

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF FLORIDA
CASE NO. 88-1886-CIV-MORENO

UNITED STATES OF AMERICA,)	
)	
Plaintiff,)	EXPERT REPORT OF WILLIAM W.
)	WALKER CONCERNING
v.)	EXCEEDANCES OF THE INTERIM
)	TOTAL PHOSPHORUS LEVELS AT THE
)	A.R.M. LOXAHATCHEE NATIONAL
SOUTH FLORIDA WATER)	WILDLIFE REFUGE IN JULY 2002 AND
MANAGEMENT DISTRICT, et al.,)	AUGUST 2004
)	
Defendants.)	

I, William Walker, submit the following report for the hearing before the Special Master as directed by the Court in its June 1, 2005 “Order Requiring Special Master To Hold A Hearing On Remedies And Submit A Report To The Court.” This report addresses causation of interim level “exceedances” (a term that is defined in the Consent Decree in this case) that occurred at the A.R.M. Loxahatchee National Wildlife Refuge (“Refuge”) in July 2002 and August 2004, and whether there is substantial evidence that those exceedances were due to error or extraordinary natural phenomena. It also includes an analysis of potential remedies that could reduce external loading to the Refuge, and thus reduce the likelihood of future exceedances. Under penalty of perjury, I affirm that the following matters are true to the best of my knowledge, information, and belief.

My curriculum vitae, which summarizes my academic background and experience as an environmental engineer providing technical assistance to various private-sector, municipal, state, and federal clients since 1972, appears in U.S. Exh 58. My participation in this case and

implementation of the ensuing Consent Decree started in 1989 and has continued since then. While most of my involvement has been financially supported by the U.S. Departments of Justice and Interior, specific tasks have been funded by the South Florida Water Management District (“SFWMD”), the Florida Department of Environmental Protection (“DEP), U.S. Environmental Protection Agency (“USEPA”), and U.S. Army Corps of Engineers (“Corps”). I have had major or supporting roles in the following areas:

- Development of testimony to support the federal position in the instant action, United States v. South Florida Water Management District, No. 88-1886 (S. D. Fla.), specifically documenting increasing trends in phosphorus concentration at Everglades National Park (“ENP”) inflow structures between 1978 and 1991;
- Participation in technical negotiations leading to the 1992 Consent Decree;
- Development of statistical models underlying Consent Decree compliance tests, including Refuge Marsh Phosphorus Levels and ENP Inflow Limits (Levels and Limits);
- Data analysis and modeling to support implementation of the Consent Decree, as an advisor to federal TOC representatives;
- Participation in technical mediation leading to the 1994 Conceptual Plan to achieve an interim goal of phosphorus concentration levels not exceeding 50 parts-per-billion (“ppb”) at inflow points to the Everglades Protection Area and subsequently to the 1995 motions by the United States, the SFWMD, and FDEP (“settling parties”) to modify the Consent Decree (granted by the Court in 2001);
- Development of a model for sizing stormwater treatment areas (“STAs”) to achieve discharge concentrations that do not exceed 50 ppb;
- Development of a model used by the state parties to optimize STAs for achieving compliance with the 10 ppb phosphorus criterion under the SFWMD’s Long-Term Plan;
- Development of software to assist the state parties in tracking compliance with the Consent Decree;
- Development of compliance tests and software used by the DEP to determine STA compliance with DEP permits containing 50 ppb discharge limits and for

tracking the performance of Best Management Practices (“BMPs”) in agricultural areas ((Everglades Agricultural Area (“EAA”) and C139) that discharge run-off into the Everglades Protection Area, including the Refuge and the Park;

- Participation on a technical panel convened by DEP to establish a phosphorus concentration goal for control of nuisance algal blooms in Lake Okeechobee and to estimate the maximum phosphorus load consistent with achieving that goal;
- Evaluation of Comprehensive Everglades Restoration Plan (“CERP”) alternatives being considered by the U.S. Army Corps of Engineers as of 1998, with respect to their impacts on STA performance and phosphorus loads to the Everglades;
- Estimation of flow and nutrient loads discharged into Florida Bay to support water quality modeling by the Corps of Engineers; and
- Participation in various technical workgroups focusing on STA design, the State of Florida’s numerical interpretation of the Class III phosphorus standard, and development/implementation of the State’s Long-Term Plan.

I am compensated by the United States for all of the consulting work done on behalf of its agencies. My testimony in this Report focuses on issues related to compliance with the Consent Decree requirements for restoration and protection of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). I am compensated by the United States for testifying as an expert on the matters that are the subject of this report. I have not testified as an expert at trial or by deposition in the preceding four years. A list of articles and studies that I have authored and co-authored appears in U.S. Exhibit 58.

1.0 – Opinion Concerning Whether There Is Substantial Evidence That The July 2002 and August 2004 Exceedances Were Due To Error or Extraordinary Natural Phenomena

Q. Dr. Walker, there is undisputed evidence that exceedances of the interim phosphorus concentrations levels in the A.R.M. Loxahatchee National Wildlife Refuge occurred during July 2002 and August 2004. The Consent Decree, in Appendix B, states that “an exceedance will

constitute a violation of this agreement and relevant water quality criteria unless the TOC determines there is substantial evidence that it is due to error or extraordinary natural phenomena.” Consent Decree, Appendix B. To date, neither the TOC nor the settling parties have been able to reach a consensus as to whether the July 2002 and August 2004 exceedances were due to error or extraordinary natural phenomena. Do you have an opinion as to whether there is substantial evidence that the July 2002 and August 2004 exceedances were due to error or extraordinary natural phenomena?

A. Yes.

Q. What is your opinion?

A. My opinion is that there is no substantial evidence that the exceedances experienced in July 2002 and August 2004, were due to error or extraordinary natural phenomena. The exceedances were consistent with the original premise of the Consent Decree that there is a causal connection between the external phosphorus loads and the interior marsh concentrations. While natural sources and cycling processes were also involved, external phosphorus loading sources were a significant factors contributing to the exceedances.

Q. What are the bases for these opinions?

A. The bases for my opinions derive from a myriad of factors, detailed below in Sections 2

through 8, but can be summarized succinctly as follows:

- The statistical methods and equations developed for the Levels and Limits were adopted by consensus of the state and federal technical representatives participating in settlement negotiations, reached after careful examination of the best available data and exploration of alternative approaches.
- Exceedances of the Interim Levels are consistent with the fact that average phosphorus loads to the Refuge were more than twice those expected if the 85% reduction in external loads required under the Consent Decree had been achieved.
- There is substantial evidence in the historical water column and soils data that external phosphorus loads penetrate the interior of the marsh from the Refuge's rim canals.
- It is unlikely that the July 2002 and August 2004 exceedances were due to Type I error, or flaws in the statistical formula for compliance with the Interim Levels in Appendix B of the Consent Decree. It is more likely that the Interim Levels test in Appendix B of the Decree would cause Type II error (allowing actual exceedances to go unrecognized and unreported) than Type I "false positive" error.
- There is no substantial evidence that the July 2002 and August 2004 exceedances were caused by changes in the Regulation Schedule for the Refuge

Based on the above factors, and the factors discussed below, I have concluded that the exceedances were causally linked to external phosphorus loadings and were not due to error or extraordinary natural phenomena. A detailed explanation of all of the foregoing bases for my opinions is set forth in Sections 2 through 8, below. In Section 9 below, I provide my opinion as to remedies (enhanced phosphorus load controls) that the TOC should recommend, and the settling parties should adopt, to increase the chances that the state parties will meet one of the central management goals of the Consent Decree – the preservation and restoration of the unique natural flora and fauna of the Refuge.

2.0 Basis for Consent Decree Levels and Limits

The Consent Decree, as modified in 2001, requires the South Florida Water Management District and the State of Florida Department of Environmental Protection (collectively, the “state parties”) to guarantee water quality and water quantity needed to preserve and restore the unique natural flora and fauna of the Park and the Refuge. Consent Decree at 9-10; U.S. Exh. 75. As it pertains to the Refuge, the Decree requires the state parties to achieve interim phosphorus concentration levels (“Interim Levels”), as reflected in Appendix B of the Decree, by February 1, 1999, and to remain in compliance with those levels continuously between February 1, 1999 and December 31, 2006. U.S. Exh. 75 at Paragraph 5. The Decree requires the state parties to achieve Long-Term phosphorus concentration levels (“Long-Term Levels”), as reflected in Appendix B, by December 31, 2006, and to remain in compliance with those levels continuously thereafter, unless the Technical Oversight Committee (“TOC”) determines that, with respect to the period after December 31, 2006, the State of Florida’s Class III numeric total phosphorus

criterion provides a lower, more protective water quality benchmark for the Refuge. Consent Decree, Appendix B.

The Interim Levels (in effect until December 31, 2006) are based on water quality that existed in the Refuge in the late 1970s. The Refuge's designation as an Outstanding Florida Water (OFW) allows no degradation from the quality of water that existed during the official OFW base period (March 1, 1978 through March 1, 1979). The Consent Decree compliance tests were specifically developed and designed to protect the OFW status through restoring and subsequently maintaining the water quality that existed during that base period. In the case of the Refuge, data from June 1978 through May 1979 (first 12 month period with available data) were assumed to be representative of the official OFW period.

Refuge Interim Levels were based upon the best available data from 14 interior marsh sites monitored by SFWMD during the OFW base period. Long-Term levels were based upon data from 3 monitoring sites considered to be least impacted by anthropogenic phosphorus loads that had already occurred prior to June 1979. OFW regulations further required that seasonal and other cyclical variations be taken into account. The equations for the Interim and Long-Term Levels were based upon a statistical model that considered:

- Hydrologic variations in the stage for the Refuge marsh, discharge for ENP inflows; consistent with OFW requirements to consider "seasonal and other cyclical variations");
- Random variations (reflecting sampling, analytical, natural components); and
- Trend (required to adjust any post-1979 data used in calibrating the model back to the 1978-1979 OFW time frame).

In order adequately to characterize hydrologic and random variations, the Refuge Levels

were calibrated to data extending beyond the OFW period (1978-1983). The Trend term of the model was used to adjust for the approximate 50% increase in marsh geometric mean phosphorus concentrations in the interior Refuge that occurred between the 1978-1979 interval and the subsequent 1980-1983 time period. As described below (Section 4), this increase was correlated with increases in Refuge inflow phosphorus loads and concentrations.

The statistical methods and equations developed for the Levels and Limits were adopted by consensus of the state and federal technical representatives participating in settlement negotiations, and reached after careful examination of the best available data and exploration of alternative approaches. The final data analyses and derivations were prepared by a statistical consultant to SFWMD and described in Appendix E of the 1992 draft Everglades SWIM Plan. U.S. Exh. 76. I subsequently developed similar statistical models that are being used by SFWMD to track BMP performance in the EAA and C139 basins, and by FDEP in determining compliance with STA discharge permits.

Consideration of hydrologic variations in these compliance methodologies not only satisfies OFW regulations, but also increases the statistical power of the tests for detecting deviations from the management objectives or requirements of the Consent Decree. Adjusting the Refuge marsh levels for stage is consistent with OFW regulations and with other compliance methodologies being applied in the region that adjust for hydrologic variations.

3.0 - Status of Water Quality in the Refuge Marsh and Inflows

One means to assess the efficacy and validity of the marsh compliance methodology is to compare results with other available numerical tests that characterize the status of the Refuge marsh and inflows with respect to Consent Decree requirements. Each test is applied below to

February 1999 thru April 2005 monitoring data that was obtained from SFWMD's DBHYDRO database. These include three tests that are currently in effect (the Consent Decree Interim Levels, 85% Load Reduction, and 50 ppb interim STA discharge concentration), as well as the Long-Term Levels that are effective December 31, 2006. Although the Long-Term Levels are not yet in effect, assessment of the current status of water quality in the Refuge will illustrate the extent to which conditions will have to improve in order to achieve compliance by December 31, 2006. When applied to February 1999 – April 2005 data, each of these numerical tests indicates that conditions in the Refuge were not consistent with present and future Consent Decree goals in that period. The fact that the various numerical tests lead to the same conclusions with respect to goal attainment further substantiates the compliance methodologies being employed.

3.1 - Interim Phosphorus Levels for the Refuge (effective February 1999)

Interim Phosphorus Levels for the Refuge marsh were derived from 14 stations monitored by SFWMD between 1978 and 1983 (see U.S. Exhibit 59 (Figure 1)). These sites had a geometric mean phosphorus concentration of 9.4 ppb during the OFW base period. Compliance is not tested in months when the marsh stage is below the minimum value in the 1978-1983 data (15.42 feet). Measured geometric means were above the Interim Levels in 10 months, or 15% of the tested months between February 1999 and April 2005 (Figure 2). At least one “exceedance” (2 or more excursions in 12 consecutive tested months) occurred in each year.

Figure 2, U.S. Exhibit 60, also compares measured geometric means with the OFW (1978-1979) distribution of values (10th, 50th, and 90th percentiles) at given stage computed from the Interim Level equations. While the compliance methodology is based only on the 90th percentile (Interim Levels), the underlying objective is to restore the entire distribution of values

that existed during the OFW period, adjusted for variations in stage. Approximately 50% of the measured geometric means would be below the 50% percentile of the OFW distribution if that objective were achieved. The data were above the 50th percentile expected at the corresponding stage under 1978-1979 conditions in 82% of the tested months. This upward shift in the distribution of values is clearly shown in lower panel of Figure 2 (U.S. Exh. 60), which plots the difference between the data and the OFW 50th percentile over time. These deviations from the OFW 50th percentile indicate that the objective of the Interim Levels had not been achieved in the 1999-2005 period, as borne out by the exceedances of the Interim Levels.

The average deviation of the data from the OFW 50th percentile shown in the bottom panel of Figure 2 (U.S. Exh. 60) is 0.20 (standard error = .03) on a logarithmic scale. This indicates that attainment of the objective would require an approximate 18% reduction in the marsh concentrations measured in February 1999 – April 2005 (8.9 ppb). As demonstrated in Section 3.3, recent loads to the Refuge will have to be reduced to a much greater extent (approximately 58%) in order to meet the Consent Decree's requirements for an 85% load reduction relative to 1978-1979 conditions.

3.2 - Long-Term Levels for the Refuge (effective December 31, 2006)

Long-Term Levels for the Refuge marsh were derived from the three sites with the lowest geometric mean concentrations in the 1978-1983 data (approximately 10 ppb -- considered in 1991 to be a reasonable forecast of the Class III criterion) and assumed to be least impacted by anthropogenic phosphorus loads (LOX5, LOX6, LOX16, in U.S. Exh. 59). These sites had a geometric mean of 7.7 ppb in the 1978-1979 OFW period. Measured geometric means were above the Long Levels in 63 months, or 95% of the tested months between February 1999 and

April 2005 (U.S. Exhibit 61, Figure 3). At least one exceedance would have occurred in each year, had the test been in effect during that period.

The measured geometric means were above the 50th percentile of the OFW distribution in 95% of the tested months, as compared with the expected 50% if the objective of the Long-Term levels had been achieved in that period. The average deviation of the data from the OFW 50th percentile shown in the bottom panel of Figure 3 (U.S. Exh. 61) is 0.38 (standard error = .03) on a logarithmic scale. This indicates that attainment of the objective would require an approximate 32% reduction in the marsh geometric mean concentrations measured in February 1999 – April 2005 (8.9 ppb). The resulting long-term target concentration (6.1 ppb) is not unrealistic, given that it is similar to values measured at background sites in other WCA's remote from inflow structures (5.4 to 6.8 ppb) and well above those measured at background sites in the Park (3.4 to 5.9 ppb)¹. As demonstrated in Section 3.3, the 32% reduction marsh concentration is much smaller than the 78% reduction in recent inflow concentrations (67 ppb) that will be required to achieve the treatment goal established under the State's Long-Term Plan (15 ppb).

