cadmium may be related to analytical procedures.

With the exception of WY94, median concentrations of total cadmium measured at rim canal stations were comparable during the monitoring periods (**Figure 4-60b**). No comparison could be made for cadmium concentrations at interior stations (**Figure 4-60c**) because no trace metal data were collected during the baseline period. Sampling started at interior stations in the Refuge during WY1995. During the last three water years, median concentrations at interior stations ranged from 0.1 to 0.2 µg/L.

Figure 4-60. Notched box and whisker plots of total cadmium data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Copper. Inflow sites exhibited median copper concentrations ranging from 1.3 to 3.3 µg/L during the recent water years (**Figure 4-61a**). During the baseline period, the median copper concentration was measured at 4.2 µg/L. No significant changes in copper concentrations were observed between the baseline period and recent water years.

At interior stations, no comparison could be made with the baseline period because trace metal sampling began in WY95 (**Figure 4-61b**). However, concentrations exhibited a slight decrease from WY95 through WY97. Rim canal stations exhibited median concentrations, ranging from 1.0 to 3.0 µg/L for the recent water years, and 1.5 µg/L for the baseline period. No apparent trends could be observed at either location in the Refuge (**Figure 4-61c**).

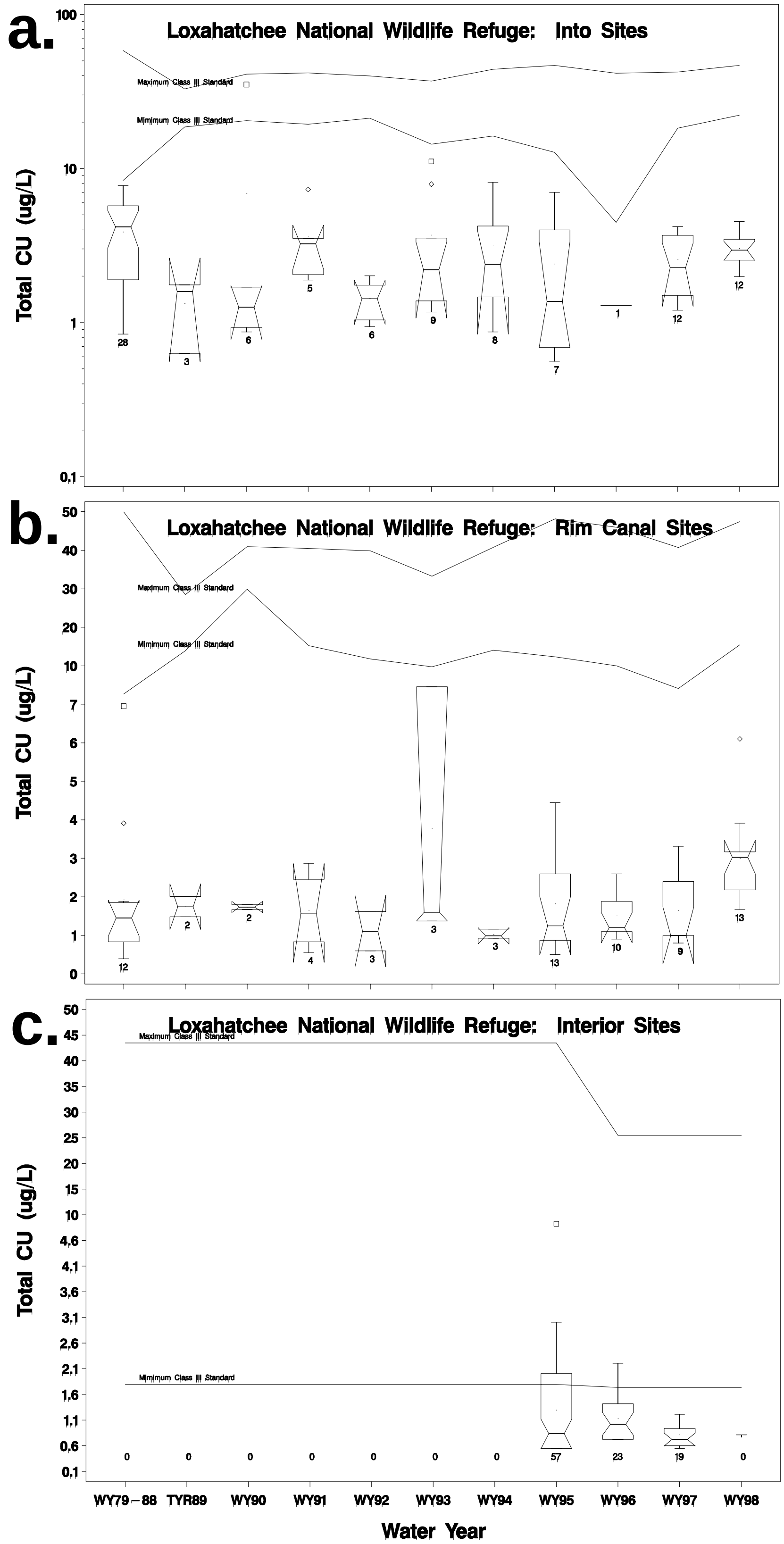


Figure 4-61. Notched box and whisker plots of total copper data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Iron. No significant changes were observed for iron concentrations in the Refuge from the baseline period to recent water years (**Figure 4-62a**). Median iron concentrations at inflow stations ranged from 0.06 to 0.41 mg/L during the recent water years, compared to 0.23 mg/l for the baseline period. Slightly lower concentrations were observed in the rim canal, where median iron levels ranged from 0.06 to 0.20 mg/L (**Figure 4-62b**). Interior iron concentrations were generally lower ranging from 0.04 to 0.06 mg/L (**Figure 4-62c**).

A correlation of mean iron concentrations with mean turbidity (r = 0.88) at inflow structures suggests that iron is associated with the particulate fraction in the water column. Iron concentrations at interior stations have also exhibited a significant decrease from the baseline period. This decrease may be related to particulate removal (i.e., settling) within the marsh.

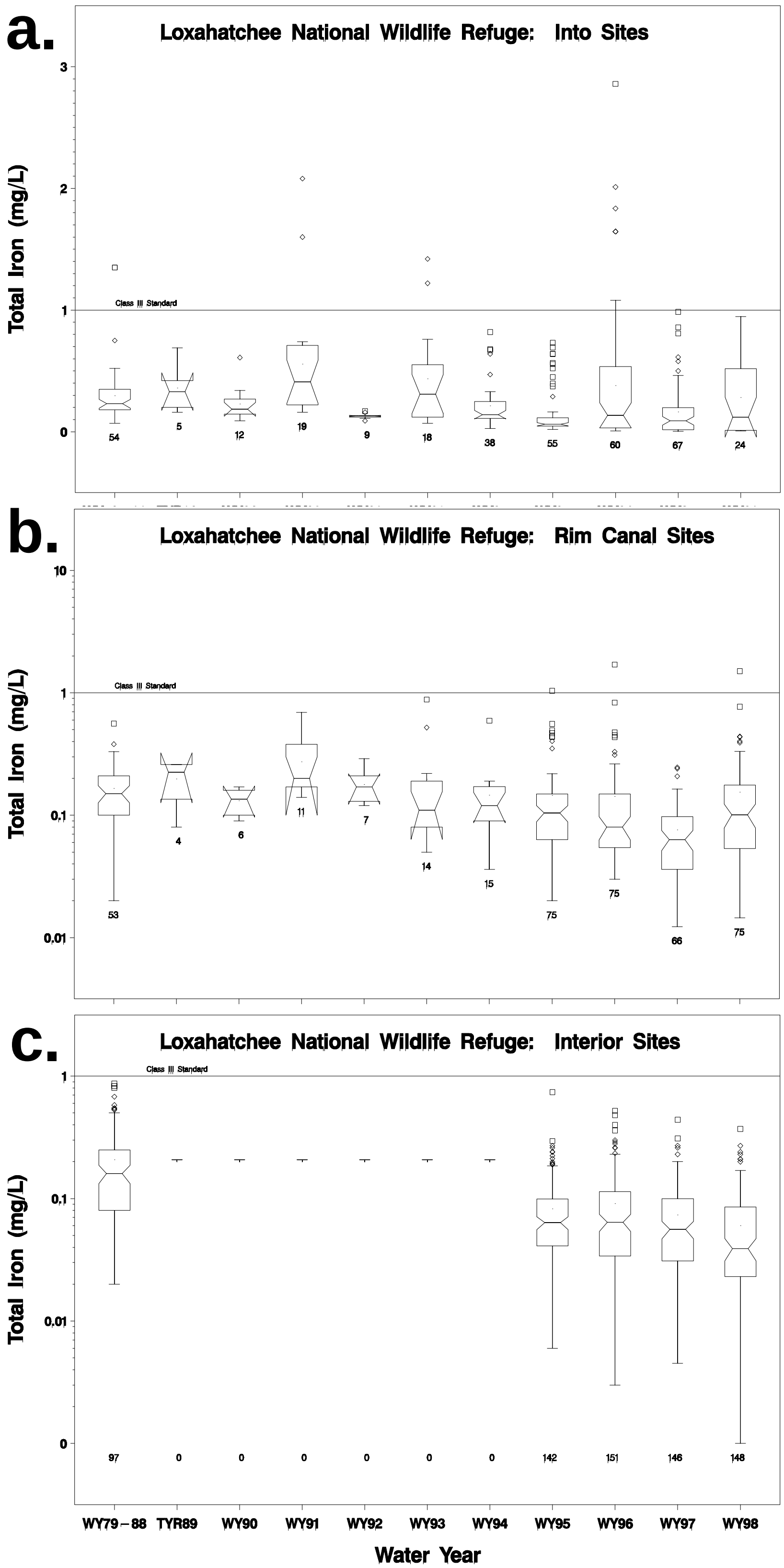


Figure 4-62. Notched box and whisker plots of total iron data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Lead. The median lead concentration during the baseline period was approximately 5 times higher than observed during recent water years. During the recent water years, median lead concentrations ranged from 0.6 to 1.3 µg/L. Due to an insufficient number of samples with concentrations above detection limits no analysis regarding changes in lead concentrations in the Refuge was warranted (**Figures 4-63a, b, c**).

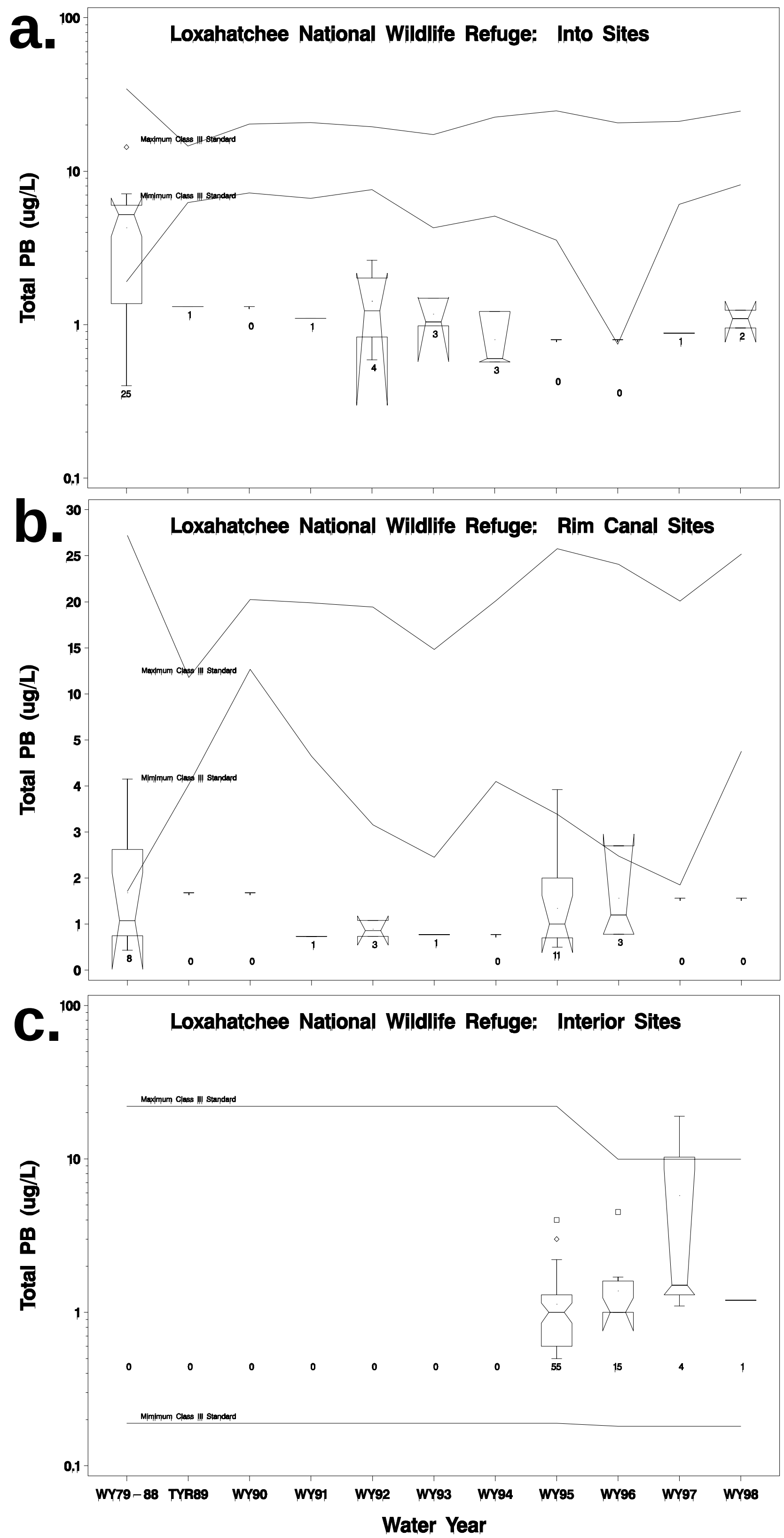


Figure 4-63. Notched box and whisker plots of total lead data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Zinc. The distribution of zinc concentrations in the Refuge from the baseline through recent water years is shown in **Figures 4-64a, b, c**. After WY95 the median zinc concentration in the Refuge exhibited a significant decrease. However, this decrease is attributed to improved laboratory detection limits.

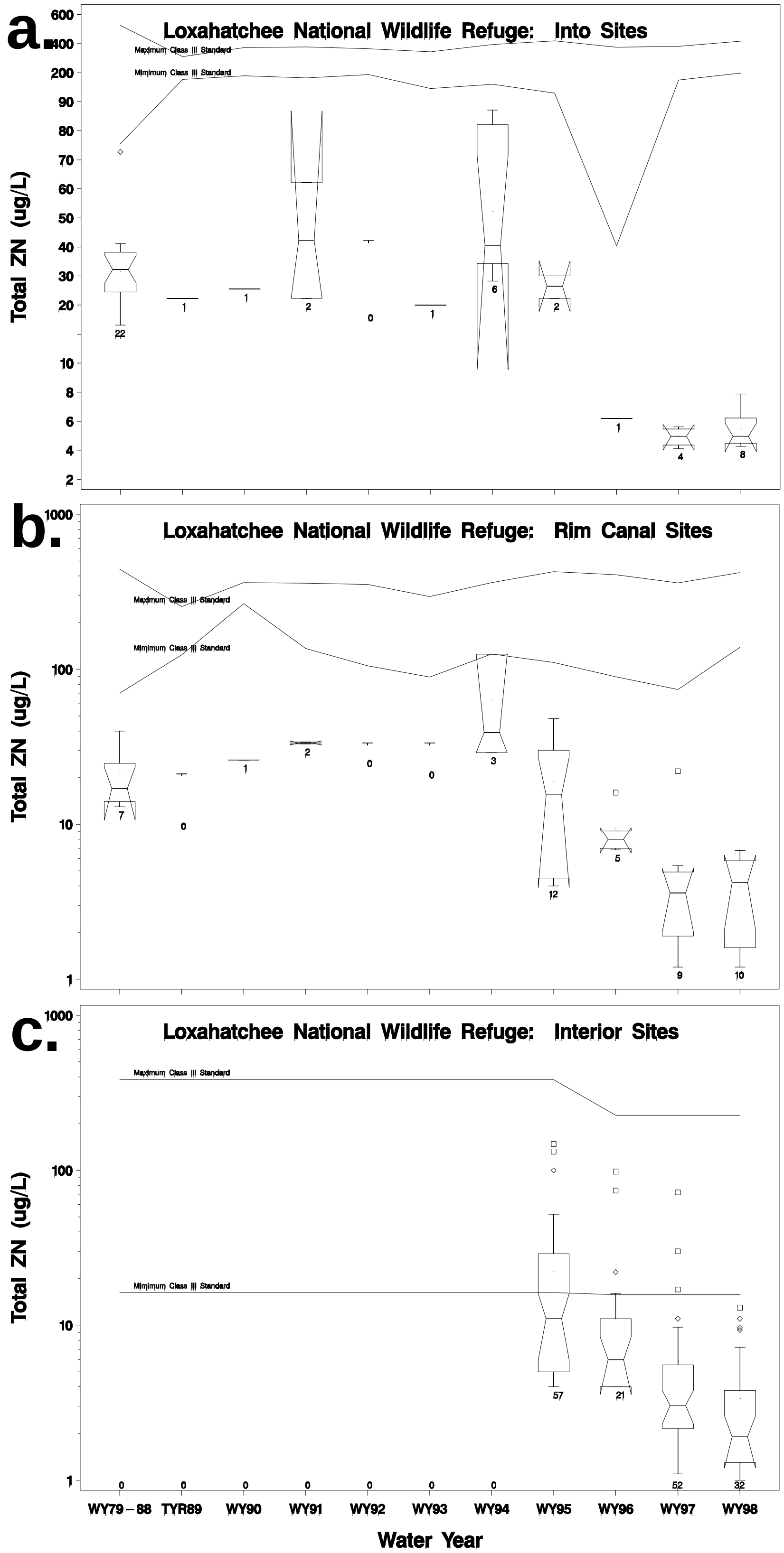


Figure 4-64. Notched box and whisker plots of total zinc data collected within the Refuge at **a.** Into, **b.** Rim Canal, and **c.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Water Conservation Area 2

Cadmium. Median cadmium concentrations at inflow structures and interior stations ranged from 0.2 to 1.5 µg/L during the recent water years (**Figures 4-65a, b, c**). Due to the limited data set with concentrations greater than the detection limit, no temporal trend could be determined.

