Chapter 5: Development of a Numeric Phosphorus Criterion for the Everglades Protection Area

Grover Payne, Kenneth Weaver and Temperince Bennett

SUMMARY

This chapter provides an update on the Florida Department of Environmental Protection's (FDEP's or Department's) efforts to establish a numeric phosphorus (P) criterion for the Everglades. The FDEP has conducted extensive evaluations of chemical and biological data from multiple trophic levels from throughout the Everglades Protection Area (EPA) to derive and support a numeric P criterion. The results of the data analyses conducted for Water Conservation Area 2A (WCA-2A) are presented in detail in the *Everglades Interim Report* (1999) and the *2000 Everglades Consolidated Report*. The analysis of data from the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge or WCA-1) is provided in the *2001 Everglades Consolidated Report*. Additionally, results of the FDEP's evaluation of the limited data sets from WCA-3A and Everglades National Park (Park or ENP) are discussed in the *2002 Everglades Consolidated Report*. A summary of the previous findings for the Refuge, WCA-2A, WCA-3A and the Park, a description of the FDEP's proposed P criterion measurement methodology, and a discussion of the FDEP's rulemaking activities are provided in this chapter.

To begin restoration of the remnant Everglades, the Everglades Forever Act (EFA), Section 373.4592, Florida Statutes requires the FDEP to establish a numeric P criterion for the EPA. The EFA further requires that the FDEP and the South Florida Water Management District (District) complete, by December 31, 2001, the research necessary to establish the P criterion. To ensure that the required research program provides adequate data to support the development of the numeric P criterion for the EPA, the Everglades Technical Oversight Committee appointed a panel of eminent scientists to prepare the Everglades Nutrient Threshold Research Plan (Lean et al., 1992). The research plan recommended a three-pronged research approach consisting of the following: (1) field transect monitoring along existing, man-made nutrient gradients; (2) field perturbations (dosing experiments); and (3) laboratory experiments. The District conducted the majority of research that the FDEP used for criterion development; however, data collection efforts in the Everglades are being conducted by several independent research groups. The District's research efforts encompass all four EPA areas and all three research types laid out in the Everglades Nutrient Threshold Research Plan, including water, sediment and biological monitoring conducted along P gradients, P-dosing studies using mesocosms, and supplemental field and laboratory studies. Due to logistics related to this massive research undertaking, data collection occurred in steps, beginning in WCA-2A and then proceeding to the Refuge, WCA-3 and Everglades National Park. Criterion development efforts were also conducted in this order based on the resulting data availability issues.

The FDEP's efforts to derive a numeric P criterion relied primarily on data collected by the District along a series of transects traversing existing, manmade P gradients in each portion of the EPA (i.e., WCA-2A, the Refuge, WCA-3 and the Park). The FDEP relied heavily on the gradient transect studies during the derivation of the P criterion due to their distinct advantages over experimental studies. Because some areas within the EPA have received elevated levels of phosphorus-rich runoff for as many as 40 years, the FDEP had an excellent opportunity to study the effects of long-term P enrichment on the natural biological communities in the marsh. Given that the spatial and temporal limitations of the experimental dosing studies, as well as technical problems experienced during operation of the studies can have a substantial impact on the derived P criterion, the FDEP primarily used observations along the existing P gradient in the natural system. However, since other variables can also change along the P gradients and have the potential to affect the natural flora and fauna, data collected from the District's experimental dosed mesocosms were used to establish cause-and-effect relationships between observed biological changes and P enrichment.

The FDEP employed a "reference site" approach during the evaluation and analysis of the District gradient transect data during the development of a numeric P criterion for the EPA. The reference site approach is commonly used in the development of water quality criteria, with the goal of maintaining balanced populations of natural flora and fauna (i.e., reference conditions). The reference site approach was used in the development of the P criterion for the EPA due to its widespread acceptance, the existence of long-term P gradients in the EPA, and the type of biological response characteristic of P enrichment. The results of the FDEP's extensive analysis of biological and chemical data from WCA-2A and the Refuge were used to differentiate a group of reference stations at which the natural biological communities exhibit minimal changes in structure and function as a result of P enrichment from sites at which the natural flora and fauna were imbalanced by excess P input. The phosphorus regime observed at the reference sites in WCA-2A and the Refuge was then used as the basis for the derivation of a P criterion that would be protective of the natural biological communities. Reference sites in WCA-2A and the Refuge exhibit median annual geometric mean total phosphorus (TP) concentrations of 8.2 and 9.2 µg/L, respectively, with annual geometric means for individual sites ranging from 5.5 to 11.7 µg/L. The slight variation between areas is thought to reflect differences in the period of record and sampling methodology between the two areas. The FDEP analyses also indicate that the normal structure and function of the natural biological communities in both WCA-2A and the Refuge are adversely altered at similar levels of P enrichment.

Further statistical analyses of the phosphorus data from the Refuge and WCA-2A to evaluate the uncertainty around the average P levels indicate that the maintenance of a long-term average annual geometric mean TP concentration at or below 10 µg/L would be protective of the natural flora and fauna without being overly protective or below the natural background levels. Additionally, results of similar evaluations of limited data available for WCA-3A and ENP indicate that these areas, being comprised of many of the same dominant taxa, contain biological communities comparable to those in WCA-2A and the Refuge. The results also suggest that the biological communities in WCA-3A and ENP exhibit a response to P enrichment similar to that documented for WCA-2A and the Refuge. Therefore, a numeric P criterion of 10 µg/L (as determined from WCA-2A and Refuge data) measured as a long-term geometric mean would be protective of the natural flora and fauna throughout the EPA without being overly protective. The adoption of a 10-µg/L phosphorus criterion is further supported by the comprehensive literature review conducted by the United States Environmental Protection Agency (USEPA) during its evaluation of the Miccosukee Tribe of Florida's proposed 10-µg/L criterion. Additionally, the FDEP's evaluation of the results of the Duke University Wetland Center (DUWC) dosing study in WCA-2A clearly indicates that the recommended 15.6-µg/L criterion, based on the average change point for biological indicators monitored during the dosing study, is not adequately protective of the natural aquatic flora and fauna. Based on these findings, the FDEP filed a notice

of rulemaking and recommended a 10-µg/L phosphorus criterion for approval by the Environmental Regulation Commission (ERC) in December 2001. The FDEP is currently participating in a series of hearings before the ERC to establish the P criterion by rule. The ERC hearings are scheduled to be completed by March 2003.

Additionally, based on information obtained during P criterion development, the FDEP has proposed a P criterion measurement methodology consisting of two components: (1) the maintenance of a long-term average TP concentration that will protect against imbalances in the natural flora and fauna, and (2) an annual concentration upper limit that allows for the natural temporal and spatial variation observed within minimally impacted areas. The recommended measurement methodology ensures that the waters represented by a sampling station are reported as having achieved the P criterion for a given year if either of the following conditions is satisfied:

1. The annual geometric mean of measured phosphorus concentrations for that station during that year does not exceed the 10-µg/L (parts per billion or ppb) criterion demonstrated to be protective of the natural flora and fauna within the EPA, or
2. The annual geometric mean of measured TP concentrations for that station during the year does not exceed 15 µg/L, and the arithmetic average of the annual geometric mean TP concentrations measured at that station during the five-year period encompassing that year and the preceding four years is maintained at or below (i.e., does not exceed) the 10-µg/L criterion.

The FDEP proposes to calculate and report the results of P criterion monitoring on a station-by-station basis for marsh stations representative of the receiving waters in the Everglades Protection Area. P criterion monitoring shall be conducted at sites dispersed throughout areas that are both impacted and unimpacted by phosphorus enrichment and which are generally consistent with (but not limited to) the current monitoring network established by the South Florida Water Management District.

The recommended measurement methodology provides for an objective and scientifically reliable assessment of the P status at individual sampling stations representative of the Everglades Protection Area, takes into account natural spatial and temporal variability, including variability above 10 µg/L, as required by the EFA, without being significantly biased by extreme events, and allows the P criterion to be applied so it protects the natural biological communities present within the EPA without restricting the natural heterogeneity of the ecosystem or being below background levels.

BACKGROUND

The Everglades Forever Act (EFA; Section 373.4592, Florida Statutes) requires the FDEP and the District to implement the Everglades Program, a comprehensive plan to begin restoration of significant portions of the remnant Everglades. The EFA also specifically finds that waters flowing into a part of the remnant Everglades known as the Everglades Protection Area (EPA) contain excessive P levels, and that a reduction in P levels will benefit the ecology of the EPA. As part of the Everglades Program, the EFA required the FDEP and the District to complete research necessary to establish a numeric P criterion by December 31, 2001. The EFA also required the FDEP to file a notice of rulemaking to establish such a criterion by that date. If the FDEP does not adopt the P criterion by rule by December 31, 2003, then the EFA establishes a default criterion of 10 µg/L. The EFA requires that the P criterion shall not be lower than the natural conditions of the EPA and must take spatial and temporal variability into account. The EFA further requires compliance with the P criterion to be based on a long-term geometric mean of concentration

levels to be measured at sampling stations reasonably representative of receiving waters in the EPA.

This chapter provides an update on data collection and analyses performed to date in support of the derivation of a numeric P criterion in the Everglades. This chapter also fulfills the EFA requirement to evaluate the ecological needs of the Everglades. General information on the effects of P enrichment on the Everglades, and detailed biological and chemical data analyses specific to WCA-2A and the Refuge, were reported in the *Everglades Interim Report* (1999) and in both the 2000 and 2001 Everglades Consolidated Reports. Supporting information obtained from analyses conducted using the limited data sets from WCA-3A and Everglades National Park were provided in the *2002 Everglades Consolidated Report*. This chapter is intended to accomplish the following objectives: (1) provide a synopsis of the FDEP's efforts to derive a numeric P criterion for the EPA, (2) describe the FDEP's proposed P criterion measurement methodology, (3) present an update regarding the FDEP's P criterion rulemaking efforts, including major developments since the publication of previous Everglades Consolidated Reports, and (4) review any other information submitted for consideration.

RESEARCH EFFORTS

To begin the process of establishing a numeric P criterion for the EPA, an Everglades Nutrient Threshold Research Plan was developed (Lean et al., 1992). The research plan was intended to provide appropriate data in support of a numerical interpretation for the existing State of Florida narrative nutrient criterion for P (Rule 62-302.530(48)(b), Florida Administrative Code) and involved a three-pronged approach consisting of the following: (1) field transect monitoring along existing, man-made nutrient gradients, (2) field perturbations (dosing experiments), and (3) laboratory experiments. The research plan was created under FDEP direction by a panel of eminent scientists appointed by the Everglades Technical Oversight Committee.

Data collection efforts in the Everglades are being conducted by several independent research groups. However, the District conducted the majority of research used by the FDEP for P criterion development. The District's data collection efforts encompass all four areas of the EPA and all three types of research specified in the Everglades Nutrient Threshold Research Plan. The District's research includes water, sediment, and biological monitoring conducted along P gradients, P-dosing studies using mesocosms, and supplemental field and laboratory studies. Due to logistics related to this massive research undertaking, data collection occurred in steps, beginning in WCA-2A and proceeding to the Refuge, WCA-3 and Everglades National Park. Phosphorus criterion development efforts were also conducted in this order based on the resulting data availability issues.

Other research efforts in the EPA include those of the Duke University Wetland Center (DUWC), Florida International University (FIU), and the USEPA's Regional Environmental Monitoring and Assessment Program (REMAP). DUWC researchers have conducted extensive research in WCA-2A consisting of both gradient and experimental dosing studies. However, the results from the dosing study were the primary basis for their recommended criterion with only a limited amount of gradient data being used to support the conclusions from the experimental work. A detailed evaluation of the data and analyses from the DUWC studies that were submitted to the FDEP are provided and discussed in Chapter 3 of the *2001 Everglades Consolidated Report* (Payne et al., 2001). Since that time, the DUWC researchers have performed a reanalysis of their data that addresses some of the FDEP's concerns. The issues that have not been resolved are restated in a later portion of this chapter along with some preliminary comments on the DUWC reanalysis. FIU has also conducted gradient and dosing studies in portions of the EPA. To the

extent that they were available at the time of the FDEP's P criterion development, data were also incorporated from the FIU research. The USEPA's REMAP is another monitoring effort conducted over the entirety of the Everglades because the sampling methodology was designed to monitor regional water and sediment quality changes using randomly selected monitoring sites. Much of the data collected by the USEPA as part of REMAP are not suitable for the evaluation of site-specific changes occurring across a P gradient, as is needed for P criterion development.

SYNOPSIS OF PHOSPHORUS CRITERION DEVELOPMENT

As directed by the EFA, the FDEP has completed an evaluation and analysis of the available data from the Everglades to support the derivation of a numeric P criterion. Due to logistics related to the massive research undertaking necessary to support P criterion development, data collection and subsequent analyses were performed in a step-wise manner, beginning in WCA-2A and proceeding to the Refuge, WCA-3 and the Park. Results of the FDEP's extensive evaluations and analyses of the biological and chemical data collected from the three Water Conservation Areas and Everglades National Park, which comprise the EPA, are presented in previous reports (McCormick et al., 1999 and 2000; Payne et al., 2001 and 2002). A more thorough discussion is provided in the drafts of the FDEP's P criterion development support documents (Payne et al., 1999, 2000, and 2001). Since that time, much of the monitoring and research conducted by the District in WCA-2A and the Refuge has been stopped or modified to monitor the long-term recovery of the system. Additionally, the FDEP has not performed additional analyses on the data collected by the District in WCA-2A and the Refuge beyond those presented in previous Everglades Consolidated Reports. A brief summary of the FDEP's approach to developing the P criterion and the results of the extensive evaluations and analyses conducted during this effort is provided below.

