Issue Paper: Analysis of the October 2007 Excursion
Of The Long-Term Phosphorus Levels for the Refuge
May 8, 2008

INTRODUCTION

The purpose of this Issue Paper is to address questions raised at the December 2007 Technical Oversight Committee (TOC) meeting regarding the cause of the October 2007 Refuge excursion and whether it indicates a need for the State and Federal Parties to alter their agreed upon course of remedies presently being implemented[1]. For October 2007, the geometric mean phosphorus concentration of the 14-station monitoring network in the Refuge was 8.4 ppb, which exceeded the long-term level of 7.2 ppb. By itself, the October 2007 excursion does not constitute an exceedance (and a potential violation of the Settlement Agreement) because, by definition, that requires two excursions within 12 consecutive sampling events. In this case, however, it makes sense to evaluate the October 2007 excursion in context with the phosphorus levels measured in September 2006. Then, the geometric mean phosphorus concentration of the 14-station monitoring network was 8.2 ppb. Although the long-term levels did not go into effect until December 31, 2006, if they had been in effect in September 2006, the observed levels would have exceeded the predicted long-term levels as well (observed geometric mean of 8.2 ppb compared to the long-term level of 7.8 ppb). Consistent with Appendix B, these two excursions -- having taken place within 12 consecutive sampling events -- would have constituted an "exceedance" within the scope of Appendix B and a potential violation of the Consent Decree[2]. This paper summarizes data and findings relevant to interpreting these events under the auspices of the Consent Decree.

TECHNICAL DISCUSSION

The objective of the Settlement Agreement's long-term phosphorus levels for the Refuge is to assure that mean phosphorus concentrations across the 14-station monitoring network are maintained at levels at or below those observed at stations LOX5, LOX6 and LOX16 (the "Clean 3") during the 1978 to 1983 period of record[3] (see Figure 1 for a map of the stations). At that time, the Clean 3 stations had the lowest geometric mean TP concentrations of all sampling stations (with geometric mean TP concentrations generally at the classical phosphorus limit for oligotrophic waters of 10 parts per billion) and were assumed to be the stations least impacted by external loading. As provided in Appendix B of the Consent Decree, the Refuge's long-term phosphorus levels represent the 10% rejection level of the predicted mean phosphorus

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[1] This paper was prepared by technical staff and a consultant of the South Florida Water Management District and the Florida Department of Environmental Protection. The TOC representative for the Department did not participate in its preparation.
[2] 12 consecutive sampling events ranged from August 2006 – October 2007, as April-June 2007 were excluded because the stages were less than 15.42 feet NGVD.
[3] See Consent Decree, App. B, page B-3.

concentrations at the Clean 3 sites as a function of average stage during the baseline period of record.[4] *See generally,* Everglades SWIM Plan (1992), App. E at E-16 to E-24.

The Appendix B compliance methodology, however, was also predicated upon several implicit assumptions believed to have existed at the time of the Decree's drafting. Those assumptions include:

1. Large scale reductions of phosphorus inflows would prevent exceedances;
2. Using surface water elevation (stage) in the compliance equation accurately reflects the relationship between marsh water depth and phosphorus concentrations;
3. The "Clean 3" sites are the three least impacted stations in the Refuge;
4. The strong inverse relationship between stage and phosphorus forming the basis for the compliance equation was real and would remain constant; and
5. A model built to predict month-to-month changes in phosphorus levels could be based on a data set without month-to-month data.

As discussed below, recent data strongly suggest that the water quality entering and within the Refuge has improved to the point that exceedances should not occur. More importantly, data collected in the Refuge over the past 14 years has shown that many of the assumptions upon which the Appendix B compliance methodology was predicated are incorrect. Based on these findings, neither the October 2007 excursion -- nor any similar future excursions -- provide grounds to alter the Parties' current suite of remedies.

Assumption 1: Large scale reductions of phosphorus inflows would prevent exceedances.

Intuitively, reducing the amount of a pollutant entering a waterbody should result in a corresponding improvement in ambient water quality. At the time of the October excursion, however, phosphorus loading to the Refuge was at an all time low. The 12 month phosphorus load entering the Refuge for the 12 months ending in October 2007 was 10.2 metric tons. This is the lowest in the history of Refuge inflow records dating back to 1979 (see Figures 2a and 2b). This 12-month load represents a 90% reduction in loads compared to the 1979-88 period of record.