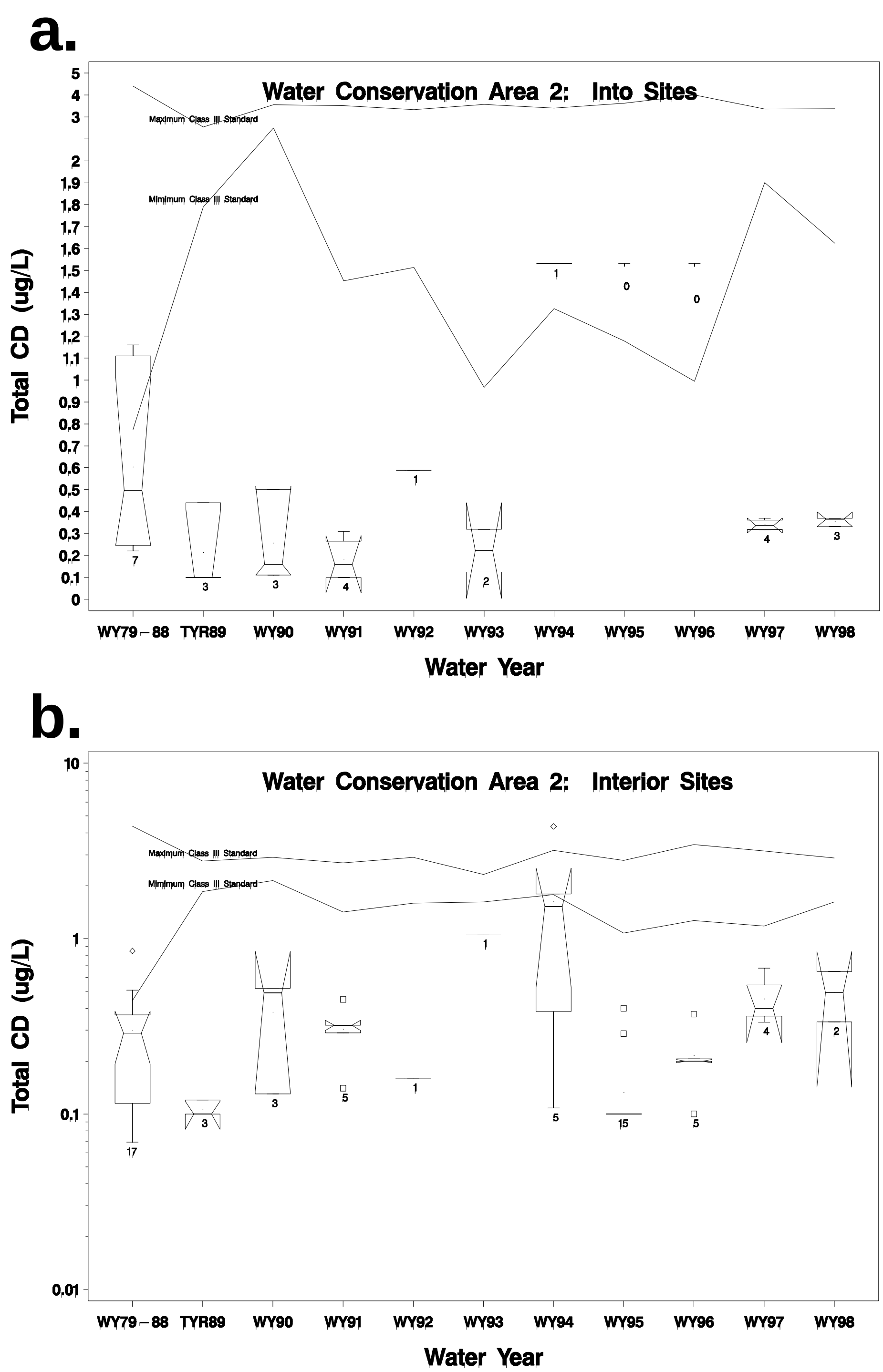


Figure 4-65. Notched box and whisker plots of total cadmium data collecte within Water Conservation Area 2 at **a.** Into and **b.** Interior sites See **Table 4-2** for a description of the parts of the notched boxe and whiskers.

Copper. Copper measured during the recent water years in WCA-2 had ranges in median concentrations from 1.0 to 4.7 µg/L at inflow structures, and 0.8 to 1.9 µg/L at interior stations (**Figures 4-66a, b**). A slight increase in cadmium concentrations was observed in WY96, which may be attributed to a change in analytical methodology.

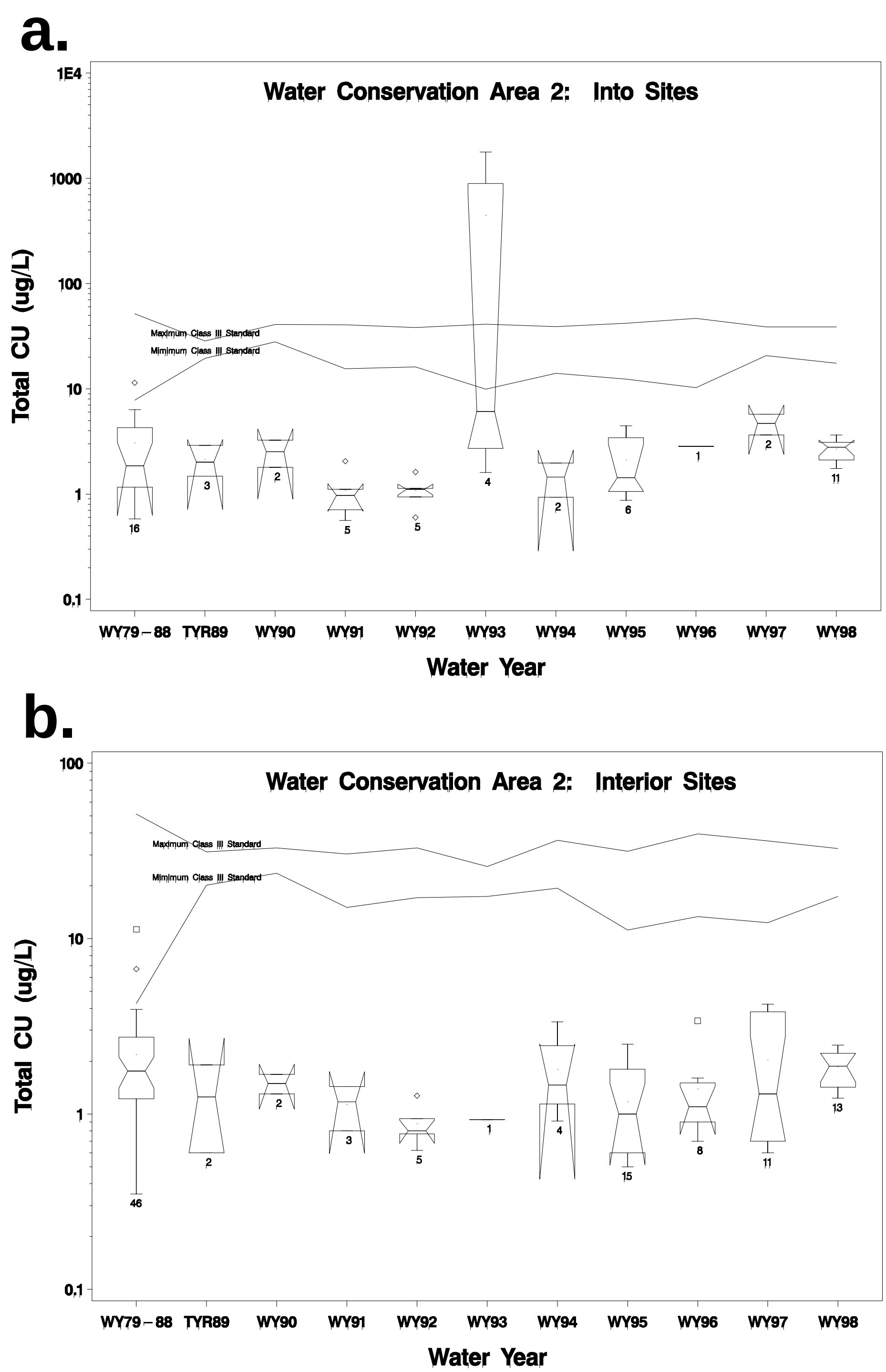


Figure 4-66. Notched box and whisker plots of total copper data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Iron. Median iron concentrations measured at inflow and interior stations were generally less than 0.2 mg/L (**Figures 4-66a, b**). A significant decrease in median concentrations was observed at inflow and interior sites. Iron was also found to correlate well with turbidity measurements in the WCA. The observed decrease may have resulted from the removal of particulate material in the WCA.

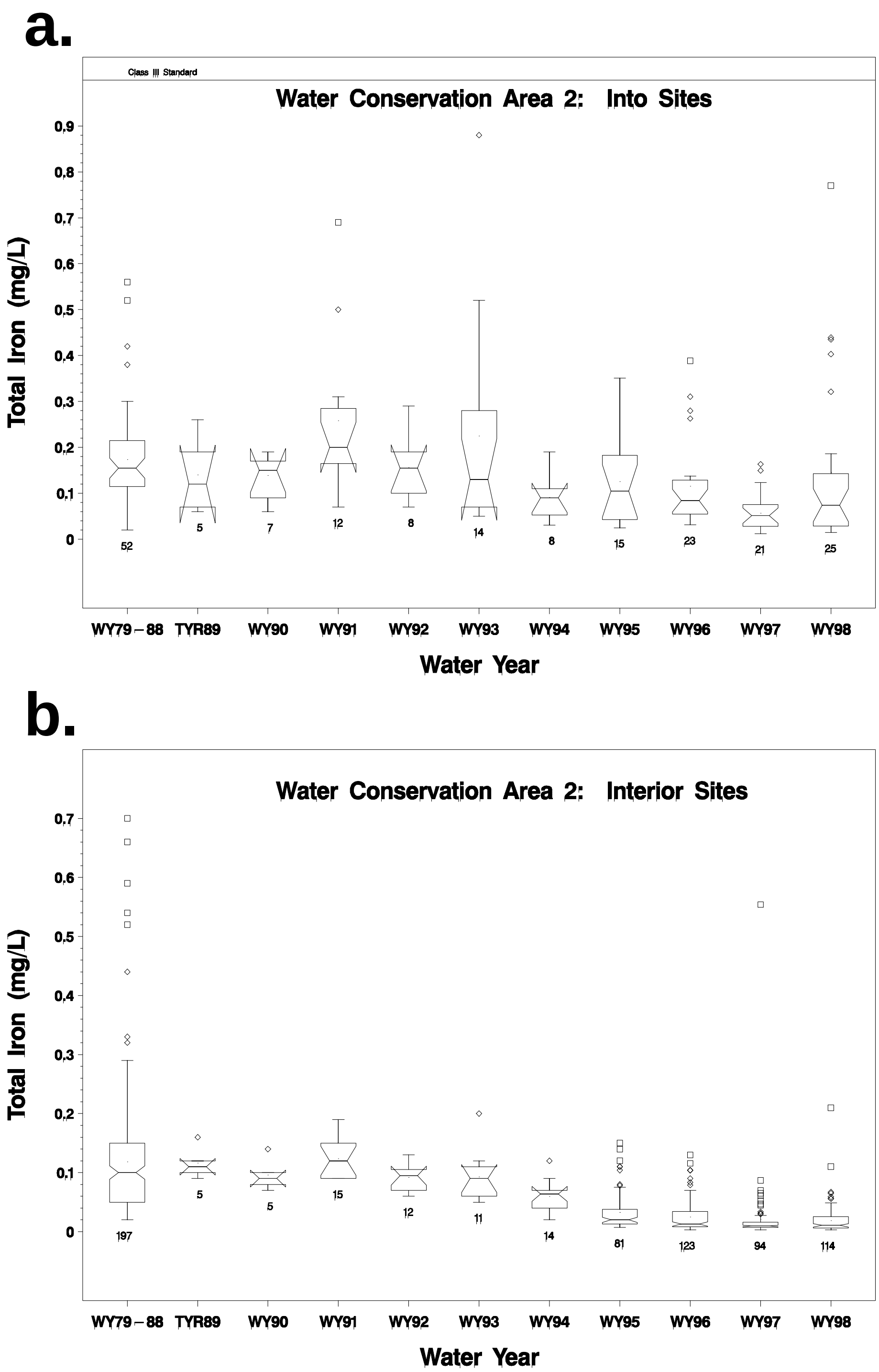


Figure 4-67. Notched box and whisker plots of total iron data collected withi Water Conservation Area 2 at **a.** Into and **b.** Interior sites. Se **Table 4-2** for a description of the parts of the notched boxes an whiskers.

Lead. Median total lead concentrations in WCA-2 ranged from 0.7 to 4.4 µg/L at inflow structures, and 0.6 to 1.2 µg/L at interior stations. Overall, no apparent trends were observed within the WCA (**Figures 4-68a, b**).

a.

b.

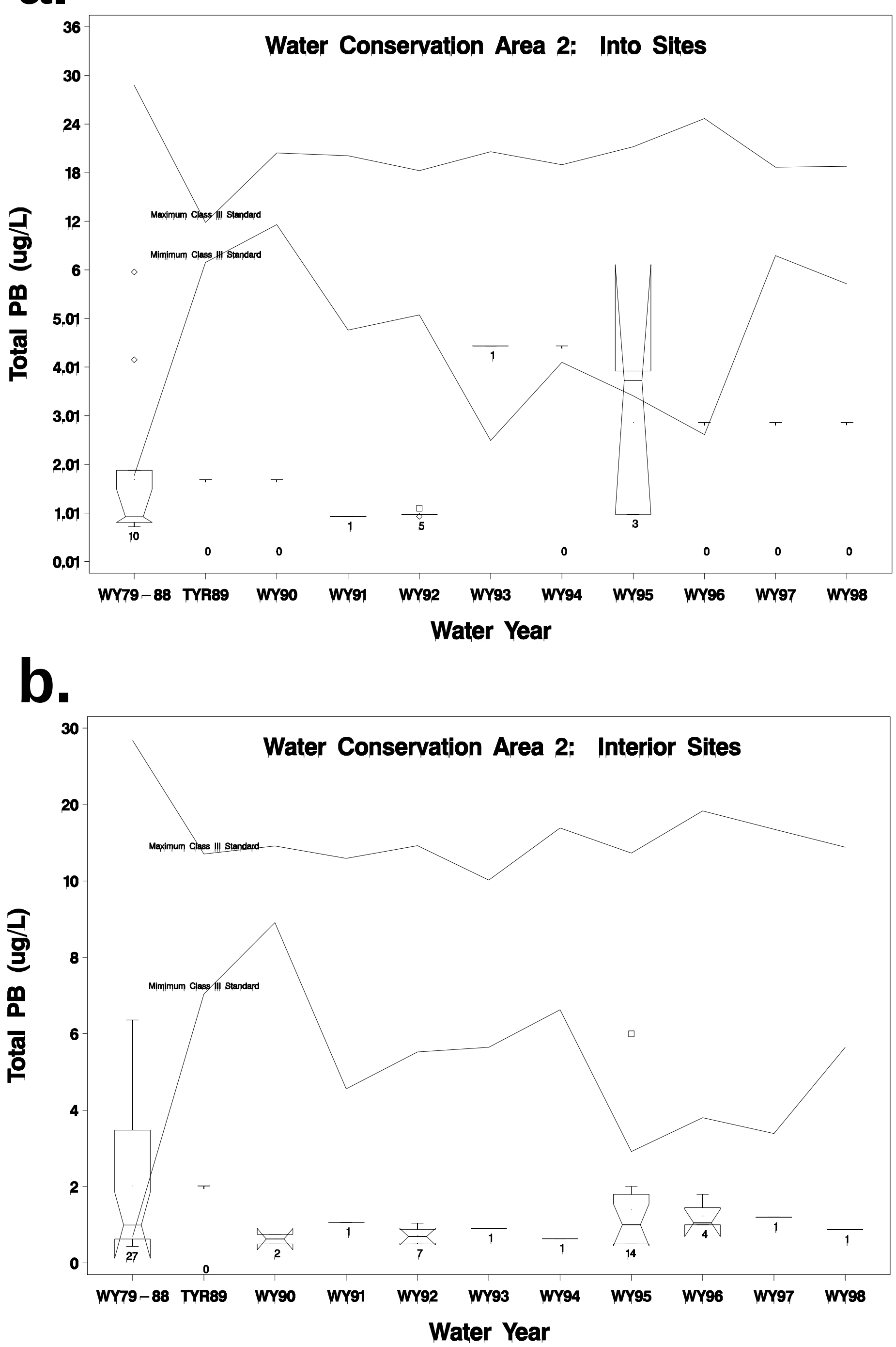
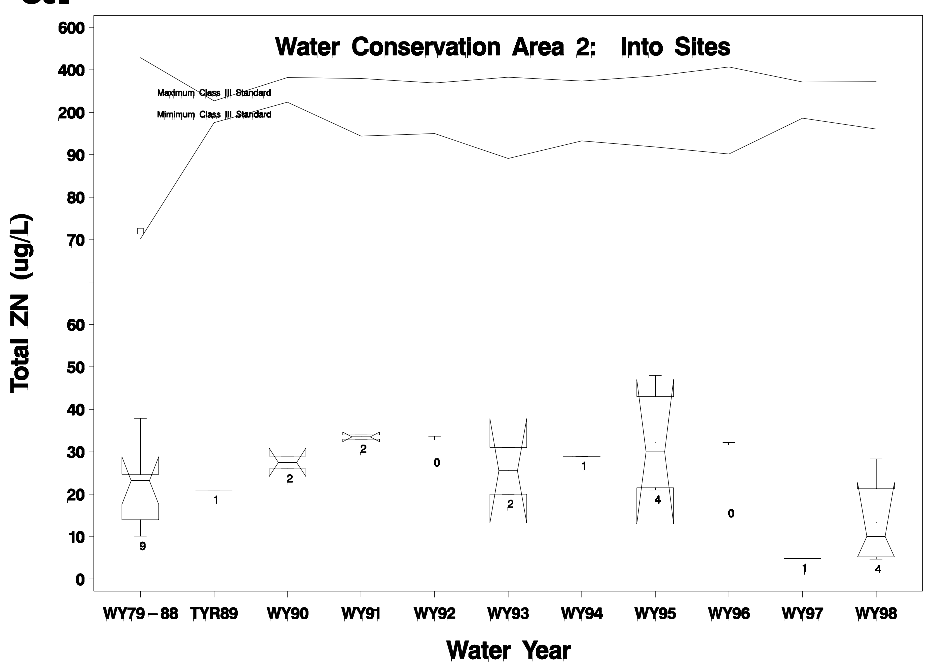


Figure 4-68. Notched box and whisker plots of total lead data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Zinc. Zinc levels during the recent water years through WY95 were relatively similar to those measured during the baseline period (**Figures 4-69a, b**). In WY96, zinc concentrations decreased significantly. This decrease is attributed to improved laboratory detection limits.

a.



b.