3.3 - 85% External Load Reduction To The Refuge (Effective February 1, 1999)

Effective February 1, 1999, the Consent Decree requires an 85% reduction in external phosphorus load to the Refuge relative to 1979-1988 conditions. In that period, phosphorus loads from the S5A and S6 pump stations averaged 105.6 metric tons per year ("mt/yr"). See 1992 SWIM Plan, Appendix F, U.S. Exh. 77, at F-6. Compliance with the 85% phosphorus load reduction requirement would require an average load less than 15.9 mt/yr, which corresponds to an average inflow concentration of 50 ppb from sources treated in the original Consent Decree

¹ SFWMD DBHYDRO Data from EVPA Project (CA215, CA29, CA311, CA315, CA38) and EVER Project (EP, P37, P33, P34). Geometric mean concentrations, calendar years 1999-2004.

(Structures S5A and S6).. In Water Years 2002 – 2004 (October 2001 -September 2004 ,after diversion of S-6 and full-scale operation of STA 1-West), loads to the Refuge from these sources averaged 37.2 mt/yr (22% untreated bypass and 78% STA 1-West discharge) and ranged from 20.3 to 45.9 mt/yr. The average inflow volume was 453 thousand acre-ft/yr and the average inflow concentration was 67 ppb.

The methodology previously used by the TOC, U.S. Exh. 78, to test for compliance with the load reduction requirement is based only upon total phosphorus concentration and has been found to be inadequate as a measure of load reduction because it assumed that the STAs would be operated in their design flow range, which has not been the case for STA 1-West (see Section 3.4, below). Figure 4 (U.S. Exh. 62) applies an improved compliance methodology that tests measured loads directly against 15% of the 1979-1988 base-period loads, while adjusting for yearly variations in rainfall. The underlying statistical model is similar to that used in the Levels and Limits, as described in Section 2.0. In each year, the measured load was above the prediction interval (10th to 90th percentiles) derived from regression of the 1979-1988 data. Yearly deviations from the 15.9 mt/yr goal are not explained by variations in rainfall. Therefore, it is unlikely that the Consent Decree load reduction requirement was met in the 1999-2005 period.

A 57% reduction in the average observed load (37.2 mt/yr) in 2002-2004 would be required to achieve the 15.9 mt/yr goal. This is much larger than the estimated percentage reductions in the 1999-2005 marsh geometric mean concentrations required to achieve the Interim Levels (18%, Section 3.2). The 15.9 mg/yr goal corresponds to an average inflow concentration of 50 ppb. The treatment goal of the State's Long-term Plan to achieve

compliance with the Class III P criterion is a flow-weighted-mean concentration of approximately 15 ppb. Attainment of that goal would require a 78% reduction in the average inflow concentrations measured in WY 2002-2004 (67 ppb). This is much larger than the estimated percentage reductions in the 1999-2005 marsh geometric mean concentrations required to achieve the Long-Term Levels (32%, Section 3.2).

Because of the complexity of marsh hydrodynamics and atmospheric sources, a given percentage in exterior load would not be expected to provide the same percentage in interior marsh concentrations. Consistent with TOC recommendations, the U.S. Fish & Wildlife Service is supporting development of mathematical models to quantify the relationship between external loads and interior marsh concentrations. The above comparisons indicate that the marsh concentrations reductions required to achieve compliance with the marsh Levels (Interim 18% and Long-Term 32%) do not appear to be unreasonable relative to the reductions required to achieve treatment goals already established under the Consent Decree and Long-Term Plan (58% and 78%, respectively, relative to October 2001 – September 2004 loads).

3.4 – STA 1-West Overloading and Discharge Concentration

Figure 5 (U.S. Exhibit 63) shows performance data for STA 1-West over the June 2000 through May 2005 period. Inflow loads are plotted relative to design assumptions (12-month rolling averages). Outflow concentrations are plotted relative to the 50 ppb initial design basis, performance range for other operating STAs, and to the 10 ppb phosphorus criterion. Optimization measures being implemented under the SFWMD's Long-Term Plan are forecasted to produce long-term flow-weighted-mean discharge concentrations of 15 to 20 ppb. Walker and

Kadlec (2003) expressed concerns about STA-1W overloading and deteriorating performance based upon data through March 2003. U.S. Exh. 79 at 9-10.

Figure 5 (U.S. Exh. 63) shows that inflow loads at STA 1-West remained above the design basis from September 2001 through May 2005 and outflow concentrations reached approximately 100 ppb. Over the entire period, 12-month rolling-average outflow concentrations from STA 1-West increased from 20 to 100 ppb and load reductions decreased from 80% to 55%. While factors other than overloading (vegetation management, construction to support optimization of vegetation, hurricane damage) were partially responsible for these increasing outflow concentrations, the overloading problem has been extensively studied and remedial measures are in various stages of implementation or evaluation. Until the overloading problem is solved and STA 1-West is restored, attainment of existing and future treatment goals is unlikely, and the risk of marsh exceedances will remain high.

4.0 - Evidence That Exceedances Were Caused by External Loads

The existence of a causal connection between external loads and interior Refuge phosphorus concentrations is a basic premise of the Consent Decree and led to the incorporation in the agreement of specific measures for reducing inflow loads in order to restore and protect the EPA marsh. Exceedances of the marsh Interim Phosphorus Levels are not surprising in light of the fact that recent external loads have averaged more than twice those consistent with achieving the 85% load reduction requirement (Section 3.3). The testimony of Garth Redfield (12-13-2004 Tr. 210) and Frank Nearhoof (12-13-2004 Tr. 249), coupled with my understanding of the views of the federal TOC representatives, indicates that there is a TOC consensus that exceedances were partially caused by external loads, but disagreements remain between the state

and federal TOC representatives about the extent to which other factors may have contributed.

In my opinion, the most effective way to resolve this dispute is to continue monitoring/evaluating and to focus on implementing load controls. As stated in Section 3.3, the percentage reductions reduction in recent loads required to achieve treatment goals already established under the Consent Decree and State's Long-Term Plan (58% and 78%, respectively) are much higher than the reductions in recent marsh concentrations required to achieve the Interim and Long-Term Levels (18 and 32%, respectively). If exceedances still occur after treatment goals have been attained and the marsh is given time to respond, the TOC can resume the debate on causation, bolstered then by the enhanced monitoring and modeling information being collected by the U.S. Fish & Wildlife Service.

While natural sources and processes (e.g., atmospheric loads, recycling from soils) can influence marsh phosphorus concentrations, my opinion that there is a causal link between excursions and external loads is corroborated by the fact that some excursions were temporally correlated with external loading events and hydraulic gradients sloping from the rim canal towards marsh (see U.S. Exh. 79 at 2 (Walker and Kadlec (2003)); U.S. Exh. 80 at 5-6 (Walker (2004)), U.S. Exh. 52 at 1-2 (Harwell et al (2005))). Additional evidence that external loads penetrate the marsh sufficiently to trigger excursions is presented in Figures 6 and 7, U.S. Exhibits 64 and 65, respectively. These figures summarize data from the 1978-1983 period used to derive the Interim and Long-Term Levels. Peak and average loads to the rim canal increased significantly between 1978-1979 (OFW period) and 1980-1983. These loading increases were accompanied by increases in interior marsh phosphorus concentration that were sufficient to trigger 5 excursions from the Interim Levels in 1980-1983 (Figure 6, U.S. Exh. 64). Phosphorus

concentrations in Refuge inflows, outflows, and interior marsh increased after the OFW period (Figure 7, U.S. Exh. 65).

Some of the recent excursions from the Interim Levels have occurred during periods of relatively little inflow to the Refuge. These excursion events are not necessarily contrary to my opinion that external loading is a major cause of the past exceedances because of the long time scales associated with storage and recycling of phosphorus in the marsh vegetation and soils. Calibrations of the DMSTA phosphorus cycling model (U.S. Exhibit 81, Walker & Kadlec, 2005) indicate that these time scales are approximately 1-3 years in marsh communities with phosphorus concentrations less than 15 ppb. Direct inference of phosphorus transport from the rim canal to the interior marsh based upon spatial patterns in the water column data on any particular date is limited by:

- Episodic transport may occur in brief periods between monthly water quality sampling when inflow pumping and hydraulic conditions are conducive. These spikes in phosphorus input would be rapidly taken up by the marsh and potentially recycled back to the water column months or years later.
- Local variations in marsh topography and vegetation promote transport along channels, sloughs, or other paths of least hydraulic resistance (e.g., air-boat trails) that may not be captured by the monitoring network.
- Phosphorus transport also occurs along the bottom in the form of loose particulates (floc)

that are not collected in the water quality samples. Floc was found to be an important transport mechanism in ENP experimental dosing studies (U.S. Exhibit 82 at 3-4, Gaeser et al, 2005). This additional transported phosphorus would be retained in the marsh vegetation and soils without being detected in the water quality data, except through subsequent recycling processes enhanced by dry-out and rewetting.

- Spatial patterns in phosphorus concentration are sometimes confounded with spatial variations in water depth. Higher concentrations at interior sites as opposed to exterior sites on some dates may reflect the fact that interior sites tend to be shallower (Harwell et al, 2005, U.S. Exh. 52, Appendix E).
- Random variations associated with marsh sampling and laboratory analyses have a standard deviation of approximately 18% (Walker, 1999, U.S. Exh. 88 at 6). These variations indicate that even if conditions were identical at each of the fourteen sites, we would expect an approximate two-fold range of concentrations across sites in any given month. (i.e., the highest concentration would be twice the lowest concentration). The spatial geometric mean concentration across the marsh is a valid signal for tracking Long-Term trends and compliance because it reduces variance associated with random variations associated with natural processes, sampling, and laboratory analyses. Consistent spatial patterns in concentration are not expected because of the above factors. Spatial patterns in phosphorus enrichment are more readily characterized by soils data that provide a more integrated and stable signal of loading history over time scales of a

few years to decades.

Additional evidence that exterior flows and phosphorus loads have penetrated into the marsh is contained in water quality, soils, and vegetation data described in previously published reports and in additional monitoring data (beyond the LOX compliance data) being collected by SFWMD:

- There is clear indication of water penetration based upon conductivity maps derived from spatially intensive monitoring being performed by SFWMD. U.S. Exh. 66 (Figure 8). Results from two sampling events in 2004 are shown in the foregoing exhibit, as reported by Harwell et al, 2005. (U.S. Exh. 52, at 21.)
- Transect monitoring data being collected since 1996 (Everglades Consolidated Report, 2001 and FDEP (2001)), show distinct gradients in nutrients (phosphorus, nitrogen, carbon) and chloride (a conservative tracer similar to conductivity) extending east 2 to 4 km into the marsh from the L7 rim canal in the vicinity of the former S6 discharge. U.S. Exhibit 67 (Figure 9) plots 1996-2004 geometric mean concentrations along two transects (X0-X4 in the north, Z0-Z4 in the south). The declining phosphorus and nitrogen gradients level out at X3 and X4 (approximately 2 km in the marsh), No such plateaus are evident along the entire Z transect that extends approximately 4 km into the marsh. This indicates that the actual extent of canal influence may extend beyond 4 km.

- Soils data collected for SFWMD by Reddy et al (1994), U.S. Exhibit 83, show decreasing soil phosphorus gradients from the rim canal to interior marsh around most of the marsh perimeter. See also U.S. Exhibit 68 (Figure 10). The pattern is evident in total phosphorus, labile inorganic phosphorus, and labile organic phosphorus contents of 0-10 cm core samples. The labile forms are more readily available for recycling into the water column. These contour maps are markedly similar in shape to recent SFWMD conductivity maps (U.S. Exh. 66 (Figure 8)). It is my understanding that SFWMD collaborated with Dr. Reddy in a follow-up soil sampling effort in 2004, but results of that survey are not yet available.
- In this same region east of L7, Childers et al (2003), U.S. Exh. 84 at 348, reported increases in cattail-dominated vegetation (indicative of extreme levels of enrichment) between 1989 and 1999 in the region between 0 and 1 km of the rim canal. Cattail dominance and other vegetation gradients were correlated with gradients in soil phosphorus levels.

5.0- Evidence Concerning Whether July 2002 and August 2004 Exceedances Were Caused by Flaws in Compliance Test

Because of inherent variability in monitoring data, there are risks of Type I errors (false positive) and Type II errors (false negative) in any compliance test designed to determine whether a management goal is being achieved. It is not possible to eliminate these errors, but they can be reduced to some extent by collecting sufficient, high-quality data and basing the test

on a statistical model that accounts for as much of the data variance as possible. In this case, the management goal is to restore and preserve unique natural flora and fauna of the Refuge by maintaining a distribution of marsh concentrations equivalent to that which existed in the OFW base period, adjusted for hydrologic variations. A Type I error, or “false positive,” would occur when the goal has actually been achieved, but an “excursion” is erroneously reported to have occurred. A Type II error, or “false negative,” would occur when the goal has actually not been achieved, but it is not recognized or reported because an “excursion” does not occur. The risks of Type I and Type II errors are greatest when the system is exactly on target; i.e. running exactly at the speed limit. At that point, the sum of the Type I and Type II risks is always equal to 100%. Both of these risks decrease as the measured value moves away from the target.

The Consent Decree compliance equations were designed to have a maximum Type I error risk of 10% and therefore, a maximum Type II error risk of 90%. If, because of limitations in the data or other factors, the maximum risk of a Type I error were actually 20%, then the maximum risk of a Type II error would be 80%. In that case, the test would be more “protective” of the resource than assumed, but the maximum risk of a Type II error (false negative) would still be significantly higher than the maximum risk of a Type I error (80% vs. 20%). The State’s methodology for measuring marsh status with respect to the 10 ppb Class III criterion has maximum Type I and Type II error risks that are approximately equal (50%). This stems primarily from a portion of the test requiring that the 5-year geometric mean be less than or equal to 10 ppb). If the marsh data were exactly consistent with the management goal (Long-Term geometric mean \leq 10 ppb), there would be a 50% chance that data from any 5-year period would fail the first part of the test because of the expected random variability in the data across

5-year intervals.

Whether or not these various distributions of Type I vs. Type II error are acceptable depends on risk tolerance of resource managers/decision makers, not upon science or statistics. The risk tolerance decisions of resource managers can be informed by comparing the consequences of Type I versus Type II errors. In this instance, if a Type I error has occurred, it might result in additional control measures, expenditures, and protection for the marsh, beyond those that would be theoretically be necessary to attain the stated management goal. If, on the other hand, a Type II error has occurred, it might result in fewer efforts and expenditures than would otherwise be required and in failure to attain the management goal (i.e. the marsh would not be restored to the OFW conditions). The Type I versus Type II error distribution inherent in the compliance formula for the Refuge in this case was a matter subject to negotiation by the settling parties with advice and assistance of their respective statistical consultants.