Similarly, average phosphorus concentrations at the 14-station monitoring network during the September 2006 to October 2007 time period were lower than the mean concentrations used to derive the long-term limits. The adjusted geometric mean for the 1978 to 1983 period of record

[4] To expand the amount of data that could be utilized in developing the interim and long-term levels, the five marsh sampling events during the 1978-79 OFW baseline year were augmented with nine additional sampling events from 1980 through 1983 the results of which were statistically "adjusted" to remove the perceived influence from increased anthropogenic loading and to project back to the ambient TP concentrations that may have existed during the 1978-1979 baseline year.

at the Clean 3 sites (LOX5, LOX6 and LOX16[5]) was 7.9 ppb (see Table 1). For the 12 compliance sampling events that encompass both the September 2006 and October 2007 excursion, the geometric mean phosphorus concentration at the 14-station network was 7.7 ppb[6] (see Table 2 and Figure 3). Notwithstanding the significant drop in phosphorus loading and improved water quality, if the long-term levels had been in effect between September 2006 and October 2007, there would have been a potential violation.

With phosphorus loading reduced dramatically, and water quality as good as that used to create the compliance equation, a review of available data and information suggests that factors other than external loading are responsible for the excursions of the long-term limit.

Assumption 2: Using surface water elevation (stage) in the compliance equation accurately reflects the relationship between marsh water depth and phosphorus concentrations

Appendix B explains that the Refuge compliance methodology is based on "the observed correlation between marsh total phosphorus concentrations and stage" that existed in the 1978-1983 baseline data set. App. B at B-1. As discussed above, the compliance equation is, in effect, a regression analysis of that correlation based on the historic phosphorus levels measured at the Clean 3 sites and the average stage, measured in terms of feet above mean sea level (NGVD), at the Refuge's three stage gauges. *See*, App. B, Attachment II.

Although the Consent Decree speaks of an "observed correlation" between ***stage*** and total phosphorus, in reality the correlation is between phosphorous concentrations and the ***depth of surface water in the Refuge.*** *i.e*., the depth of the water column (sediments to surface). The height of a water body's surface above sea level (*i.e.,* stage), by itself, has no direct bearing on the concentration of phosphorus (or any other constituent, for that matter) in the water beneath it. Instead, it is the depth of the water that can influence the concentration of phosphorus.. As water gets deeper in the Refuge, phosphorus levels can potentially decrease due to dilution and processing by the marsh. In contrast, when the water gets shallower, the phosphorus can become more concentrated and levels increase.

This does not mean, however, that the elevation of the marsh's surface above sea level is irrelevant. Because data on actual measured water depths for the Refuge during the baseline period do not exist, stage serves as a critical ***surrogate*** for water depth for purposes of quantifying the relationship between phosphorus and water depth. Thus, even though we don't know what the precise water depth was when there was a stage reading of 16.0 feet NGVD, we do know that it -- whatever "it" was -- correlated to an estimated long-term phosphorus limit of 12.5 ppb. Similarly, while we don't know what the water depth was when there was a stage reading of 16.5 feet NGVD, we do know that it was 0.5 feet deeper than that which existed when

[5] In addition to the "LOX#" nomenclature, stations in the Refuge are also referred to as "CA1-#".
[6] Average phosphorus concentrations during recent periods of record were calculated by using only those monthly averages when stages were at or above 15.42 feet NGVD.

the stage was 16.0 feet NGVD and, equally important, that it had correspondingly lower predicted long-term phosphorus limit of 9.7 ppb. Thus, by using stage as a surrogate for water depth, we can evaluate the relationship between phosphorus and water depth even in the absence of water depth data.[7]

Recognizing that stage is only a surrogate for water depth becomes important when assessing modern day compliance using Appendix B. As discussed above, stage can be used to quantify the inverse relationship between phosphorus levels and water depth even in the absence of data documenting the latter. As shown below, however, stage's usefulness as a surrogate is entirely dependent upon its relationship with water depth remaining static with time. If that relationship changes (if, for example, a stage of 16.0 feet NGVD today equates to a shallower water depth than it did during the baseline period), then the underlying relationship between phosphorus levels and stage that forms the basis of the Appendix B compliance method is shifted. Therefore, the original relationship can no longer be used to accurately predict the expected phosphorus concentration.

For example, assume that during the baseline period a stage of 16.0 feet NGVD corresponded to a water depth of one foot with an estimated long-term phosphorus limit of 12.5 ppb (approximating the theoretical exercise in footnote 5, *supra*). If, over the past 30 years, the ground level at the bottom of the Refuge increased by 0.5 feet due to peat accretion, but there was no corresponding increase in surface water elevation, the actual water depth would have decreased by half a foot while the stage level remained constant. Because compliance is based solely upon stage readings, not actual depth, the current stage reading of 16.0 feet NGVD would still result in a long-term limit of 12.5 ppb, even though the actual water depth experienced in the marsh decreased by half a foot to the baseline equivalent of 15.5 feet NGVD (which should have generated a long-term limit of 16.5 ppb). The original stage/phosphorus relationship would underestimate the compliance limit by 4 ppb solely as a result of a change is ground elevation, making compliance more difficult without any change in inflow concentrations or loads.