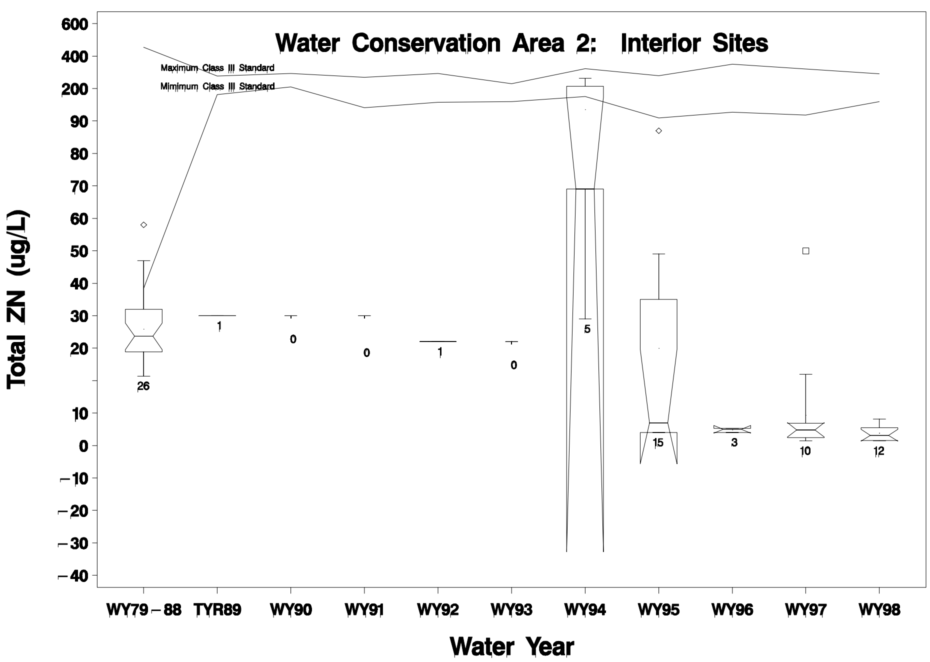
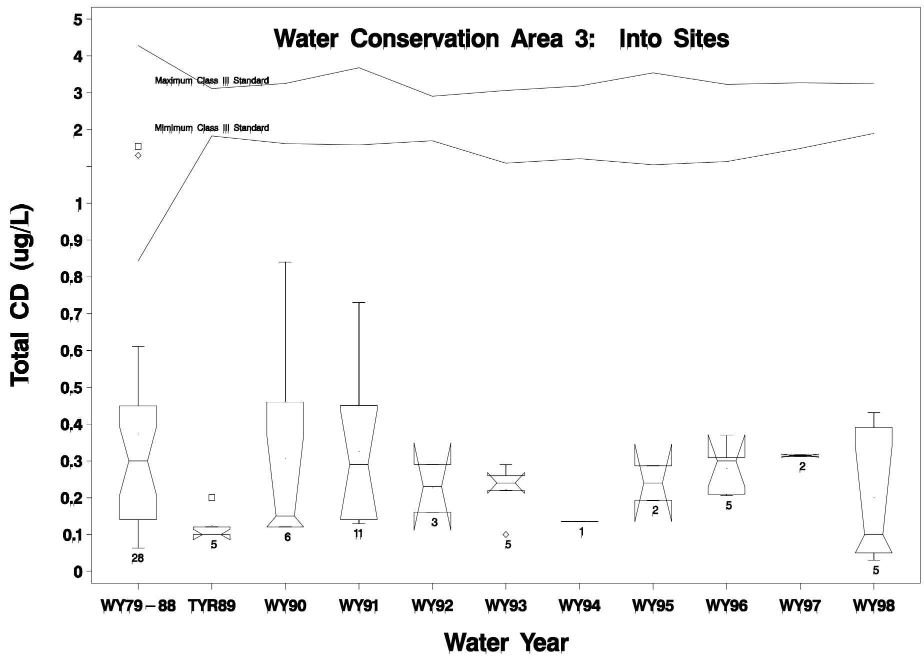


Figure 4-69. Notched box and whisker plots of total zinc data collected withi Water Conservation Area 2 at **a.** Into and **b.** Interior sites. Se **Table 4-2** for a description of the parts of the notched boxes an whiskers.

a.



b.

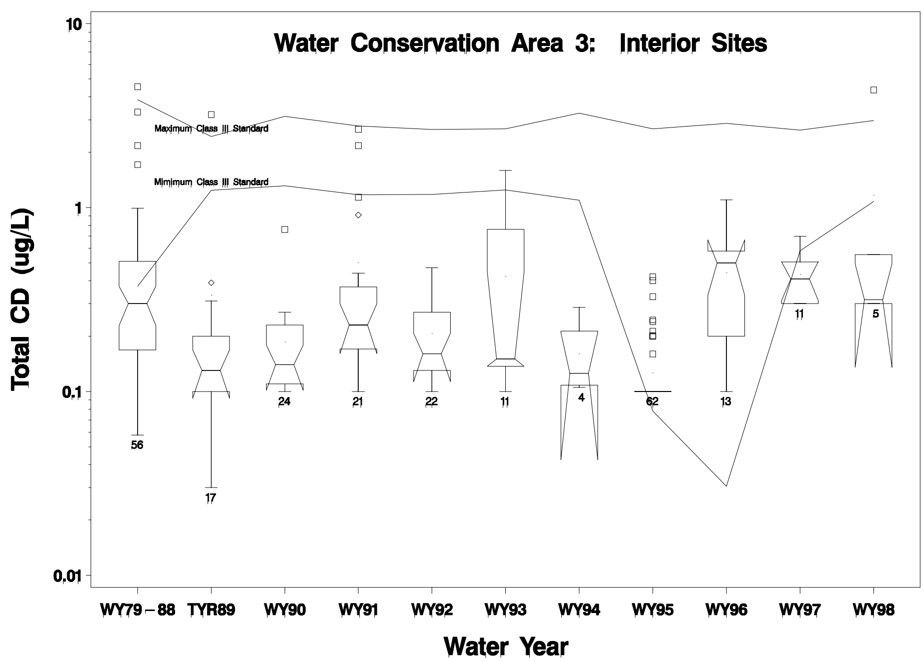


Figure 4-70. Notched box and whisker plots of total cadmium data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Water Conservation Area 3

Cadmium. Median cadmium concentrations in WCA-3 ranged from 0.1 to 0.3 µg/L at inflow structures, and from 0.1 to 0.5 µg/L at interior stations (**Figures 4-70a, b**). The median cadmium concentration in recent water years compared well with the median concentration measured during the baseline period. The high variability of the cadmium data prohibited any determination of trends.

Copper. During the baseline period, the median copper concentration at inflow stations was 1.5 µg/L and within the range observed for the recent water years (i.e., 0.7 to 2.7 µg/L). Interior stations generally exhibited a narrower range in median concentrations. No apparent trend was observed at either the inflow sources or interior marsh sites in the WCA (**Figures 4-71a, b**).

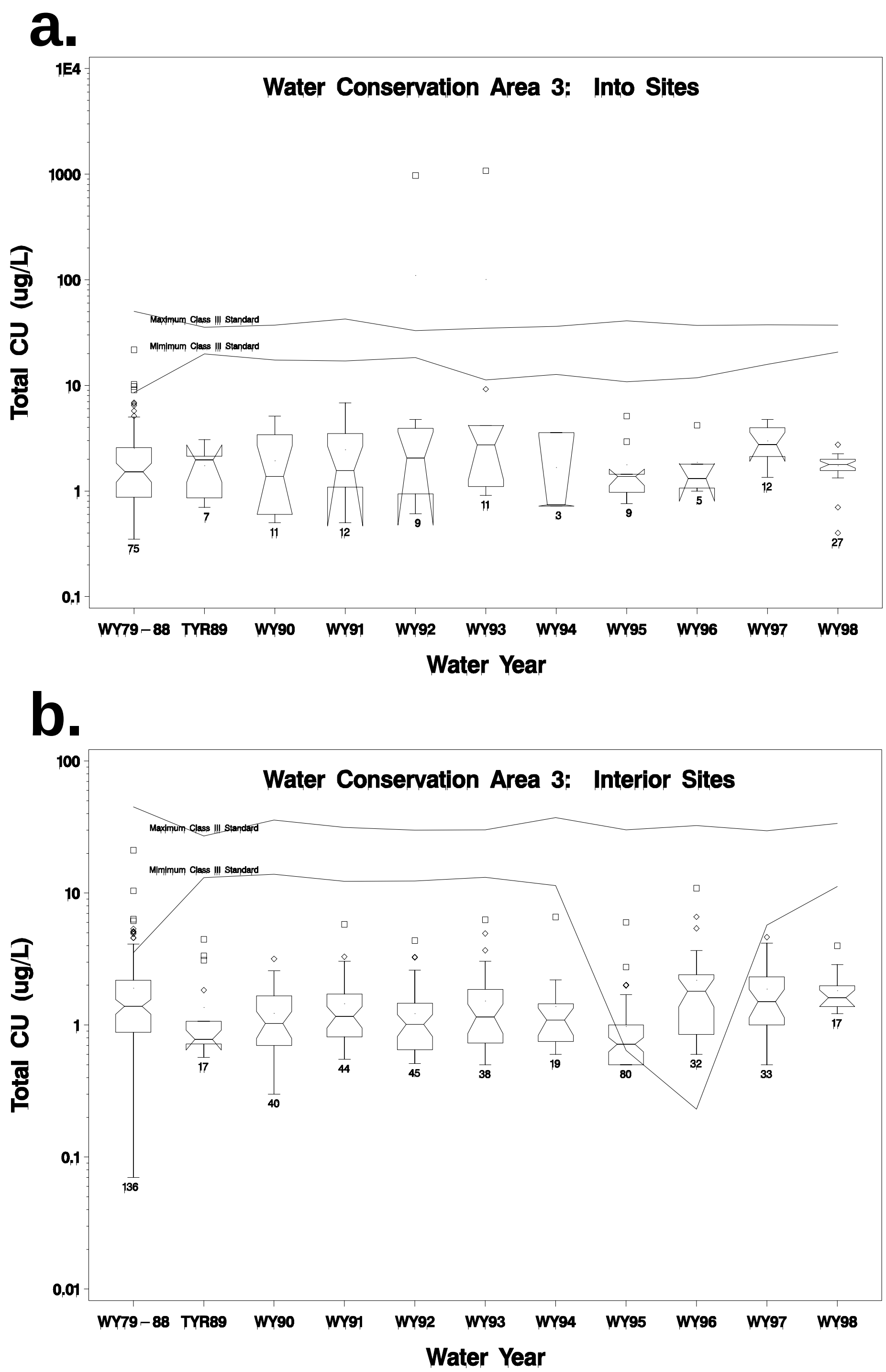


Figure 4-71. Notched box and whisker plots of total copper data collecte within Water Conservation Area 2 at **a.** Into and **b.** Interior sites See **Table 4-2** for a description of the parts of the notched boxe and whiskers.

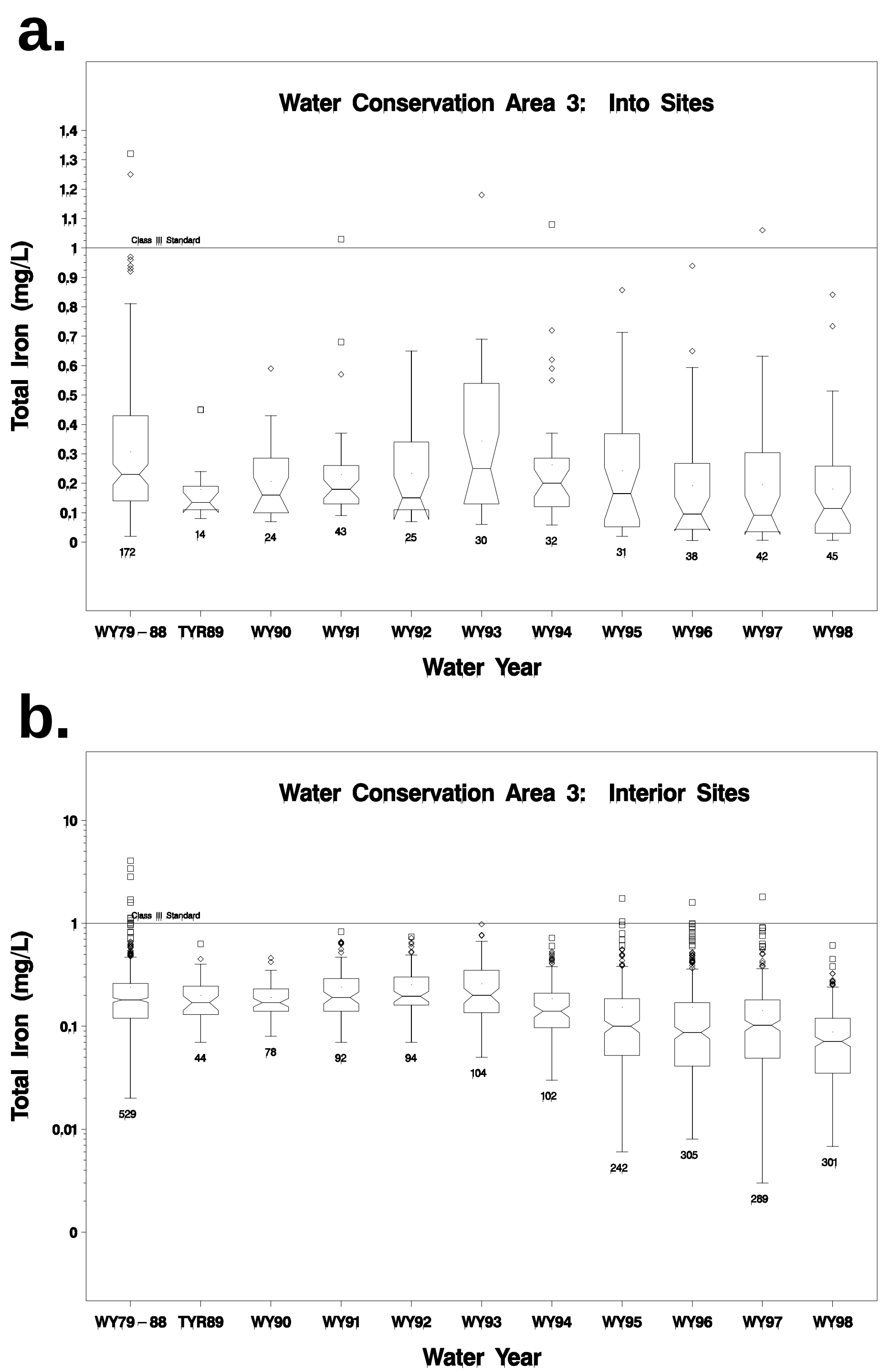


Figure 4-72. Notched box and whisker plots of total iron data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Iron. At inflow structures, the median iron concentration for the baseline period was comparable to concentrations measured during recent water years. No apparent trend was observed for these structures (**Figure 4-72a**). A significant decrease in iron concentrations from the baseline period through recent water years was observed at interior marsh stations (**Figure 4-72b**).

Lead. Median lead concentrations in WCA-3 ranged from 0.6 to 1.4 µg/L (**Figure 4-73a**). No significant trends were observed at either the inflow structures or interior marsh stations. However, a slight increase in median lead concentrations was observed at the marsh stations for the last three years of monitoring (**Figure 4-73b**).

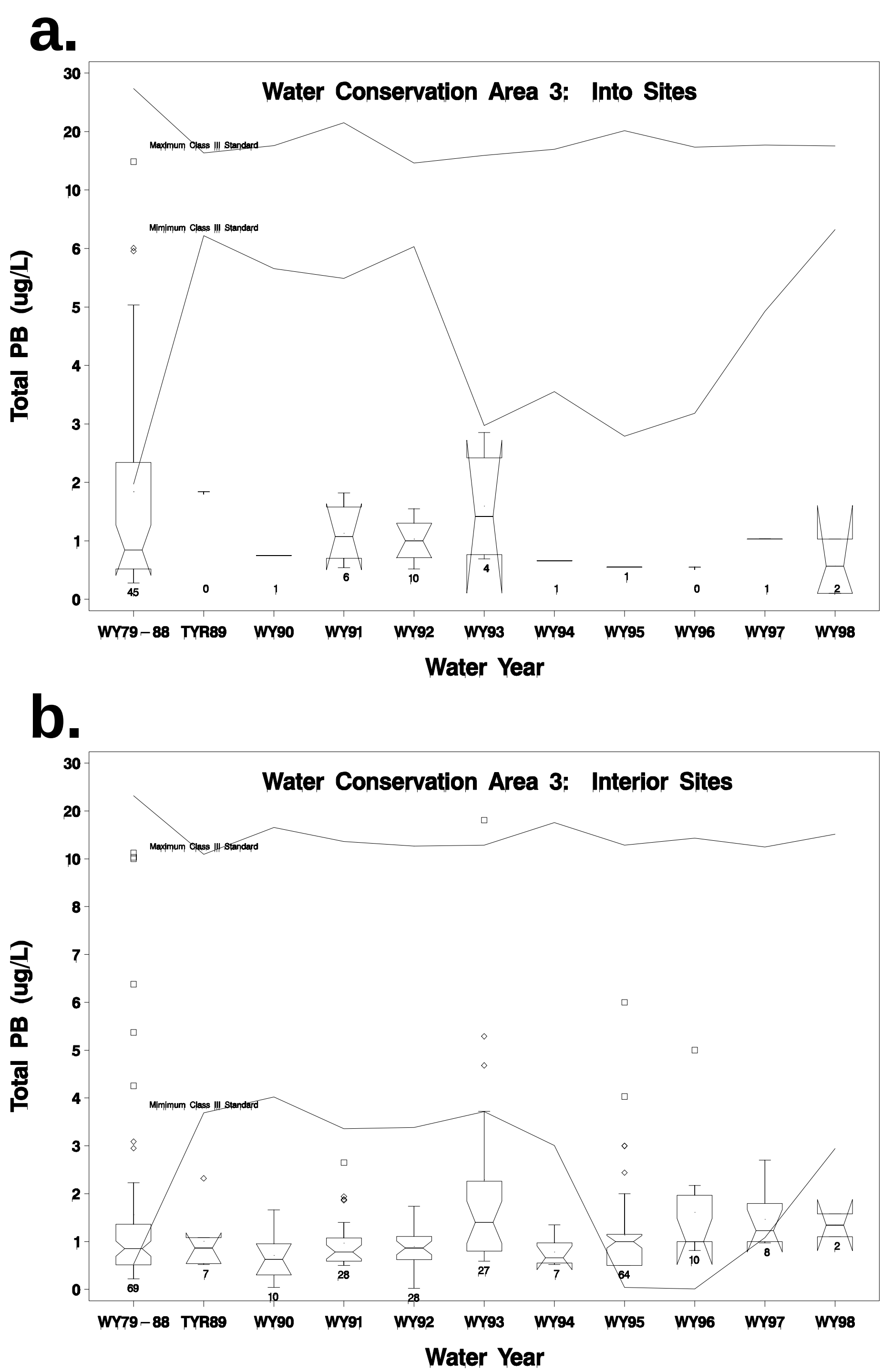


Figure 4-73. Notched box and whisker plots of total lead data collected withi Water Conservation Area 2 at **a.** Into and **b.** Interior sites. Se **Table 4-2** for a description of the parts of the notched boxes an whiskers.