6.0 – Evidence Concerning Whether July 2002 and August 2004 Exceedances Were Due To Type I Error

To my knowledge, no specific evidence that the July 2002 and August 2004 exceedances were due to Type I Error has been presented or discussed at TOC. While the Interim and Long-Term Levels account for random variations (difference between 50th and 90th percentiles in Figures 2 and 3, U.S. Exhs. 60 and 61, respectively), it is possible that the compliance determination has been impacted by differences in sampling methodologies or by a systematic shift in the stage/concentration relationship. A variety of hypothetical factors could have had positive or negative impacts on concentration at a given stage. Below, I discuss independent factors confirming the tests or suggesting that Type I error may actually be lower than the assumed 10%, essentially minimizing the likelihood that the July 2002 and August 2004

exceedances were attributable to Type I error.

6.1 - Validity of Interim Levels Is Supported By Other Measures of Refuge Status

As discussed in Section 3, the fact that marsh data do not pass other numerical tests designed to measure Refuge status with respect to Consent Decree requirements is consistent with results obtained from the Interim Level equations. Exceedances of the Interim Levels in 1999-2005 are to some degree expected, given that the load reduction goals were not achieved in that period. This agreement among statistically unrelated tests is a basis for rejecting the hypothesis that the marsh Level equations are generating false positives or are fatally flawed.

6.2 - Historical Data May Over-Estimate Concentrations Actually Present In The Marsh During the OFW Period Because Of Primitive Sampling Techniques

The 1978-1983 samples were collected using a bucket dropped from a hovering helicopter. Current samples are collected in laboratory bottles from the ground using a refined technique developed by the FDEP and TOC that minimizes risk of contamination by sediment or plant debris and avoids sampling at depths less than 10 cm. The current minimum depth criterion results in fewer sites being monitored at low stages, relative to the historical protocol (see Section 6.4 below). The greater risk of contamination and likelihood that some of the historical samples were collected at depths below the current 10 cm criterion suggest that concentrations measured in the OFW period (thus, the interior marsh levels) would have been lower had they been collected with the current refined techniques and depth criterion. In other words, if historical data had been collected with current techniques and the same equations for the Refuge Levels were re-calibrated, recent excursion frequencies would have been higher. While I do not advocate altering the current compliance sampling methodology for the Refuge, or attempting to replicate the historical sampling procedures in determining compliance, these

differences in sampling methodologies, if anything, are likely to increase the risk of Type II error (i.e. causing exceedances to become under-reported) and decrease the risk of Type I error (reporting exceedances that did not actually happen) in determining compliance.

6.3 - Lower Variance in Recent Data Decreases Risk of Type I Error and Increases Risk of Type II Error

The Consent Decree's Interim and Long-Term Levels equations applicable to the Refuge assume that variance around the predicted concentration at a given stage did not change between the 1978-1983 derivation period and the 1999-2005 compliance period. Recent data have lower variance, possibly as a result of the refined sampling techniques (i.e., improvements the current sampling protocol applied in the Refuge vs. the 1978-1983 sampling protocol). The standard error of the regression model that is the basis for the Interim Levels is 0.31 on a natural logarithmic scale (SFWMD, 1992, Appendix E, Table 8, U.S. Exh. 76 at E-21). This variation is reflected in the data scatter around the stage/concentration regression line shown in the upper left corner of U.S. Exh. 69 (Figure 11).

For the February 1999-April 2005 period (upper right in Figure 11; U.S. Exh. 69), the difference between the measured and expected value (50th percentile computed from the Interim Level regression) has a mean of 0.20 and standard deviation 0.24, again on natural log scale. These same deviations are plotted over time in the bottom panel of U.S. Exh. 60 (Figure 2). This reduction in standard deviation between the two time periods (0.31 vs. 0.24) has the effect of reducing the frequency of excursions and increasing risk of Type II error, relative that which would have occurred had the standard deviation not decreased.

Based upon a Student's-t test, the mean difference between the measured and expected

value (mean = 0.20, standard error = 0.03, 65 sampled months) is significantly greater than zero at $p < .001$. In other words, there is less than a 0.1% chance that the distribution of recent data adjusted for stage variations has not shifted upward. The upward shift is also reflected in the fact that 82% of the recent data are above the 50th percentile for 1978-1979 conditions expected for compliance with the Interim Levels (Figure 2). These additional statistical comparisons consider the reductions in variance between the two time periods and confirm that the management goal had not been attained in 1999-2005 and that the Interim Levels test were not generating Type I errors or false positives.

6.4 - Recent Concentrations Exceed Historical Values in Comparable Ranges of Stage and Station Coverage

U.S. Exhibit 69 (Figure 11, lower left) shows that 13-14 stations were consistently sampled in 1978-1983 over a stage range of 15.4 to 17.1 feet. In the 1999-2005 data, the average number of sampled sites decreased from ~13 to ~6 as stage decreased from >16 feet to 15.4 feet. There is a clear distinction between historical and recent data in comparable ranges of stage and spatial coverage (13-14 stations). Low stage data are more likely to be influenced by recycling from the marsh as opposed to external loads. More than 90% of the external load in 1999-2005 occurred at stages above 16 feet, so that ignoring the deviations from the regression line at high stage would mask potential effects of external loads on variations in marsh phosphorus concentrations and increase risk of Type II error.

Differences between historical and recent data are less distinct if the stage adjustment is ignored. As discussed in Section 2, that adjustment was included to satisfy the OFW requirement to consider seasonal and other cyclical variations in determining compliance. It also improves the compliance test by explaining a portion of the data variance and thereby reducing risks of

Type I and Type II errors. Eliminating the stage dependence would mask effects of exterior loads that enter the marsh at high stages and place greater emphasis on the data collected at low stage, which are less comparable to the historical data because of differences in spatial coverage.

7.0 - Evidence that Exceedances Were Caused by Changes in the Regulation Schedule

Theoretically, the increase in Refuge regulation schedule in the early 1990s (U.S. Exhibit 70, Figure 12) could have had positive or negative impacts on marsh phosphorus concentrations. On the one hand, penetration of flow and phosphorus load from the rim canal to the interior marsh may have increased because of the greater volume required to meet the higher regulation schedule. On the other hand, marsh assimilative capacity may have increased as a consequence of the higher schedule because of the greater water depths, lower dry-out frequency, and greater wetted area. The assimilative capacity is the amount of load that the marsh can process (i.e. trap permanently in the bottom sediments) at a given concentration level.

These fundamental relationships linking exterior phosphorus load to depth-dependent marsh phosphorus uptake are expressed in models used to design the 50 ppb STAs (U.S. Exhibit 85 (Walker, 1995) and the enhanced STAs (Walker& Kadlec, 2005, U.S. Exh. 81). These models simulate hydraulics and phosphorus cycling in wetlands, and have been extensively tested against data from the STAs and Everglades marshes. Because of these counter-acting mechanisms (increased load penetration from the rim canal offset by increased load assimilation in the exterior and interior marsh because of greater depths and less-frequent dry-out), the increase in regulation schedule could have had positive or negative impacts on concentration. It is not possible to determine the net effects on concentration without a mathematical model that integrates these mechanisms. The Department of the Interior has initiated development of such a

model, consistent with the enhanced water quality monitoring and modeling recommendations made by the TOC following the July 2002 exceedance.

Patterns in the 1978-1983 data, see U.S. Exhs. 64 and 65 (Figures 6 and 7), are contrary to the hypothesis that the change in regulation schedule could have caused the recent excursions and exceedances. Increases in inflow concentrations, loads, marsh phosphorus concentrations, and excursion frequencies occurred between 1978-1979 and 1980-1983. The regulation schedule was unchanged over this period.

In its April 14, 2004 memorandum in opposition to the Tribe's motion for declaration of violations related to the exceedances at the Refuge (at p. 7), the SFWMD stated that the average frequency of overflow events (days when the rim canal was elevation was above marsh elevation) increased from 35 to 80 times per year after 1991 and was a factor contributing to the exceedances. The accounting of overflow events would depend upon which stations were used to compute the gradients and how the various tailwater and marsh elevations were averaged. The magnitude and spatial distribution of phosphorus load penetrating the marsh depends in several factors, including

- duration of positive gradients
- magnitude of the gradients
- inflow volumes
- inflow concentrations
- inflow locations
- pumping dynamics
- hydraulic resistance controlled by marsh topography and vegetation.

All of the above changed over the 1978-2004 time period. For example:

1. The locations of the inflow points shifted dramatically as STA1W gradually came on line starting in August 1994 and when S6 was diverted away from the Refuge in 2001.

2. The rim canal inflow concentrations decreased over this same period, as STA1W came on line and S6 was diverted. The 1978-1991 period included severe droughts in 1981 and 1989-1990 when EAA rainfall (U.S. Exhibit 73, Figure 15) and marsh stage (U.S. Exhibit 70, Figure 12) were very low. The regulation schedule was apparently not reached in those years. The apparent increase in the number of overflow events before and after 1991 partially reflects variations in climate, as opposed to the change in regulation schedule.

3. Pumping dynamics changed significantly. The S5A and S6 pump stations generate large pulses to provide rapid flood control in response to storm events. In contrast, STA outflow pumping tends to be steadier because of STA operation rules and vegetative hydraulic resistance. The marsh inflow pulse following a given storm would tend to be longer after STA operation, even though the total volume of discharge would be similar. This would cause an increase in the number days with positive gradient that was unrelated to the change in regulation schedule. The factor may have been particularly important between 1994 and 1998, when a portion of the S5A runoff was diverted through the Everglades Nutrient Removal Project (ENRP, Cells 1-4 of STA1W) and discharged into the Refuge through pump station G251. The ENRP was operated at nearly steady flows. Similarly, Lake Okeechobee releases to STA1W & the Refuge also

increased over the 2000-2002 period. Lake releases are steadier than runoff pulses that dominated the inflow hydrographs prior to 1994.

Because of these multiple factors, percentage increase in duration of overflow events cannot be translated into a percentage increase in load. Many factors, in addition to overflow frequency, should be analyzed before forming conclusions regarding impacts of the change in regulation schedule. The net impacts on the marsh P concentrations can only be evaluated with a model that accounts for changes in marsh assimilative capacity and hydrodynamics. Reducing recent inflow loads and concentration to levels consistent with achieving Consent Decree and Long-Term Plan treatment goals would significantly reduce any impacts of the regulation schedule change. As described in Section 3.3, attaining those goals would require further reductions of 58% and 78%, respectively, relative to values measured in 2002-2004.

8.0 July 2003 Report on July 2002 (And Previous) Exceedances At The Refuge

In July 2003, I co-authored a report entitled “Compliance of Marsh Phosphorus Concentrations in A.R.M. Loxahatchee National Wildlife Refuge with Interim Levels Required under the Consent Decree.” U.S. Exhibit 79. In that report, which addressed an exceedance in July 2002 (and prior exceedances), I concluded that

“Despite reductions in phosphorus loads and exceedance frequencies subsequent to full-scale operation of STA-1W (July 2000) and STA-2 (July 2001), Interim Levels have been exceeded one or more times in each of the four years since they went into effect. There has been no “substantial evidence that the exceedances were due to error or extraordinary natural phenomena.””

U.S. Exh. 79 at 1 (emphasis in original). The opinion and conclusions in that report remain valid and complement my testimony in this Report, and are specifically incorporated by reference here.

9.0 - Remedies – Enhanced Phosphorus Load Controls

In this section, I compare design assumptions with observed performance of phosphorus load controls that have been implemented under the Consent Decree and the State’s Long-Term Plan. In general terms - what is working, what is not, and why? I also make general recommendations regarding additional measures and strategies that will increase the probability of achieving management objectives and compliance, as measured by the numerical tests described in Section 3.

Phosphorus controls designed under the original 1991 Consent Decree and later modified under the 1994 Conceptual Plan for the Everglades Construction Project were based upon two key assumptions: (1) 25% reduction in loads attributed to Best Management Practices in the Everglades Agricultural Area; and (2) STA performance modeled using historical data from a portion of WCA-2A that had a history of high phosphorus loadings and intensive monitoring. These assumptions were applied to a 10-year record (1979-1988) of historical flows and phosphorus loads from the EAA, Lake Okeechobee, and other source basins to design STAs with 50 ppb outflow concentrations. That interim design target was selected based upon the perceived limits of technology as of 1991. It was anticipated that further reductions in discharge concentration would be required to achieve compliance with the State’s Class III phosphorus criterion and the Consent Decree Long-Term Levels and Limits. Extensive research, monitoring, and modeling have been performed since 1994 to develop “green” technology for achieving lower discharge concentrations with a reasonable degree of assurance. Measures to achieve those lower concentrations are being implemented under the State’s Long-Term Plan

(Burns & McDonnell 2003).

Overall, both of the original design assumptions for the 50 ppb STAs have turned out to be “conservative” in the sense that BMP load reductions began earlier than expected and averaged ~50% (vs. 25%) and the STAs have performed better than expected when operated in design ranges. As a consequence of these conservative assumptions and successful implementation of the Everglades Construction Project (ECP), it is likely that the combined cumulative load to the EPA from all sources treated under the Consent Decree since the control program started in 1994 has been lower than expected based upon the original design assumptions. There are significant regional variations, however. These are partially related to regional variations in BMP performance (U.S. Exhibit 71, Figure 13) and discharge concentrations from Lake Okeechobee (U.S. Exhibit 72, Figure 14). Both of these factors have contributed to higher concentrations and loads in discharges from the S5A basin, as compared with the others (S6, S7, and S8). Lake regulatory and water supply releases to S5A/STA 1-West have been greater than assumed in either the Everglades Construction Project 1994 Conceptual Design or the Long-Term Plan designs. These variations have partially contributed to the overloading problem at STA 1-West and exceedances of the Refuge Interim Levels.

With some exceptions (described below), recent flows and loads have been generally consistent with the original ECP design assumptions (Burns & McDonnell, March 2005). Even though an assumed 20% reduction in EAA runoff volume due to BMP's did not occur, that has had no consequence because STA performance is primarily determined by phosphorus loads, which were conservatively estimated because BMP performance has exceeded expectations (50% vs. 25%).

An entirely new set of flows and loads was subsequently developed to support design of enhanced STAs under the Long-Term Plan (October 2003) to achieve discharge concentrations of 15 ppb (flow-weighted mean) and 10 ppb (geometric mean). The flows in this case were simulated by the regional water management model and significantly under-estimated because the assumed 20% reduction in EAA runoff volume did not materialize and other model calibration issues. These problems were subtle and not caught in extensive reviews by state, federal, and industry consultants. Those simulated flows were applied to measured concentrations in the post-BMP period (already accounting for the 50% BMP load reduction). As a consequence, both the flows and the loads were under-estimated in designing enhanced STAs, as described in the October 2003 Long-Term Plan. These discrepancies were fully evaluated by Burns & McDonnell (2005). As described below, efforts are now underway address the overloading problem.

U.S. Exhibit 73 (Figure 15) shows that regional variations in observed STA performance are largely explained by deviations from design load assumptions. Design loads, expressed in grams per square meter of STA surface area per year, range from 1.3 to 1.5 g/m²-yr for the 1994 Conceptual Plan (50- ppb STAs) and 1.0 to 1.1 g/m²-yr for the 2003 Long-Term Plan. Those STAs that have been run in design ranges (STA2, STA6, and ENRP (a portion of STA 1-West prior to full-scale operation)) have had average discharge concentrations ranging from 17 to 21 ppb. In contrast, STA1W and STA5 have operated at loads more than twice their designs and had average discharge concentrations of 60 to 100 ppb, respectively. The SFWMD's Everglades Agricultural Area Regional Feasibility Study ("EAARFS") is evaluating alternatives to reduce these inflow loads to design ranges, including STA expansion, diversion, and integration with

CERP reservoir(s). Efforts to “optimize” the STAs will not achieve the goal of preserving and restoring the unique natural flora and fauna of the Refuge until inflow volumes and loads are reduced to design ranges or additional treatment capacity is installed to accommodate the excess loads.