EVERGLADES FOREVER ACT REQUIREMENTS

The current Class III narrative nutrient criterion (Rule 62-302.530(48)(b), Florida Administrative Code) states that: "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 or fauna." The EFA codifies the Class III narrative nutrient criterion by specifying that: "In no case shall such phosphorus criterion allow waters in the EPA to be altered so as to cause an imbalance in the natural populations of aquatic flora or fauna." Therefore, the development of a P criterion for the EPA requires that the existing narrative criterion be interpreted specifically for P in the EPA using the best available scientific information.

The determination of what constitutes an imbalance must be based on the particular ecosystem being affected, in this case a naturally oligotrophic Everglades ecosystem. The FDEP determined when an imbalance had occurred by evaluating the best available biological and water chemistry data for statistically significant departures from the ecosystem's normal, unaltered structure and function. Natural populations of aquatic flora and fauna in the Everglades are comprised of biological communities ranging from bacteria to emergent vegetation to higher mammals adapted to the system's oligotrophic nature, with interrelationships among these biological communities and trophic levels controlling how the ecosystem functions. In evaluating structure and function to determine when an imbalance has occurred, the FDEP considered the assemblage of flora and fauna characteristic of the ecosystem, water quality indicators of ecosystem function, such as dissolved oxygen (DO), and the interrelationships among trophic levels. Not only is this approach consistent with the EFA and existing FDEP rules, it is also consistent with the requirements of the federal settlement agreement and the USEPA's published

guidance for adoption and review of state and tribal nutrient criteria for the South Florida eco-region.

Consistent with this approach, the FDEP conducted extensive analyses of the best available biological and water chemistry data to determine the point at which statistically significant departures from the normal unaltered structure and function of the ecosystem occur within the various EPA regions. Further details concerning the FDEP's approach to establishing a numeric P criterion for the EPA are provided below.

APPROACH TO P CRITERION DEVELOPMENT

The FDEP's efforts to derive a numeric P criterion relied primarily on data collected by the District along a series of transects traversing existing phosphorus gradients in each portion of the EPA (WCA-2A, the Refuge, WCA-3 and ENP). The FDEP relied heavily on the gradient transect studies during the derivation of the P criterion due to their distinct advantages over experimental studies. Because some areas within the EPA have received elevated levels of phosphorus-rich runoff for as long as 40 years, the FDEP had an excellent opportunity to study what had happened to the natural biological communities in the marsh as the result of long-term P enrichment. Given that the spatial and temporal limitations of the experimental dosing studies, as well as technical problems experienced during operation of the studies, can have a substantial impact on the P criterion derived, the FDEP primarily used observations along the existing P gradient in the natural system. However, since other variables can also change along the P gradients and can potentially affect the natural flora and fauna, data collected from the District's experimental dosed mesocosms were used to establish cause-and-effect relationships between observed biological changes and P-enrichment. Additionally, the results from the laboratory studies were used to help understand the mechanisms involved in the biological shifts observed as a result of P-enrichment. While the District's mesocosm and laboratory studies provide much information about how and why the biological changes occur, they were not designed nor intended to be used to derive a numeric criterion. Limited results from the mesocosm and laboratory experiments have been presented in previous Everglades Consolidated Reports.

The FDEP employed a "reference site" approach during the evaluation and analysis of the District gradient transect data. The use of reference sites to evaluate biological integrity, establish restoration goals and develop water quality criteria has become standard practice (Davis, 1995; Hughes, 1995; Arkansas Department of Pollution Control and Ecology, 1988; USEPA, 1998; Hughes et al., 1990) since the USEPA issued an explicit definition of "biological integrity" in 1982 that incorporated the concept of reference sites (Hughes et al., 1982). The FDEP used the reference site approach during the development of a numeric P criterion for the EPA based on maintaining balanced populations of natural flora and fauna (reference conditions) because of its widespread acceptance, the existence of long-term manmade P gradients in the EPA, and the type of biological response characteristic of P enrichment. The FDEP's use of the reference site approach in developing a P criterion is summarized below using an example from WCA-2A for clarification.

First, a series of transects and monitoring sites were established extending across the existing P gradient from the source of P enrichment and well into an area unimpacted by P enrichment. **Figure 5-1** shows the transect-monitoring sites established across the P gradient in WCA-2A. Once established, the best available information was used to identify initial "reference" sites that characterize the normal unaltered structure and function of the ecosystem across the normal range of hydrology, biogeochemistry, and biology that exists using an evaluation of water quality and biological data along with available historical data. In the case of WCA-2A, stations U1, U2 and

U3 (located farthest from the canal inflows) were designated as initial "reference" sites based on preliminary data analyses and field observations.

The FDEP then conducted extensive analyses using multiple measures of the biological communities at multiple trophic levels to determine where, along the phosphorus gradient, a significant change occurred from the normal unaltered structure and function of the ecosystem (as characterized by the initial reference sites). The purpose of these analyses was not to derive a phosphorus threshold, but to delineate the sites impacted by P enrichment from those that are biologically similar to the initial reference sites and could thus be used to derive a long-term P criterion. Multiple measures of the periphyton, macroinvertebrate and macrophyte communities in WCA-2A, along with measures of ecosystem function, such as DO levels, were examined during the FDEP's data analyses using multiple statistical tests (including cluster and change point analyses). This allowed the FDEP to use a weight-of-evidence approach, which factored all the analyses into the determination of where along the transects an imbalance had occurred in the natural biological communities. For WCA-2A, the statistically significant changes in the structure and function of the various biological communities generally occurred between stations E4/F4 and E5/F5 (i.e., between approximately 7 and 8 km downstream of the inflows). The results of the analyses were used to determine which sites along the gradient are minimally impacted by P enrichment and could therefore be incorporated into a set of reference sites. Stations E5 and F5 along the WCA-2A transects were determined to be biologically similar to the initial reference sites and were incorporated into a single group of reference sites consisting of stations U1, U2, U3, E5 and F5.

Since the ecosystem's normal, unaltered structure and function is being maintained at the stations delineated as reference sites, the phosphorus regime observed at these sites was used to statistically derive a long-term P criterion protective of the area's natural flora and fauna. In WCA-2A the mean/median annual geometric mean TP concentration at the five reference sites and a measure of statistical uncertainty in the mean/median were used to establish the long-term P criterion that must be maintained to prevent imbalances in the normal, unaltered structure and function of the various biological communities. The appropriateness of the derived criterion was then verified using additional data collected from areas throughout the EPA as part of various SFWMD monitoring programs.

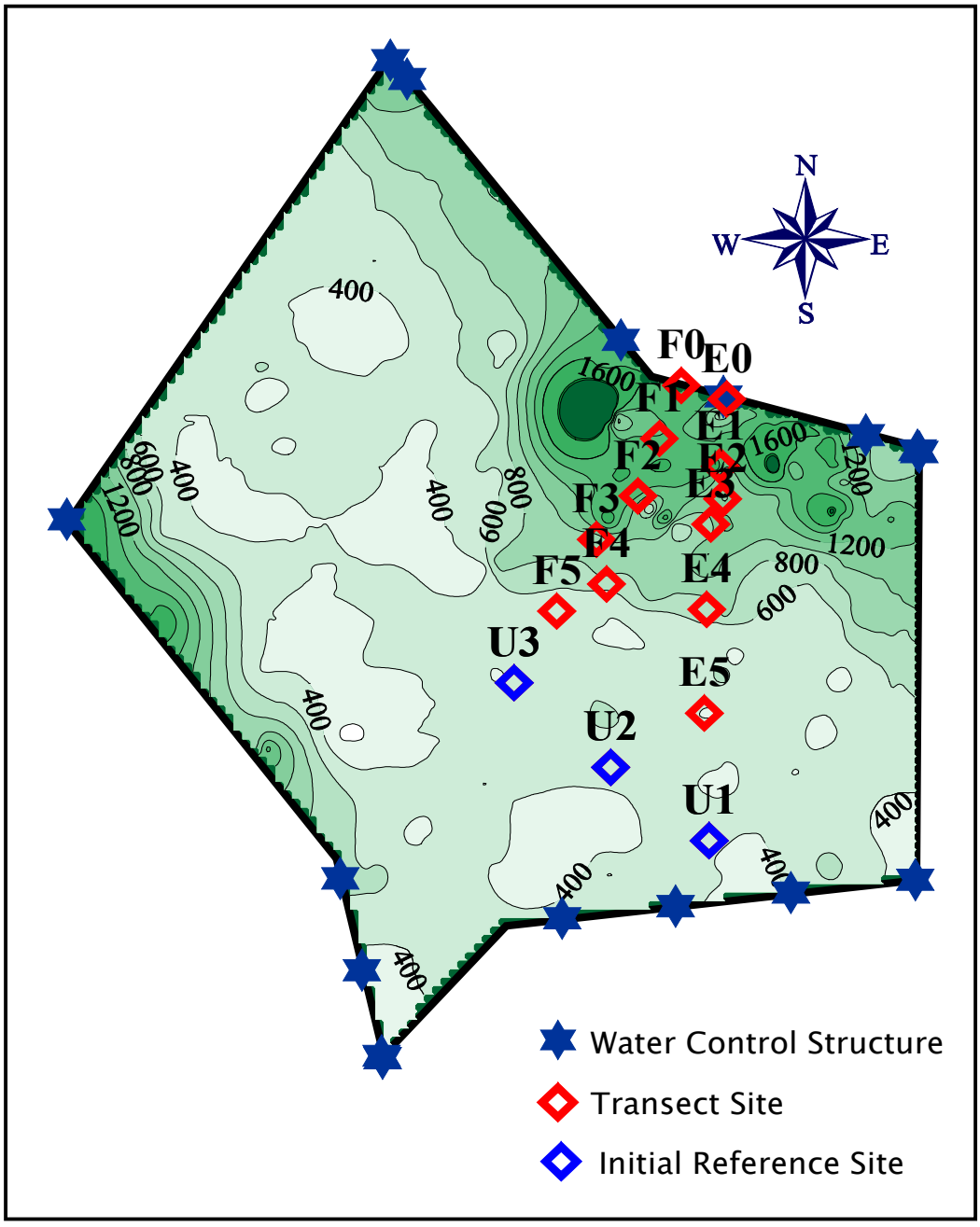

Figure 5-1. Locations of gradient transect monitoring sites established across phosphorus gradient in WCA-2A, as shown on a sediment contour map. Sediment contours provide P concentrations as mg/kg in the upper 10 cm of sediment, developed using a combination of District, DUWC and USEPA data

SUMMARY OF RESULTS FROM WCA-2A AND THE REFUGE (WCA-1)

The remaining Everglades is primarily an oligotrophic, phosphorus-limited wetland system that supports a unique assemblage of flora and fauna adapted to the low productivity, nutrient restricted environment. During the derivation of a numeric phosphorus criterion for the EPA, the FDEP conducted extensive evaluations and analyses of water quality and biological data collected from both WCA-2A and the Refuge, as previously described. The evaluations of the two areas were conducted independently to determine if the biological communities were responding to similar levels of P enrichment and to assure that a single criterion would be protective of both areas.

Based on general water quality conditions, WCA-2A and the Refuge can be considered to represent the two extremes of the system. The hydrologic inputs to WCA-2A are dominated by mineral-rich agricultural runoff in the canal inflows, which results in an alkaline, hard-water system that supports the characteristic calcareous periphyton mats typical of many of the oligotrophic marshes in the EPA (McCormick et al., 1999; Swift, 1981). In contrast, the rainfall dominated hydrology of the interior portions of the Refuge results in a unique acidic soft-water system that supports flora and fauna adapted to the natural oligotrophic soft-water conditions. This system includes a characteristic periphyton assemblage comprised of numerous desmid and filamentous green algae species that form a thin, green to brown coating on plant stems (Swift, 1981; Swift and Nicholas, 1987; Payne et al., 2001). Since other portions of the system generally exhibit water quality conditions intermediate to those of WCA-2A and the Refuge, the biological communities found in these areas are also a combination of those found in WCA-2A and the Refuge. Therefore, a P criterion protective of the natural flora and fauna in the extreme portions of the system should also be protective of those in other areas with moderate conditions.

Water Conservation Area 2

Phosphorus-enriched water originating in the Everglades Agricultural Area (EAA) enters WCA-2A through the S-10 structures along the northern levee with smaller amounts entering through the S-7 structure located on the southwest boundary. Both water and sediment P data show that extensive P gradients have formed in WCA-2A as the result of settling, sorptive processes, and other biogeochemical mechanisms. The primary gradient extends from its source at the S-10 canal inflow structures in a southerly direction toward the marsh interior for a distance of at least 8 km. Average TP concentrations along the primary gradient in WCA-2A range from less than 10 µg/L at sites located in the interior portions of the marsh to more than 50 µg/L at sites nearer the S-10 inflows.