Zinc. Zinc followed the same trend in WCA-3 as in the other regions of the EPA (**Figures 4-74a, b**). Relatively similar median concentrations were observed from the baseline period through WY95. After WY95, median concentrations decreased significantly. These observed decreases are related to improved laboratory detection limits.

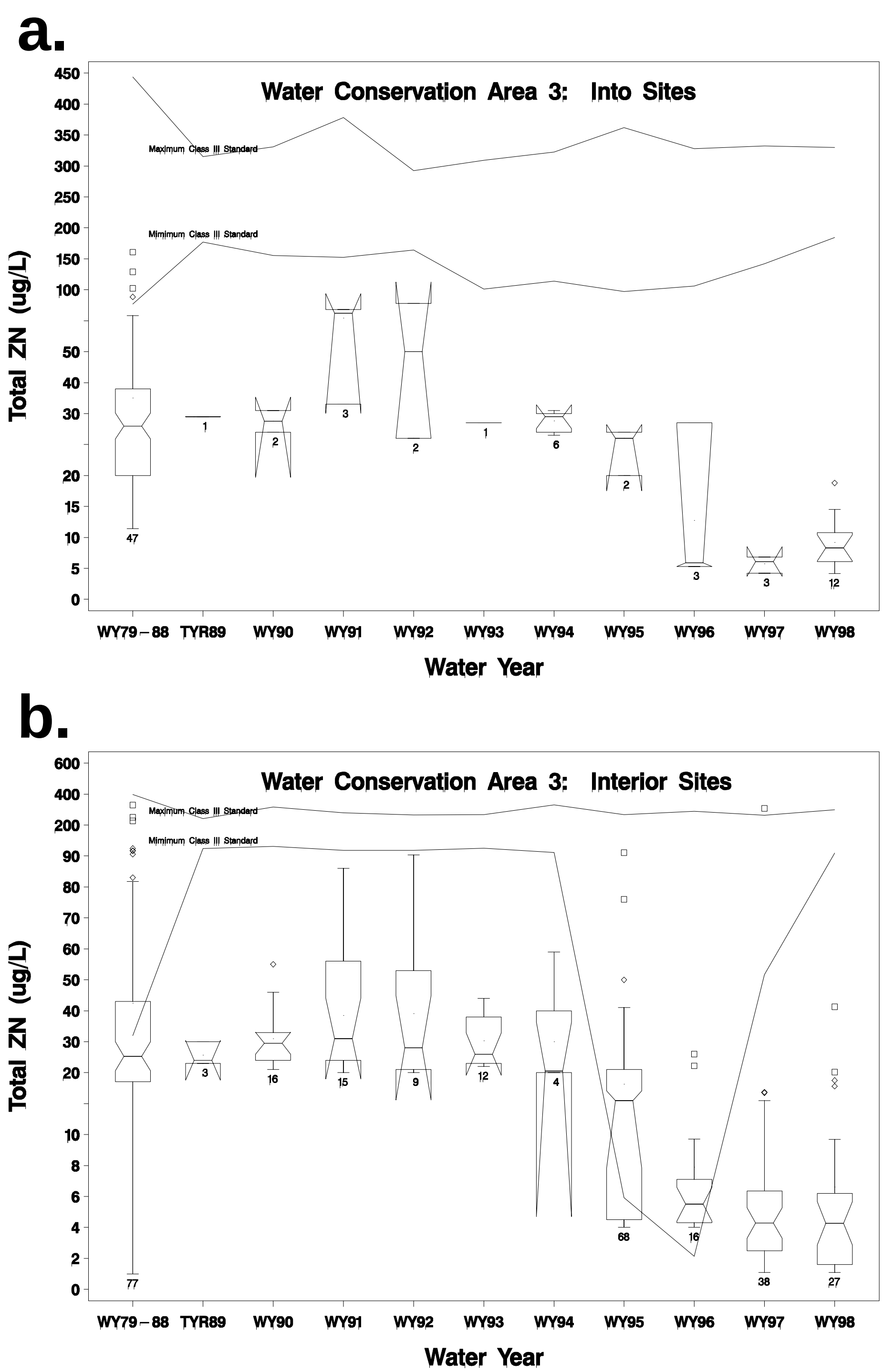


Figure 4-74. Notched box and whisker plots of total zinc data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Everglades National Park

Cadmium. Median cadmium concentrations in the Park ranged from 0.1 to 0.5 µg/L at inflow structures and 0.2 to 0.4 µg/L at interior marsh stations (**Figures 4-75a, b**). No significant trends were observed in the Park with respect to cadmium. However, slight higher median cadmium concentrations were observed after WY95. These increases could be related to the analytical method used after WY95.

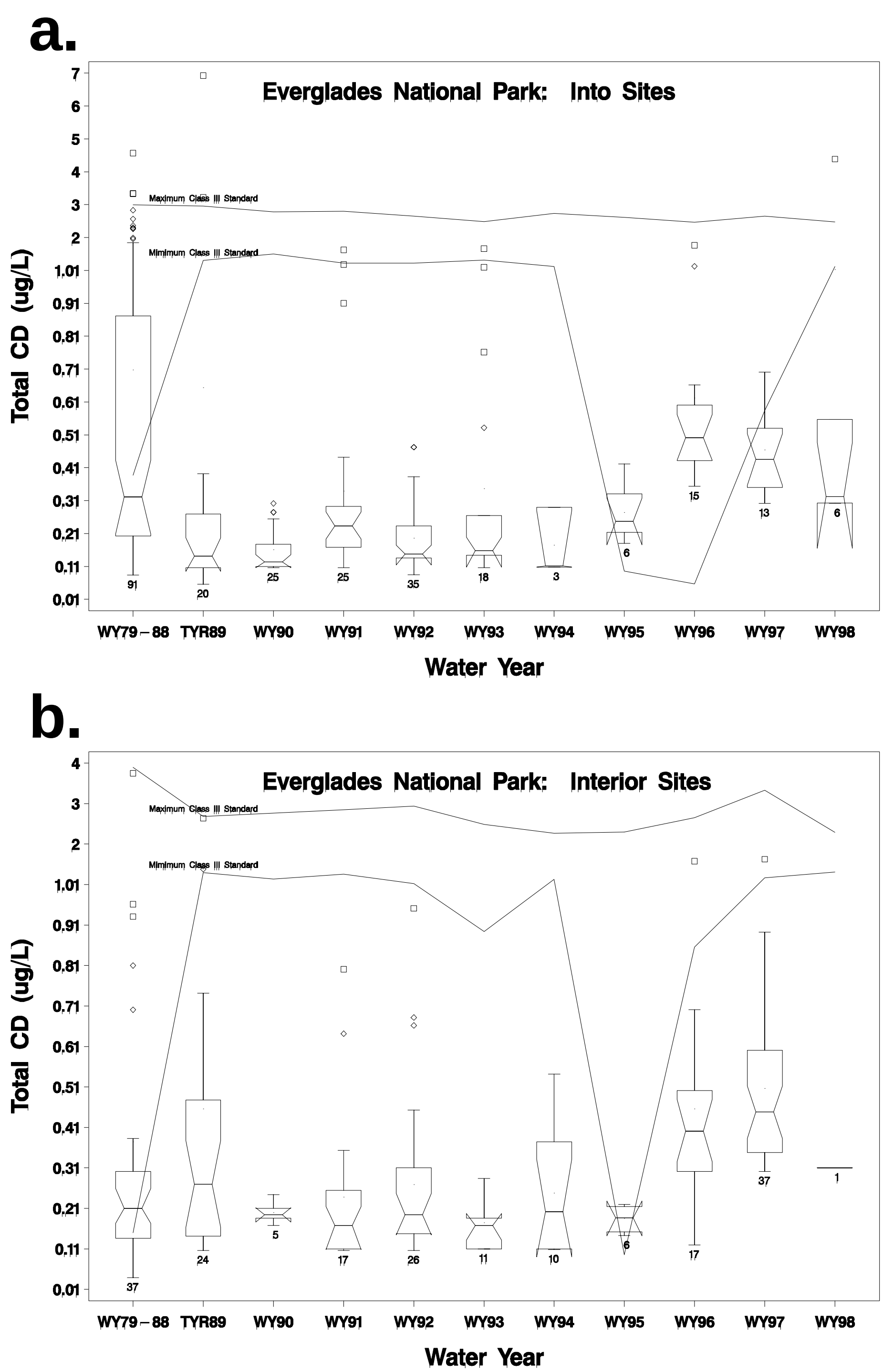
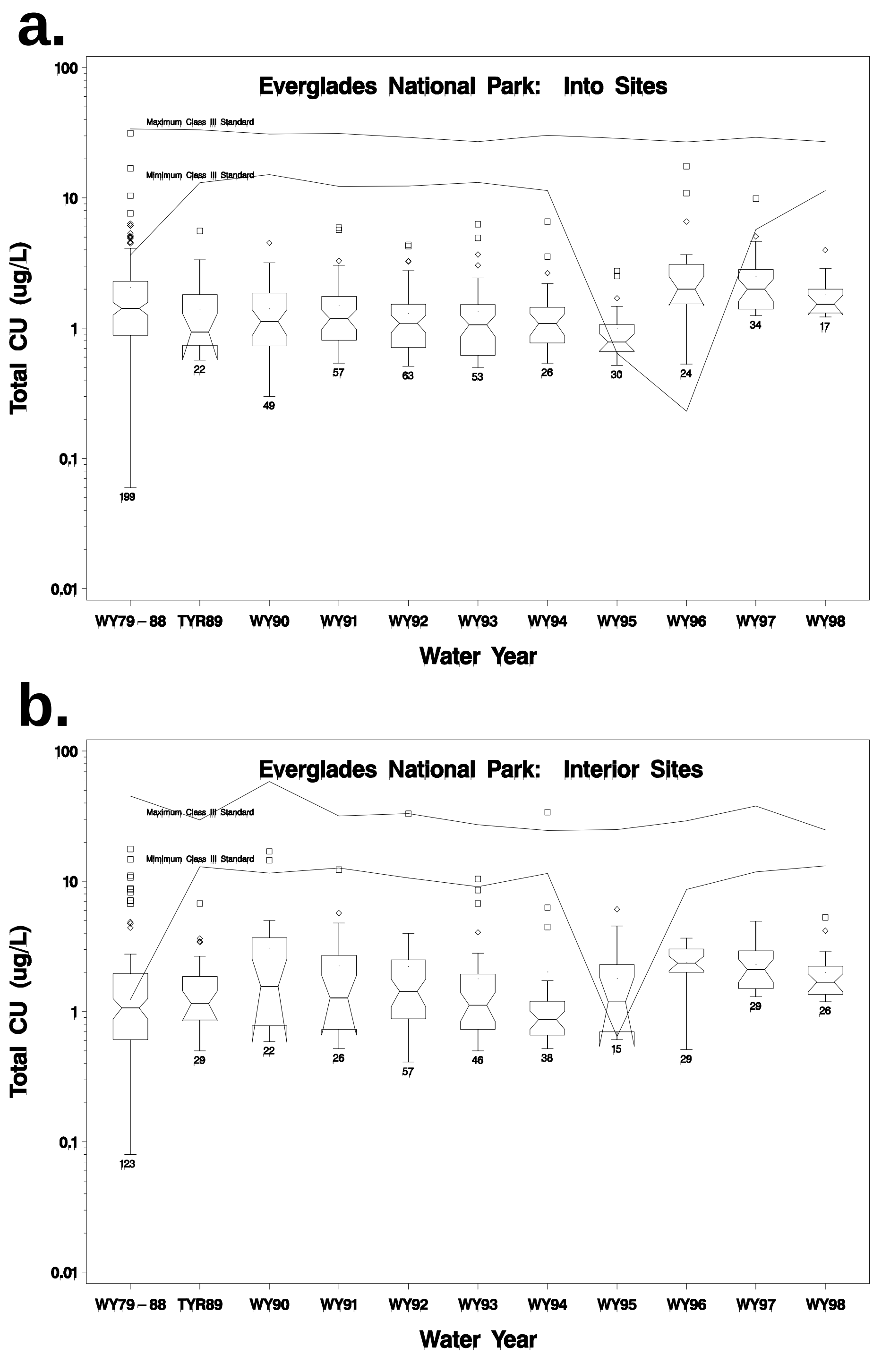


Figure 4-75. Notched box and whisker plots of total cadmium data collecte within Water Conservation Area 2 at **a.** Into and **b.** Interior sites See **Table 4-2** for a description of the parts of the notched boxe and whiskers.

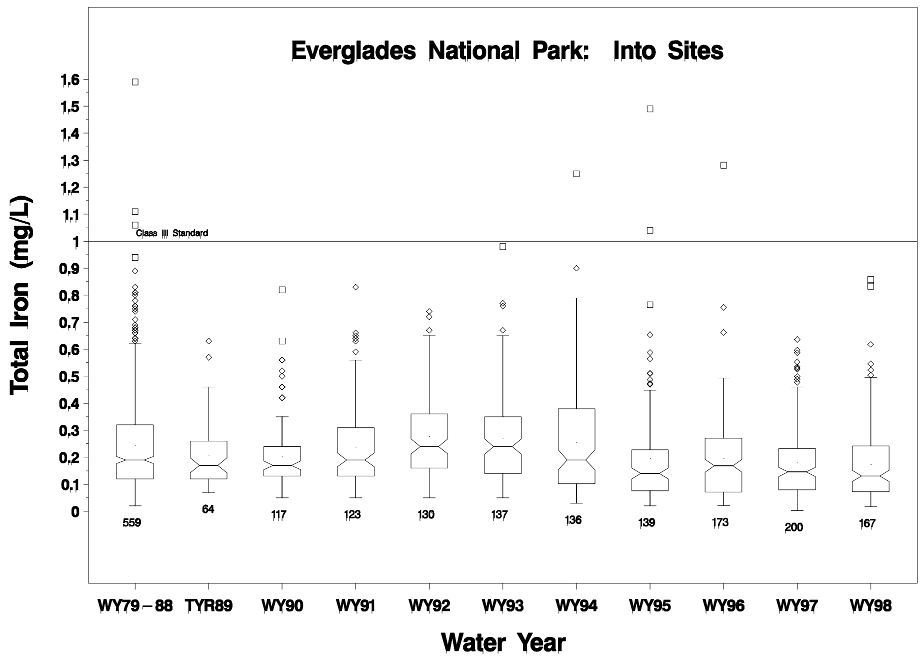


Copper. Inflow and interior marsh stations exhibited median copper concentrations ranging from 0.9 to 2.4 µg/L (**Figures 4-76a, b**). In general, median concentrations in the Park showed little variability from the baseline period through WY95. Starting with WY96, slightly higher copper concentrations were observed in the Park. The change in the analytical method for copper may have resulted in slightly increased copper concentrations.

Figure 4-76. Notched box and whisker plots of total copper data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Iron. Iron concentrations in the Park did not exhibit a significant change during the monitoring periods (**Figures 4-77a, b**). Median iron concentrations ranged from 0.09 to 0.52 mg/L from the baseline period through WY98. Slightly higher iron concentrations were observed in the interior marsh stations compared with the inflow structures.

a.



b.

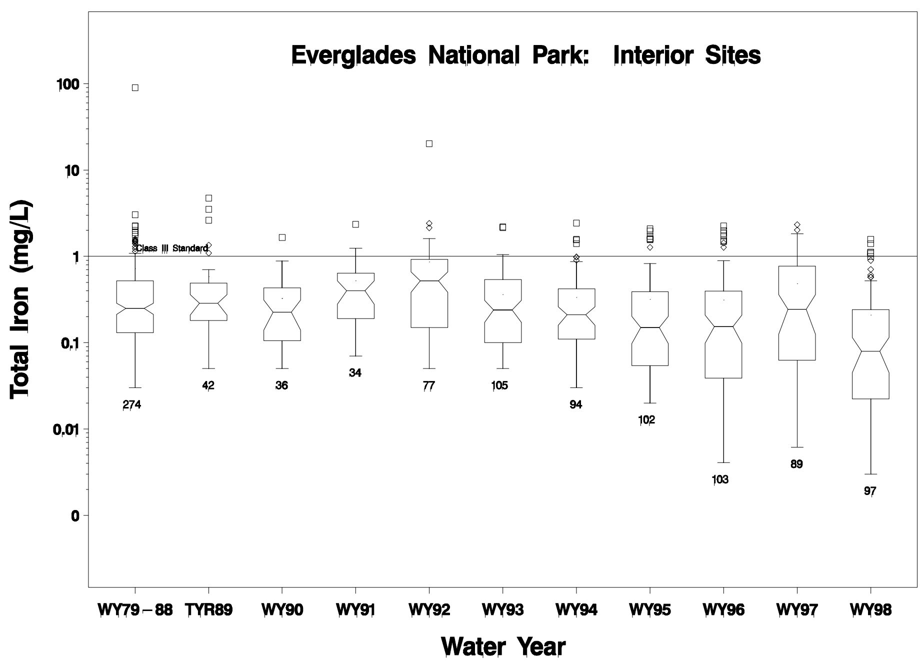


Figure 4-77. Notched box and whisker plots of total iron data collected withi Water Conservation Area 2 at **a.** Into and **b.** Interior sites. Se **Table 4-2** for a description of the parts of the notched boxes an whiskers.

Lead. Median lead concentrations at inflow structures to the Park have varied from 0.7 to 2.4 µg/L (**Figure 4-78a**). With the exception of an outlier in WY98, median concentrations of lead at interior marsh stations have been relatively constant, ranging from 0.7 to 1.0 µg/L (**Figure 4-78b**). No significant changes in lead concentrations were observed in the Park from the baseline period through WY98.