Additional source controls, STA optimization, and/or STA expansion will be needed to achieve compliance with the Long-Term Levels, or compliance with the Class III numeric criterion for total phosphorus, if the TOC, under Appendix B of the Decree, determines the latter criterion to be lower. There is a great deal of uncertainty associated with designing STAs to achieve flow-weighted mean concentrations below the 15-20 ppb range. Research and monitoring components of the Long-Term Plan provide mechanisms for improving technology and reducing that uncertainty, so that the ultimate goal (however measured) can be achieved in a reasonably cost-effective manner.

The performance of STA-1W deteriorated significantly after the September 2004 hurricanes (Figure 5). That event does not appear to have been extraordinary with respect to flow entering the S5A complex in the context of the 1994-2005 record (U.S. Exhibit 74, Figure 16). Runoff from the L8 basin (east of the EAA) was a significant component of the flows entering the STA1W distribution works during the hurricanes. The L8 flows were comparable to untreated bypass that occurred. The longer tail on the L8 runoff (vs. the S5A runoff) at the beginning of October was perhaps more significant. Those flows occurred at a time when it was impossible to bypass flows around STA1W because of high stage conditions in the Refuge and inflow distribution works. Those L8 flows were discharged into STA1W even though water depths in some cells exceeded design ranges for maintenance of vegetation and levees.

The 1994-2005 flow record, see U.S. Exh. 74 (Figure 16), shows that L8 runoff typically accounts for a significant portion of the total inflow to the S5A complex during periods when S5A runoff is also high. Risks of untreated bypass to the Refuge, impaired STA performance, STA vegetation damage caused by high water levels, and intrusion of phosphorus loads into the Refuge marsh are also highest during these high-flow periods. STA1W & 1E designs under the 1994 Conceptual Plan and 2003 Long-Term Plan assumed that L8 flows would be diverted to other basin(s) prior to full-scale operation. The currently-planned CERP project will divert a portion of the L8 runoff to the North starting in 2008-2010. That plan is designed to handle L8 flows that are currently discharged east to the Lake Worth Lagoon, but not those that currently discharged to STA 1-West/Refuge, as depicted in Figure 16. Remedies for the L8 basin loads are being explored in the current EAARFS.

General recommendations regarding remedies and TOC actions are listed below:

1. As discussed above, conservative assumptions with respect to BMP and STA performance were made in designing the Everglades Construction Project STAs to achieve 50-ppb discharge concentrations. Aside from problems associated with STA 1-West overloading and performance discussed above, that program was highly successful. The 2003 Long-Term Plan for enhanced STAs was based upon neutral to optimistic forecasts of STA performance. As a result of ongoing research, monitoring, and modeling, the uncertainty band associated with predicting STA performance in low concentration ranges is decreasing. While modeling uncertainties have been reduced, there are future uncertainties about the actual loads vs. the design assumptions (as recently demonstrated), changes in regional water management, lowering

of Lake Okeechobee water levels, increasing trends in Lake Okeechobee concentrations (Figure 14), potential increases in hurricane frequency, and temporary reductions in STA treatment capacity associated with maintenance and enhancement measures. Conservative assumptions made in the design process with respect to these and other uncertain factors would provide greater assurance that compliance with the Long-Term Levels and treatment goals

2. Evaluate the diversion of all urban water supply around Refuge to reduce regulation schedule conflicts, especially given increasing trends in Lake phosphorus concentrations (see U.S. Exh. 72, Figure 14) and increasing urban water needs. The best ultimate solution to any regulation schedule conflicts, however, would be to attain the inflow treatment goals that have already been established under the Consent Decree and Long-Term Plan.

3. I support TOC's decision to focus on remedies (load reductions) and additional diagnostic work that will eventually help to resolve causation disputes with respect to compliance (See USFWS Enhanced Monitoring program and Model Development, U.S. Exhs. 6 and 52). Disputes on causation will be more easily resolved after external loads have been reduced to levels consistent with attaining the treatment goals already established under the Consent Decree and Long-Term Plan. Theoretically, the State's Long-Term Plan provides a driving force for achieving inflow concentrations at the limit of technology (now roughly 15 ppb), regardless of compliance with the Interim or Long-Term Levels.

4. Interim Levels are about to sunset. An expanded monitoring network for determination

of Class III compliance in impacted and unimpacted areas of the Refuge should be designed and implemented as soon as possible. This must be done before the TOC compares with the Long-Term Levels with the Class III numeric criterion for total phosphorus to determine whether the latter is lower, as required under Appendix B of the Consent Decree. This is critical to monitoring and restoration of the impacted areas of the Refuge.

5. The TOC should also begin focusing on measures to foster the recovery of impacted marsh areas. Attainment of treatment goals and implementation of such measures will accelerate the restoration and protection of the entire Refuge marsh.

Executed this 4th day of August 2005



William W. Walker

9.0 References

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Walker, W.W., “Analysis of Refuge Interim P Level Excursions - September 2003 & August 2004”, TOC Presentation, November 2004.

Walker, W.W. and R.H. Kadlec, “Dynamic Model for Stormwater Treatment Areas – Version 2”, prepared for U.S. Department of the Interior and U.S. Army Corps of Engineers, June 2005. <http://www.walker.net/dmsta>

10.0 Data Sources Used In U.S. Exhibits 59 through 74 (Figures 1 through 16)

Sources of data used in my testimony are listed below.

SFWMD DBHYDRO Database - DBKEYS for Daily Flow Data

<u>SITE</u>	<u>PRIMARY</u>	<u>SECONDARY*</u>	<u>FIGURES</u>
G300	TA411	KD315	4, 16
G301	TA412	JJ809	4, 16
G310	M2901	PK919	4, 16
G251	JW222	15848	4, 16
S5AS	L7444		16
S5AE	P1018	L7443	16
S6	15034	06741	4, 6
S5AW	MG614	L9825	16
S5A5AW	15031	00317	4, 6, 16
S5A_P	JW226	06739	4, 16

SFWMD DBHYDRO Database - DBKEYS for Daily Stage Data

<u>SITE</u>	<u>PRIMARY</u>	<u>SECONDARY*</u>	<u>FIGURES</u>
1-7	FE775	P1029	2, 3, 6, 11, 12
1-9	FE777	P1032	2, 3, 6, 11, 12
1-8C	FE776	P1030	2, 3, 6, 11, 12

* Secondary DBKEYS used when Primary Keys had no data

SFWMD DBHYDRO Database - Water Quality Station Codes

<u>PROJECT</u>	<u>STATIONS</u>	<u>FIGURES</u>
CAMB	S10A, S10C, S10D, S10E, S39	7
ST1W	G300, G301, G310, G251	4
CAMB	S5A, S6	4, 6, 7
EVPA	LOX3-LOX16	2, 3, 6, 7, 11, 12
EVPA	CA215, CA29	Section 3.2, Footnote
EVPA	CA311, CA315, CA38	Section 3.2, Footnote
EVER	EP, P37, P33,P34	Section 3.2, Footnote

Additional Data Files Obtained from Sources Other than DBHYDRO

<u>FILE</u>	<u>CONTENTS / SOURCE</u>	<u>FIGURES</u>
2002_hearing.xls	79-88 loads used in original STA design Gary Goforth (data used in 2002 hearing)	4
EAABASIN.XLS	Monthly Rainfall from S5A Basin SFWMD Everglades Regulation Division	15
EAA.MON	Loads from EAA Structures, 1978-2005 SFWMD Everglades Regulation Division	13, 14
WWW_WCA1_404.xls	WQ Data from XYZ Transects, 1996-2004 FDEP	9
STA1WINFLOW- OUTFLOWTP.xls	STA1W Water and Mass Balances SFWMD Water Quality Assessment Div	5, 15
STA5INFLOW- OUTFLOWTP2.xls	STA5 Water and Mass Balances SFWMD Water Quality Assessment Div	15 -
STA6RESULTS.xls	STA5 Water and Mass Balances SFWMD Water Quality Assessment Div	15

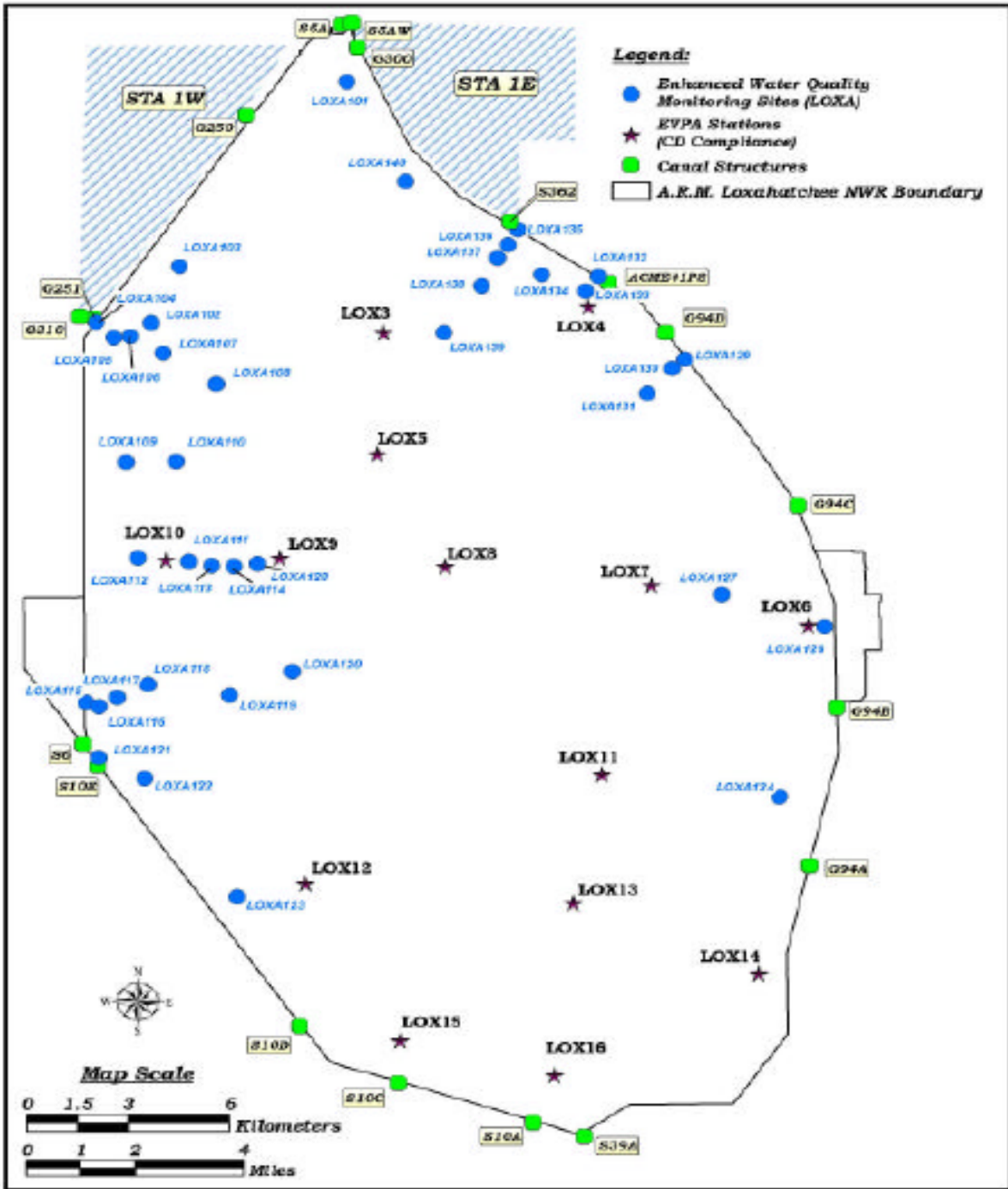


Figure 1

Refuge map showing Consent Decree compliance sites (black stars), DOI enhanced monitoring sites (blue circles), and inflow/outflow structures (green circles); from Harwell et al, ARMLNWR Enhanced Water Quality Monitoring and Modeling - Interim Report, April 2005

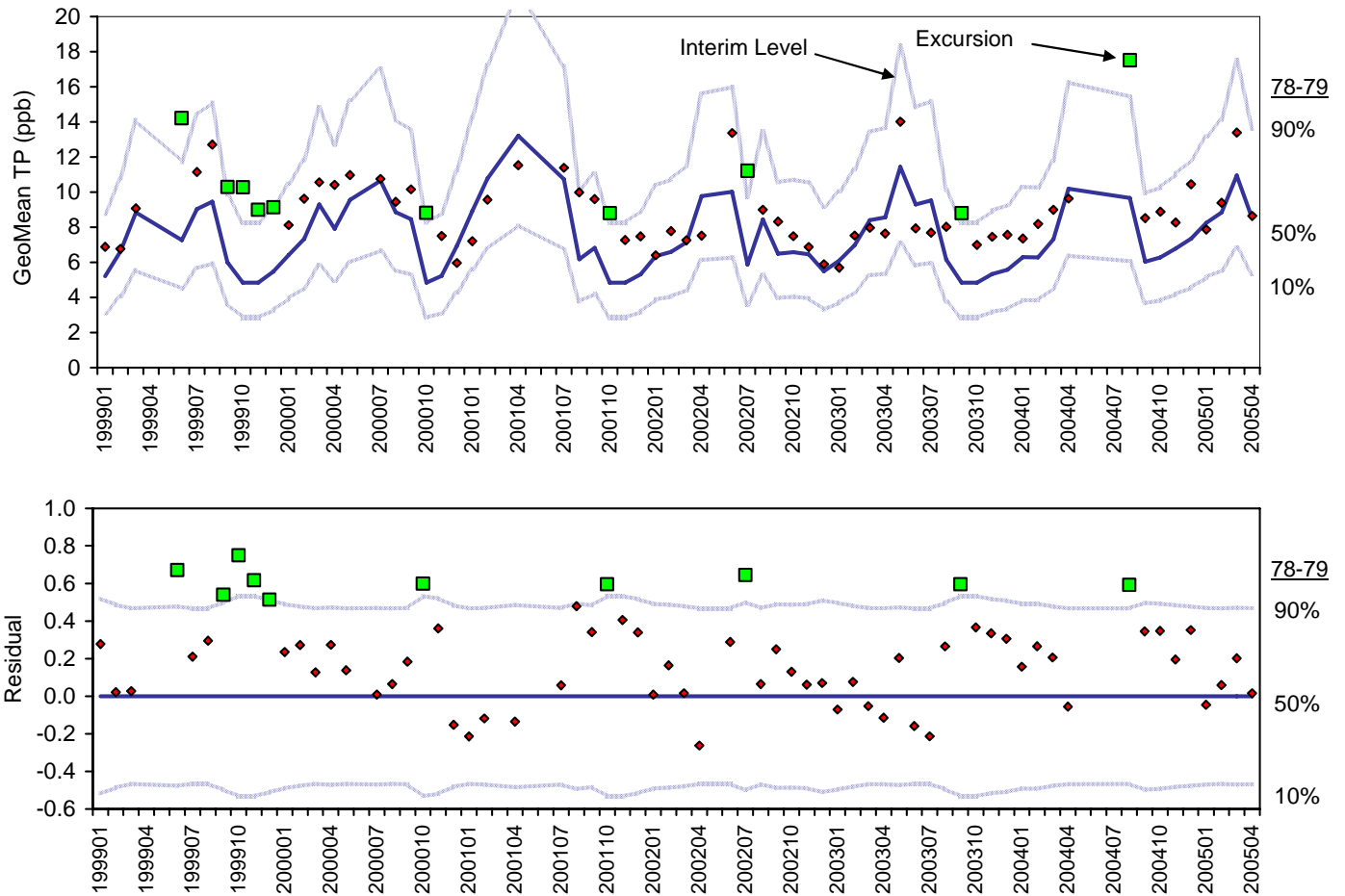


Figure 2
 Interim P Levels for the Refuge Marsh (Effective February 1999) Period: January 1999 - April 2005

Top Observed geometric means vs. Interim level (top line) and frequency distribution of 1978-1979 data
 Bottom Residuals from Interim Level regression = natural log (observed gm / predicted 50th percentile for 1978-1979 at current stage)
 This removes stage variations from the data to facilitate comparison of current vs. historical values and long-term trends.