The FDEP's evaluation of the changes occurring along the P gradient in WCA-2A included multiple measures of the structure and function of the natural biological communities including bacteria, algae, vascular plants, and benthic macroinvertebrates, to account for possible variations in sensitivity to P enrichment across trophic levels. The results of the FDEP's analyses documented extensive changes in biological communities at all trophic levels resulting from P enrichment. These changes include the loss of characteristic sensitive assemblages including the calcareous periphyton mat, increased dominance by tolerant assemblages capable of increased growth under P-enriched conditions, loss of open water habitat critical for fish and birds, and depressed DO regime. Even though different biological communities may exhibit varying sensitivity to P enrichment, the evaluation of the biological and chemical data collected within WCA-2A indicate that many of the P-induced changes occur at the same location along the gradient and therefore under similar levels of P enrichment. The similar response to P enrichment

observed across trophic levels results from the complex interrelationships among trophic levels and the unique ecological function of the sensitive species that are not duplicated by those of the tolerant replacement species. Therefore, the initial shifts in community structure occurring in the lower trophic levels, such as periphyton, are ultimately reflected in impacts throughout the trophic structure. For example, the replacement of the natural calcareous periphyton mat with tolerant green or blue-green algae results in depressed dissolved oxygen levels which in turn results in significant changes to the macroinvertebrate and fish communities. Therefore, the numeric phosphorus criterion adopted must be sufficiently stringent to protect against such shifts in community structure at all levels.

The results of most analyses conducted by the FDEP indicate that the biological communities are altered significantly at distances between approximately 7 and 8 km from the S-10 inflows (i.e., between stations E4, F4, and the E5, F5 sites). Since many of the individual changes observed can be interpreted as constituting an imbalance in the natural flora and fauna, the fact that many of the changes observed in the various trophic levels occur at the same location along the transect makes the definition of the imbalance point more robust and less controversial. Based on the results of this evaluation, stations E5, F5, and U1, U2, and U3 (located 8 km or more from the S-10 structures) are considered to have similar biological and water quality characteristics and can therefore be combined into a single reference group that can be used to characterize the range of P conditions found in the minimally impacted areas of WCA-2A (Payne, et al., 1999 and 2001). **Table 5-1** provides a summary of the P levels measured at the five WCA-2A reference sites during the 1994–2001 period of record. The TP regime from the five reference sites in WCA-2A is characterized by annual geometric means ranging from approximately 5.3 µg/L to 10.6 µg/L, with a median value of 8.0 µg/L.

Arthur R. Marshall Loxahatchee National Wildlife Refuge

The Refuge is exposed to the same EAA drainage waters that have caused extensive P enrichment in WCA-2A. Runoff enters the Refuge through the S-5A and S-6 structures and overflow of the L-7 rim canal along the northern and western levees. Water and sediment data indicate that P gradients have formed to the west of the L-7 rim canal. Total phosphorus concentrations in the water range from more than 30 µg/L near the L-7 canal to less than 10 µg/L in the interior marsh. The rainfall-driven hydrology of the Refuge results in a much steeper P gradient than observed in WCA-2A with water and sediment TP concentrations generally decreasing to background levels within 2.2 km of the L-7 canal.

As described for WCA-2A, the evaluation of data from the Refuge was not limited to a single trophic level, but instead consisted of analyses of multiple measures of biological communities across trophic levels to account for the possibility of varying sensitivity to P enrichment. Various measures of the periphyton and macrophyte communities, as well as the dissolved oxygen regime, were examined to establish the point along the Refuge transects where statistically significant changes in the structure and function of the natural biological communities occurred.

Results of the analyses performed using data collected along the P gradient in the Refuge, which has been exposed to elevated P concentrations for more than three decades, indicate that many significant P-induced changes in natural flora and fauna occur at similar locations along the gradient, similar to that described for WCA-2A. This finding also supports the conclusion from WCA-2A that interrelationships among biological communities result in significant changes in lower trophic levels being reflected throughout the trophic structure. The results of the FDEP's analyses also indicate that the P related changes in the structure and function of the biological communities predominately occur between stations X3 and Z3 (2.2 km from canal) and stations X2 and Z2 (1.3 and 1.1 km from the canal, respectively). Therefore, stations X3 and Z3 can be

differentiated from the sites impacted by P enrichment and can be combined with stations X4, Y4, and Z4 (initial "reference" sites) into a single group of reference sites that can be used to derive a suitable criterion. **Table 5-2** provides a summary of the P levels measured at the five Refuge reference sites during the 1996–2001 period of record. During the 1996 through 2001 period of record, the five reference sites in the Refuge exhibited annual geometric mean TP concentrations ranging from 7.2 to 12.3 µg/L, with a median geometric mean concentration of 9.3 µg/L.

Table 5-1. Summary of total phosphorus concentrations (µg/L) measured at five reference sites in WCA-2A during the period of record from 1978 through 2001

Year	E5 Geometric Mean	F5 Geometric Mean	U1 Geometric Mean	U2 Geometric Mean	U3 Geometric Mean	All Sites	
						Geometric Mean	N
1978					6.36	6.36	7
1979					4.56	4.56	9
1980					5.77	5.77	15
1981					8.34	8.34	17
1982					10.85	10.85	12
1983					8.85	8.85	14
1984					5.77	5.77 [1]	3
1985					22.91	22.91 [1]	2
1986					14.07	14.07	10
1987					10.79	10.79	17
1988					10.95	10.95	21
1989					6.37	6.37	7
1990					12.31	12.31	13
1991					7.45	7.45	18
1992					8.49	8.49 [1]	2
1994	8.80	9.76	7.85	7.98	6.81	8.22	49
1995	5.95	7.69	5.25	5.63	5.37	5.89	97
1996	7.75	9.95	8.70	8.23	8.44	8.58	81
1997	8.50	10.63	9.79	8.04	8.35	9.04	64
1998	7.94	10.12	7.43	9.42	9.61	8.83	94
1999	7.55	10.43	6.99	8.32	6.72	7.93	51
2000	5.50	9.69	5.47	8.66	6.16	6.88	63
2001	7.65[1]	10.0	7.79	8.13[1]	7.46[1]	8.24	25
Summary of 1994 – 2001 Annual Geometric Means							
Mean	7.46	9.78	7.41	8.05	7.37	7.95	8
Median	7.70	9.98	7.61	8.18	7.14	8.23	
Std. Dev.	1.16	0.90	1.52	1.08	1.38	1.06	
95% CI	0.80	0.63	1.06	0.75	0.96	0.74	
Summary of 1978 – 2001 Annual Geometric Means							
Mean					8.82	9.02	23
Median					8.34	8.34	
Std. Dev.					3.89	3.78	
95% CI Mean ±					1.59	1.55	

[1] Annual geometric mean concentrations determined for station U3 for 1984, 1985, and 1992, and for stations E5, U2, and U3 for 2001 are not considered to be adequately representative of the P regime during those years due to less than six measurements being made during the monitoring year.

Table 5-2. Summary of total phosphorus concentrations (µg/L) measured at five reference sites in the Refuge (WCA-1) during the period of record from 1996 through 2001

Year	X3 Geometric Mean	X4 Geometric Mean	Y4 Geometric Mean	Z3 Geometric Mean	Z4 Geometric Mean	All Sites	
						Geometric Mean	N
1996	7.78	7.63	8.76	7.16	7.61	7.77	65
1997	8.08	10.29	9.48	8.53	8.63	8.97	83
1998	11.76	10.04	11.25	9.34	10.03	10.45	84
1999	8.35	9.24	10.48	9.94	8.13	9.21	59
2000	11.66	11.63	9.05	10.76	7.40	9.91	47
2001	10.46	12.32	8.06	11.03	7.70	9.71	41
Summary of 1996 – 2001 Annual Geometric Means							
Mean	9.68	10.19	9.51	9.46	8.25	9.34	6
Median	9.41	10.17	9.27	9.64	7.92	9.46	
Std. Dev.	1.83	1.68	1.17	1.45	0.98	0.93	
95% CI Mean ±	1.47	1.34	0.94	1.16	0.78	0.74	

Conclusions from the Evaluation of WCA-2A and Refuge Data

To proceed with the development of a P criterion, the P regime that exists within the set of reference sites must be defined. Based on EFA requirements, the annual geometric mean TP concentrations are used to characterize the P regime in the minimally impacted areas of the Refuge and WCA-2A. Generally, the annual geometric mean TP concentrations were similar among the Refuge and WCA-2A reference sites. In the Refuge, the combined set of reference sites exhibits annual geometric means from 7.8 to 10.5 µg/L with a median of 9.2 µg/L (**Table 5-2**) compared to a range of 5.9 to 9.0 µg/L and median of 8.4 µg/L determined for the combined group of five WCA-2A reference sites (**Table 5-1**). The slight variation between areas is thought to reflect differences in the period of record and sampling methodology between the two areas.

A long-term P criterion that is protective of the natural flora and fauna, characterized by the group of reference sites in WCA-2 and the Refuge can be derived using a measure of the central tendency (i.e., mean or median) of the annual geometric mean total phosphorus concentrations measured at this group of reference sites, along with a measure of the statistical confidence in the central tendency (i.e., 95 percent confidence interval). For WCA-2A, the period of record for the complete group of designated reference sites is from 1994 through 2001. Additionally, one site (i.e., station U3) has a longer period of record extending back to 1978. Therefore, the criterion can be derived in multiple ways (e.g., using only the 1994 to 2001 period of record or incorporating the U3 historical period) that are equally valid statistically. For the Refuge, the derivation of the criterion is more straightforward since only the 1996 through 2001 period of record is available for the designated reference sites. **Table 5-3** provides a comparison of the results from the possible methods of deriving the criterion using both WCA-2A and Refuge data. Regardless of the derivation method selected, the results fell within a narrow range from 8.8 to 10.7 µg/L with most methods producing results slightly above or slightly below 10 µg/L with an average value of 9.7 µg/L. Since the multiple derivation methods for both WCA-2A and the Refuge produced

results that appeared to be centered on approximately 10 µg/L, a P criterion of 10 µg/L was proposed by the FDEP.

Table 5-3. Comparison of results of phosphorus criterion derivation for WCA-2A and WCA-1 using several methods and data sets

Description of Data Used	Central Tendency of Annual Geometric Means		95% Confidence Interval (Mean ±)	Upper Limit
	Measure	Value		
Water Conservation Area 2A				
1994 – 2001 Reference site data	Mean	7.95	0.74	8.69
	Median	8.23	0.54	8.77
1978 – 2001 Reference site data[1]	Mean	9.02	1.55	10.57
	Median	8.34	1.08	9.42
1978 – 2001 Reference site data minus three years with less than four measurements[2]	Mean	8.51	1.03	9.55
	Median	8.29	0.96	9.25
Water Conservation Area 1				
1996 – 2001 Reference site data	Mean	9.34	0.74	10.08
	Median	9.46	0.54	10.00
Overall Average Result				9.54

[1] Includes 1978 – 1992 historical period for Station U3 (See Table 5.1)

[2] Data for 1984, 1985, and 1992 were excluded from the historical period for Station U3 and 2001 data for stations E5, U2, and U3 due to less than six measurements being made during the year (See Table 5.1).

The FDEP's derivation of a 10 µg/L P criterion is also supported by a slightly different derivation method recommended by the USEPA in their guidance to the states and authorized Indian tribes on development of nutrient criteria. The principal recommendation is to identify reference or minimally impacted sites, then use the 75th percentile for those sites as the criterion. "EPA advocates selecting the 75th percentile of a distribution of reference condition values as a recommended target for a sufficiently protective value that provides an appropriate margin of safety and excludes the effects of outliers (EPA's preferred approach)" (USEPA, 2001b). **Figure 5-2** provides a cumulative frequency distribution of the annual geometric mean TP concentrations for the Refuge and WCA-2A reference sites. Applying the USEPA recommended approach to the annual geometric means for the 10 reference sites in WCA-2A and the Refuge results in a criterion at or very near 10 µg/L depending on whether the analyses are performed on WCA-2A

and Refuge data combined or separately. Using the combined data set from the 10 reference sites in both the Refuge and WCA-2A, the 75th percentile occurs at exactly 10 µg/L. Performing the analysis for each area separately results in a 75th percentile of 9.7 µg/L for the WCA-2A reference sites and 10.3 µg/L for the reference sites in the Refuge.