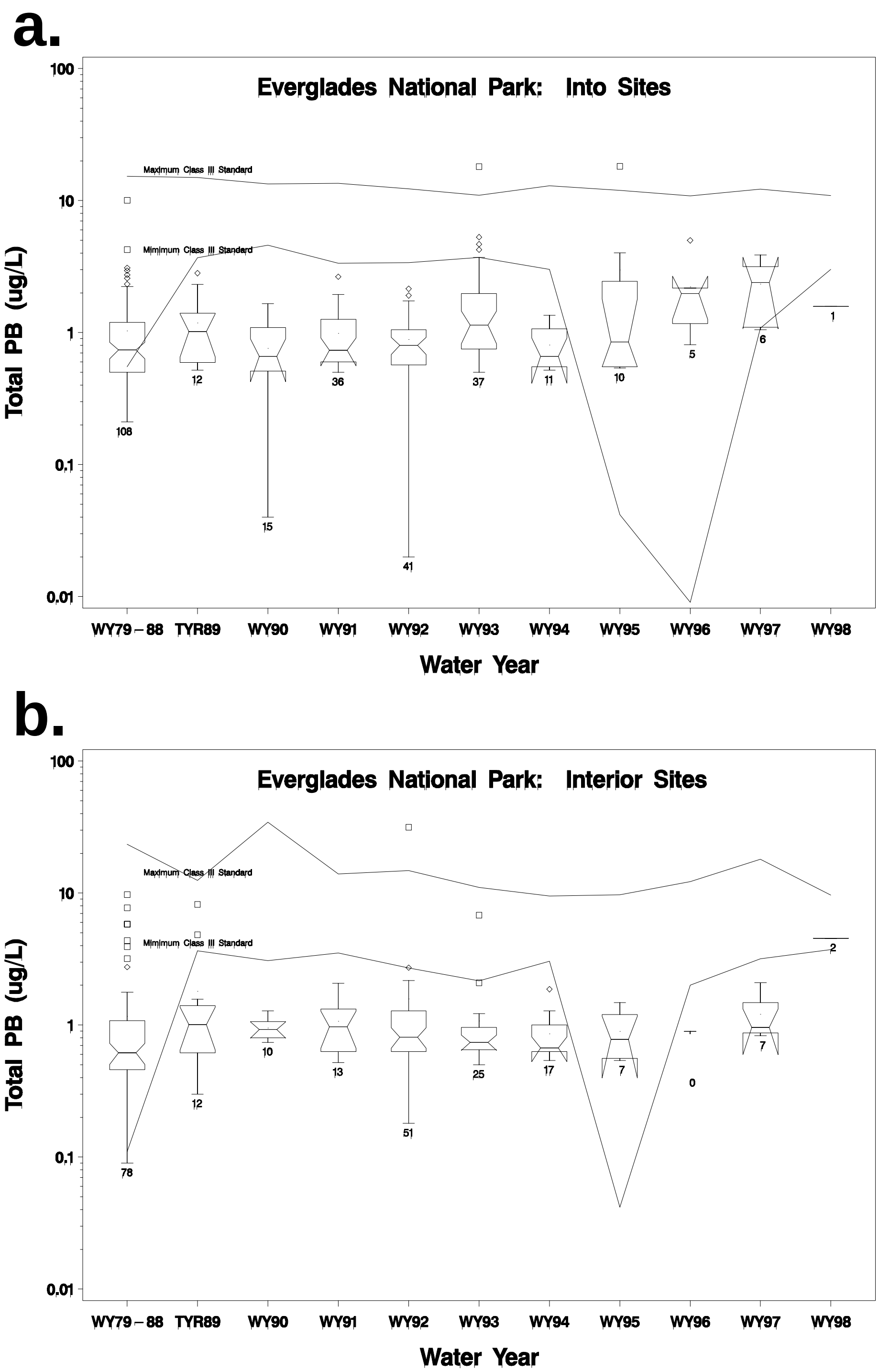


Figure 4-78. Notched box and whisker plots of total lead data collected within Water Conservation Area 2 at **a.** Into and **b.** Interior sites. See **Table 4-2** for a description of the parts of the notched boxes and whiskers.

Zinc. Zinc concentrations in the Park followed the same trend as observed in the other regions of the EPA (**Figures 4-79a, b**). Generally higher zinc concentrations were observed from the baseline period through WY95, after which zinc concentration decreased. This decrease is attributed to improved laboratory detection limits.

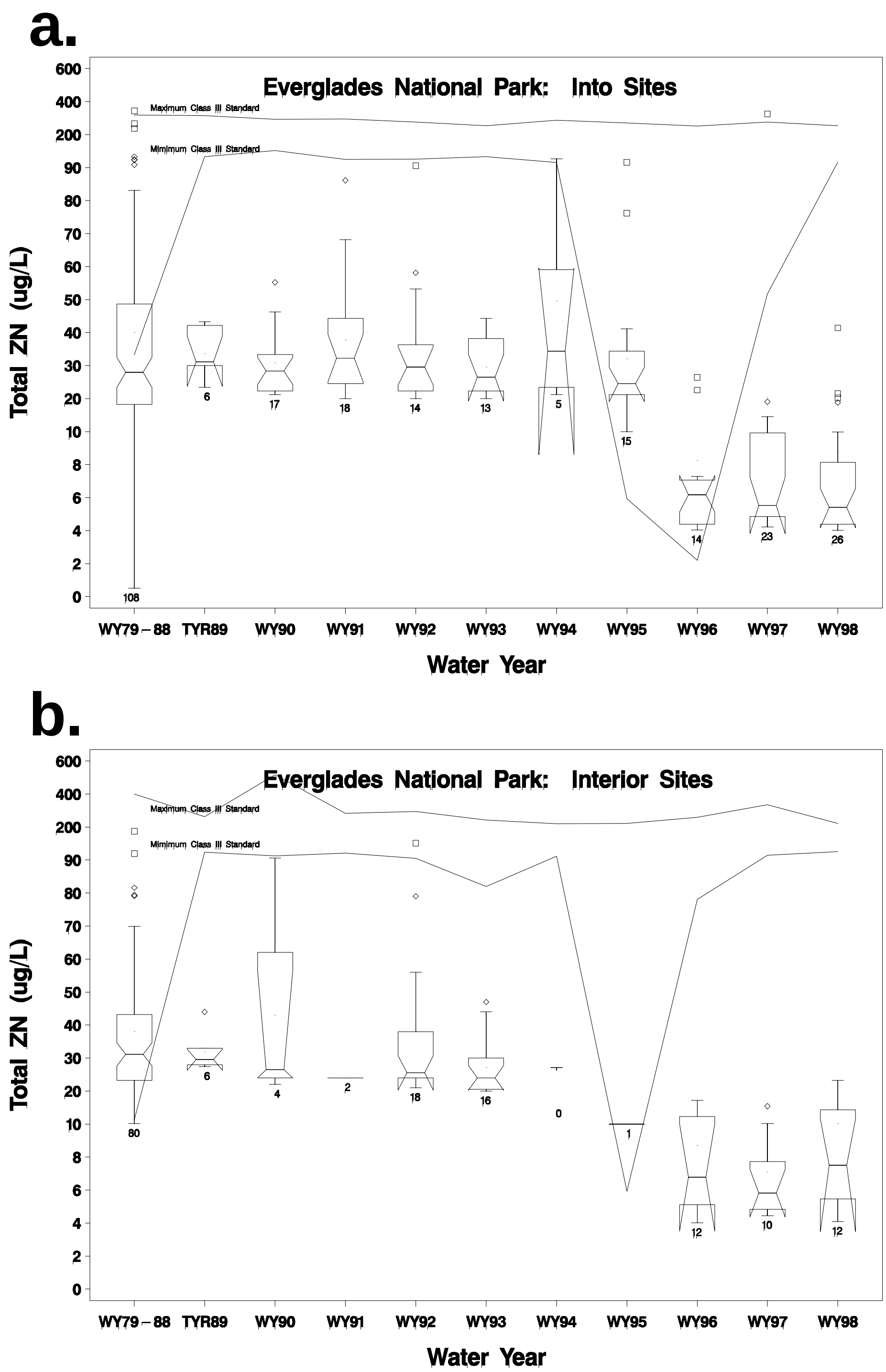


Figure 4-79. Notched box and whisker plots of total zinc data collected withi Water Conservation Area 2 at **a.** Into and **b.** Interior sites. Se **Table 4-2** for a description of the parts of the notched boxes an whiskers.

Pesticide Monitoring in the EPA

The District has maintained a pesticide monitoring program in south Florida since 1984. The pesticide monitoring network includes sites designated in the Everglades National Park Memorandum of Agreement, the Miccosukee Tribe Memorandum of Agreement, the Lake Okeechobee Operating Permit and the Non-ECP Structure Permit. The program has been dynamic over time, due to concerns that arise about pesticide use, additional sampling for new pesticides, and the additional sampling sites in the network. The current monitoring program consists of analyses for 66 pesticides at 37 sites within District boundaries (**Figure 4-80**). Of the 66 pesticides for which tests have been made over the course of this program, 43 had at least one detection (**Appendix 4-5**). **Appendix 4-5** also shows that the number of pesticide detections and the detection percentage for sampling events slowly have been increasing over time. This trend is due to eliminating pesticides that were never detected, adding recently approved pesticides to the analyses, and increasing sampling in areas of suspected or known pesticide use. Additionally, analytical methods have improved so that lower pesticide concentrations are now detectable. The increase in detections does not necessarily mean that pesticides are becoming a bigger problem *per se*. Rather, the increase demonstrates that the pesticide monitoring program is a flexible and effective tool for defining where and what pesticides are being transported from application sites to adjacent water bodies and eventually into the EPA.

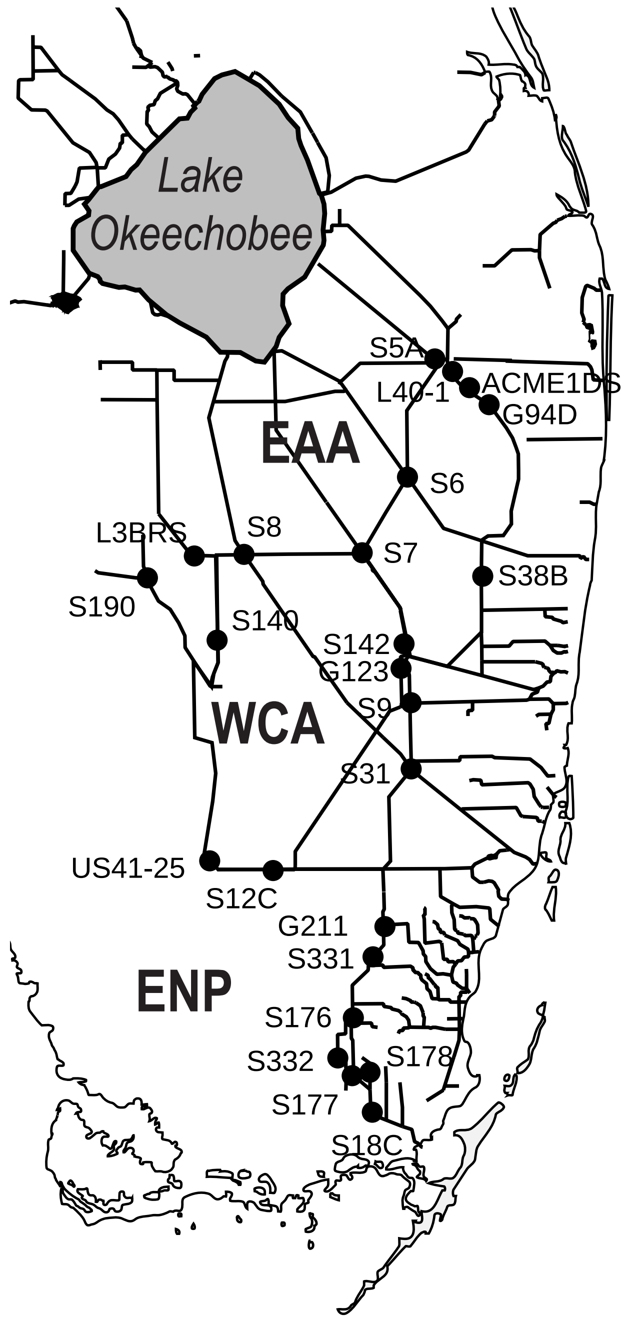


Figure 4-80. Pesticide Monitoring Network

This Report analyzes data collected from February 1992 through March 1998 at 24 monitoring sites: 17 sites that discharge into the EPA, two sites that are interior to the EPA and five sites in the C111 Basin. (**Figure 4-80**). A summary of pesticide detections and the excursion categories for the four EPA regions and the C111 Basin is presented in **Tables 4-11** to **4-16**. During this period 22 pesticides were detected, with six being detected only once. Endosulfan, which is the sum of endosulfan alpha and beta, was placed in Category A because it exceeds the Class III criterion of 0.056 μg/L on seven occasions: once at L3BRS on 1/27/93 and on six occasions at S178 between 3/18/93 and 1/25/96. The toxicity limits for aquatic invertebrates were exceeded one time each by the following pesticides: chlorpyrifos ethyl at S6 on 4/17/1996, ethion at S178 on 10/16/1997, and parathion methyl at S8 on 10/11/95. These pesticides were also ranked in Category A.

It should be noted that the existing Florida Criteria for Surface Water Quality Classifications (F.A.C. Section 62-302.530) does not list many contemporary pesticides such as ametryn, atrazine, hexazinone, bromacil, norflurazon or simizine. These pesticides are the top six for number of detections between 1992 and 1997 (**Appendix 4-5**). For pesticides not specifically listed, the acute or chronic toxicity criteria under Surface Waters, Minimum Criteria (F.A.C. 62-302.500) are utilized. The acute and chronic toxicity standards are calculated as one-third and one-twentieth, respectively, of the amount lethal to 50% of the test organisms in 96 hours, where the 96-hour LC_{50} is the lowest value which has been determined for a species significant to the indigenous aquatic community (F.A.C. 62-302.200). However, finding LC_{50} data for aquatic species indigenous to south Florida aquatic ecosystems can be difficult. DEP staff currently are engaged in this process of searching for and reviewing appropriate toxicity studies for the pesticides noted above, and intend to use such information and provide it to the District for use in comparison against detected concentrations of these compounds.

Pesticide sampling event reports are distributed to a variety of public and private agencies after each event. These reports provide a convenient format for communicating excursions of water quality and toxicity criteria. Although several months can pass before the reports are distributed (lab turn-around, quality control/quality assurance checks, report writing, *etc*.), the appropriate state agencies with pesticide regulation/enforcement authority (FDACS, DEP) can and do investigate a particular incident to rectify any discernible problems. In situations like the endosulfan problem in the C111 Basin, a working group was convened. The group consisting of federal, state, local regulation/enforcement agencies, farming interests, members of the local agricultural community and staff from the University of Florida (Cooperative Extension Service, Institute of Food Agricultural Service). Through a series of meetings, including public forums, the farming community was informed of the issues, and took actions to control endosulfan applications. As a result of this process, the Class III criteria has not been exceeded since January 1996, and the number of endosulfan detections has decreased. In addition, funding was secured for research into alternative management practices, as well as enhancement of existing management programs.

Table 4-11. Pesticide detections and excursion categories in inflows to the Refuge, February 1992 to March 1998. Samples collected at S5A,L40-1, ACME1DS, G94D and S6.

Pesticide	Total # of samples	Excursion Categories		
		Category C (# of samples <= PQL)	Category B (# of samples > PQL)	Category A (# samples exceeding criterion or toxicity limit)
Alachlor	69	69		
Ametryn	69	41	28	
Atrazine	69	14	55	
Bromacil	69	69		
Chlorpyrifos ethyl	69	68		1[a]
Diazinon	69	68	1	
Diquat	69	69		
Diuron	69	69		
Endosulfan (alpha + beta)	69	68	1	
Endosulfan sulfate	69	69		
Ethion	69	69		
Ethoprop	69	68	1	
Hexazinone	39	34	5	
Metalaxyl	69	69		
Metolachlor	69	65	4	
Metribuzin	69	69		
Norflurazon	39	39		
Parathion methyl	69	69		
Prometryn	69	66	3	
Simazine	69	67	2	
2,4-D	69	68	1	

a. exceeds toxicity levels for aquatic invertebrates.

Table 4-12. Pesticide detections and excursion categories in inflows to WCA-2, February 1992 to March 1998. Samples collected at S7 and S38B.

Pesticide	Total # of samples	Excursion Categories		
		Category C (# of samples <= PQL)	Category B (# of samples > PQL)	Category A (# samples exceeding criterion or toxicity limit)
Alachlor	30	30		
Ametryn	30	20	10	
Atrazine	30	4	26	
Bromacil	30	30		
Chlorpyrifos ethyl	30	30		
Diazinon	30	30		
Diquat	30	30		
Diuron	30	30		
Endosulfan (alpha + beta)	30	30		
Endosulfan sulfate	30	30		
Ethion	30	30		
Ethoprop	30	30		
Hexazinone	15	15		
Metalaxyl	30	30		
Metolachlor	30	30		
Metribuzin	30	30		
Norflurazon	15	15		
Parathion methyl	30	30		
Prometryn	30	30		
Simazine	30	29	1	
2,4-D	30	30		

Table 4-13. Pesticide detections and excursion categories in inflows to WCA-3, February 1992 to March 1998. Samples collected at S8, L3BRS, S190, S140, G123 and S9.

Pesticide	Total # of samples	Excursion Categories		
		Category C (# of samples <= PQL)	Category B (# of samples > PQL)	Category A (# samples exceeding criterion or toxicity limit)
Alachlor	123	123		
Ametryn	123	111	12	
Atrazine	123	65	58	
Bromacil	123	111	12	
Chlorpyrifos ethyl	123	123		
Diazinon	123	122	1	
Diquat	123	122	1	
Diuron	123	120	2	
Endosulfan (alpha + beta)	123	122		1[a]
Endosulfan sulfate	123	123		
Ethion	123	123		
Ethoprop	123	123		
Hexazinone	63	55	8	
Metalaxyl	123	123		
Metolachlor	123	121	2	
Metribuzin	123	120	3	
Norflurazon	63	56	7	
Parathion methyl	123	122		1[b]
Prometryn	123	123		
Simazine	123	123		
2,4-D	123	122	1	

a. Exceeds Class III surface water criterion of 0.056 µg/L.
b. Exceeds toxicity levels for aquatic invertebrates.

Table 4-14. Pesticide detections and excursion categories at WCA-3 interior sites, February 1992 to March 1998. Samples were collected at S142 and S31.

Pesticide	Total # of samples	Excursion Categories		
		Category C (# of samples <= PQL)	Category B (# of samples > PQL)	Category A (# samples exceeding criterion or toxicity limit)
Alachlor	33	33		
Ametryn	33	25	8	
Atrazine	33	18	15	
Bromacil	33	33		
Chlorpyrifos ethyl	33	33		
Diazinon	33	33		
Diquat	33	33		
Diuron	33	33		
Endosulfan (alpha + beta)	33	33		
Endosulfan sulfate	33	33		
Ethion	33	33		
Ethoprop	33	33		
Hexazinone	18	16	2	
Metalaxyl	33	33		
Metolachlor	33	33		
Metribuzin	33	33		
Norflurazon	18	18		
Parathion methyl	33	33		
Prometryn	33	33		
Simazine	33	33		
2,4-D	33	32	1	

Table 4-15. Pesticide detections and excursion categories in inflows to the Park, February 1992 to March 1998. Samples were collected at S332, S18C, US41-25, and S12C.