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[7] Determining the average water depth in any natural water body is not an easy task. This is especially true in the case of a 140,000 acre marsh, such as the Loxahatchee National Wildlife Refuge, where there is a substantial, i.e. three feet or more, north-south gradient in ground elevation underneath the marsh's surface water.

Based on Refuge hydrologic model simulations done for the 1970 to 1985 period (Richardson 1991), however, it was estimated that when average stage at the Refuge's three stage gauges was less than 15.4 feet, the average water depth at the compliance monitoring network was less than six inches. Taking these simulation results one step further, this would mean that, theoretically, the average water depth at the compliance network station would be zero when the average stage at the three stage gauges measured 14.9 feet, a depth of 1.1 feet when the average stage was 16.0 feet, and a depth of 1.6 feet when the average stage was 16.5 feet (the key word in the preceding discussion being "theoretically").

A similar result happens even if there is a corresponding increase in the height of the surface water. Thus, if, over the past 30 years the ground level in the Refuge increased by 0.5 feet but, this time, there was a corresponding increase in the average height of the water's surface, modern day compliance would be based on a stage reading of 16.5 feet NGVD (which results in a predicted long-term limit of 9.7 ppb.) In reality, though, the depth of the water and its associated phosphorus levels have not changed. The marsh is still one foot deep but the equation generates a phosphorus limit as if were now 1.5 feet deep. And, instead of the 12.5 ppb observed during the baseline, the long-term limit is now 9.7 ppb. Once again, the original stage/phosphorus would underestimate the compliance limit by 2.8 ppb making compliance more difficult even though the measured water depth and phosphorus concentration and loads have not changed.

That sediment builds up on the bottom of the Refuge is not really in dispute; rather, it is the rate by which it accumulates. Accretion of vegetation biomass (peat) is the primary mechanism of soil formation in the Everglades.[8] Rates of soil accretion vary, however, with vegetation type, nutrient loading and other environmental conditions. A long-term geologic rate of accretion may be approximated by dividing the average peat thickness in the Refuge (11.5 feet) by the approximate age of the peat (4000 years). This results in a soil accretion rate of 0.00288 feet/yr (Gleason and Ogden 1976). Short-term soil accretion rates can be much higher, though, as have been seen in the Stormwater Treatment Areas which receive significantly higher phosphorus concentrations and loads than those experienced by the Everglades historically. A short-term accretion rate of 0.0184 feet/yr has been estimated for STAs based upon a period of record of 1995-1999 (Chimney et al. 2000). Applying these rates to the 30 years that have lapsed since the 1978 baseline period, the average ground elevation in the Refuge would have increased between approximately 0.09 feet and 0.55 feet based on long-term and short-term accretion rates, respectively. A third method for estimating soil accretion would be based on the mass of phosphorus accumulated as estimated by the effective settling rate. Assuming a settling rate of 10 m/yr, (consistent with the assumption made by Walker (2005)), a 0.29 feet average increase in Refuge ground elevation is estimated to have occurred since 1978 (based on the geometric mean phosphorus concentrations at the 14-station network during that time period (see Table 3)).

As depicted in Table 4, if prior stage measurements are adjusted to reflect an increase of ground surface elevation of 0.09 feet, 0.29 feet, and 0.55 feet since the baseline, a number of excursions and exceedances disappear. In the case of a 0.29 feet increase in ground elevation, the potential exceedance of October 2007 and September 2006 goes away, as well as all other exceedances since October 2000. The same is true in the case of a 0.55 feet increase. For the 0.09 feet increase the excursions/exceedances would remain the same as the unadjusted stages.[9]

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[8] *See, e.g.*, Paragraph 3B of Settlement Agreement: "Excess phosphorus accumulates in the peat underlying the water, alters the activity of microorganisms in the water, and disturbs the natural species composition--of the algal mat (periphyton) and other plant communities in the marsh."
[9] As discussed above, relatively little data are available measuring actual changes in depth at the three Refuge stage gauges. The USGS does have ground elevation data, however, for changes in ground elevation at gauges 1-7 and 1-9 between 1991 and 2005. For gauge 1-7, the USGS data

Assumption 3: The "Clean 3" sites are the three least impacted stations in the Refuge.