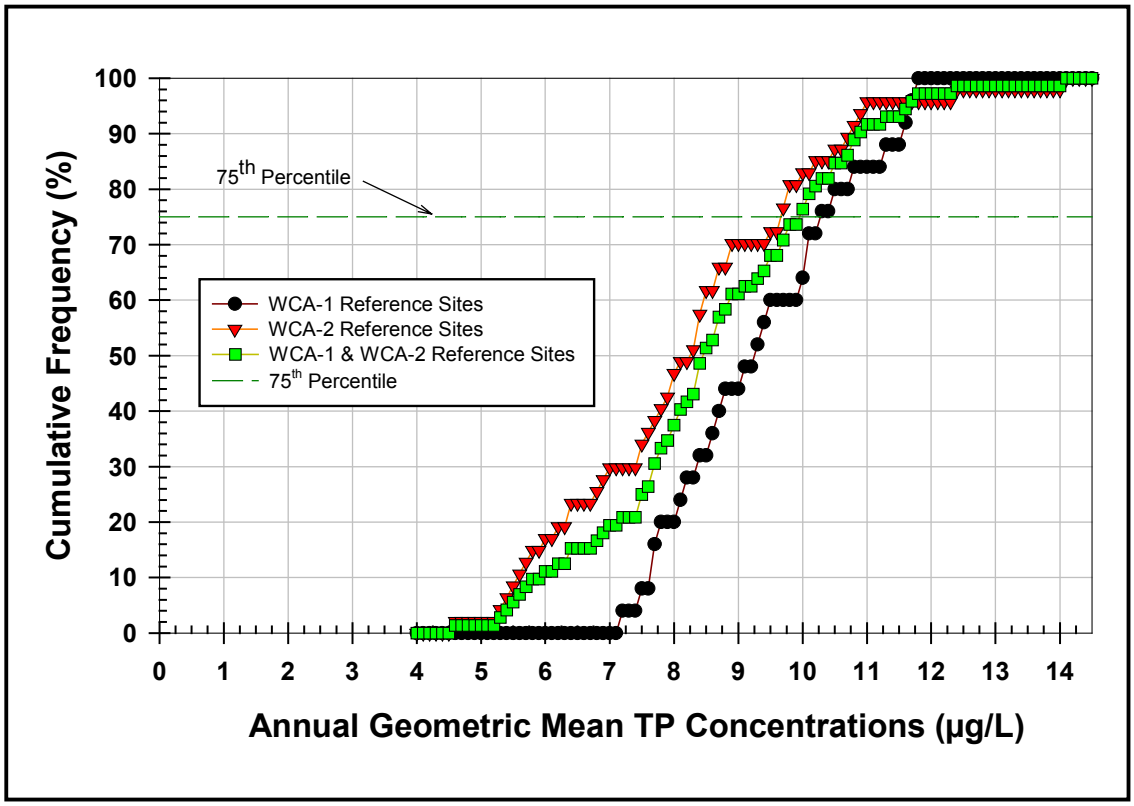

Figure 5-2. Cumulative frequency distribution of annual geometric mean total phosphorus concentrations for reference sites in WCA-2A and the Refuge

Therefore, based on evaluations performed by the FDEP, the normal structure and function of the natural biological communities in both WCA-2A and the Refuge are adversely altered by similar levels of P enrichment. Further, independent attempts to derive a P criterion based on the P regime at the reference sites delineated in both the Refuge and WCA-2A using multiple methods, including those developed by the FDEP and those recommended by the USEPA, generated recommended values at or slightly below 10 µg/L. Additionally, similar results were obtained when the criterion derivation was performed on a combined data set from the ten reference sites in both the Refuge and WCA-2A. Thus, the results of the Refuge and WCA-2A data evaluations indicate that a P criterion that will maintain a long-term average annual geometric mean TP concentration of 10 µg/L or less will be protective of the natural flora and fauna without being overly protective or below the natural background levels.

SUPPORTING EVIDENCE FROM WCA-3A AND ENP

The analysis of data collected in Water Conservation Area 3 (WCA-3) and the Everglades National Park (Park) generally followed the same protocols established for WCA-2A and the

Refuge, when data availability permitted. Multiple trophic levels were examined to document the observed response of various biological communities to P enrichment along existing phosphorus gradients. However, the relatively recent initiation of the studies in WCA-3A and ENP along with the severe drought conditions experienced during much of the study period greatly limited the amount of data collected in these areas.

This lack of data for WCA-3A and ENP prevented the same exhaustive evaluation as was conducted for WCA-2A and the Refuge. In addition, an independent derivation of a P criterion, as performed for WCA-2A and the Refuge, was not possible for WCA-3A and ENP due to the limited amount of data available. Even though an exhaustive evaluation was not possible, many of the same parameters examined in WCA-2A and the Refuge were analyzed to determine if they exhibited similar responses to P enrichment in WCA-3A and ENP. Additionally, when possible, the biological communities found in WCA-3A and ENP were compared to those found in WCA-2A and the Refuge to determine if they were similar and likely to display similar sensitivity to P enrichment. A complete discussion of the analyses conducted in WCA-3A and the Park, including a presentation of the results, can be found in part III of the FDEP's draft P-criterion development support document (Payne et al., 2001) with a summary provided in the *2002 Everglades Consolidated Report* (Payne et al., 2002).

The results of the evaluation of the limited chemical and biological data collected along the District P-gradient transects in WCA-3A and ENP indicate that well-defined, man-made P gradients are apparent in WCA-3A with minimal levels of P enrichment being observed in ENP, especially adjacent to the S-332 inflow. Additionally, the biological communities (periphyton and macrophytes) present in WCA-3A and ENP appear to be very similar to those found in WCA-2A and the Refuge, with nearly all of the taxa identified in WCA-3A and the freshwater portions of the Park also being documented in the northern areas. The FDEP's analysis of the sparse amount of data available for WCA-3A and the ENP does suggest that the biological response to P enrichment is comparable to that documented for WCA-2A and the Refuge. As in the other areas, the results of the analyses for WCA-3A and ENP indicate that significant changes in the structure and function of the biological communities across trophic levels occurring at geometric TP concentrations above 10 µg/L. Therefore, the results of the analysis of the data from WCA-3A and ENP provide evidence that the 10 µg/L P criterion based on the exhaustive evaluations conducted for WCA-2A and the Refuge would be protective of the flora and fauna throughout other freshwater portions of the Everglades.

ADDITIONAL INFORMATION AVAILABLE

In addition to the FDEP's extensive analyses of data collected along the SFWMD's gradient transects, the adoption of a 10 µg/L criterion is also supported by the results of a comprehensive literature review performed by the U.S. Environmental Protection Agency (USEPA). Additional information can be obtained from the results of the phosphorus dosing study conducted by DUWC. The additional information from the USEPA and DUWC work is briefly discussed below.

During the process of approving the 10 µg/L P criterion proposed by the Miccosukee Tribe of Indians of Florida for application to the federal reservation located in the western portion of WCA-3, the USEPA conducted a comprehensive review of the available scientific literature providing the results of studies conducted in the Everglades by many different researchers to determine reference conditions in the area and to evaluate the effects of P enrichment on various components of the ecosystem. The initial set of literature reviewed included approximately 300 peer-reviewed scientific journal publications and technical reports. Based on this review of the available information, the USEPA approved the Miccosukee Tribe's proposed criterion on May

25, 1999 finding that the 10 μg/L standard was a scientifically defensible value that was not overly protective and yet sufficiently protective of the water's designated use (USEPA, 1999). The USEPA further specified that while some portions of the Everglades typically had long-term median or geometric mean P concentrations below 10 μg/L, there was no evidence that increases in P concentrations from background levels up to 10 μg/L produced imbalances in the natural flora and fauna. In a January 19, 2001 memorandum (USEPA, 2001a), the USEPA updated its approval of the Miccosukee criterion by reviewing another 110 technical publications since the initial approval. This addition increased the total number of documents reviewed to over 400. Following the re-evaluation of the available literature, the USEPA concluded that the new information corroborated their initial findings. The USEPA also specified that there has been no scientific determination that a long-term P criterion exceeding 10 μg/L would be protective of the natural flora and fauna in the Everglades or the designated use of surface water in the Everglades.

As documented in previous Everglades Consolidated Reports (Payne et al., 2001) DUWC researchers conducted a six-year experimental P-dosing study in WCA-2A to assist in the derivation of a P criterion for the EPA. The FDEP's evaluation of DUWC's initial analysis of their dosing study is summarized in the *2001 Everglades Consolidated Report*. In that previous evaluation, the FDEP noted several key issues that conceivably resulted in an erroneously high P-criterion being recommended by the DUWC researchers. Some of the important concerns that have been raised by the FDEP include:

1. A significant portion (46 percent) of the TP data from the DUWC dosing studies since 1995 (when DUWC started operation under an approved QA/QC plan and began using blanks) were associated with contaminated blanks when the data were screened using a protocol developed by the Everglades Technical Advisory Committee during the early stages of the research. The protocol was developed and applied to data used by the FDEP to assure the highest quality data were used in criterion development. **Figure 5-3** provides the measured TP levels in the blanks collected during the DUWC dosing study. These data suggest that there was a significant problem associated with DUWC sample collection in the flumes throughout the term of the project. It can also be seen that the magnitude of the blank contamination could easily account for much if not all of the difference between the FDEP's and DUWC's recommended criterion. The use of the samples identified as being associated with blank contamination, as was done in the DUWC analyses, significantly biases the results and reduces the scientific validity and defensibility of the data as well as any conclusions drawn from the data.

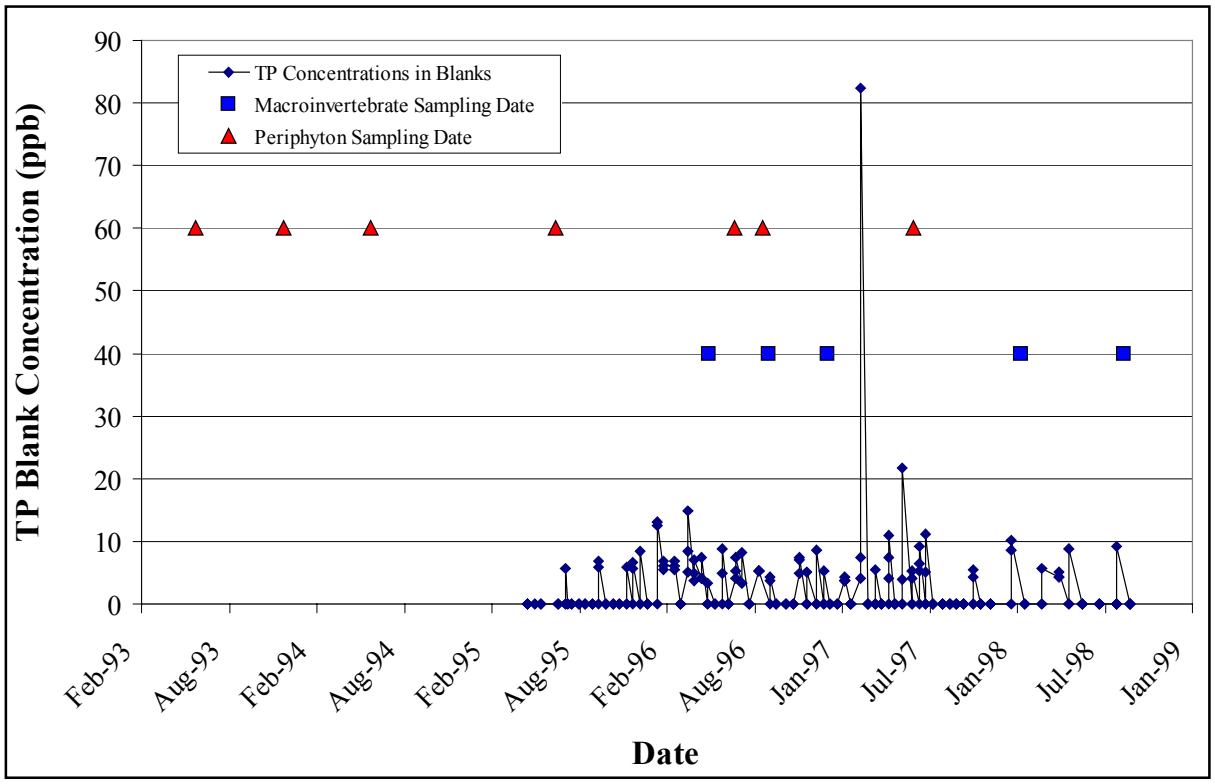

Figure 5-3. Distribution of TP concentrations measured in QA/QC blanks by DUWC researchers during the 1992-1999 dosing study conducted in WCA-2A. Note: No blank data were collected prior to April 1995

2. The use of short-term, artificially dosed experiments that have not achieved the full extent of biological change (as compared to the gradient) to establish a long-term P criterion applicable to the full-scale system is problematic. The extent of biological change observed in the dosing flumes was limited by both the small size of the flumes and the relatively short period over which the study was conducted compared to the gradient. The extent of biological change was further minimized by giving the biological measurements collected soon after the initiation of dosing the same weight as those collected after several years of dosing. Since the P criterion must provide adequate protection to the natural flora and fauna, it is important to take into account the long-term effects of P-enrichment (such as those resulting from long-term sediment enrichment or depression of the DO regime) that were not possible in the small short-term dosed flumes. This issue is especially important since a very limited amount of data from the full-scale gradient was used to verify the conclusions drawn from the dosing study. The gradient data that was used was interpreted using a highly questionable "one-gram" rule (see discussion of item 6 below). Furthermore, the DUWC dosing and gradient studies are limited to a very small area in WCA-2A with no information being provided that the conclusions drawn would be applicable to other portions of the Everglades Protection Area that have somewhat different biological communities and chemical conditions.

3. The high degree of variability in the TP concentrations measured in the dosed flumes results in average TP levels that are biased high relative to levels along the gradients and are not representative of the P regime experienced by the biological communities. Due to a combination of mechanical problems and climatic conditions encountered during the study, there were frequent periods in which no dosing occurred in combination with frequent concentration spikes in all flumes. This resulted in the TP measurements within the dosed flumes being much more variable than those along the natural gradient near the location where the biological changes are occurring (Payne et al., 2001). The significance of the variability in the measured TP values was further exaggerated by the use of two to six month average TP values (consisting of the average of a few highly variable measurements) to pair with the biological measurements. That practice maximized the bias introduced by the concentration peaks occurring during that averaging period. If longer averaging periods that were more consistent with EFA requirements that compliance with the criterion be based on a long-term geometric mean were utilized, the result would likely have been lower variability and a lower recommended criterion as a result of less influence from the concentration peaks.

   In addition to the variability in the measured TP concentrations, the extended non-dosing periods (some lasting up to eight months) that occurred during the flume study further compromised the results by potentially allowing the biological communities to recover to some degree proportional to the duration of the non-dosing period. This would effectively minimize the biological changes observed and result in an erroneously high criterion being recommended.

4. The appropriateness of the CART statistical methods used to analyze the dosing study results was also questioned by FDEP. During the initial evaluation of the DUWC results, the FDEP indicated that CART is not an acceptable method of change point analysis; rather, CART is designed for predicting responses (usually with high-dimensional predictors).