Pesticide	Total # of samples	Excursion Categories		
		Category C (# of samples <= PQL)	Category B (# of samples > PQL)	Category A (# samples exceeding criterion or toxicity limit)
Alachlor	116	116		
Ametryn	116	115	1	
Atrazine	116	100	16	
Bromacil	116	116		
Chlorpyrifos ethyl	116	116		
Diazinon	116	116		
Diquat	116	116		
Diuron	116	116		
Endosulfan (alpha + beta)	116	114	2	
Endosulfan sulfate	116	115	1	
Ethion	116	116		
Ethoprop	116	116		
Hexazinone	56	56		
Metalaxyl	116	116		
Metolachlor	116	116		
Metribuzin	116	116		
Norflurazon	56	56		
Parathion methyl	116	116		
Prometryn	116	116		
Simazine	116	116		
2,4-D	116	115	1	

Table 4-16. Pesticide detections and excursion categories in C111 Basin canals, February 1992 to March 1998. Samples were collected at G211, S331, S176, S177 and S178.

Pesticide	Total # of samples	Excursion Categories		
		Category C (# of samples <= PQL)	Category B (# of samples > PQL)	Category A (# samples exceeding criterion or toxicity limit)
Alachlor	95	95		
Ametryn	95	95		
Atrazine	95	86	9	
Bromacil	95	95		
Chlorpyrifos ethyl	95	95		
Diazinon	95	95		
Diquat	95	95		
Diuron	95	95		
Endosulfan (alpha + beta)	95	78	11	6[a]
Endosulfan sulfate	95	74	21	
Ethion	95	94		1[b]
Ethoprop	95	95		
Hexazinone				
Metalaxyl	95	95		
Metolachlor	95	95		
Metribuzin	95	94	1	
Norflurazon	50	50		
Parathion methyl	95	95		
Prometryn	95	95		
Simazine	95	95		
2,4-D	95	95		

a. Exceeds Class III surface water criterion of 0.056 µg/L.
b. Exceeds toxicity levels for aquatic invertebrates.

Water Quality Status and Anticipated Improvements

The status of compliance with water quality criteria in the Everglades Protection Area as of April 1998 is summarized as follows:

- An excursion analysis was performed on constituents with numeric criteria **(Tables 4-17 to 4-20)**.
- Positive or negative trends of constituents in WY90-98 were evaluated based upon a comparison with the baseline period **(Tables 4-17 to 4-20)**.
- TP and TN load changes and changes in constituent concentrations between the EPA regions were compared to the baseline period **(Table 4-21)**.

Excursion analysis

Three categories were developed to rank water quality constituents, including TP and pesticides, that had excursions in the EPA. **Table 4-3** is reproduced here as a guide to the excursion categories presented in **Tables 4-17** to **4-20**. In these tables a diamond symbol (◆) is used for TP, since 50 ppb and 10 ppb are not Class III criteria. Comments on those water quality constituents that are in **Category A** are provided in each table. Dissolved oxygen was placed in Category A because of the high excursion percent in all EPA regions at both the inflow and interior sites. Specific conductance was assigned to Category A at all inflow sources and in the Refuge rim canal, and to Category B at all interior sites. Alkalinity and pH were place in Category A in the interior marshes of the Refuge. Unionized ammonia, pH, and turbidity were assigned to Category B in the inflows to the Refuge, in the Refuge rim canal, and at the inflow and interior sites in WCA-2, WCA-3 and the Park. TP was placed in Category A in all EPA regions except for the Park and interior marshes of the Refuge, where it was placed in Category B.

Significant trends

Notched box and whisker plots were used to determine if any water quality constituents had significant trends between 1990 and 1998, compared to the baseline period. At the inflow structures to the Refuge, significant improvement trends were found for specific conductance, alkalinity and TP, as compared to the baseline period. There were no significant trends in the rim canal. At the interior sites improvement trends for TP and iron occurred, but there was a worsening trend for dissolved oxygen. At WCA-2 inflow structures TN and total iron had improvement trends, while only total iron showed an improvement trend at the interior sites. At WCA-3 inflow sites there were no significant trends, but turbidity, TP, TN and total iron all had improvement trends at interior sites. The Park had improvement trends in TP and TN at the inflow structures. There were no significant trends at any interior sites.

Table 4-17. Characterization of water quality in Loxahatchee National Wildlife Refuge.

	Excursions			Trends	
	Category A	Category B	Category C	Significant Change? (Y or N)	Comments on Concerns
INFLOW STRUCTURES					
Physical Parameters					
Specific Conductance	●			Y+	STAs should further improve water quality
Dissolved Oxygen	●			N	Low dissolved oxygen in canals, standard should be revised
pH		●		N	
Total Alkalinity			●	Y+	
Turbidity		●		N	
Nutrients					
Un-ionized Ammonia		●		N	
Total Phosphorus	◆			Y+	STAs will further reduce phosphorus concentrations
Trace Metals					
Total Cadmium			●	N	
Total Copper			●	N	
Total Iron		●		N	
Total Lead			●	N	
Total Zinc			●	N	
RIM CANAL STATIONS					
Physical Parameters					
Specific Conductance	●			N	STAs should further improve water quality
Dissolved Oxygen	●			N	Low dissolved oxygen in canals, standard should be revised
pH		●		N	
Total Alkalinity			●	N	
Turbidity		●		N	
Nutrients					
Un-ionized Ammonia		●		N	
Total Phosphorus	◆			N	STAs will further reduce phosphorus concentrations
Trace Metals					
Total Cadmium			●	N	
Total Copper			●	N	
Total Iron		●		N	
Total Lead			●	N	
Total Zinc			●	N	
INTERIOR SITES					
Physical Parameters					
Specific Conductance		●		N	
Dissolved Oxygen	●			Y-	Dissolved oxygen naturally low in marsh, standard should be revised
pH	●			N	pH naturally low in marsh, standard should be revised
Total Alkalinity	●			N	Naturally low alkalinity, standard should be revised
Turbidity			●	N	
Nutrients					
Un-ionized Ammonia			●	N	
Total Phosphorus		◆		Y+	
Trace Metals					
Total Cadmium			●	N	
Total Copper			●	N	
Total Iron			●	Y+	
Total Lead			●	N	
Total Zinc			●	N	

+ = improving trend - = worsening trend

Table 4-18. Characterization of water quality in Water Conservation Area 2.

	Excursions			Trends	
	Category A	Category B	Category C	Significant Change? (Y or N)	Comments on Concerns
INFLOW STRUCTURES					
Physical Parameters					
Specific Conductance	●			N	STAs should further improve quality
Dissolved Oxygen	●			N	Low dissolved oxygen in canals, standard should be revised
pH		●		N	
Total Alkalinity			●	N	
Turbidity		●		N	
Nutrients					
Un-ionized Ammonia		●		N	
Total Phosphorus	◆			N	STAs will further reduce phosphorus concentrations
Trace Metals					
Total Cadmium			●	N	
Total Copper		●		N	
Total Iron			●	Y+	
Total Lead			●	N	
Total Zinc			●	N	
INTERIOR SITES					
Physical Parameters					
Specific Conductance		●		N	
Dissolved Oxygen	●			N	Low dissolved oxygen in canals, standard should be revised
pH		●		N	
Total Alkalinity			●	N	
Turbidity		●		N	
Nutrients					
Un-ionized Ammonia		●		N	
Total Phosphorus	◆			N	STAs will further reduce phosphorus concentrations
Trace Metals					
Total Cadmium		●		N	
Total Copper			●	N	
Total Iron			●	Y+	
Total Lead			●	N	
Total Zinc		●		N	

\+ = improving trend - = worsening trend

Table 4-19. Characterization of water quality in Water Conservation Area 3.

	Excursions			Trends	
	Category A	Category B	Category C	Significant Change? (Y or N)	Comments on Concerns
INFLOW STRUCTURES					
Physical Parameters					
Specific Conductance	●			**N**	STAs should further improve quality
Dissolved Oxygen	●			**N**	Low dissolved oxygen in canals, standard should be revised
pH		●		**N**	
Total Alkalinity			●	**N**	
Turbidity		●		**N**	
Nutrients					
Un-ionized Ammonia		●		**N**	
Total Phosphorus	◆			**N**	STAs will further reduce phosphorus concentrations
Trace Metals					
Total Cadmium			●	**N**	
Total Copper		●		**N**	
Total Iron			●	**N**	
Total Lead			●	**N**	
Total Zinc			●	**N**	
INTERIOR SITES					
Physical Parameters					
Specific Conductance		●		**N**	
Dissolved Oxygen	●			**N**	Low dissolved oxygen in canals, standard should be revised
pH		●		**N**	
Total Alkalinity			●	**N**	
Turbidity		●		**Y+**	
Nutrients					
Un-ionized Ammonia		●		**N**	
Total Phosphorus	◆			**Y+**	STAs will further reduce phosphorus concentrations
Trace Metals					
Total Cadmium		●		**N**	
Total Copper			●	**N**	
Total Iron			●	**Y+**	
Total Lead			●	**N**	
Total Zinc		●		**N**	

\+ = improving trend - = worsening trend

Table 4-20. Characterization of water quality in the Park.

	Excursions			Trends	
	Category A	Category B	Category C	Significant Change? (Y or N)	Comments
INFLOW STRUCTURES					
Physical Parameters					
Specific Conductance	●			**N**	STAs should further improve quality
Dissolved Oxygen	●			**N**	Low dissolved oxygen in canals, standard should be revised
pH		●		**N**	
Total Alkalinity			●	**N**	
Turbidity		●		**N**	
Nutrients					
Un-ionized Ammonia		●		**N**	
Total Phosphorus		◆		**Y+**	
Trace Metals					
Total Cadmium			●	**N**	
Total Copper		●		**N**	
Total Iron			●	**N**	
Total Lead			●	**N**	
Total Zinc			●	**N**	
INTERIOR SITES					
Physical Parameters					
Specific Conductance		●		**N**	
Dissolved Oxygen	●			**N**	Low dissolved oxygen in canals, standard should be revised
pH		●		**N**	
Total Alkalinity			●	**N**	
Turbidity		●		**N**	
Nutrients					
Un-ionized Ammonia		●		**N**	
Total Phosphorus		◆		**N**	
Trace Metals					
Total Cadmium		●		**N**	
Total Copper			●	**N**	
Total Iron			●	**N**	
Total Lead			●	**N**	
Total Zinc		●		**N**	

+ = improving trend - = worsening trend

Load and concentration changes in the EPA

The changes in 1) TP and TN loads and in median concentrations and 2) in median concentrations or values of the other constituents that had excursions were analyzed following the water flow from north to south through the EPA **(Table 4-21)**. When comparing the TP loads discharged into the EPA between the baseline and recent water years, it appears that the Refuge is the only region to have received a slightly higher load in the recent water years. This increase in TP loads will be rectified by ECP implementation, which is expected to substantially reduce TP loads. TN loads have increased slightly in WCA-3 and the Park in recent water years. Both the TP and TN load data show that the Refuge and conservation areas have been removing TP and TN prior to its discharge southward. The TP and TN median concentration data also indicate the assimilation of nutrients by WCA-2 and WCA-3. The calculated un-ionized ammonia concentration at the Refuge interior marsh sites is 100 times lower than the calculated concentration of the inflow, due to the large decrease in pH that exists between the inflows and the rain-driven waters of the interior marsh. Specific conductance has shown some large decreases in the Refuge, WCA-2 and inflows to WCA-3. The Park has had specific conductance increases at both the inflows and interior sites. There are no trends in the EPA for dissolved oxygen or pH. The Refuge pH is a natural condition that is significantly lower than the other marshes of the EPA. Alkalinity has consistently decreased between the baseline period and recent water years in each region and also between regions in both periods. Turbidities are higher in the recent water years in inflows to the Refuge and WCA-2. The Refuge rim canal reflects the higher inflow turbidity, with some decrease due to particulate settling in the canal. The marsh site turbidity range of 1 to 2 NTU most likely reflects a natural condition.

Anticipated improvements

The positive changes in water quality within the EPA described in this Report are probably just beginning. There have been major reductions in TP entering the EPA from the Everglades Agricultural Area through implementation of Best Management Practices (see **Chapter 5**). The ENR project demonstrated the effectiveness of STA technology by retaining an average of 81% of the inflow TP load from WY95 through WY98 (see **Chapter 6**). This retention reduced the total TP load discharged to the Refuge by an average of 15% over the same time period. Through monitoring and regulatory action programs (see **Chapter 11**), the District’s Everglades Stormwater Program, (required by the Act), will be further improving water quality in the drainage basins of all the remaining structures that discharge into the EPA.

The STAs will have the biggest impact on reducing TP and, to a lesser extent, TN. There will also be water quality improvements in turbidity and un-ionized ammonia in the EAA waters treated in the STAs. It is also expected that low dissolved oxygen concentrations in the waters from the EAA canals will be improved when passed through the STAs. The relationship between excessive nutrients, alteration of natural aquatic plant, microbial and animal communities and dissolved oxygen levels lower than natural background conditions is reasonably well understood, and is being further documented by ongoing District research efforts. The continuous dissolved oxygen data from nutrient gradient studies in the Refuge and WCA-2 presented in this chapter indicate how the marsh systems may respond as nutrient levels continue to be lowered by BMPs and STAs. The key question to be addressed is, “How long will it take to meet the current water quality criteria?”

Table 4-21. Changes in total phosphorus (TP) and total nitrogen (TN) loads and in constituent concentrations between the four EPA regions.

	Loads (metric tons)		Median Concentrations/Units							
	TP	TN	TP (µg/L)	TN (mg/L)	Unionized Ammonia (mg/L)	Specific Conductance (umhos/cm)	Dissolved Oxygen (mg/L)	pH (units)	Alkalinity (mg/L)	Turbidity (NTU)
Refuge										
Inflows										
Baseline avg.	106	3504	95.5	4.3	0.0036	1234	3.1[a]	7.25[a]	279	2.5
WY90-98 avg.	114	3132	67.5	2.5	0.0014	1002	3	7.13	228	3.7
Rim Canal										
Baseline avg.	n/a	n/a	58.5	2.8	0.00063	992	4.1	7.3	222	1.5
WY90-98 avg.	n/a	n/a	59.2	2.2	0.00068	924	3.5	7.2	220	3.2
Interior Sites										
Baseline avg.	n/a	n/a	12	2.4	0.000043	160	5.6	6.47	44	1.1
WY90-98 avg.	n/a	n/a	7.4[b]	1.1[c]	0.000024[c]	145[d]	3.4[d]	6.66[d]	31[d]	1.2[d]
WCA-2										
Inflows										
Baseline avg.	86	3009	62	3.3	0.00098	1104	3.7	7.3	293	2.2
WY90-98 avg.	80	2570	66	2.4	0.00095	924	3.5	7.2	246	3.4
Interior Sites										
Baseline avg.	n/a	n/a	16	2.4	0.00041	944	4.2	7.3	230	1.1
WY90-98 avg.	n/a	n/a	18	1.8	0.00026	863	3.5	7.2	221	1.2
WCA-3										
Inflows										
Baseline avg.	136	3788	44	2.2	0.00078	804	3.9	7.3	229	2
WY90-98 avg.	119	3879	38	1.7	0.00058	649	3.9	7.2	206	2.1
Interior Sites										
Baseline avg.	n/a	n/a	11	1.7	0.00027	523	3.9	7.2	176	1
WY90-98 avg.	n/a	n/a	12	1.4	0.00027	527	3.7	7.1	170	1.3
Park										
Inflows										
Baseline avg.	15	1525	10	1.5	0.00031	472	3.9	7.2	172	1
WY90-98 avg.	12	1656	10	1.2	0.00034	517	4	7.2	179	1.3
Interior Sites										
Baseline avg.	n/a	n/a	7	1.3	0.00049	460	5	7.5	163	1.5
WY90-98 avg.	n/a	n/a	5.4	1.3	0.00065	520	5.3	7.5	160	1.5

a. All dissolved oxygen and pH data may have upward bias due to sampling during daylight hours only.
b. Only five years data.
c. Only two years data
d. Only four years data.

Recommendations for Modifying Class III Criteria

While many of the District's water quality concerns are substantive and require the specific restoration programs discussed in other chapters of this Report, some of the problems can be rectified by adopting more appropriate water quality criteria. Specifically, dissolved oxygen throughout the EPA, and alkalinity and pH in the Refuge marshes are three water quality constituents for which evidence suggests that the current criteria are not representative of natural conditions, i.e. inappropriate criteria are forcing natural variations in water quality to be defined as excursions.

Dissolved Oxygen

When evaluating both baseline period and recent water years excursion data, it was apparent that the minimum dissolved oxygen criterion was the one most frequently exceeded, and that the excursions occurred system-wide and throughout the year.

The nature of dissolved oxygen in water is one of continuous change over a temporal scale on the order of minutes. The concentration of dissolved oxygen in a water body is influenced by water temperature, the amount of salts dissolved in the water, the amount of oxygen transferred from air to the water, and the balance between the amount of oxygen produced by photosynthesis of aquatic plants and that consumed through respiration by aquatic animals, plants and microbes.

In a natural marsh system photosynthetic production of oxygen is the prime cause of the daytime increase in dissolved oxygen concentration. Although plants respire while they photosynthesize, the oxygen produced through photosynthesis generally exceeds their respiratory needs. In highly productive systems more oxygen can be produced than can be held in a dissolved state in the water column. In this state, the water is considered to be supersaturated and oxygen bubbles may be released from the water. As daylight wanes, photosynthesis ceases and respiration processes consume the dissolved oxygen in the water column. The dissolved oxygen concentration decreases throughout the night, usually reaching a minimum about dawn. The rate of decrease of dissolved oxygen concentrations during the night, and the minimum concentration are directly related to the nighttime respiration rate. Respiration rate, in turn, is a function of aquatic community type and the amount of decomposing vegetation present, *i.e.* a densely vegetated marsh community can consume all of the dissolved oxygen present before dawn.

When the results of the photosynthetic and respiration processes are measured as dissolved oxygen concentrations over short time intervals (for a period of 24 hours or more) and the data are then plotted in time order, the resulting graph is called a diel curve. Analysis of diel curves provides insight into the nature of an aquatic community and allows for comparisons between different communities and similar communities subjected to various levels and types of environmental stress.

The Florida Class III fresh water quality criterion states that dissolved oxygen “shall not be less that 5.0 mg/L. Normal daily and seasonal fluctuations above these levels shall be maintained.” This criterion, as well as those promulgated in the other states, follows EPA guidelines for dissolved oxygen.

As can be seen in the excursion summary in **Tables 4-4** through **4-7** and **Appendix 4-4**, dissolved oxygen values less than 5.0 mg/L have occurred in wide-spread areas within the EPA. Since these excursions are in areas documented to be impacted by agricultural and suburban stormwater runoff, as well as in areas considered least impacted by human activities within the EPA, it is obvious that the dissolved oxygen criterion is inappropriate for all of the waters in the EPA.