- Lines Frequency distribution of 1978-1979 data (10th, 50th, 90th percentiles), computed from Interim Level equations
- Top Line Interim Level
- Red Diamonds Monthly sample tested for compliance (stage > 15.42 ft)
- Green Squares Monthly excursion (sample > Interim Level)

An "Excursion" occurs when the monthly GM is above the 90th percentile of 1978-1979 data, adjusted for stage (top line, Interim Level)
 Monthly GM's were above the Interim Level in 10 out of 66 months with sufficient stage for testing (15%).
 The objective of the Interim Levels is to restore the 1978-1979 distribution of data at the 14 sites.
 If that objective had been attained, the data would be evenly distributed around the 50th percentile of the 1978-1979 data (solid blue lines)
 Samples were above the blue line in 54 out of 66 months (82%), as compared with the expected 50%.
 This difference (82% vs. 50%) is an additional indication (beyond excursions/exceedances) that Consent Decree goal has not been met.

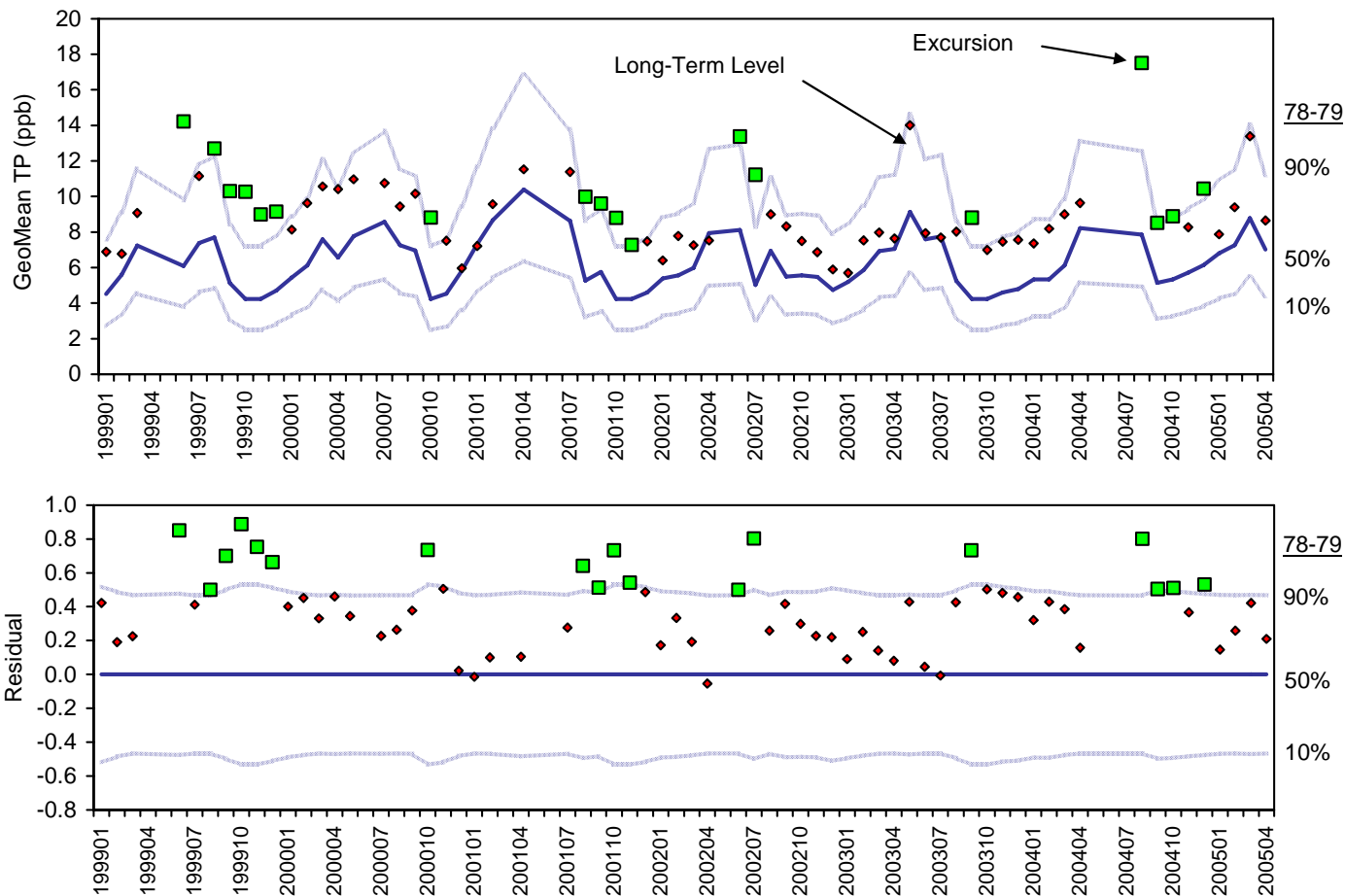


Figure 3
 Long-Term P Levels for the Refuge Marsh (Effective December 31, 2006) Period: January 1999 - April 2005

Top Measured geometric means (symbols) vs. distribution of 1978-1979 data at 3 reference sites (LOX 5, 6, 16) (lines)
 Bottom Residuals from Long-Term Level regression = natural log (observed gm / predicted 50th percentile for 1978-1979 at current stage)
 This removes stage variations from the data to facilitate comparison of current vs. historical values and long-term trends.

- Lines Frequency distribution of 1978-1979 data (10th, 50th, 90th percentiles), computed from Long-Term Level equations
- Top Line Long-Term Level
- Red Diamonds Monthly sample tested for compliance (stage > 15.42 ft)
- Green Squares Monthly excursion (sample > Long-Term Level)

An "Excursion" occurs when a monthly GM is above the 90th percentile of 1978-1979 data, adjusted for stage (top line, Long-Term Level)
 Monthly Geometric Means were above the Long-Term Level in 18 out of 66 months with sufficient stage for testing (27%).

The objective of the Long-Term Levels is to restore the 1978-1979 distribution of data measured at the 3 least impacted sites.

If that objective had been attained, the data would be evenly distributed around the 50th percentile of the 1978-1979 data (solid blue lines)

Samples were above the blue line in 63 out of 66 months (95%), as compared with the expected 50%.

This difference (95% vs. 50%) is an additional indication (beyond the excursions/exceedances) that Consent Decree goal has not been met.

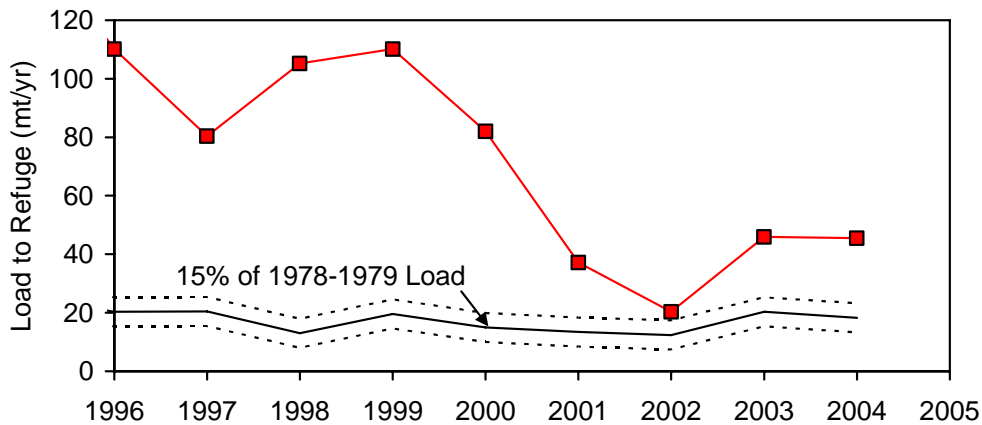
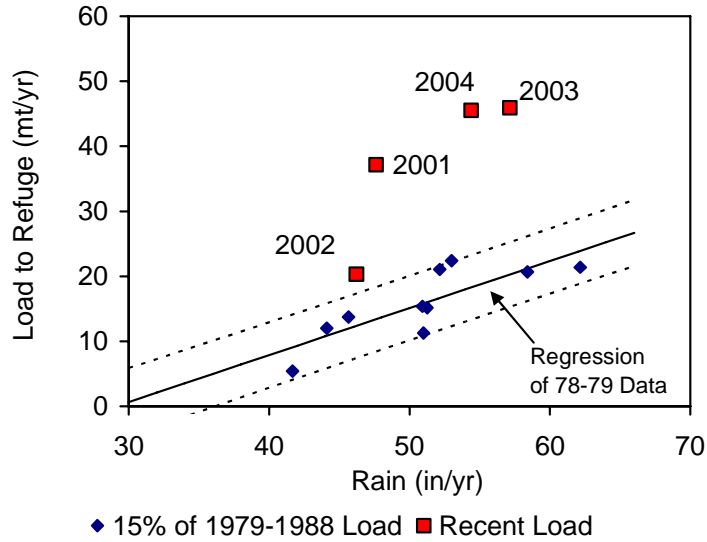


Figure 4

Recent Total P Loads to Refuge Compared with 85% Load Reduction Requirement

Water Years ending in September (i.e. 2003 = Oct 2002 - Sept 2003)

That was the WY definition used in the original STA design calculations.

Top: Regression of 1979-1988 loads vs. S5A basin rainfall
 Blue diamonds = 15% of 1979-1988 loads to the Refuge from S5A & S6
 Lines = linear regression of load vs. rainfall (10th, 50th, 90th percentiles)

Bottom: 1996-2004 data compared with rainfall regression
 Red squares = measured loads from S5A, S6, G251, G310, G300, G301 to Refuge
 Loads include discharges from STA1W and untreated bypass.
 Lines = loads consistent an 85% reduction, based upon current year's rainfall.

A mean load of 15.9 mt/yr is expected if the 105 mt/yr base period load were reduced by 85%. Measured values ranged from 20 to 46 mt/yr in WY 2002-2004 and exceeded the expected range in each year if an 85% reduction had been achieved.

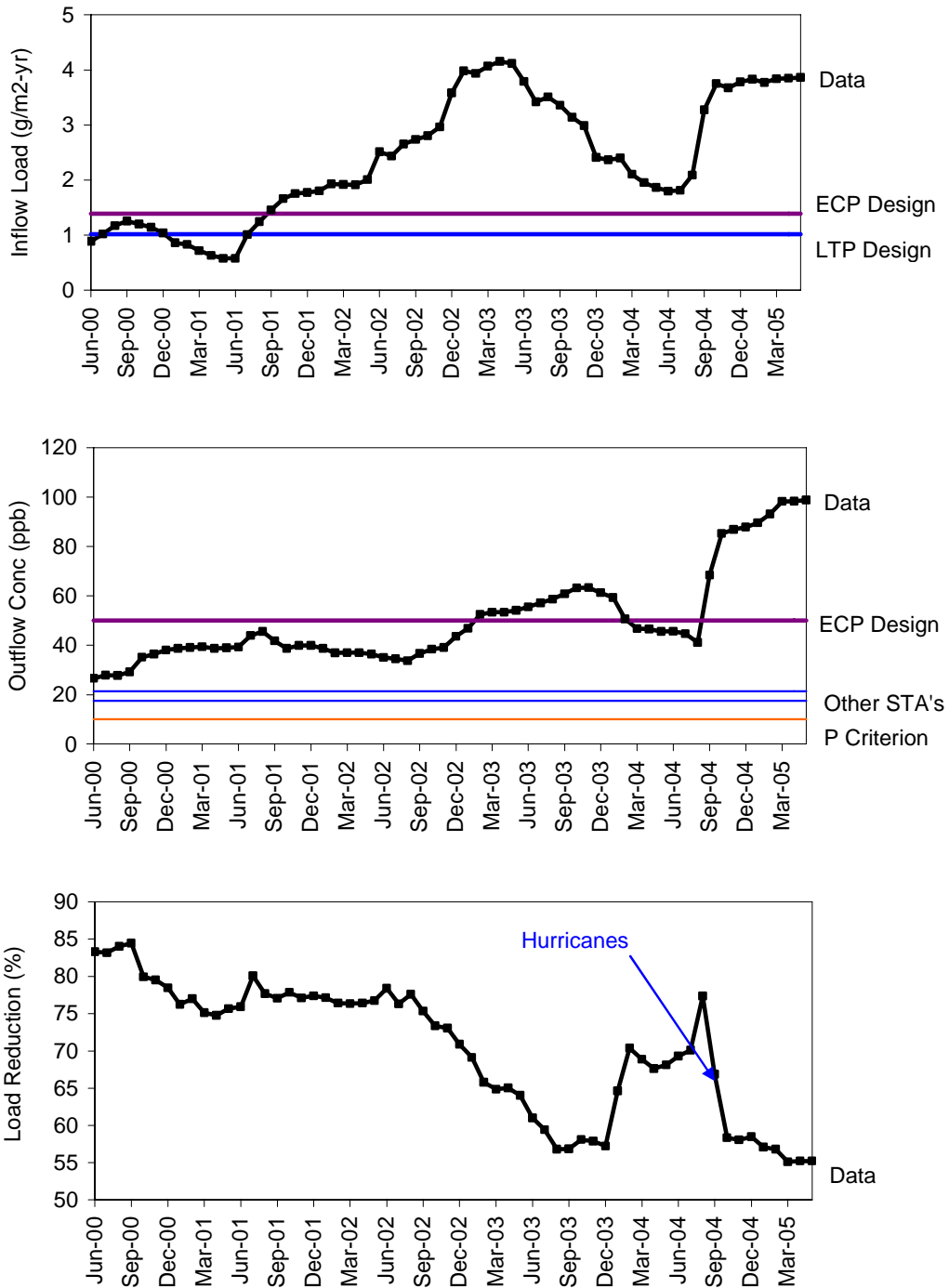


Figure 5

STA1W Inflows Loads, Outflow Concentrations, & Load Reductions

12-Month Rolling Averages, June 2000 - May 2005

ECP = Everglades Construction Project (Phase I STA)

LTP = Long-Term Plan (enhanced STA)

Other STA's = STA2, STA6, ENR Project, operated within design ranges

ENR Project is a portion of STA1W that operated in 1994-1999, before full-scale operation began.