   The DUWC analysis assumes that the change point is the first split point of the CART model that uses the environmental variable as the predictor. The statistical interpretation of this definition is clear (as the best piecewise constant fit with one split point, where "best" is defined in the sense of minimizing mean squared prediction error), but no ecological justification for this type of change point is provided.

   More recently, DUWC has reanalyzed their data using a Bayesian statistical approach. The FDEP is currently reviewing those analyses to determine their appropriateness. Some of the FDEP's preliminary comments on the DUWC's use of the Bayesian statistics in the re-analysis of its data are provided below.

5. The use of average change point across trophic levels to define a criterion adequately protective of the natural flora and fauna and the lack of any confidence limits on the recommended criterion is also problematic. The FDEP is legally mandated to adopt a P criterion that is protective of the natural aquatic flora and fauna. The necessary assumption behind the use of an average change point as the criterion is that a certain number of biological indicators whose change points fall below the average must not be significant in defining when an imbalance occurs. This is clearly not the case for the biological communities in the Everglades. The natural flora and fauna of the Everglades are comprised of biological communities ranging from bacteria to emergent vegetation to higher mammals with complex interrelationships among these biological communities across various trophic levels that control the structure and function of the Everglades system. These complex interrelationships result in changes to an individual biological community being reflected throughout the entire trophic structure given sufficient time. For example, the replacement of the natural calcareous periphyton mat with tolerant green or blue-green algae results in depressed dissolved oxygen levels which in turn results in significant changes to the

macroinvertebrate and fish communities. Another example of these interrelationships is the loss of sensitive slough vegetation (*Utricularia* spp and *Eleocharis* spp.) and the increased growth of water lily and emergent vegetation resulting in the loss of open water habitat and less light penetration which causes the further loss of algae and lower photosynthetic rates (further decreases in dissolved oxygen) and ultimately the loss of habitat and decreased food availability for fish, birds, and higher animals.

The use of an average change point as the recommended criterion is especially troubling in a case in which the biological indicators vary widely in their apparent sensitivity to P-enrichment as is depicted in **Figure 5-4**. Relying on more sensitive indicators would minimize the effects of selecting the average change point as the criterion and would result in a lower recommended criterion. Therefore, even though the results of a short-term dosing study indicate that the average change point is protective of a particular biological community, observations along the full-scale gradient that has been affected for up to 40 years indicated that changes in the more sensitive biological communities will, over-time, result in changes in the less sensitive communities. This phenomenon is supported by the FDEP's finding that the biological changes (regardless of trophic level) observed along the gradient occur within a very narrow distance and range of TP concentrations. In conclusion, the use of the average change point based on short-term observations will result in an elevated criterion that is not adequately protective of the aquatic flora and fauna.

6. The development of the "one-gram" rule and its application to WCA-2 gradient data to support the conclusions drawn from the dosing study has been seriously questioned in the peer-reviewed literature. One of the authors of the database used to develop the one-gram rule (Kadlec, 1999a and 1999b) identified serious flaws in the use of the data for this purpose. Additionally, review further noted that the 1.0-g $m^{-2} yr^{-1}$ loading rate does not correspond to biological or chemical changes occurring along the gradient.

7. There is no indication the DUWC-recommended criterion accounts for natural spatial and temporal variability and no associated measurement methodology has been offered to further explain the suggested criterion. The Everglades Forever Act requires that the P criterion take into account natural spatial and temporal variability and provides limited guidance on the application of the criterion. Since the criterion proposed by DUWC was derived primarily from a highly "unnatural" short-term dosing experiment that was much more variable than the natural system, it is not clear how the natural variability of the system is or can be incorporated into a criterion derived from this study. As widely acknowledged, the numeric criterion has little meaning without details concerning how it will be applied to the Everglades Protection Area.

Based in part on the FDEP's comments, the DUWC researchers performed a reanalysis of their data. DUWC researchers presented the results of the reanalysis of their data during a P criterion workshop in September 2001 and again at an Environmental Regulation Commission hearing on the P criterion held during October 2002. The reanalysis involved: (1) the recalculation of the average 2–6 month TP concentrations using geometric means as required by the EFA instead of arithmetic means; and (2) the use of Bayesian statistics in conjunction with the CART methods to analyze the data. The other more significant data quality, study design, data interpretation, and application issues were not addressed during the reanalysis. However, the reanalysis did result in a decrease in DUWC's recommended criterion (from 20 µg/L to 15.6 µg/L) as predicted by the FDEP in Payne, et al., 2001.

The results of the reanalysis are summarized in **Figure 5-4,** which was reproduced from the DUWC presentation at the September 2001 workshop. The results provided indicate that the weighted average change point is 15.6 µg/L. The summary graphic clearly indicates that the change points for the Bray-Curtis indices, percent tolerant macroinvertebrates, percent sensitive

macroinvertebrates, percent macroinvertebrate predators, and *Utricularia purpurea*, are below the average of 15.6 µg/L. By using the average change point of 15.6 µg/L as the recommended criterion, it is necessary to assume that either the biological communities represented by these indicators are not significant to the overall ecosystem structure and function, or that their ecological function will be duplicated by the more tolerant communities that replace them. In the Everglades, where the structure and function of the ecological system is controlled by complex interrelationships among communities as discussed above, this is simply not the case. This consideration is especially critical when four of the five indicators changing below the 15.6 µg/L average are indicators of a single important trophic level (macroinvertebrates). Since it is unrealistic to assume that the macroinvertebrate community can undergo a complete shift in structure without the effects being reflected in changes to other trophic levels, the use of the average change point as the criterion appears unjustified. Therefore, to establish a P criterion that is protective of all the natural biological communities characteristic of the Everglades, the criterion would need to be derived using the lower end of the range of observed change points, which is 11 µg/L or less.

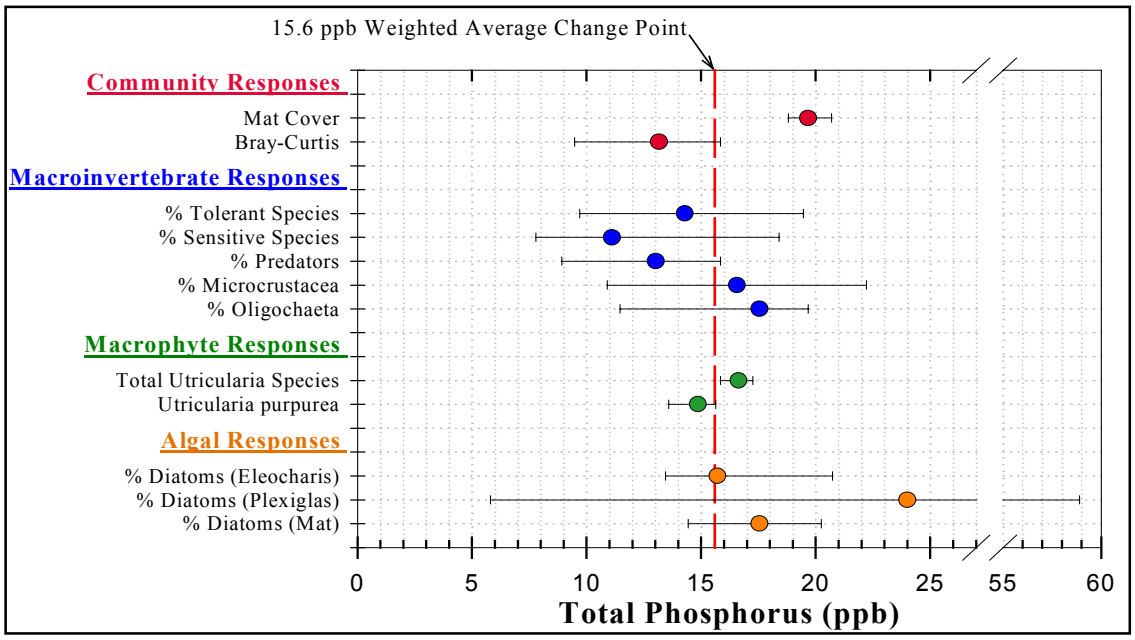

Figure 5-4. Summary of DUWC hierarchical analyses of geometric mean change points and 95-percent confidence levels (reproduced from DUWC presentation made during P criterion workshop on September 21, 2001)

It should be noted that only limited documentation concerning the details of the reanalysis have been provided to the FDEP. However, based on a preliminary evaluation of the information presented, the following initial comments can be made.

1. The DUWC results concerning the uncertainty about the change point are based on a bootstrap simulation. However, the bootstrap is unacceptable for quantifying uncertainty about split points (Buhlmann and Yu, 2002). The bootstrap fails in this context because the estimator of the split point has non-standard asymptotics, with a non-normal limit and a slower than $1/\sqrt{n}$ rate of convergence.

2. The normal Bayesian distribution model used by DUWC assumes that the response variable has constant mean and constant variance up to the change point, and that either the mean or the variance changes after the change point. Thus, the change point is allowed to represent a change in variance rather than a change in mean response. The model ignores the fact that changes in mean response are more important indicators of ecological imbalance than changes in variance. It is impossible to separate these two types of changes using the DUWC model, and it cannot be trusted to provide an ecologically meaningful change point estimate. Moreover, the restricted nature of the model (constant means and variances up to the change point), which is clearly violated by the data in most cases, gives a false degree of credibility that a change point is being estimated accurately.
3. The more restricted nature of the binomial distribution model (which has only one parameter) leads to the same problem of a false degree of credibility in the accuracy of the estimated change point. In addition, there is no reason to believe that the number of tolerant species has a binomial distribution, which amounts to the assumption that the species are independent and that each has the same chance of being tolerant.

A more thorough evaluation of the DUWC analysis will be completed as additional details concerning the analyses are provided. However, it is likely that the issues concerning the interpretation of the study results, the study design, data quality, and the statistical methods identified by the FDEP and discussed above account for much of the difference between the FDEP's proposed 10 µg/L criterion and the 15.6 µg/L criterion recommended by the DUWC researchers.

CONCLUSIONS

The FDEP has conducted an extensive evaluation of the biological and chemical data collected along the District P-gradient transects in WCA-2A and the Refuge, with less exhaustive evaluations being conducted for WCA-3A and ENP, due to insufficient data. Based on the results of these evaluations, a group of ten "reference" sites (five from WCA-2A and five from the Refuge) were identified as being representative of the conditions occurring within the minimally impacted portions of WCA-2A and the Refuge. The P regimes at the WCA-2A and Refuge reference sites are characterized median annual geometric mean TP concentrations 8.2 and 9.2 µg/L, respectively, for the 1994–2001 and 1996–2001 period of record for the two areas.

For each area, a P criterion was determined using the P regime at the reference sites along with a measure of the statistical uncertainty in the observed P levels. Depending on which measure of central tendency was used (mean or median) and which period of record was used for WCA-2A, the results indicate that an appropriate criterion would fall within the range from 8.8 to 10.7 µg/L with most calculation methods producing results slightly above or slightly below 10 µg/L with an average value of 9.7 µg/L. Since the multiple derivation methods for both WCA-2A and the Refuge produced results that appeared to be centered on approximately 10 µg/L, a P criterion of 10 µg/L was proposed by the FDEP.

The adoption of a 10 µg/L P criterion is further supported using a slightly different derivation method recommended by the USEPA in their guidance to the states and authorized Indian tribes on development of nutrient criteria. The USEPA's recommendation is to identify reference or minimally impacted sites, then to use the 75th percentile concentration for those sites as the criterion. Applying the USEPA recommended approach to the annual geometric means for the ten reference sites in WCA-2A and the Refuge results in a criterion between 9.7 and 10.3 depending upon whether the analyses are performed on WCA-2A and Refuge data combined or separate. Using the combined data set from the 10 reference sites in both the Refuge and WCA-2A, the 75th percentile occurs at exactly 10 µg/L. Performing the analysis for each area separately results in a

75th percentile of 9.7 µg/L for the WCA-2A reference sites and 10.3 µg/L for the reference sites in the Refuge.

Thus, the results of the Refuge and WCA-2A data evaluations indicate that a P criterion that will maintain a long-term average annual geometric mean TP concentration of 10 µg/L or less will be protective of the natural flora and fauna without being overly protective or below the natural background levels. This conclusion is further supported by the FDEP's analyses of the limited data available from WCA-3A and ENP gradient transect studies, which provide evidence that a 10 µg/L criterion would be protective of the natural flora and fauna throughout the EPA without being below background conditions.

Further support for the FDEP's proposed 10 µg/L criterion is provided by the USEPA's finding that the 10 µg/L P standard adopted by the Miccosukee Tribe of Indians of Florida was scientifically defensible, that it was not overly protective, and yet it was sufficiently protective of the water's designated use. This conclusion was based on a comprehensive review of the vast amount of available scientific literature that provides the results of studies conducted by many different research groups examining various aspects of the biological response to P enrichment.

Additionally, the results of the DUWC dosing study presented to the FDEP indicate that change points for individual biological indicators monitored during the study ranged from approximately 11 to 24 µg/L with a weighted average change point of 15.6 µg/L. Because five of the 12 biological indicators used in the DUWC evaluation have change points below the 15.6 µg/L average change point, the FDEP does not consider the 15.6 µg/L criterion based on the average change point adequately protective of the natural flora and fauna. Therefore, to be protective of all the biological communities, the P criterion would need to be established using the lower end of the range of observed change points, which is near 11 µg/L or less.