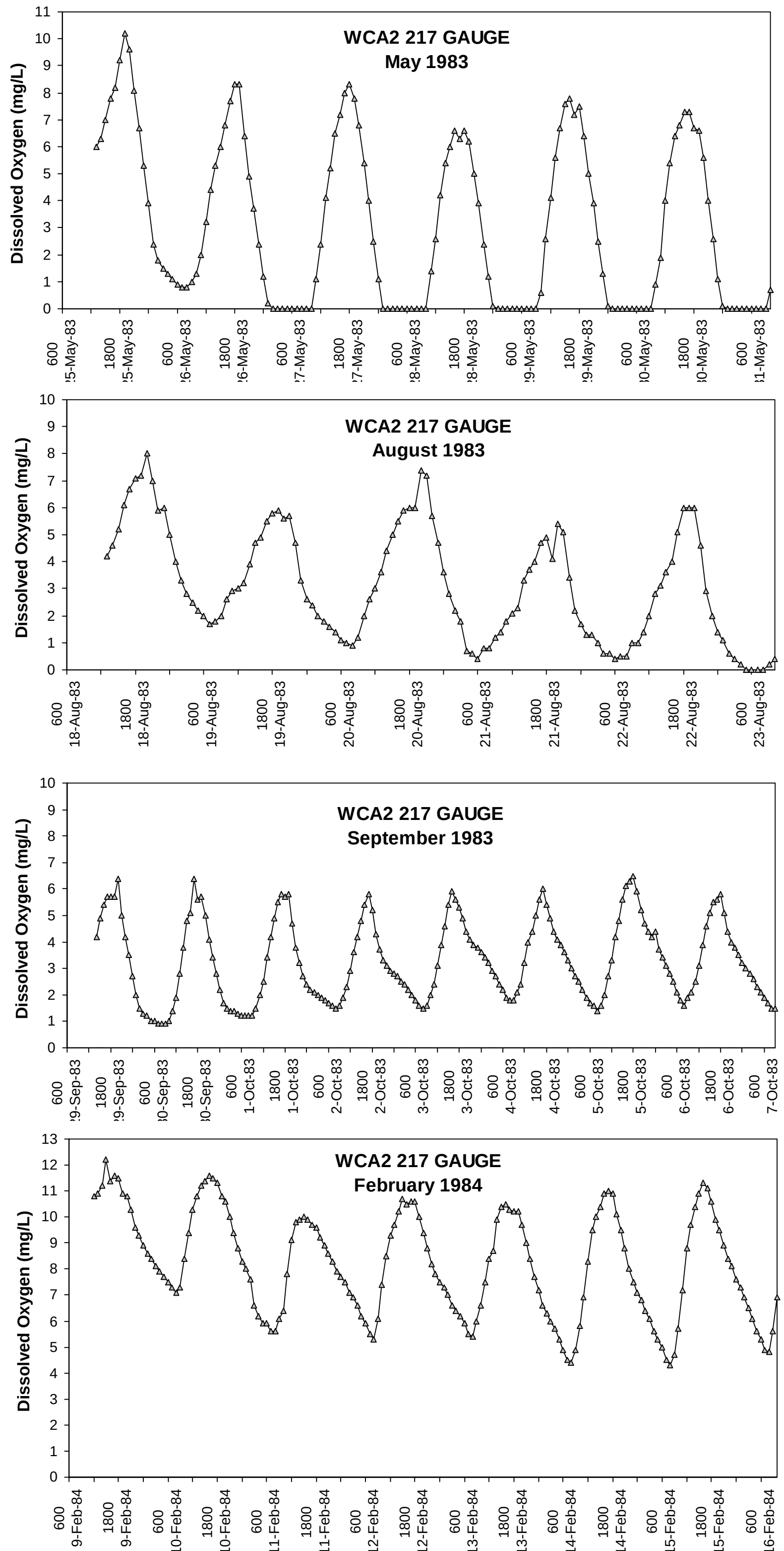


Figure 4-81. Diel DO curves at the WCA-2A 217 Gauge site.

Use of Diel Curves to Determine a Dissolved Oxygen Criterion

A number of researchers have developed dissolved oxygen diel curves from data collected in a variety of aquatic communities in the EPA. As part of a marsh community metabolism study, McCormick et al. (1997) presented diel curves representing three minimally nutrient impacted sites in WCAs 1 (A3), 2A (217 gauge) and 3A (3-4 gauge), and a nutrient enriched site in WCA-2A (B2), using data collected between 1979 and 1985. **Figure 4-81** presents diel curves from four months in 1983-84 at the WCA-2A217 gauge location. High photosynthetic rates and high respiration rates in May 1983 produced dissolved oxygen daily variations of 8 to 9 mg/L, and nighttime concentrations of zero for 7 to 8 hours. In August and September daily variations ranged from 5 to 7 mg/L, with only August 23 having a nighttime low of zero for four hours. By February 1984 the minimum dissolved oxygen values were 4.3, and daily variations ranged from 5.5 to 7.5 mg/L. These four graphs demonstrate that variability in dissolved oxygen concentration has a daily component and a seasonal component. The daily range (maximum and minimum values) reflects the magnitude of the photosynthesis and respiration rates which, in turn, are a function of daily water temperature changes, light intensity, nutrient availability and varying short-term weather conditions. The seasonal component is influenced predominantly by longer-term temperature change, rainfall, hours of daylight and plant growth cycles. Representative diel graphs from the other sites studied by McCormick et al. (1997) are presented in **Appendix 4-6** to demonstrate the variability of dissolved oxygen inherent in EPA marsh surface waters. Note that WCA-2 (B-2), the nutrient impacted site, has little daily and seasonal variation with dissolved oxygen concentrations consistently less than 2 mg/L. Belanger and Platko (1986) also investigated dissolved oxygen dynamics in a nutrient-enriched cattail site, a sawgrass site, and a slough in WCA-2A. Their observation was that diel oxygen variation was greatest in the slough, slightly less in the sawgrass site, and very low in the cattail site. The cattail site was nearly anaerobic from July through September.

In their studies to support derivation of a Class III P criterion for the Refuge, McCormick et al. (1996, 1997, 1998) established surface water quality transects in the vicinity of pump station S6 (**Figure 4-82**). The transects align with a steep gradient of changing water quality characteristics that extends from the L7 rim canal through the peripheral marsh bordering the canal, into the interior marsh about 4.5 km from the canal. Dissolved oxygen data collected in 1996 and 1997 averaged less than 5mg/L at all sites along the transects. Oxygen concentrations were lowest at marsh sites near the canal, and the authors suggested that sediment respiration was the cause. Diel oxygen concentration measurements made the week of June 5, 1997 along transect Z are presented in **Figure 4-83**. The higher nutrient content waters within the peripheral marsh had the lowest dissolved oxygen concentrations and were anaerobic during most of the nighttime hours. In contrast, the Z3 and Z4 sites had minimum concentrations between 0.5 and 2.5 during this same period. The daily range of oxygen variation was about 4 mg/L at Z1, while the other sites had daily ranges up to 9 mg/L. Additional diel curves developed during this study can be found in **Appendix 4-6**.

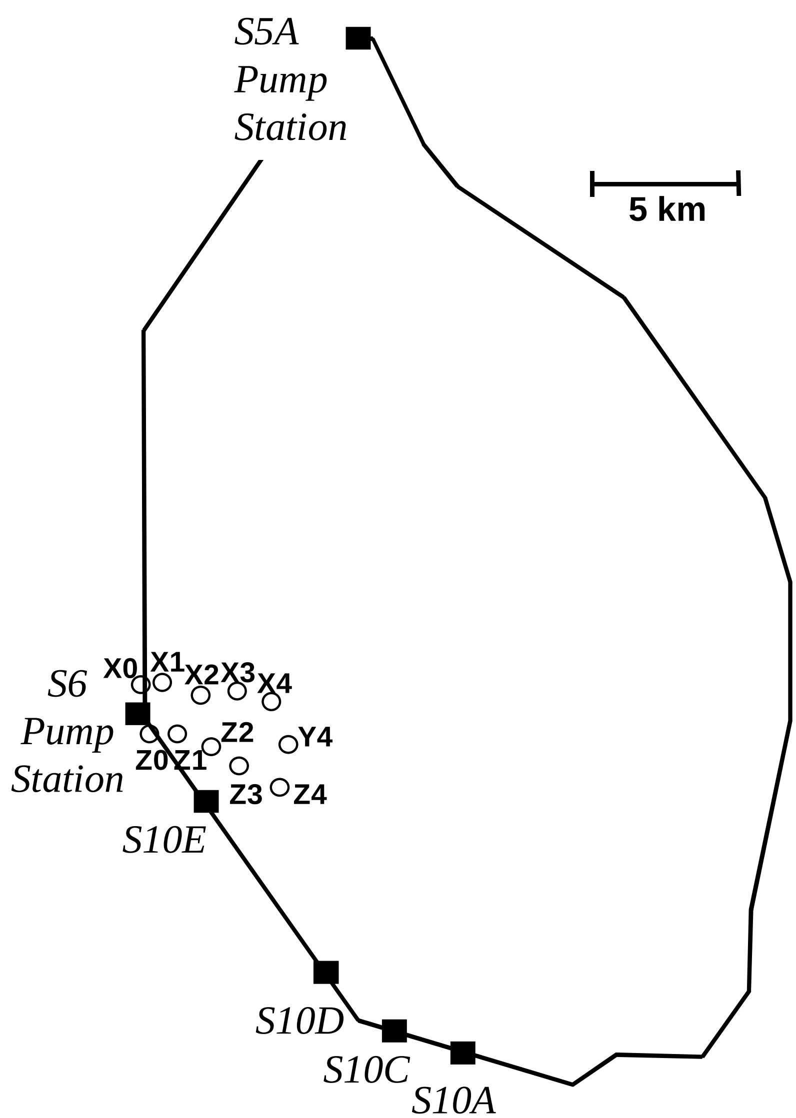


Figure 4-82. Loxahatchee National Wildlife Refuge research ar monitoring stations.

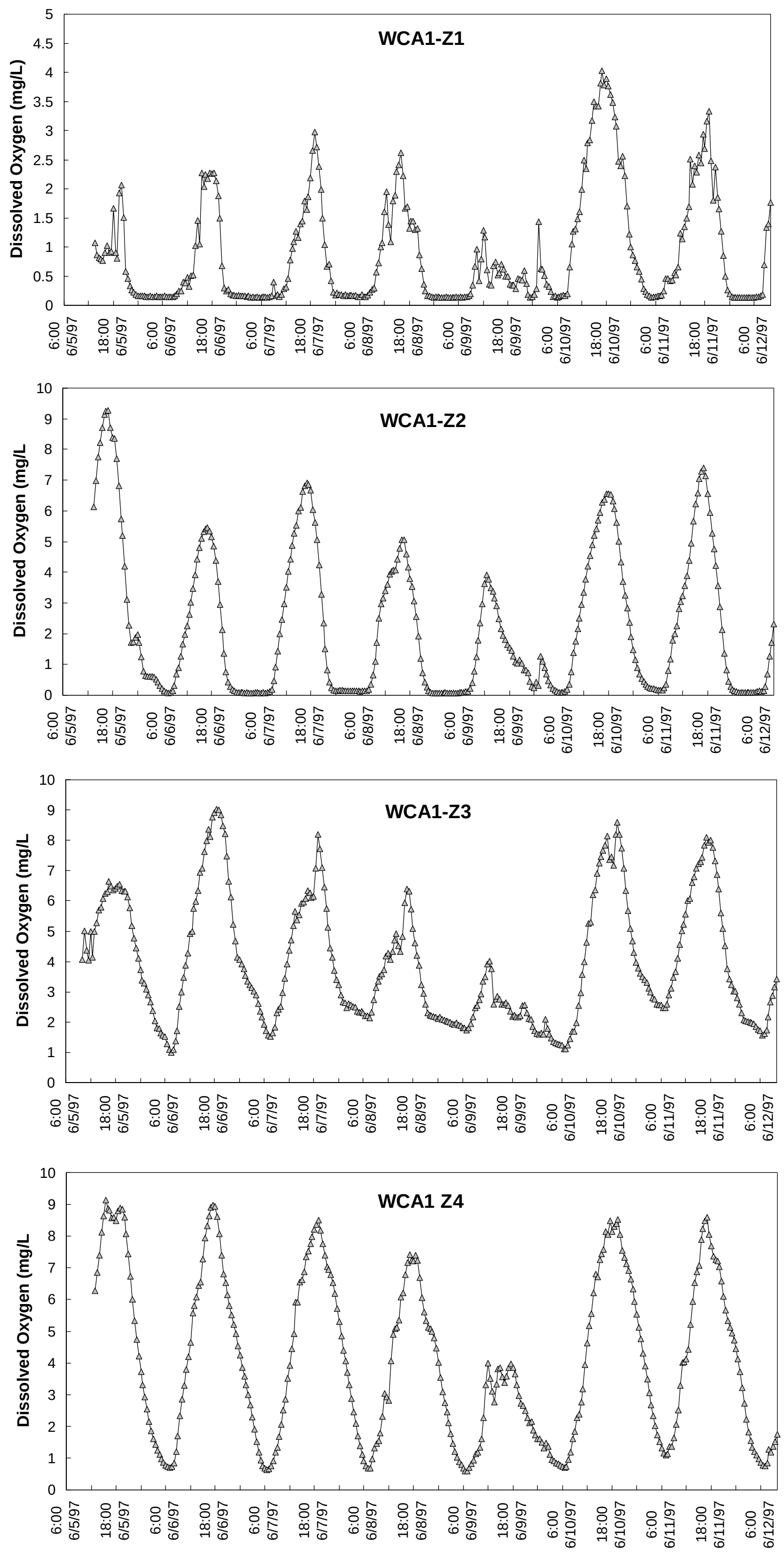


Figure 4-83. Diel DO curves along Refuge Transect Z.

The results from the Refuge are similar to the diel curves generated in WCA-2A in that the daily minimum oxygen concentration, the length of time the concentration is at the minimum, and the magnitude of the daily range are all a function of aquatic community type, which in turn is the result of the long-term concentrations of nutrients present, changes in hydroperiod and physical manipulation of the landscape. No single number is an appropriate criterion for minimum dissolved oxygen in the EPA. Based on the variation in diel oxygen concentrations between different aquatic communities, as well as the variation within an individual community over time (i.e. seasonal effects), it appears that the three aforementioned components of the diel curve must be considered when establishing a dissolved oxygen criterion in the EPA.

Alkalinity and pH in the Refuge

Alkalinity and pH data collected in the Refuge since December 1993 include a number of values that are below the minimum pH criterion of 6.0 and the alkalinity criterion of 20 mg/L (**Figure 4-84**). The spatial distribution of data exceeding the criteria is presented in **Figure 4-85** for pH, **Figure 4-86** for alkalinity and **Figure 4-87** for the area containing excursions of both pH and alkalinity. These data are also summarized by site (in **Table 4-22**) for percent pH, alkalinity and joint pH, and alkalinity excursions. Sites LOX8, LOX11 and LOX13 have the highest pH excursion percent because they are located in the naturally low pH waters of the interior marsh. Similarly, LOX5, LOX8, LOX9, LOX11 and LOX13 have alkalinity excursions over 90 percent because alkalinity is also naturally low at these sites. The LOX8, LOX11 and LOX13 sites also have the highest joint excursion percentages, reflecting a duality of natural purity of the interior marsh water.

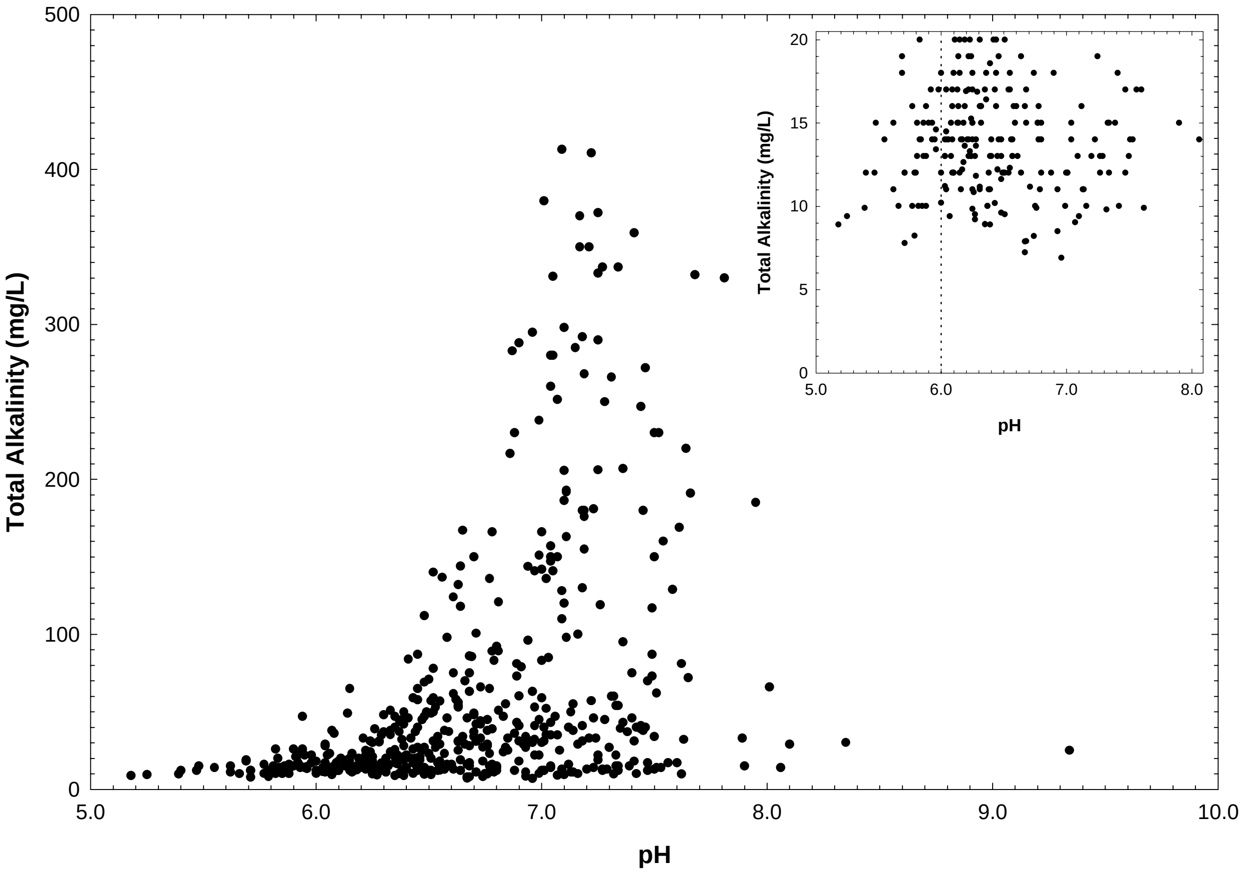


Figure 4-84. Relationship between pH and alkalinity in the Loxahatchee National Wildlife Refuge marshes.