Inflow loads, outflow concentrations, & load reductions do not reflect untreated bypasses to Refuge.

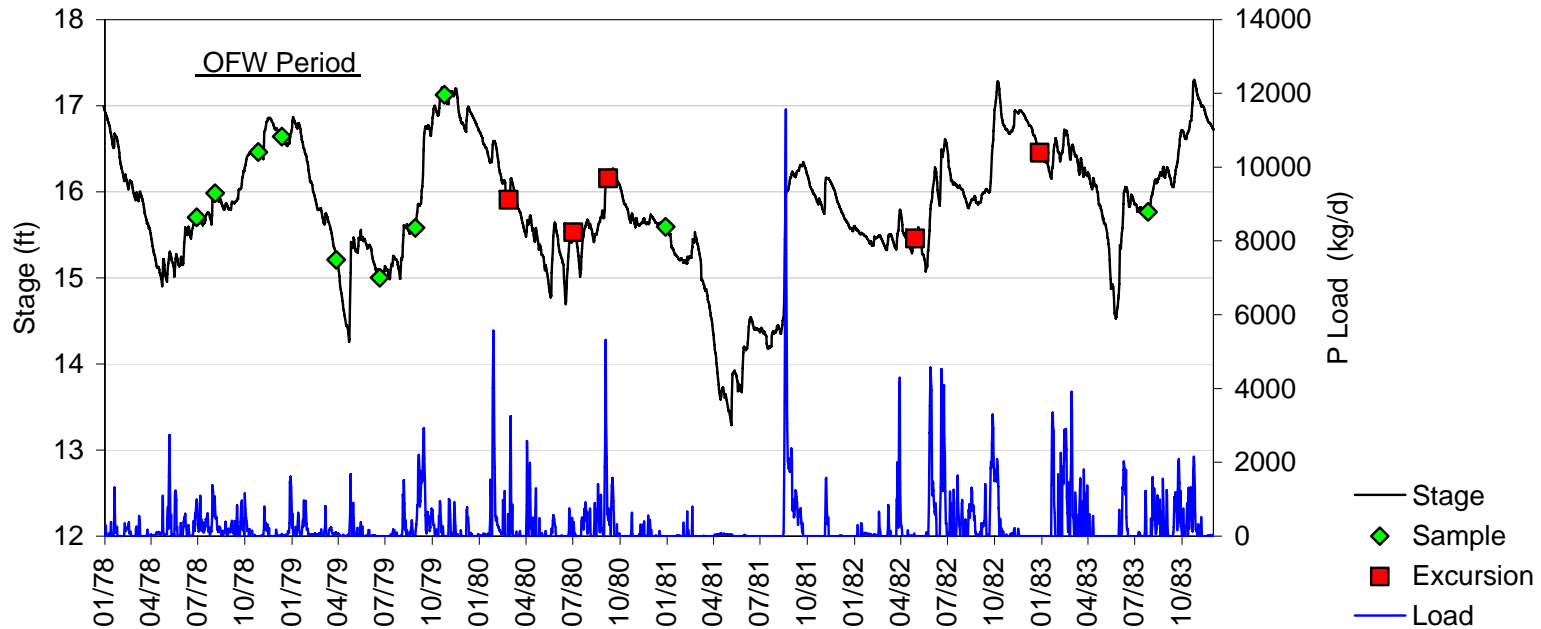


Figure 6

Daily load, stage, and sampling events for 1978-1983 period used in deriving the Consent Decree marsh P Levels

Blue line - daily P load to Refuge from S5A & S6

Black line - marsh stage (3-station mean)

Green diamonds - sampling dates when marsh P concentrations were measured

Red squares - sampling dates when geometric mean concentration exceeded Interim Level.

Peak and average loads increased significantly after the OFW base period (June 78 - May 79).

This was accompanied by an increase in marsh P concentration and excursions of the Interim Levels.

Refuge inflow and outflow concentrations also increased after the OFW period (Figure 7).

The increase in P load was caused primarily by an increase in S5A concentrations and peak flows.

Results are consistent with hypothesis that external P loads penetrate the marsh sufficiently to trigger excursions.

Since the regulation schedule was not changed during this period, results are contrary to the hypothesis that recent excursions were triggered by the change in regulation schedule.

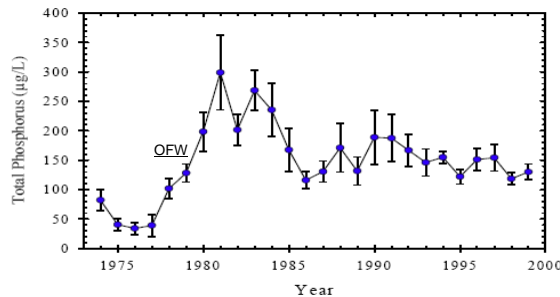
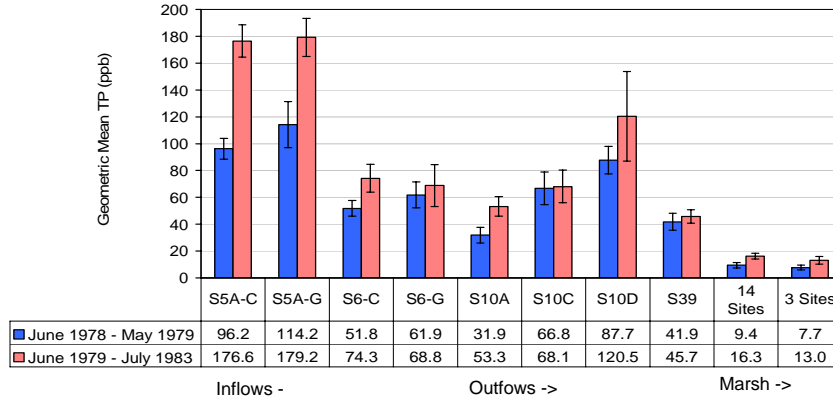


Figure 4.1.2. Mean ± 95% confidence interval annual total phosphorus concentration for canal waters entering WCA-1 through the S-5A inflow structure. Data are from the EMA database.

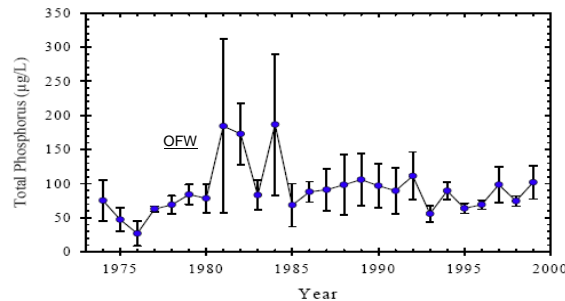


Figure 4.1.3. Mean ± 95% confidence interval annual total phosphorus concentration for canal waters entering WCA-1 through the S-6 inflow structure. Data are from the EMA database.

Figure 7

Summary of P concentrations from 1978-1983 used for deriving the marsh P levels

Top Concentrations in OFW base period (June 78 - May 79) vs June 79 - July 83. Bars show geometric mean concentrations +/- 1 standard error. S6A-C and S5A-G represent 7-day composite and grab samples, respectively. Same for S6. Other sites are grab samples. 3 marsh sites (far right) were used to derive Longterm Levels (LOX 5, 6, 16) Data from SFWMD DBHYDRO database

Bottom Yearly mean concentrations at S5A and S6, 1974 - 1999 Lines are means; bars are 95% confidence intervals Figures from FDEP Technical Support Document for Class III P Rule Part II, Chapter 4, 2001.

P increases in marsh, inflows, and outflows consistent with causal linkage between external loads and interior marsh P concentrations measured at the 14-LOX sites. Refuge inflow concentrations increased significantly after the 1978-1979 OFW base period Before the OFW period, S5A & S6 concentrations were similar to interim STA design goal (50 pp

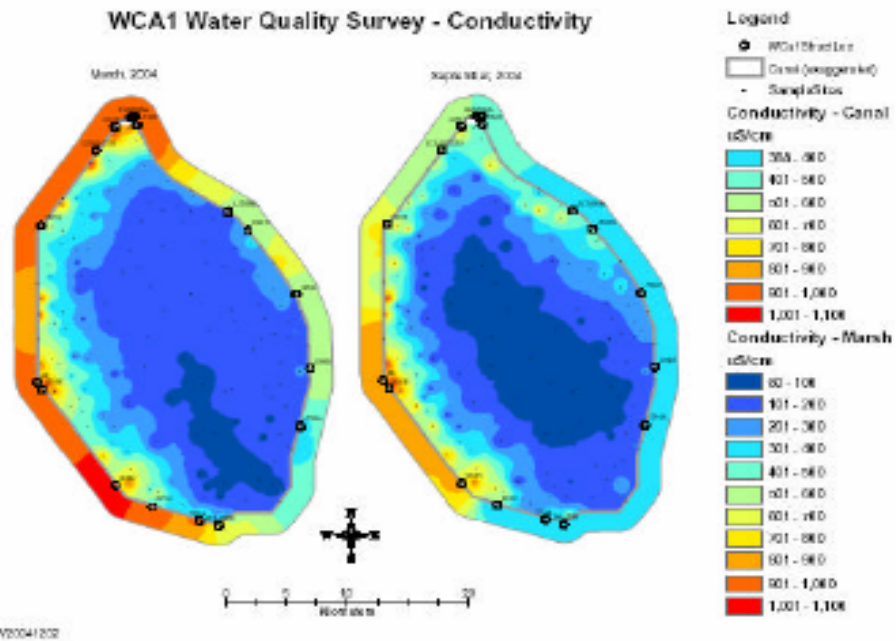


Figure 10: Surface water specific conductivity synoptic maps from March 2004 (dry season) and September 2004 (wet season). Data from South Florida Water Management District and Refuge staff. (SFWMD 2005).

Figure 8

Conductivity patterns in March and September 2004

SFWMD data presented by Harwell et al. (2005)

External inflows have much higher conductivities, compared with rainfall.

Higher values (red end of spectrum) indicate external canal influence.

Lower values (blue end of spectrum) indicate rainfall influence.

The spatial patterns are qualitatively similar to soil P contour maps (Fig 10)

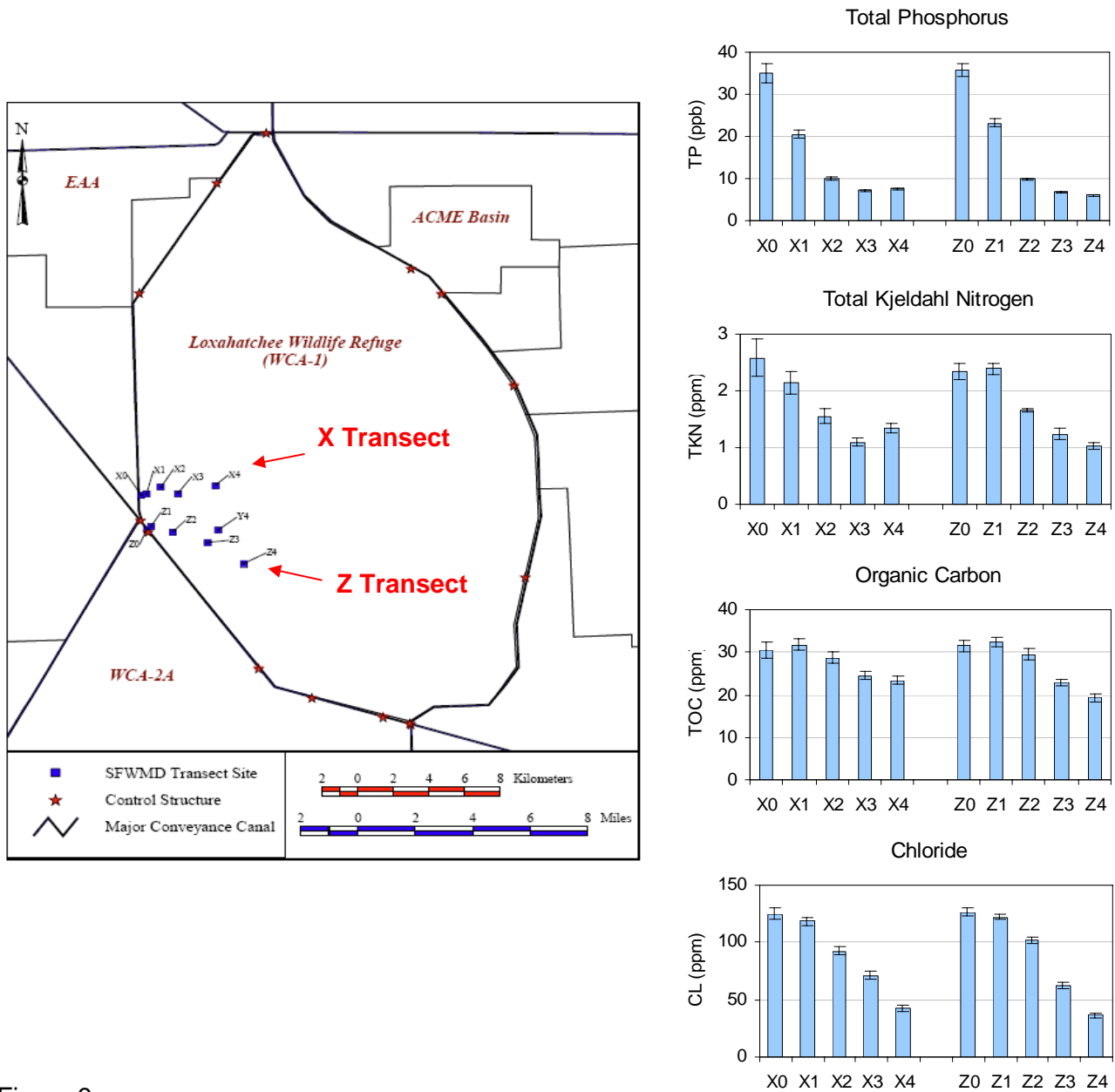


Figure 9

Evidence of Canal Water Intrusion in SFWMD Marsh Transect Monitoring Data

Left Map of transect sites monitored monthly by SFWMD since 1996 (from FDEP, 2001)

Right 1996-2004 Geometric mean concentrations and 90% confidence intervals

Nutrient species (Total P, Kjeldahl Nitrogen, Organic Carbon)

Conservative tracer (Chloride)

The transects extend approximately 4 kilometers east of the rim canal.

Declining concentration gradients along each transect are indicative of canal water intrusion.

This influence may extend further into the marsh (beyond the last transect site) in cases where a plateau is not reached between the 3rd and 4th sites (X3/X4 and Z3/Z4).