All of the information evaluated by the FDEP relative to the development of a numeric P criterion indicate that a criterion that will require the maintenance of a long-term average annual geometric mean total phosphorus concentration of 10 µg/L or less would be protective of the natural flora and fauna in the EPA without being overly protective or below natural background levels. Therefore, the adoption of a 10-µg/L P criterion is recommended by the FDEP as being scientifically valid and legally defensible.

PHOSPHORUS CRITERION MEASUREMENT METHODOLOGY

The effectiveness of the numeric P criterion in preventing imbalances within the Everglades biological communities will largely depend on how the criterion is applied. During the development of an appropriate measurement methodology to accompany the P criterion, the heterogeneous nature of the Everglades' ecosystem must be acknowledged. It must also be understood that while there was likely a historical P gradient extending south of Lake Okeechobee, evidence indicates that .the gradient did not extend into the current remaining portions of the Everglades (i.e., the Everglades Protection Area). There is also overwhelming evidence that indicates that the portion of the Everglades now in the EPA developed and exists today under highly oligotrophic conditions. Evidence also indicates that historically, most of the biological heterogeneity resulted from variations in hydrology, not differences in P levels.

While some biological communities (such as tree islands) in the EPA can tolerate higher P levels, they all generally originated under oligotrophic conditions and exist as "islands" surrounded by the highly oligotrophic marsh. There is no evidence to suggest that these

communities require higher P levels to survive. Since it is inconceivable that a different P criterion be developed for each habitat type, the proposed criterion was derived to be protective of the most sensitive biological communities as is typically done for most water quality criteria. In the Everglades, the most sensitive communities are generally found in the open water/slough habitats. Therefore, the gradient transects monitoring sites were located in this type of habitat. Likewise, it is also anticipated that the location of the monitoring sites for the measurement methodology will also be located in similar sensitive habitats. By developing the measurement methodology in a manner consistent with the derivation of the criterion intended to protect the sensitive biological communities, the heterogeneous nature of the Everglades ecosystem will not be restricted, nor will it result in the criterion being applied to areas affected by natural perturbations such as rookeries, alligator holes, tree islands, etc.

For the criterion to achieve the desired result, the measurement methodology needs to be sensitive to changes in P levels without being too restrictive. Therefore, the P criterion measurement methodology needs to account for natural variability (temporal, spatial, depth, etc.) above the proposed 10-µg/L criterion in the areas in which the criterion is being applied. In providing guidance for developing an appropriate measurement methodology, the EFA states that:

> "Compliance with the phosphorus criterion shall be based on a long-term geometric mean of concentration levels to be measured at sampling stations recognized from the research to be reasonably representative of receiving waters in the Everglades Protection Area, and so located so as to assure that the Everglades Protection Area is not altered so as to cause an imbalance in natural populations of aquatic flora and fauna and to assure a net improvement in the areas already impacted." (Subsection 373.4592(4), Florida Statute).

The EFA further requires that in the Park and Refuge the method of measuring compliance with the phosphorus criterion be consistent with appendices A and B, respectively, of the July 26, 1991 settlement agreement dated July 26, 1991, entered in case No. 88-1886-Civ-Hoeveler, United States District Court for the Southern District of Florida.

To assure that the recommended criterion is protective of the natural biological communities within the EPA without being overly protective or below background levels, it is essential that the associated measurement methodology be developed in a manner that is consistent with the derivation of the criterion while taking into account the requirements of the EFA. Details concerning the development of the FDEP's proposed measurement methodology to accompany the recommended phosphorus criterion are provided below.

DEVELOPMENT OF MEASUREMENT METHODOLOGY

Results of the FDEP's extensive evaluations of the research data collected in the EPA indicate that the maintenance of a long-term average annual geometric mean TP concentration of 10 µg/L would be protective of the natural flora and fauna in the EPA. However, the results also indicate that the annual geometric mean TP concentration at individual reference sites can naturally vary significantly above 10 µg/L in any particular year without long-term biological impacts (Payne et al., 1999 and 2000). Therefore, the FDEP's recommended measurement methodology consists of both: 1) the maintenance of a long-term average total phosphorus concentration that will protect against imbalances in the natural flora and fauna and 2) an upper annual concentration limit that allows for the natural temporal and spatial variation observed for individual annual geometric mean total phosphorus concentrations within minimally impacted areas. This approach is not only protective of the natural populations of flora and fauna, it also allows for the observed natural spatial and temporal variability above the 10 µg/L criterion as required by the EFA.

Maintenance of a Long-Term Average Total Phosphorus Concentration

The 10 µg/L criterion was derived based on the central tendency (average) of the annual geometric mean total phosphorus concentrations measured at a group of minimally impacted "reference" sites in WCA-2A and the Refuge over four- to six-year periods of record, as described above. The reference sites were delineated through an extensive evaluation of the biological communities within the EPA and their response to P enrichment along established P gradients (Payne et al., 1999 and 2000). This derivation of the phosphorus criterion indicated that the maintenance of a long-term average annual geometric total phosphorus concentration of 10 µg/L or less would be protective of the natural flora and fauna within the EPA. Therefore, the requirement to maintain a long-term average annual geometric mean total phosphorus concentration of 10 µg/L or less was incorporated as part of the measurement methodology. However, in maintaining this long-term average geometric mean concentration, variation above and below the 10-µg/L phosphorus criterion, as naturally observed among the reference sites, must also be allowed by the criterion and the measurement methodology.

Upper Annual Concentration Limit

Phosphorus concentrations within unenriched portions of the EPA can vary significantly both spatially and temporally due to reasons unrelated to the anthropogenic inputs of phosphorus enriched water. Uncontrollable factors such as water depth, rainfall, sediment type, vegetation type, hydrology, fire, and climatic changes can result in considerable variation in the measured phosphorus concentrations even within unenriched areas. To account for this natural spatial and temporal variability as required by the EFA, an upper annual concentration limit was established based on data collected from the reference sites delineated through the extensive evaluations conducted during the FDEP's development of the phosphorus criterion (Payne et al., 1999 and 2000).

The upper annual concentration limit was computed as the 95th percentile of long-term annual geometric means estimated from annual values at the WCA-2A reference sites including the historical data for site U3, assuming a lognormal distribution. The upper limit was calculated as the prediction interval:

$$Upper\,Limit = exp(\bar{y} + t_{(0.05,n-1)} \cdot \sqrt{s_y^2 + \frac{s_y^2}{n}}),$$

where $\bar{y}$ is the natural log of the long-term annual geometric mean [i.e., ln(10 µg/L criterion) = 2.30] and s_y^2 is the variance of the natural logs of annual geometric means.

Years with fewer than six measurements (i.e., 1984, 1985, and 1992) were excluded from the historic U3 data set prior to calculation of the upper limit to maintain consistency with the derivation of the criterion and measurement methodology. As shown in **Table 5-4**, the results suggest an upper limit of approximately 15 µg/L would be appropriate. Additionally, the data from the WCA-1 reference sites were combined with the WCA-2 data and the calculation was repeated to determine if the upper limit adequately accounted for the spatial variability between areas (**Table 5-4**). The results indicate that an upper limit of 15 µg/L would be sufficient to account for the natural variation observed for the reference sites during the period of record.

Therefore, the proposed measurement methodology would allow the annual geometric mean for any site to range up to 15 µg/L during any individual year. However, the measurement methodology would also require that these elevated annual mean concentrations be balanced by

lower annual geometric means during the preceding years to maintain the long-term (five-year) average annual geometric mean for that site at or below 10 µg/L.

Table 5-4. Summary of data for calculating upper P criterion compliance limit

WCA-2A Annual Geometric Mean TP				WCA-1 Annual Geometric Mean TP			
Site	**Year[1]**	**TP**	**LN TP**	**Site**	**Year**	**TP**	**LN TP**
E5	1994	8.80	2.17	X3	1996	7.79	2.05
E5	1995	5.95	1.78	X3	1997	8.08	2.09
E5	1996	7.75	2.05	X3	1998	11.76	2.46
E5	1997	8.50	2.14	X3	1999	8.35	2.12
E5	1998	7.94	2.07	X3	2000	11.66	2.46
E5	1999	7.55	2.02	X4	1996	7.63	2.03
E5	2000	5.50	1.70	X4	1997	11.31	2.43
F5	1994	9.76	2.28	X4	1998	10.04	2.31
F5	1995	7.69	2.04	X4	1999	9.24	2.22
F5	1996	9.95	2.30	X4	2000	11.63	2.45
F5	1997	10.64	2.36	Y4	1996	8.76	2.17
F5	1998	10.12	2.31	Y4	1997	9.48	2.25
F5	1999	10.43	2.34	Y4	1998	11.25	2.42
F5	2000	9.69	2.27	Y4	1999	10.48	2.35
U1	1994	7.85	2.06	Y4	2000	9.05	2.20
U1	1995	5.25	1.66	Z3	1996	7.16	1.97
U1	1996	8.70	2.16	Z3	1997	8.53	2.14
U1	1997	9.79	2.28	Z3	1998	9.34	2.23
U1	1998	7.43	2.01	Z3	1999	9.94	2.30
U1	1999	6.99	1.95	Z3	2000	10.76	2.38
U1	2000	5.47	1.70	Z4	1996	7.61	2.03
U2	1994	7.98	2.08	Z4	1997	8.63	2.16
U2	1995	5.64	1.73	Z4	1998	10.03	2.31
U2	1996	8.23	2.11	Z4	1999	8.13	2.10
U2	1997	8.04	2.08	Z4	2000	7.40	2.00
U2	1998	9.42	2.24				
U2	1999	8.32	2.12				
U2	2000	8.66	2.16				
U3	1978	6.36	1.85				
U3	1979	4.56	1.52				
U3	1980	5.77	1.75				
U3	1981	8.34	2.12				
U3	1982	10.85	2.38				
U3	1983	8.85	2.18				
U3	1986	14.07	2.64				
U3	1987	10.79	2.38				
U3	1988	10.95	2.39				
U3	1989	6.37	1.85				
U3	1990	12.31	2.51				
U3	1991	7.45	2.01				
U3	1994	6.81	1.92				
U3	1995	5.37	1.68				
U3	1996	8.44	2.13				
U3	1997	8.35	2.12				
U3	1998	9.61	2.26				
U3	1999	6.72	1.91				
U3	2000	6.16	1.82				

	Upper Limit Based on WCA-2A	Upper Limit Based on WCA-1 and WCA-2A
Long-term threshold ($\bar{y}$)	2.30	2.30
Standard Deviation	0.246	0.229
Years [1]	47	72
$t_{(0.05,n-1)}$	1.68	1.67
One-Year Limit	15.1[2]	14.6[3]

[1]Years with fewer than 6 measurements (1984, 1985, and 1992) were excluded from the historical data for U3.
[2]Upper limit =Exponential (2.30+1.68*0.246) [3]Upper limit =Exponential (2.30+1.67*0.229)

MONITORING SITES AND SAMPLING METHOD

Location of Monitoring Sites

The FDEP proposes to calculate and report the results of the P criterion monitoring on a station-by-station basis for marsh stations representative of the receiving waters in the Everglades Protection Area including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge: also referred to as Water Conservation Area 1), Everglades National Park and all other water conservation areas. Monitoring stations in these waters shall be dispersed throughout areas that are both impacted and unimpacted by phosphorus enrichment. As discussed above, since the intent of the criterion is to protect the phosphorus sensitive biological communities while maintaining the natural heterogeneity of the system, the monitoring sites for the P criterion will be located in the open water/slough habitats where these communities primarily exist. The location of the monitoring sites in these areas is further supported by the fact that the open water/slough habitats represent a critical component of the ecosystem and comprise a large portion of the EPA. In order to make the most efficient use of existing monitoring programs and historical data, it is recommended that the P criterion measurement monitoring sites be generally consistent with (but not limited to) the current monitoring network established by the South Florida Water Management District**. Figures 5-5** through **5-8** show the location of the current SFWMD monitoring networks in the Refuge, WCA-2, WCA-3 and ENP, respectively.

The FDEP has further proposed that the District's current monitoring network be optimized to provide adequate spatial coverage of both the impacted and unimpacted areas in each portion of the EPA. The District intends to conduct analyses to develop the most efficient and effective network for this purpose and will hold one or more public workshops to incorporate recommendations from interested parties into the development of the optimized network. The District will formally document this network through publication of a District technical publication. Such documentation will also include detailed standard operating procedures to be used to obtain samples from the network. Additionally, to assess any impacts from discharges to the EPA, it is anticipated that a series of additional monitoring sites will be needed downstream of the discharges with their exact locations being specified in the permits issued for these facilities by the FDEP.

Phosphorus Criterion Measurement Monitoring and Data Screening

Phosphorus criterion monitoring shall consist of monthly sampling and TP analyses at each of the designated monitoring sites in the EPA, with a minimum of six monthly samples required for reporting purposes. If abnormal conditions or data QA/QC problems result in sites with fewer than six monthly measurements, the annual geometric mean for that site-year will not be reported.

However, to prevent abnormal conditions from biasing the annual analysis of the phosphorus status within the EPA, the quality and suitability of all data collected during P criterion monitoring shall be evaluated prior to conducting the annual analysis and reporting the results. The data evaluation shall be conducted as follows:

1. Any data not complying with the QA/QC requirements specified in Chapter 62-160, F.A.C. shall not be used for reporting purposes.
2. During each monitoring event, samples will only be collected from sites at which the water depth is 10 cm or greater. Any data collected from sites with water levels below 10 cm will not be used for reporting purposes due to the increased possibility of sample contamination resulting from disturbed sediments and detritus.