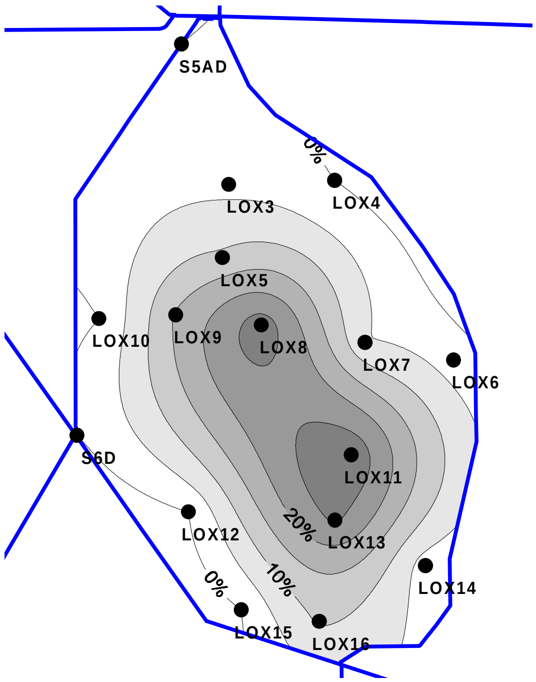


Figure 4-85. Percent exceedances from Class III Standard for pH within the Refuge.

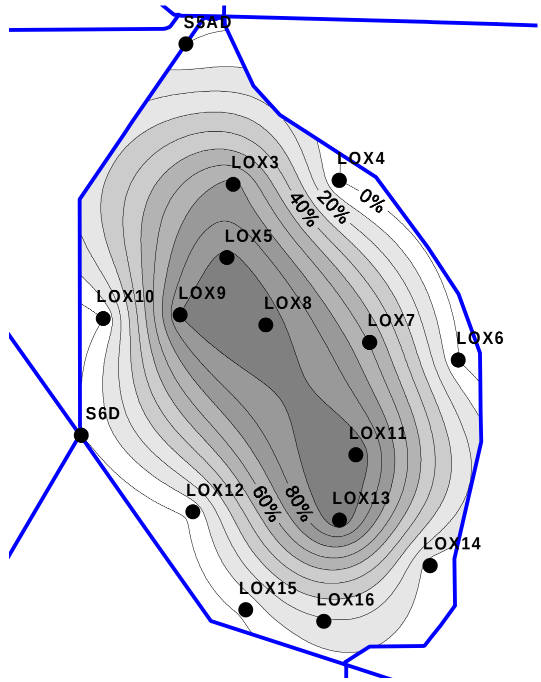


Figure 4-86. Percent exceedances from Class III Standard for total alkalinity within the Refuge.

The penetration of rim canal water into the interior marsh can be visualized from examination of the contours in **Figures 4-85**, **4-86** and **4-87**. The contours represent the percentage of individual values less than the respective pH and alkalinity criteria. If we assume that the natural condition for the soft-water, rainfall-driven, interior marsh water is pH ≥ 5 (lowest recorded value was 5.18 at LOX8) and alkalinity is ≥ 6.5 mg/L (lowest recorded value was 6.9 mg/L at LOX5), revised minimum pH and alkalinity criteria that accommodate these values would eliminate the necessity for investigating, documenting and reporting naturally occurring low pH and alkalinity water quality criteria excursions in the Refuge, an Outstanding Florida Water. _

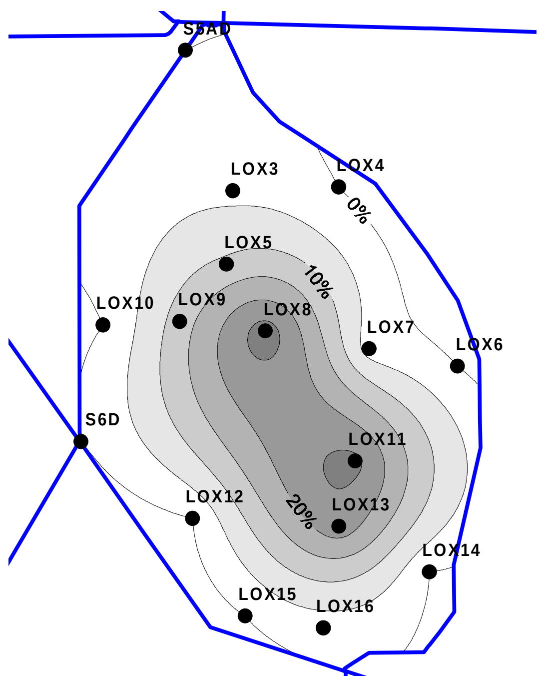


Figure 4-87. Percent exceedances from Class III Standard for total alkalinity and pH within the Refuge.

Table 4-22. Percent excursions from Class III criteria for pH, alkalinity and the combination of pH and alkalinity for Refuge sampling stations.

		Percent Exceedances from Class III Standards		
Station Number	Number of Samples	Alkalinity and pH	pH	Alkalinity
LOX3	26	3.8	3.8	73.1
LOX4	28	0.0	0.0	0.0
LOX5	27	11.1	11.1	92.6
LOX6	38	0.0	2.6	0.0
LOX7	37	2.7	5.4	59.5
LOX8	36	27.8	27.8	94.4
LOX9	32	12.5	15.6	90.6
LOX10	29	0.0	0.0	0.0
LOX11	38	26.3	28.9	97.4
LOX12	39	0.0	0.0	2.6
LOX13	39	23.1	25.6	97.4
LOX14	39	0.0	2.6	5.1
LOX15	40	0.0	0.0	2.5
LOX16	38	2.6	10.5	18.4
S5AD	19	0.0	0.0	0.0
S6D	22	0.0	0.0	0.0

Ongoing RAM-3 and RAM-4 Activities

The Department and the District are continuing in their efforts to evaluate and address water quality standards and classifications issues in the EPA as required by the Act. In addition to the evaluation of existing water quality standards for constituents such as dissolved oxygen, alkalinity and pH in the EPA as described in this section, other ongoing projects include:

- Planned biological assessments of main canals within the EAA and EPA since biological assessments to date have been conducted almost exclusively in EPA marshes;
- Ongoing evaluations in support of determinations of appropriate classifications of canals in the EAA and adjacent to the EPA;
- Ongoing evaluations of appropriate standards for EAA canals;
- Ongoing search for and evaluation of appropriate toxicity studies for herbicides and pesticides for comparison with detected EAA and EPA concentrations of those compounds.

Programs to resolve water quality concerns and meet Class III Water Quality Criteria

While the water quality concerns in the Everglades Protection Area are numerous, so are the efforts to meet Class III water quality criteria both within and external to the EPA. Through the combination of Stormwater Treatment Areas (**Chapter 6**), Best Management Practices (**Chapter 5**), and

Supplemental Technologies (**Chapter 8**), the District has a program to improve water quality runoff from the Everglades Agricultural Area. Similarly, as part of the Everglades Stormwater Management Program (**Chapter 11**) and the Central & Southern Florida Flood Control System Restudy effort (**Chapter 10**), the District is working on improving water quality discharges into the Everglades from the ACME, North Springs, C-11 West, C-111, and Lower Western Basins. As a result of these efforts, water quality concerns at every discharge point into the Everglades Protection Area will be addressed.

Future Water Quality Concerns

While the District's primary focus is on water quality concerns relating to P, mercury, and pesticides, other water quality concerns, such as nitrogen, specific conductance or trace metals, may arise as the District continues to analyze its water quality data, and as scientific knowledge of the EPA develops. In the event that additional parameters of concern are identified, the Everglades Forever Act requires the District to address the concerns through the long-term compliance effort, and to ensure that all water quality standards are met by December 31, 2006. At this time water quality data do not indicate that parameters other than those discussed in this chapter warrant consideration.

Findings on Water Quality in the Everglades Protection Area

- The pesticide endosulfan exceeded its Class III numeric criterion in the EPA seven times, while 3 other compounds exceeded toxicity limits on one date.
- With few exceptions, water quality in the EPA is in compliance with existing State water quality standards and numeric criteria.
- The recent water years were substantially wetter than the baseline period with respect to rainfall, flows and water levels. Some of the apparent improvements in water quality (especially at interior sites) that were discussed, may be related to hydrologic effects rather than water quality improvement projects such as BMPs.
- Excursions of water quality from numeric criteria were placed in Category A or B depending on severity:
  - Dissolved oxygen, specific conductance, alkalinity, and pH were constituents placed in category A within some regions of the Everglades Protection Area.
  - Based on a 10 ppb default standard and a 50 ppb interim criteria specified in the Act, total phosphorus is in Category A in all EPA regions except for the Park and interior areas of the Refuge, where TP is in Category B.
- Trends in water quality include:
  - In the recent water years, the inflow flow-weighted mean TP concentrations to the Refuge, WCA-2, and WCA-3 have generally been lower than the baseline period, but above 50 ppb most of the time. The Refuge and WCA-3 interior sites also showed improvement trends in TP concentration.

    - Inflow water quality to the Refuge showed improvement trends in recent years for specific conductance and alkalinity.
    - Water quality for WCA-2 was relatively unchanged compared to the baseline period.
    - For WCA-3, interior sites showed improvements in turbidity, TN, and total iron, while no obvious trends were seen in water quality of the inflows.
- Findings on nutrient loading in the Everglades Protection Area include:
    - Nutrient loads to the Park in recent years are similar to the levels seen in the baseline period.
    - TP concentrations for tributaries to STA-3/4 have decreased over the last eight years, but long-term average concentrations are still well above 50 ppb interim level, and are far greater than any level that may be reasonably anticipated as a TP criterion for the EPA.
    - The ENR Project has met its water quality objectives and retained about 81% of inflowing TP. This treatment has reduced loading to the Refuge by about 15%.
    - P inputs to Florida Bay via creeks from the Park are small; nitrogen inputs appear to be more significant for the Bay ecosystem.
- Finding & Recommendation: Water quality criteria for dissolved oxygen, pH and alkalinity are not appropriate for unimpacted waters of the Everglades Protection Area, and should be reviewed by the Florida Department of Environmental Protection.

Literature Cited

Armentano, T., J. Hunt, D. Rudnick, N. Thompson, P. Ortner, M. Robblee and R. Halley. 1997. Strategic plan for the interagency Florida Bay Science Program. Unpublished document from the Florida Bay Program Management Committee.

Bates, A.L., W.H. Orem, and E.C. Spiker. 1997. Sulfur and mercury in the South Florida Ecosystem. Paper presented at *U.S. Geological Survey Program on the South Florida Ecosystem – Proceedings of the Technical Symposium* in Ft. Lauderdale, Florida. August 25-27, 1997.

Bechtel, T., S. Krupa, S. Hill and R. Xue. 1996. Evaluation of water quality criteria in the Everglades Protection area. Report to Florida Department of Environmental Protection in support of the Everglades Program Management Plan, Research and Monitoring Project 3 (RAM-3). South Florida Water Management District, West Palm Beach, FL.

Belanger, T.V. and J.R. Platko II. 1986. Dissolved oxygen budgets in the everglades WCA-2A. Reportto the South Florida Water Management District, West Palm Beach, FL.

Belanger, T.V., D.J. Scheidt and J.R. Platko II. 1989. Effects of nutrient enrichment on the Florida Everglades. *Lake and Reservoir Management* 5(1):101-111.

Brooks, H.K. 1984. Lake Okeechobee, p. 38-68. In: P.J. Gleason, ed., Environments of South Florida: Present and Past II, Miami Geological Society, Coral Gables, FL.

Cohen, A.D. and W. Spackman, Jr. 1984. The petrology of peats from the Everglades and coastal swamps of southern Florida, p. 352-374. In: P.J. Gleason, ed., Environments of South Florida: Present and Past II, Miami Geological Society, Coral Gables, FL.

CRC. 1998. Handbook of Chemistry and Physics, 78th edition. D.R. Lide (Ed.). CRC Press.

Davis, S.M. 1994. Phosphorus inputs and vegetation sensitivity in the Everglades. In: *Everglades: The Ecosystem and Its Restoration*. Steven M. Davis and John C. Ogden (eds.), St. Lucie Press, 357-378.

Flora, M.D. and P.C. Rosendahl. 1982. An analysis of surface water nutrient concentrations in the Shark River Slough, 1972-1980. South Florida Research Center Report T-653. Homestead, FL.

Forstner, U. and G.T.W. Wittman. 1983. Metal Pollution in the Aquatic Environment. 2nd Edition. New York. Springer-Verlag. 486 p.

Goodrick, R.L. 1984. The wet prairies of the northern Everglades, p. 185-190. In: P.J. Gleason, ed., Environments of South Florida: Present and Past II, Miami Geological Society, Coral Gables, FL.

Hendry, C.D., P.L. Brezonik and E.S. Edgerton. 1981. Atmospheric deposition of nitrogen and phosphorus in Florida. In: S.J. Eisenreich (ed.), Atmospheric pollutants in natural waters. Ann Arbor Science, Ann Arbor, MI.

Hurley, J.P., D.P. Krabbenkroft, G. Aiken., M.L. Olsen and L.B. Cleckner. 1997. System control on water column total and methyl mercury in the Northern Everglades. Paper presented at *U.S. Geological Survey Program on the South Florida Ecosystem – Proceedings of the Technical Symposium* in Ft. Lauderdale, Florida. August 25-27, 1997.

Krabbenhoft, D.P. 1996. Mercury studies in the Florida Everglades. USGS FS-166-96. 4 pp.

Kolipinski, M.C. and A.L. Higer. 1968. Some aspects of the effects of the quantity and quality of water on biological communities in the Everglades National Park. USGS Open File Report, Tallahassee, FL. 116 pp.

Limno-Tech, Inc. 1995. Data analysis in support of the Everglades Forever Act. Report to South Florida Water Management District, West Palm Beach, FL.

Limno-Tech, Inc. 1996. Supplemental water quality analysis and processing. Report to South Florida Water Management District, West Palm Beach, FL.

Mattraw, H.C., D.J. Scheidt, and A.C. Federico. 1987. Analysis of trends in water quality for Water Conservation Area 3A, the Everglades, Florida. USGS Water Resources Investigations Report 87-4142. 52 pp.

McCormick, P.V., P.S. Rawlik, K. Lurding, E.P. Smith and F.H. Sklar. 1996. Periphyton-water quality relationships along a nutrient gradient in the northern Florida Everglades. J. N. Am. Benthol. Soc. 15(4):433-449.

McCormick, P.V. and M.B. O'Dell. 1996. Quantifying periphyton responses to phosphorus in the Florida Everglades: a synoptic-experimental approach. *J. N. Am. Benthol. Soc.* 15(4), 450-468.

McCormick, P.V., M.J. Chimney and D.R. Swift. 1997. Diel oxygen profiles and water column community metabolism in the Florida Everglades, U.S.A. *Arch. Hydrobiol.* 140(1):117-129.

McCormick, P., S. Newman, S. Miao, F. Sklar and T. Fontaine. 1996. Field research and monitoring studies to support derivation of a Class III water quality criterion for phosphorus in the Arthur R. Marshall

Loxahatchee National Wildlife Refuge: A Three-month Progress Report. Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL.

McCormick, P., S. Newman, S. Miao, F. Sklar and T. Fontaine. 1997. Field research and monitoring studies to support derivation of a Class III water quality criterion for phosphorus in the

Arthur R. Marshall Loxahatchee National Wildlife Refuge: An Annual Progress Report. Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL.

McCormick, P., S. Newman, S. Miao and T. Fontaine. 1998. Field research and monitoring studies to support derivation of a Class III water quality criterion for phosphorus in the Arthur R. Marshall Loxahatchee National Wildlife Refuge: Year Two (1997) Progress Report. Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL.

McGill, R., J.W. Tukey and W. A. Larsen. 1978. Variations of Box Plots. Am. Statistician 32(1): 12-16.

Moustafa, M.Z. 1998. Long-term equilibrium phosphorus concentrations in the Everglades as predicted by a Vollenweider-type model. *J. Am. Wat. Res. Assoc.* 34(1):135-147.

Parker, G.G. 1984. Hydrology of the pre-drainage system of the Everglades in southern Florida, p. 28-37. In: P.J. Gleason, ed., Environments of South Florida: Present and Past II, Miami Geological Society, Coral Gables, FL.

Raghunathan, R., T. Slawecki, D.W. Dilks, V.J. Birman, Jr., S. Wade, T.D. Fontaine and Z. Chen. 1998. Exploring the dynamics and fate of total phosphorus in the Florida Everglades using a calibrated mass balance model. Manuscript to be submitted to Ecological Modeling.

Rosendahl, P.C. and P.W. Rose. 1979. Water quality standards: Everglades National Park. *Environmental Management* 3 (6):483-491.

Rudnick, D.T., Z. Chen, D.L. Childers, J.N. Boyer, and T.D. Fontaine III. 1998. Phosphorus and nitrogen inputs to Florida Bay: the importance of the Everglades watershed. Manuscript submitted to *Estuaries*.

Salomons, W. and U. Forstner. 1984. Metals in the Hydrocycle. New York. Springer-Verlag. 349 p.

Scheidt, D.J., M.D. Flora, and D.R. Walker. 1987. Water quality management for Everglades National Park. Presented at the *N. Am. Lake Manage. Soc.* 7th Int. Symp., Nov. 4, 1987, Orlando, FL.

Scheidt, D.J. 1988. Nutrient enrichment in the Everglades. *National Wetlands Newsletter*, May-June 1988, 5-7.

Settlement Agreement. 1991. USA v. SFWMD et al. Lawsuit; Case No. 88-1886-CIV-HOEVELER.

SFWMD/FDEP. 1997. Everglades Program Implementation, Program Management Plan, Revision 3, December 29, 1997.

Stober, J., D.J. Scheidt, R. Jones, K. Thornton, R. Ambrose and D. France. 1996. South Florida Ecosystem Assessment – Monitoring for Adaptive Management: Implications for Ecosystem Restoration (Interim Report). EPA 904-R-96-008, 26 pp.

Struve, D. 1998. Personal communication, November 9, 1998.

Swift, D.R. and R.B. Nicholas. 1987. Periphyton and water quality relationships in the Everglades water conservation areas. Technical Publication 87-2, South Florida Water Management District, West Palm Beach, FL.

Walker, W.W., Jr. 1991. Water quality trends at inflows to Everglades National Park. *Water Res. Bull.*, 27(1), 59-72.

Walker, W.W., Jr., 1998. Deliverable under contract C-8510, Everglades Regulation Technical Support.Everglades Regulation Division, South Florida Water Management District.

Waller, B.G. and J.E. Earle. 1975. Chemical and biological quality of water in part of the Everglades, Southeastern Florida. USGS Water Resources Investigation 56-75. 157 pp.

Waller, B.G. 1982. Water quality characteristics of Everglades National Park, 1959-1977, with reference to the effects of water management. USGS Water Resources Investigations Report 82-34. 58 pp.