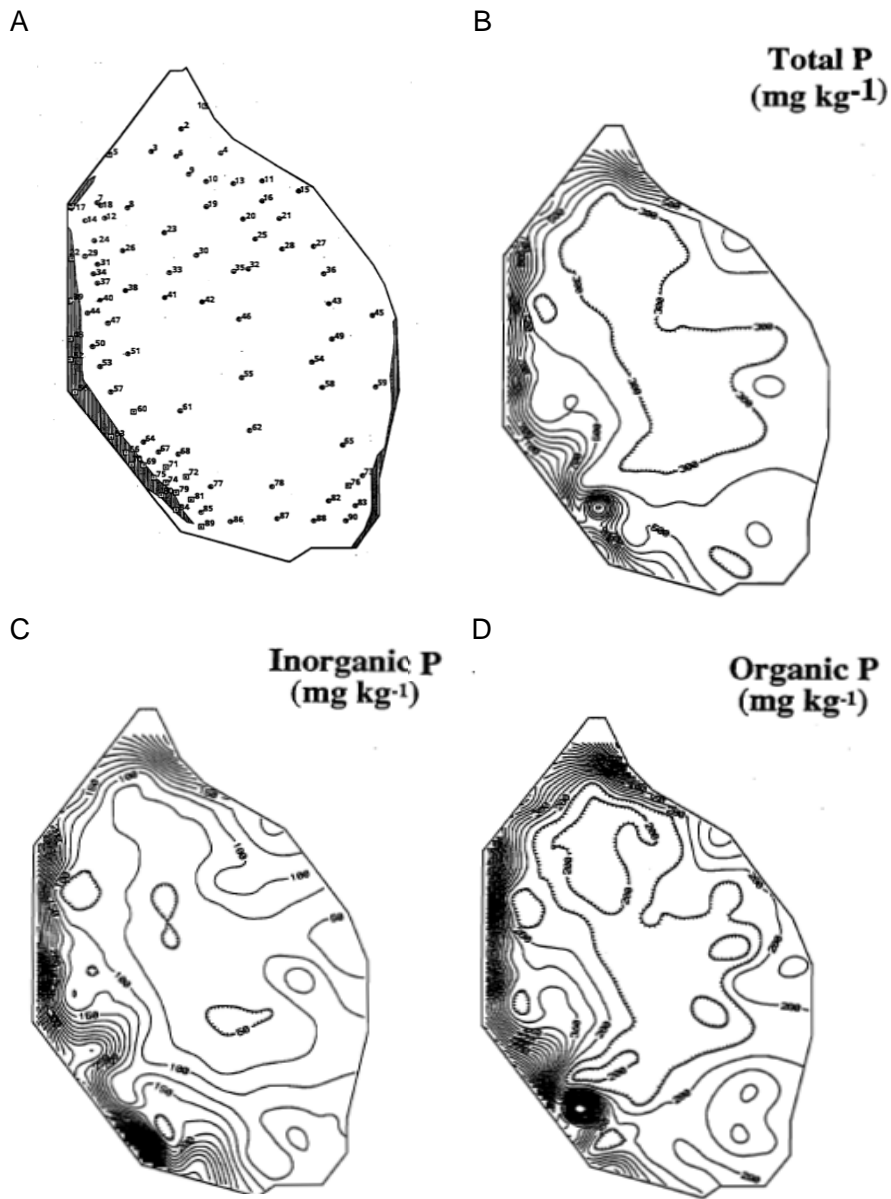


Figure 10

Evidence of P Intrusion from Rim Canal based upon Marsh Soils Data

Data collected for SFMWD and reported by Reddy et al (1994)

A Map of sites where soil samples were collected in 1991

B-D Contours of total, labile inorganic, and labile organic P, 0-10 cm samples

Patterns reflect cumulative effects of historical P loadings penetrating the marsh from the exterior rim canal.

Intrusion was apparently greatest on the western and northern boundaries.

Weaker gradients were also detected on the eastern and southern boundaries.

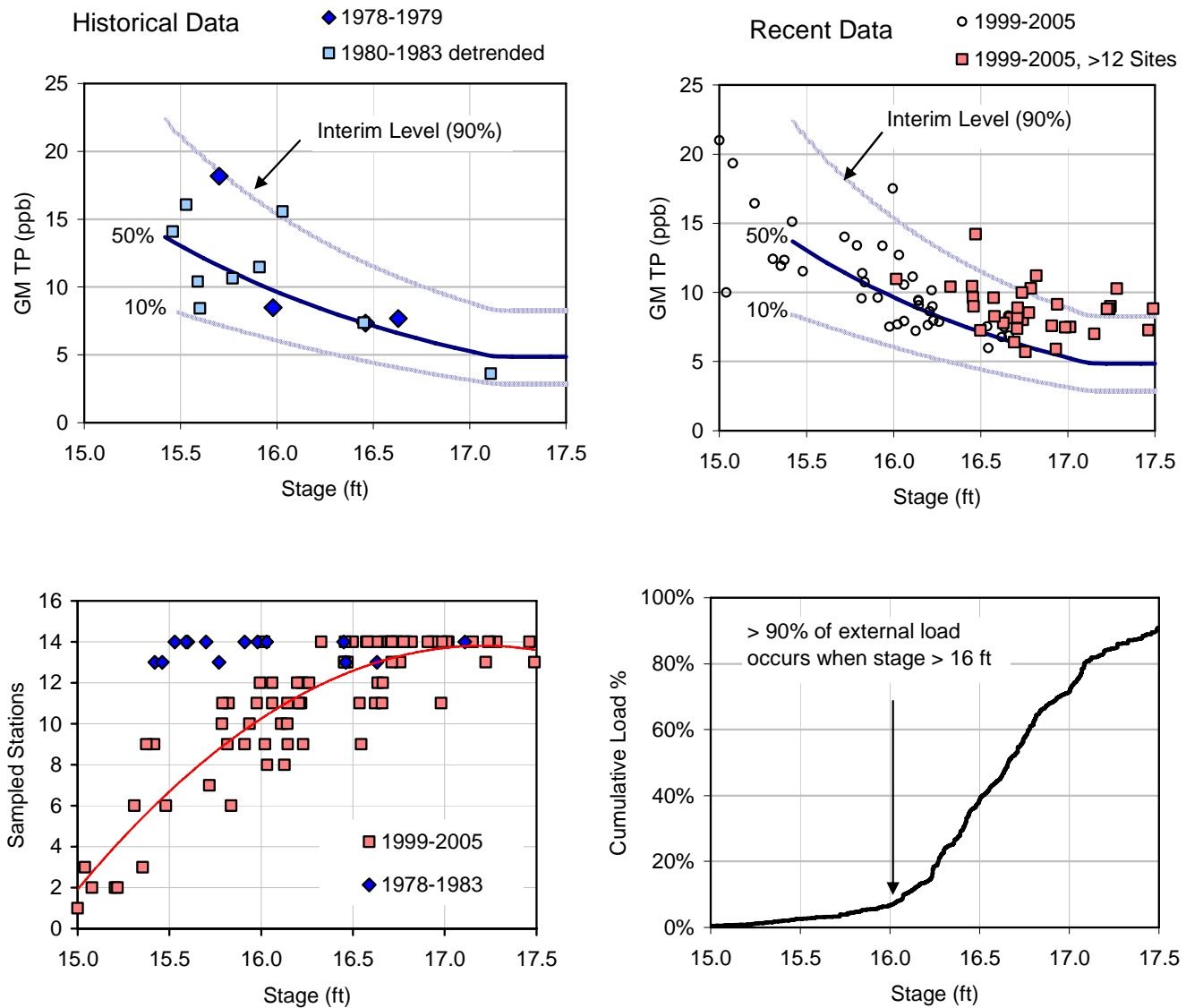


Figure 11

Comparison of marsh concentrations and sampling regimes, 1978-1979 with 1999-2005 (thru April)

Upper Left Historical data used to calibrate Interim Level equations

Upper Right Recent data compared with 1978-1979 frequency distribution based upon Interim Levels

Lower Left Number of sampled stations vs. stage for each time period

Lower Right Cumulative percent of external P load vs. stage, 1999-2005

Comparisons of historical & recent data are uncertain at low stage because fewer sites are now sampled. More than 90% of the external load in 1999-2005 occurred at stages above 16 feet.

On dates when 13-14 sites are sampled (consistent with historical protocol), most of the external load occurs, and the entire marsh is flooded, differences between recent and historical data are most distinct.

Ignoring the stage-dependence would mask external load effects and include data that may not be comparable because of differences in the number of sampled stations at low stage.

Daily Stage & Interim P Level Excursions, 1978-2005

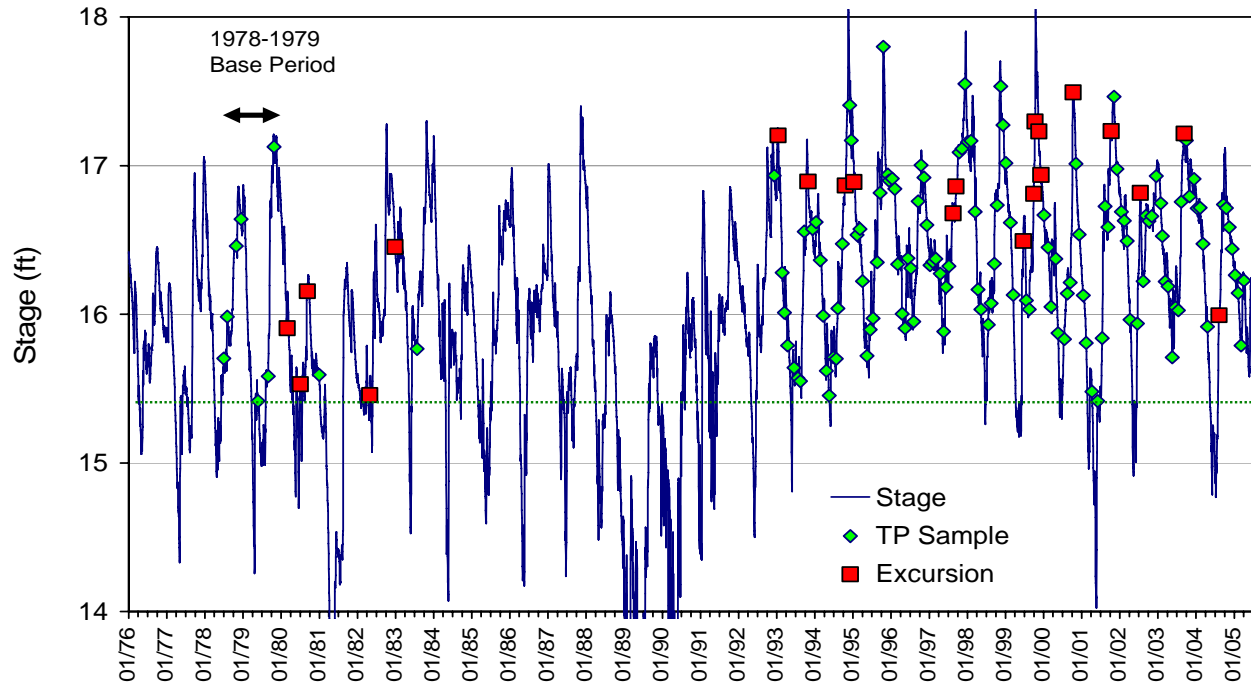


Figure 12

Refuge Daily Stage and Marsh Sampling Events, 1976-2005

Blue line daily stage (1-7, 1-9, 1-8C mean)

Green dashed line minimum stage for compliance testing (15.42 ft)

Green diamonds marsh sampling events

Red squares Interim Level excursions

Excursions occurred in 1980-1983 immediately after the OFW base period before the regulation schedule changed in 1991

These excursions were correlated with increases in external P loads & concentrations (Figures 6-7)

The regulation schedule was not met in 1981 and 1989-1990 due to extreme droughts.

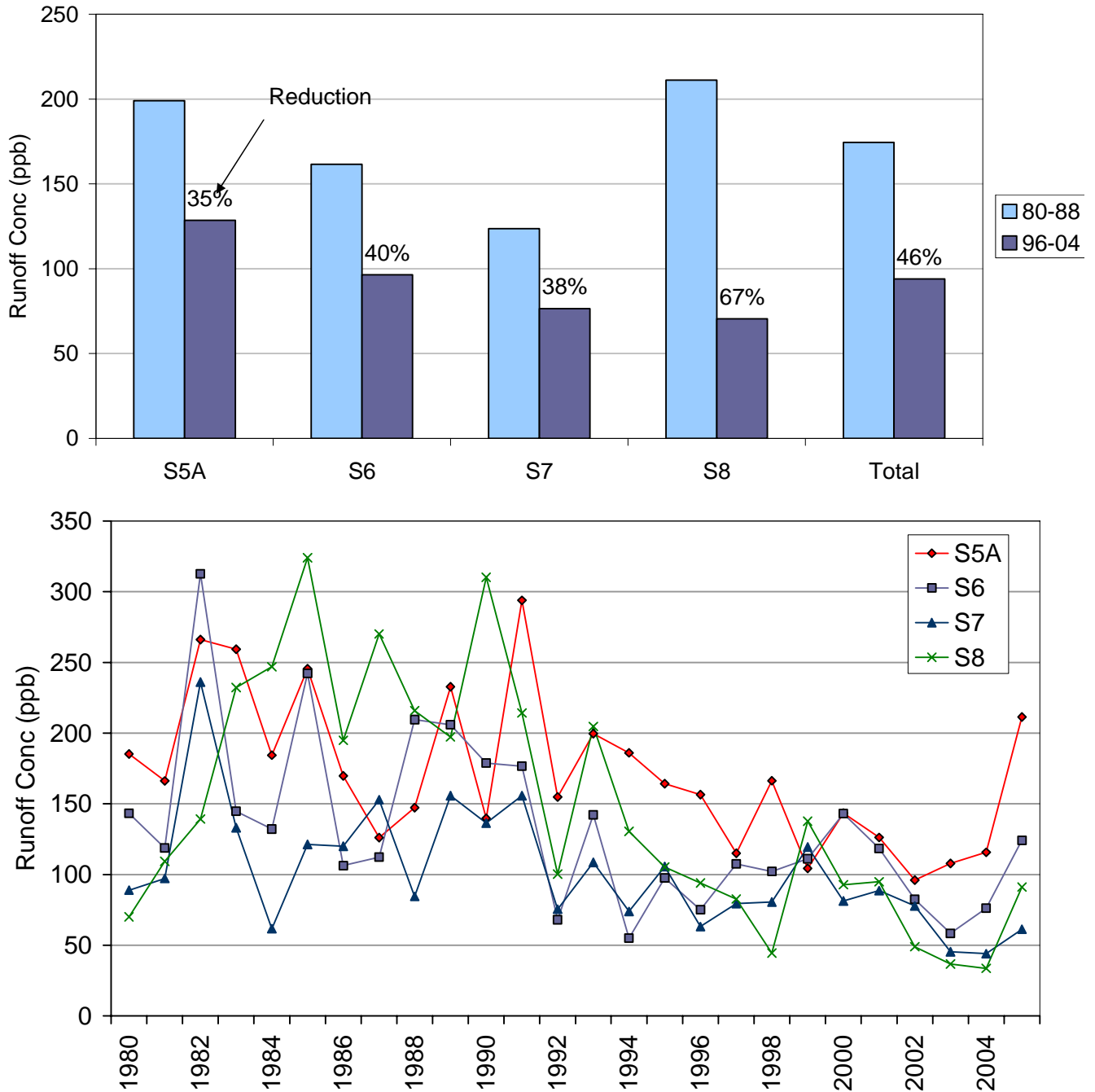


Figure 13
Regional Variations in EAA Runoff Concentrations, Water Years 1980 - 2005

Top - Flow-weighted-mean concentrations for pre-BMP (1980-1988) and post-BMP (1996-2004) periods

Bottom- Yearly time series in each basin, May-April Water Years 1980-2005

Water Year 2005 results are incomplete (May - March) and influenced by hurricanes in Sept 2004

Since BMP's have generally been found not to cause significant reductions in runoff volume, concentrations provide approximate indicators of load reduction and regional BMP performance. Reductions range from 35 to 67% and exceed the 25% Consent Decree requirement in each basin. Percentage reductions were lower and 1996-2005 concentrations were higher in the S5A basin, relative to the others.