3. Outliers identified through statistical procedures shall be evaluated to determine whether they represent valid measures of Everglades Protection Area phosphorus levels. Data determined by the FDEP to be invalid measures of Everglades Protection Area phosphorus levels will not be used for reporting purposes. Data may be deemed not valid measures of Everglades Protection Area phosphorus levels due to temporary influences from conditions such as bird rookeries, alligator holes, or perturbations resulting from airboat or vehicle activities.

The FDEP will document any data that are excluded from reporting and will provide an explanation as to why they were excluded.

APPLICATION OF THE MEASUREMENT METHODOLOGY

Therefore, based on the measurement methodology developed in section 2 above, waters represented by a sampling station shall be reported as achieving the phosphorus criterion for a given year if either of the following conditions are satisfied:

1. The annual geometric mean of measured phosphorus concentrations for that station during that year does not exceed the 10 µg/L criterion demonstrated to be protective of the natural flora and fauna within the EPA
2. The annual geometric mean of measured phosphorus concentrations for that station during that year does not exceed 15 µg/L and the arithmetic average of the annual geometric mean TP concentrations measured at that station during the five-year period encompassing that year and the preceding four years is maintained at or below (i.e., does not exceed) the 10 µg/L criterion.

The recommended measurement methodology was evaluated using long-term monitoring data from WCA-2A and the Refuge to determine if the phosphorus criterion was being applied so that it would be protective of the natural biological communities present within the EPA without being overly restrictive or below background levels. **Table 5-5** provides an example of the application of proposed phosphorus criterion and measurement methodology using WCA-2A gradient transect data collected from 1994 through 2001. The results indicate that in each case, the minimally impacted reference sites (i.e., stations E5, F5, U1, U2, and U3) were correctly designated as achieving the P criterion. Additionally, when the measurement methodology was applied to data from the first sites along the gradient designated as biologically imbalanced (i.e., stations E4 and F4), the sites were accurately identified as exceeding the criterion.

The proposed measurement methodology: 1) provides for an objective and scientifically reliable assessment of the phosphorus status at individual sampling stations representative of the Everglades Protection Area; 2) takes into account natural spatial and temporal variability (including variability above 10 µg/L) as required by the EFA, without being significantly biased by extreme events; and, 3) allows the phosphorus criterion to be applied so that it is protective of the naturally P sensitive biological communities within the EPA without restricting the natural heterogeneity of the system or being below background levels.

PERIODIC REVIEW OF THE P CRITERION AND MEASUREMENT METHODOLOGY

To assess the effectiveness of the Everglades phosphorus criterion in assuring that the Everglades Protection Area is not altered so as to cause an imbalance in natural populations of aquatic flora or fauna, the FDEP shall undertake a technical review of the results of the measurement methodology no later than 10 years following adoption of the phosphorus criterion.

The FDEP estimates that this more formal review will occur no later than 2013. The FDEP shall hold a public workshop to present the results of this review and provide opportunities for interested parties to comment.

STATUS OF PHOSPHORUS CRITERION RULE MAKING

The EFA required that the research necessary to establish a numeric P criterion in the Everglades Protection Area be completed by the FDEP and the District by December 31, 2001, by which date the FDEP was also required to file notice of rulemaking to establish such a criterion. In compliance with this requirement of the EFA, the FDEP filed a notice of rulemaking for the P criterion on December 11, 2001. The Florida Environmental Regulation Commission (ERC) is currently holding a series of hearings for the approval of the FDEP's proposed 10 µg/L P criterion. The ERC hearings are expected to be completed by March 2003. If the FDEP does not adopt a P criterion by December 31, 2003, then the EFA establishes a default criterion of 10 µg/L.

RECOVERY RESEARCH

As was previously mentioned, much of the threshold research efforts in WCA-2A and the Refuge have been re-focused to examine the recovery of the system as the P concentrations are reduced. The FDEP, the District, and agricultural interests are currently developing plans for demonstration projects to evaluate potential methods of expediting the recovery of the biological communities in the impacted areas. The primary objective of the projects is to accelerate the replacement of the cattail monocultures currently in the impacted areas with more diverse biological communities consisting of native Everglades flora and fauna. Current knowledge suggests that a combination of fire to eliminate the existing cattail, and manipulation of the hydrologic regime to promote the establishment of more desirable species and prevent reestablishment of the cattails, will likely be needed in conjunction with the reduction of P levels to successfully promote the system's recovery (Richardson and Huvane, 2001). More details concerning these efforts will be provided in future reports as the scopes of work for the projects are developed and implemented.

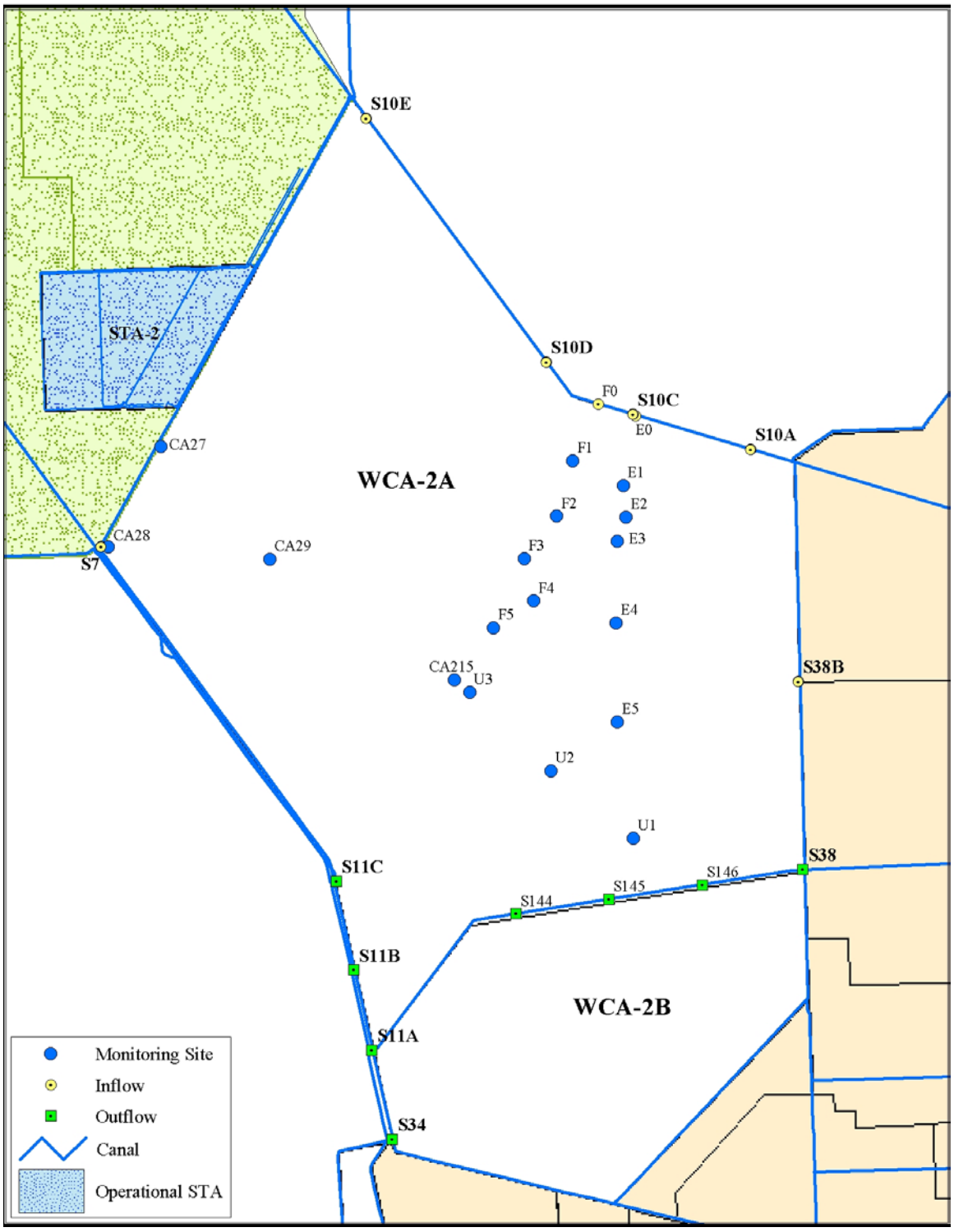

Figure 5-5. Current SFWMD monitoring networks in the Refuge (WCA-1)