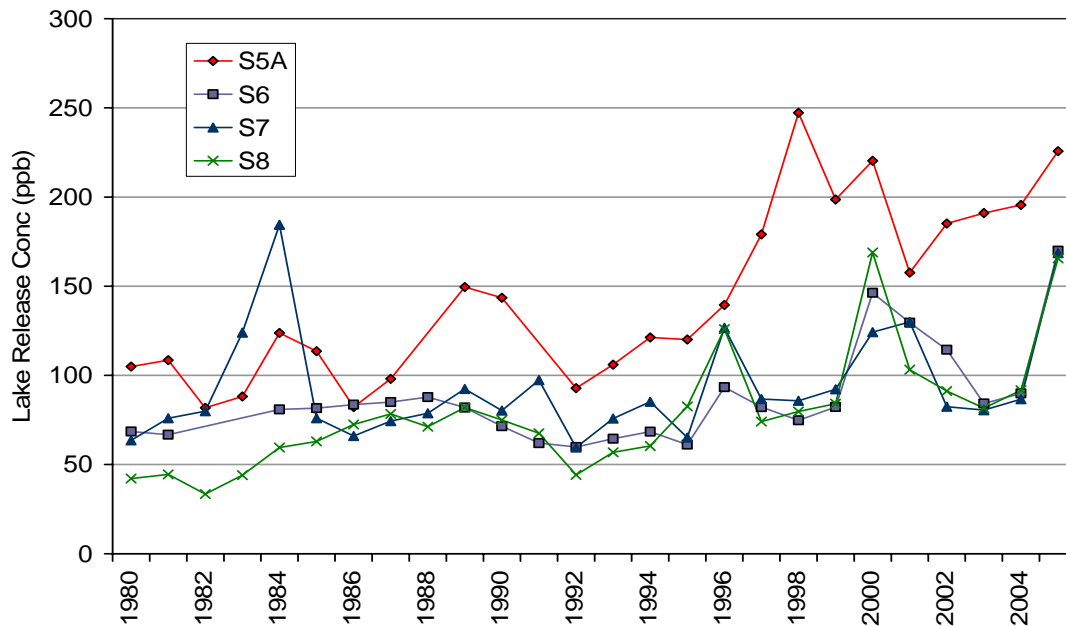
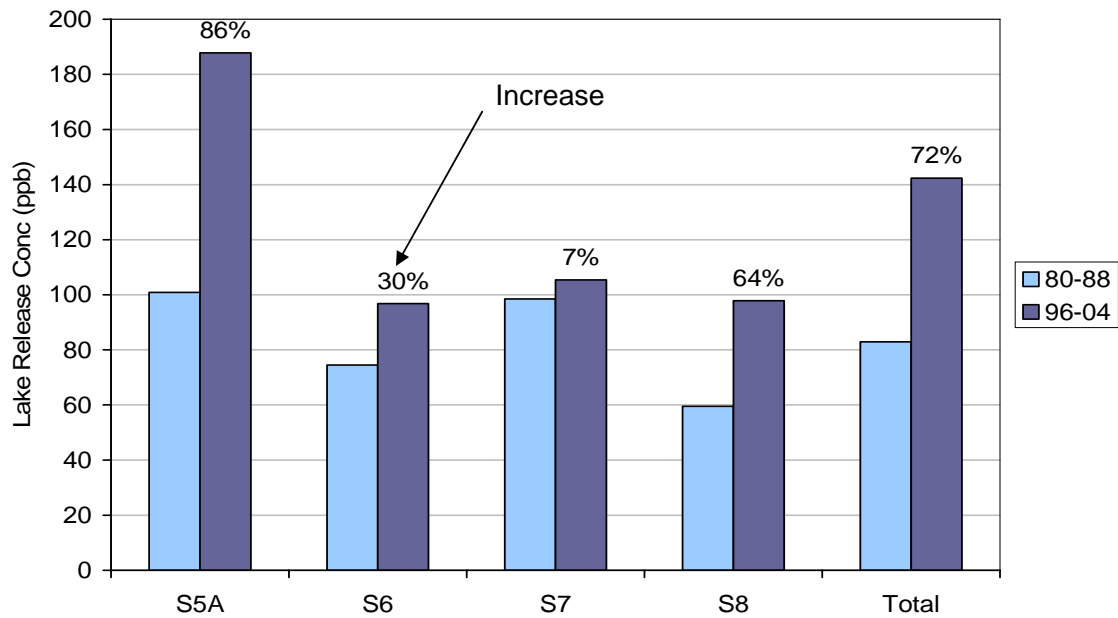
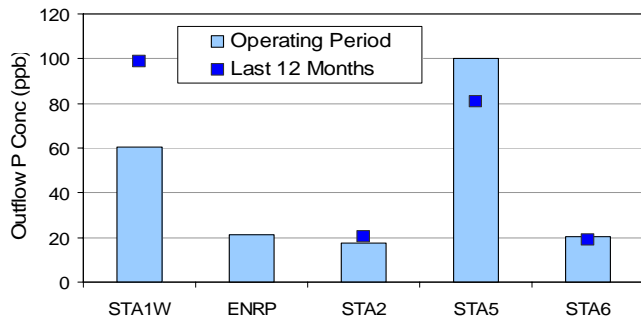
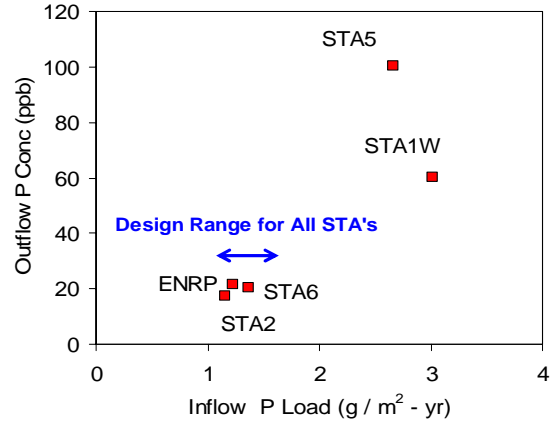
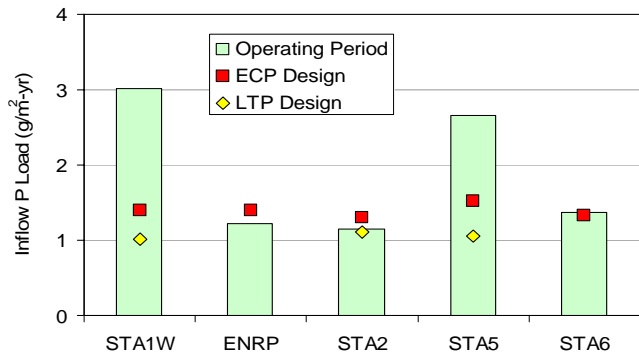


Figure 14
 Regional Variations and Trends in Lake Release Concentrations, Water Years 1980-1985
 Flows delivered from Lake Okeechobee to Water Conservation Areas or STAs through each EAA basin.

Top - Flow-weighted-mean concentrations for 1980-1988 and 1996-2004
 Bottom- Yearly flow-weighted-means for each basin (May-April water years)
 WY 2005 results are incomplete (May - March) and influenced by hurricanes in Sept 2004

Release concentrations were much higher in the S5A basin, as compared with the others. This may reflect the fact that the flows to S5A are released an open area of the lake, where the water is relatively turbid and has higher P content. Releases to the other basins thru S2 & S3 are from more sheltered region of the lake and and pass through a marsh area before entering the structures. Increasing trends in each basin are attributed to a long-term trend in lake water quality.



Summary of STA Inflow Loads & Performance

STA	P Load (g / m ² - yr)			Outflow P (ppb)		Operating Pd	
	ECP/ 1994	LTP	Operating	All	Last 12mo	First	Last
STA1W	1.4	1.0	3.0	60	99	Jul-01	May-05
ENRP	1.4	-	1.2	21	-	Aug-94	Jun-99
STA2	1.3	1.1	1.2	17	20	Jul-01	May-05
STA5	1.5	1.1	2.7	100	81	Apr-02	May-05
STA6	1.3	-	1.4	20	19	Aug-00	Apr-05

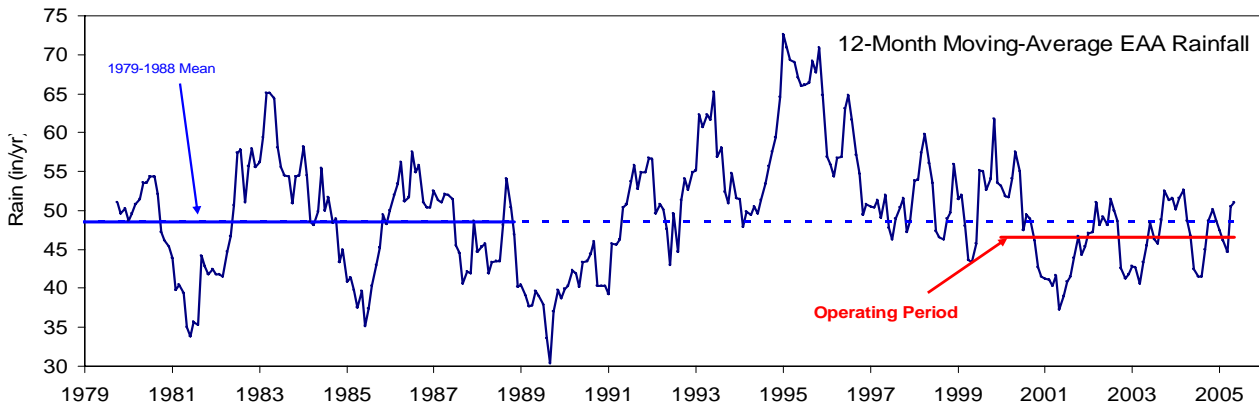


Figure 15 Summary of STA Inflow Loads & Performance

Inflow loads are expressed in grams per square meter of STA surface per year. This is one predictor of STA performance (upper right corner). Design loads are shown for the 1994 Conceptual Plan (ECP, 50 ppb STA's) and the Long-Term Plan (LTP, Enhanced STA's) Inflow loads to STA2, STA6, and the ENR Project were similar to their design loads. Outflow concentrations ranged from 17 to 21 ppb. Inflow loads to STA1W & STA5 exceeded designs by 2-3 fold. Outflow concentrations ranged from 60 to 100 ppb. The loads and outflow concentrations do not include bypass of untreated flows, which occurred in the cases of STA1W & STA5. EAA rainfall was below average in the STA operating period. Therefore, recent data may be optimistic indicators of long-term performance.

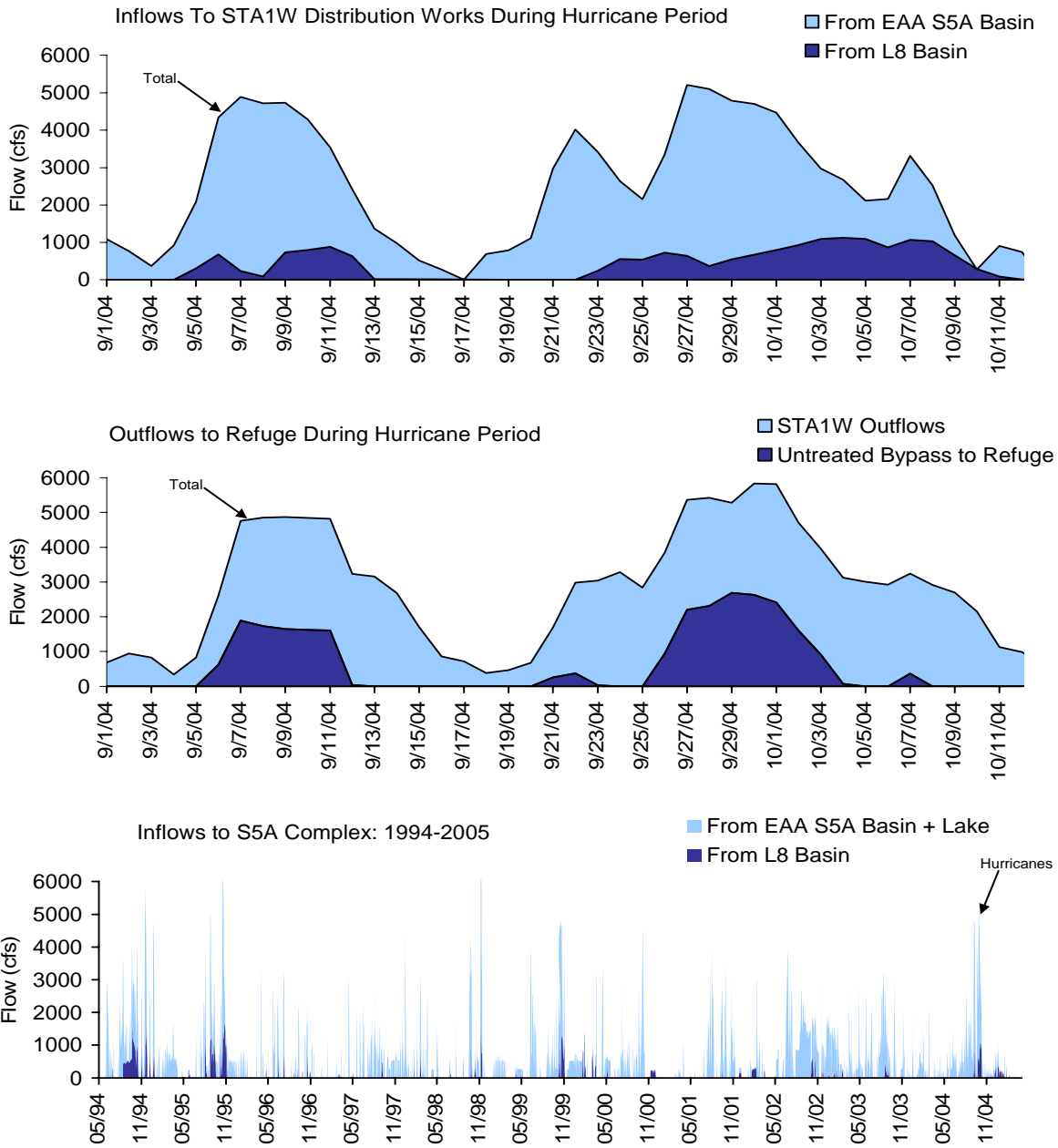


Figure 16 Flow Data from September 2004 Hurricane Period Compared with Long-Term Records

- Top: Daily Inflows to STA1W distribution works from the EAA and L8 basins during the hurricane periods.
- Middle: Daily outflows to Refuge from STA1W and untreated bypass during the hurricane periods.
- Bottom: Long-term record of daily inflows to STA1W or Refuge from EAA/Lake and L8 Basins (May 1994 - March 2005)

Runoff from the L8 basin was a significant component of the flows entering the STA1W distribution works during the hurricanes. Daily inflows during the hurricane period do not appear a-typical of the longterm record. L8 runoff typically accounts for a significant portion of the total inflow flow during periods when S5A runoff is also high. Risks of untreated bypass to the Refuge, impaired STA performance, STA vegetation damage caused by high water levels, and intrusion of phosphorus loads into the Refuge marsh are also highest during these high-flow periods. STA1W & 1E designs assumed that L8 flows would be diverted to other basin(s) prior to full-scale operation. Alternatives for handling L8 runoff are being explored in the current EAARS basin feasibility study