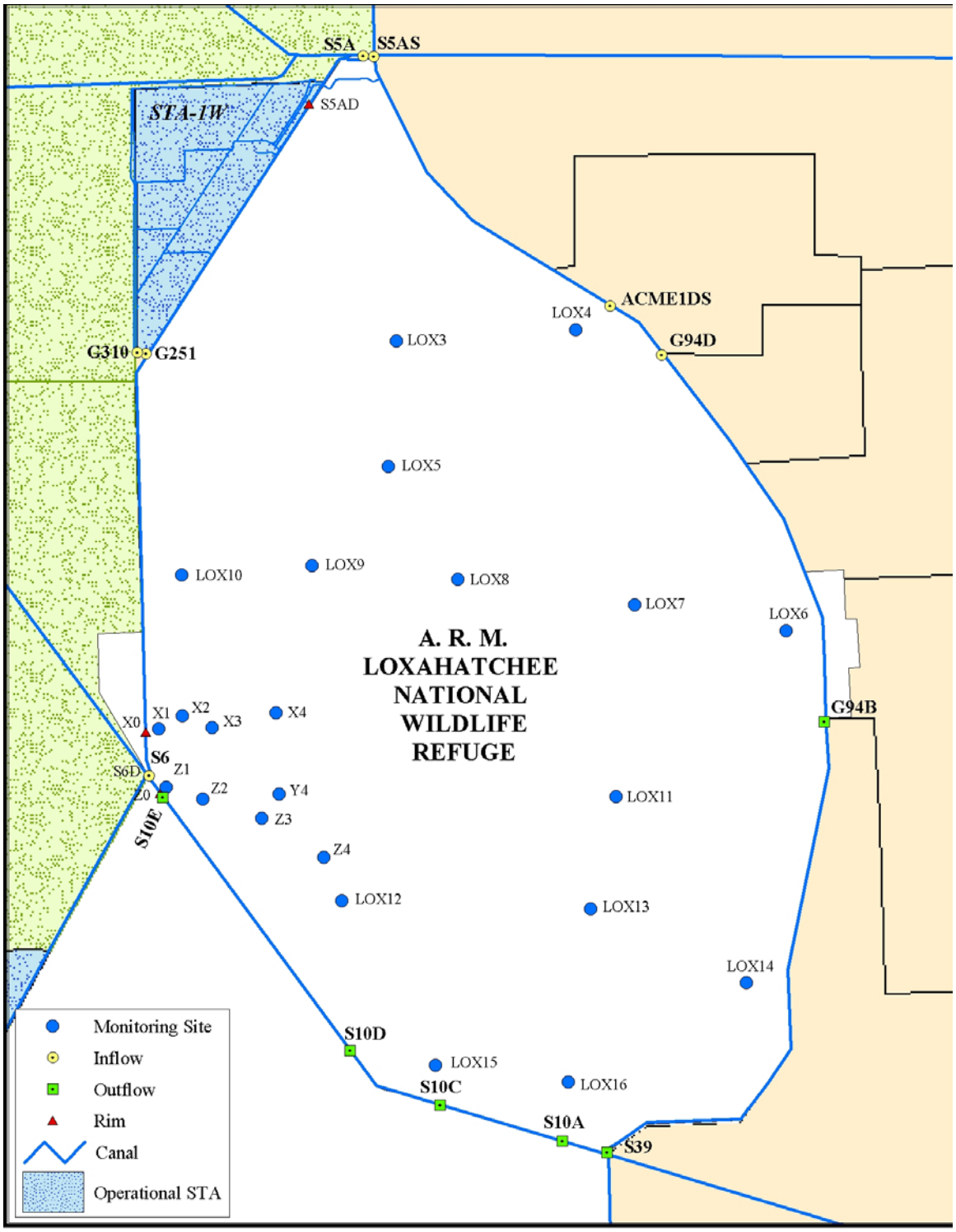

Figure 5-6. Current SFWMD monitoring networks in WCA-2

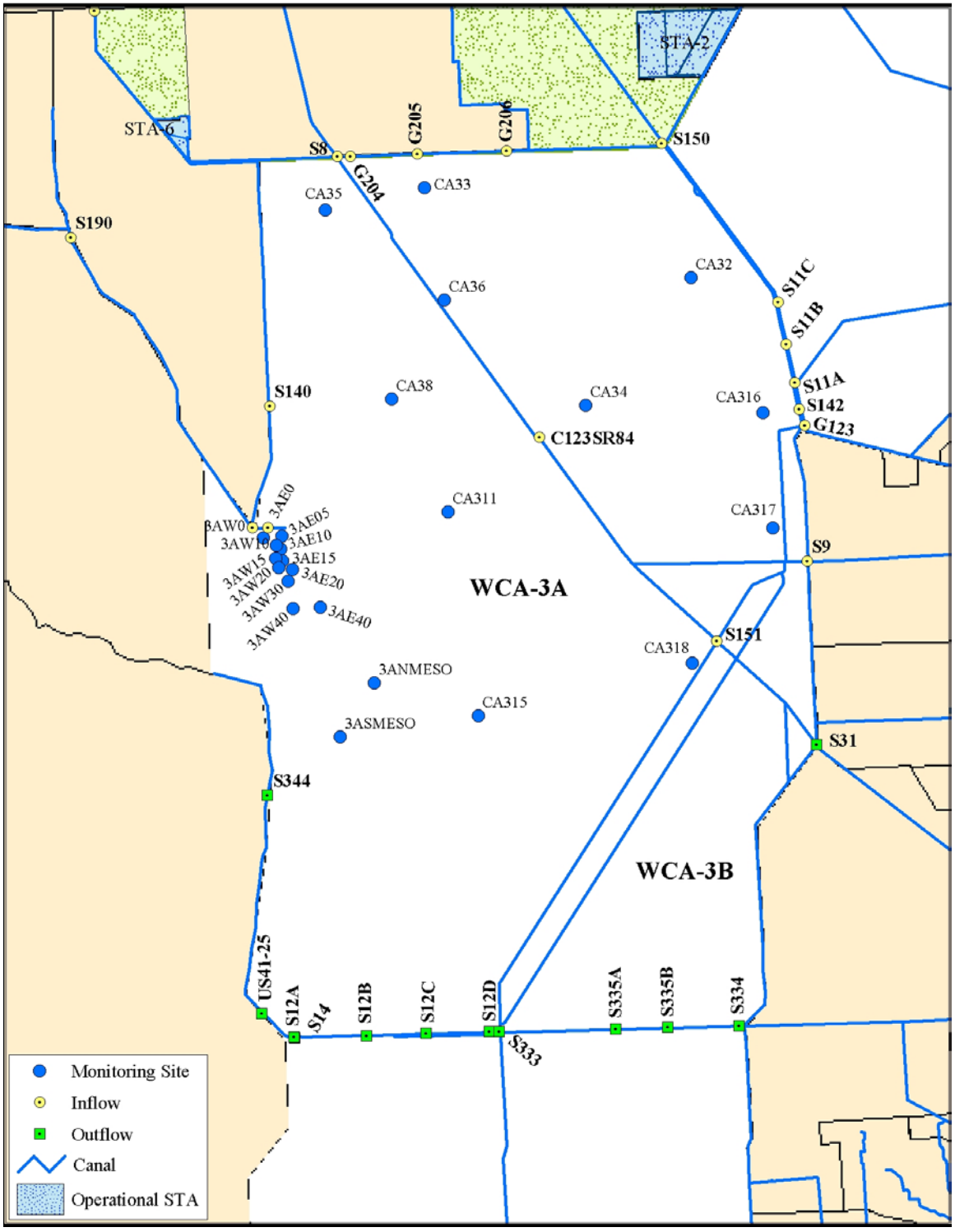

Figure 5-7. Monitoring locations for the SFWMD's current water quality monitoring program in WCA-3

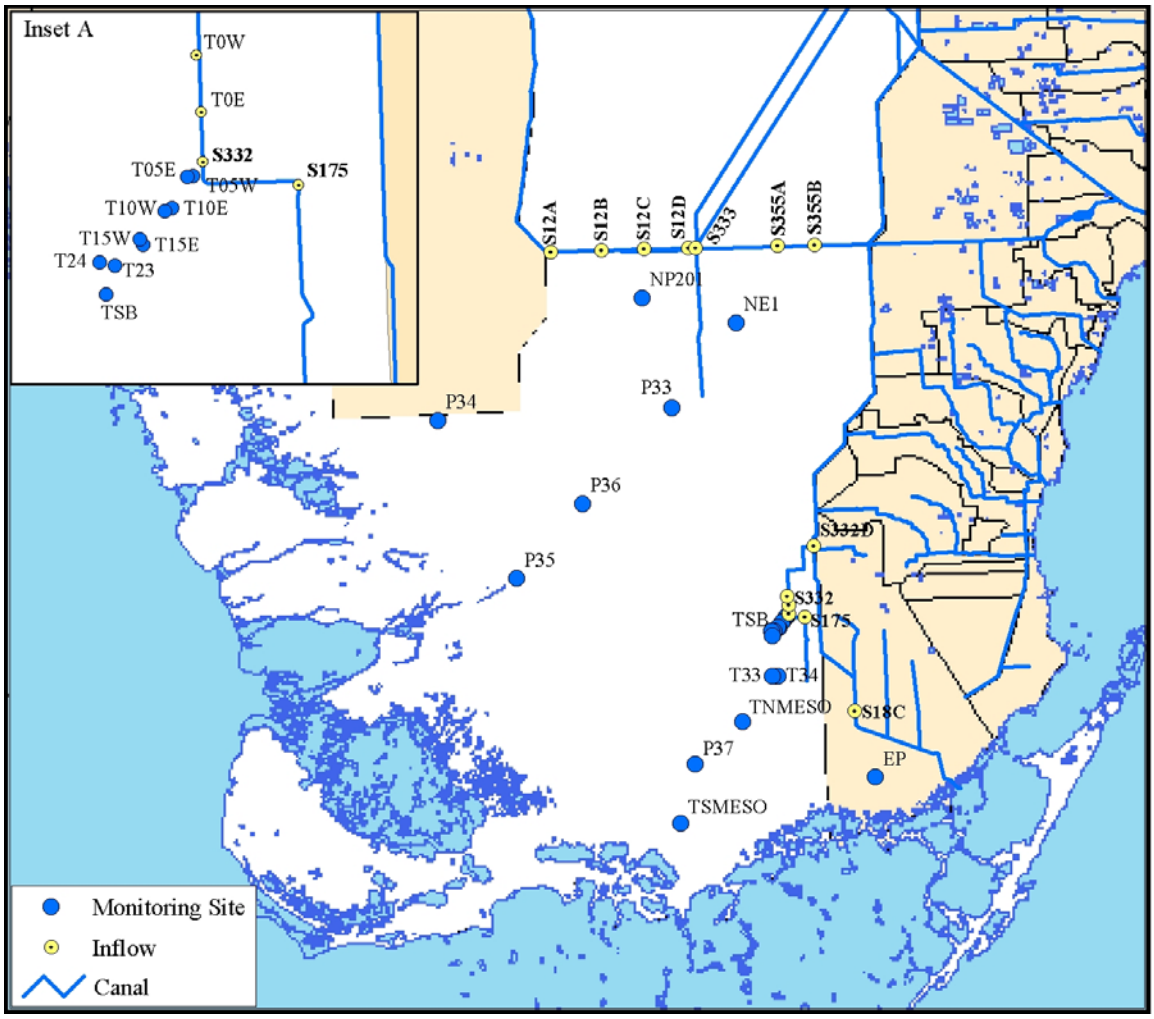

Figure 5-8. Monitoring locations for the SFWMD's current water quality monitoring program in the Everglades National Park

Table 5-5. Example application of phosphorus criterion measurement methodology using WCA-2A gradient transect data

Year	Annual Geometric Mean TP concentrations (ppb)						
	Reference Sites					1st Impacted Sites	
	E5	F5	U1	U2	U3	E4	F4
1994	8.80	9.76	7.85	7.98	6.81	19.26	16.94
1995	5.95	7.69	5.25	5.63	5.37	13.08	17.47
1996	7.75	9.95	8.70	8.23	8.44	14.56	16.68
1997	8.50	10.63	9.79	8.04	8.35	13.91	17.45
1998	7.94	10.12	7.43	9.42	9.61	14.77	13.75
1999	7.55	10.43	6.99	8.32	6.72	12.41	17.57
2000	4.58	9.45	5.18	8.64	6.15	13.53	16.74
2001	7.65	10.00	7.79	8.13	7.46	13.29	17.33
Step 1. Is annual geometric mean 10 ppb or less.					**If "Yes" then in criterion achieved. If "No" then go to Step 2.**		
1994	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**
1995	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**
1996	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**
1997	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**No**	**No**
1998	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**No**	**No**
1999	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**No**	**No**
2000	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**
2001	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**
Step 2. Is annual geometric mean greater than 15 ppb.					**If "Yes" then criterion exceeded. If "No" then go to Step 3.**		
1994						**Yes**	**Yes**
1995						**No**	**Yes**
1996						**No**	**Yes**
1997		**No**				**No**	**Yes**
1998		**No**				**No**	**No**
1999		**No**				**No**	**Yes**
2000						**No**	**Yes**
2001						**No**	**Yes**
Step 3. Is 5-year average annual geometric mean 10 ppb or less. **If "Yes" then criterion achieved.**							
1994							
1995							
1996							
1997							
1998		**Yes**				**No**	**No**
1999		**Yes**				**No**	
2000						**No**	
2001						**No**	

LITERATURE CITED

Arkansas Department of Pollution Control and Ecology. 1988. Regulation establishing water quality standards for surface waters of the State of Arkansas. Arkansas DPCE, Little Rock, AR.

Buhlmann, P. and B. Yu. 2002. Analyzing Bagging. *The Annals of Statistics*, 30(4):927-961.

Coffelt, G., J. Majer Newman, T. Aziz, D. Campbell, B. Gu, J. Jorge, J. Lopez, K. Pietro and L. Wenkert. 2001. Chapter 8: Advanced Treatment Technologies for Treating Stormwater Discharges into the Everglades Protection Area. In *2001 Everglades Consolidated Report*. South Florida Water Management District, pp. 8-1 to 8-46.

Davis, W.S. 1995. Biological assessment and criteria: Building on the past. W.S. Davis and T.P. Simon, eds. In *Biological Assessment and Criteria*. Lewis Publishers, Boca Raton, FL.

Florida International University. 1999. *Numerical Interpretation of Class III Narrative Nutrient Water Criteria for Everglades Wetlands - 1999 Annual Report*. Southeast Environmental Research Center, Florida International University, Miami.

Florida International University. 2000. *Numerical Interpretation of Class III Narrative Nutrient Water Criteria for Everglades Wetlands - Annual Report 2000*. Southeast Environmental Research Center, Florida International University, Miami.

Hughes, R.M. 1995. Defining acceptable biological status by comparing with reference conditions. In *Biological Assessment and Criteria*. W.S. Davis and T.P. Simon, eds., pp. 877-888. Lewis Publishers, Boca Raton, FL.

Hughes, R.M., J.H. Gakstatter, M.A. Shirazi and J.M. Omernik. 1982. *An approach for determining biological integrity in flowing waters*. T.B. Brann, L.O. House and H.G. Lund, eds. Inplace Resource Inventories: Principles and Practices, A National Workshop. Pages 31-48. Society of American Foresters, Bethesda, MD.

Hughes, R.M., T.R. Whittier, C.M. Rohm and D.P. Larsen. 1990. A regional framework for establishing recovery criteria. *Enviro. Mgmnt.*, 14:673-683.

Kadlec, R.H., 1999a. The limits of phosphorus removal in wetlands. *Wetlands Ecol. and Mgmnt.*, 7:165-175.

Kadlec, R.H., 1999b. Response to the Richardson and Qian comments. *Wetlands Ecol. and Mgmnt.*, 7:239-265.

Lean, D., K. Reckhow, W. Walker and R. Wetzel. 1992. Everglades Nutrient Threshold Research Plan. Research and Monitoring Subcommittees of Everglades Technical Oversight Committee.

McCormick, P.V., S. Newman, G. Payne, S. Miao and T. Fontaine. 2000. Ecological Effects of P Enrichment. Chapter 3 in *2001 Everglades Consolidated Report*. South Florida Water Management District, West Palm Beach, FL.

McCormick, P.V., S. Newman, S. Miao, R. Reddy, D. Gawlik, C. Fitz, T. Fontaine and D. Marley. 1999. Ecological needs of the Everglades. Chapter 3 in 1999 *Everglades Interim Report*. G. Redfield, ed. South Florida Water Management District, West Palm Beach, FL.

Payne, G., K. Weaver, T. Bennett and F. Nearhoof. 1999. *Everglades Phosphorus Criterion Development Support Document, Part 1: Water Conservation Area 2*. Everglades Technical Support Section, Division of Water Resource Management, Tallahassee, FL.

Payne, G., T. Bennett and K. Weaver. 2001. Chapter 3: Ecological effects of phosphorus enrichment in the Everglades. Chapter 3 in *2001 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

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

Payne, G., T. Bennett, K. Weaver and F. Nearhoof. 2001. Everglades Phosphorus Criterion Development Support Document, Part 3: Water Conservation Area 3 and Everglades National Park. Everglades Technical Support Section, Division of Water Resource Management, Tallahassee, FL.

Richardson, C.J., J.K. Huvane. 2001. *Everglades Restoration: A Primer*. Duke University Wetland Center, Durham, N.C.

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

Swift, D.R. 1981. *Preliminary Investigations of Periphyton and Water Quality Relationships in the Everglades Water Conservation Areas (March 1978 to September 1979)*. South Florida Water Management District, Research Planning Department, Technical Publication No. 81-5, 83 p.

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

USEPA. 1998. National Strategy for the Development of Regional Nutrient Criteria. EPA 822-R-98-002. USEPA Office of Water.

USEPA. 1999. Numeric phosphorus water quality criterion for the Everglades as adopted by the Miccosukee Tribe of Indians of Florida for Class III-A waters. May 20, 1999 memo from Dan Scheidt to Robert McGhee.

USEPA. 2001a. Update on Everglades phosphorus science used to support May 1999 USEPA approval of 10-ppb numeric water quality phosphorus criterion for the Miccosukee Tribe of Indians of Florida, January 19, 2001. Memo from Dan Scheidt to John Hankinson.

USEPA, 2001b. November 14, 2001 letter on development and adoption of nutrient criteria into water quality standards from the Director of the Office of Science and Technology to the Directors of all State and Tribal Water Programs, pp. 14-15.