As depicted in Table 7 of Appendix E to the 1992 Everglades SWIM Plan, monitoring sites LOX5, LOX6 and LOX16 had the lowest mean phosphorus concentrations during 1978 to 1983 sampling events with levels of 10.4 ppb, 10.9 ppb, and 10.2 ppb, respectively. For the 12 months beginning June 1978, the geometric mean phosphorus concentration of the "Clean 3" was 7.7 ppb (excluding dates when the stage was less than 15.4 ft NGVD). After adjustments for the 1979-1983 sampling events, the geometric mean of the "Clean 3" for the entire period of record was 7.9 ppb (see Table 10 of Appendix E to the 1992 Everglades SWIM Plan, repeated as Table 5 below).

As shown in Table 1, the geometric mean phosphorus concentration at the "Clean 3" since the 2004 hurricanes (i.e., January 2005 – November 2007) is 7.3 ppb, and for the 12 compliance sampling events from September 2006 through November 2007, the geometric mean is also 7.3 ppb. The "Clean 3," however, are no longer the cleanest three monitoring stations in the Refuge. The cleanest 3 since the diversion of S-6 inflows to the Refuge in June 2001 have been LOX6, LOX14 and LOX15 (with a geometric mean concentration of 7.0 ppb)(*see* Table 6). The cleanest 3 after the 2004 hurricanes have been LOX6, LOX14 and LOX16 (with a mean concentration of 7.0 ppb). The cleanest 3 since September 2006 have been LOX6, LOX11 and LOX14 (with a geometric mean concentration of 6.7 ppb).

These data are important for several reasons. First, they undermine the original assumption that the "Clean 3" are the least impacted stations in the Refuge and, as a result, their low phosphorus levels during 1978-1983 may be attributed to other causes, such as normal spatial and temporal variability. They also suggest that physical or hydrologic changes to the Refuge since 1983 have potentially altered the hydrological flow patterns within the Refuge, thereby affecting the phosphorus concentrations at the "Clean 3" and other stations. Finally, at a minimum, these data reinforce the conclusion that the water quality in the Refuge is as good as, or better than, the base period.

Assumption 4: The strong inverse relationship between stage and phosphorus forming the basis for the compliance equation was real and would remain constant.

As discussed above, the Appendix B compliance methodology assumes that there is a strong inverse relationship between stage and phosphorus levels. This assumption was based on a regression analysis of the combined monthly geometric means measured at the "Clean 3" with the average stage measured at the three stage gauges in the Refuge (gauges 1-7, 1-9 and 1-8C).

In order to evaluate the presumed strength of this inverse relationship, several additional stage to phosphorus level regression analyses were conducted. Ideally, the best way to quantify a phosphorus – stage relationship would be to evaluate stage and phosphorus data collected at the

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indicate an increase of 0.72 feet, while for gauge 1-9, USGS data indicate a decrease of 0.09 ft over the same time period, for an average increase of 0.36 ft in 14 years (USGS 2008).

same time at the same monitoring station, thereby minimizing the effect of other variables that can affect phosphorus concentrations over space and time. Such data does not exist for the Refuge. Nor, as depicted in Figure 1, are the "Clean 3" sites the monitoring stations closest to the three stage gauges (in fact, "Clean 3" stations LOX14 and LOX15 are several miles from the closest stage gauges.)

As a result, individual phosphorus-stage regression analyses were done between the three Refuge monitoring stations that are closest to the three stage gauges (in this case, LOX8, LOX11, and LOX-6 which are very close to the stage gauges 1-7, 1-9, and 1-8C, respectively). In addition, individual phosphorus-stage regression analyses were done between the "Clean 3" sites and the closest stage gauge (here, LOX5, LOX6, and LOX16 were compared to 1-7, 1-8, and 1-9, respectively). Finally, because the Appendix B compliance methodology relies upon a regression analysis of the ***combined*** geometric mean phosphorus concentration measured at the "Clean 3" and the ***average*** stage measured at the three stage gauges, a third regression analysis was done between the combined geometric mean phosphorus concentrations measured at LOX8, LOX11, and LOX6 with the average stage measured at the three stage gauges (LOX8, LOX11, and LOX6 being the closest monitoring stations to the stage gauges.) In each case, the regression analyses used phosphorus concentrations and stages measured during the 1978-1983 baseline period, as well as the same detrending approach described in the Everglades SWIM Plan (1992).

The results (Table 7) indicate that the relationships between stage gauges and their closest monitoring stations are very weak, with factors other than stage accounting for 67% to 85% of the observed variability in the monthly phosphorus concentrations. In all cases, the relationship was found to be not statistically significant at the 90% and 95% confidence levels. The additional regression analyses between the Clean 3 sites and their nearest stage gauge (Table 7) showed that only the relationship between LOX16 and LOX9 was found to be significant at the 95% confidence level. Strangely, the R-squared values got better with greater distance from the stage gauge.

Finally, using the combined approach similar to that used as the basis for the Appendix B equation, but substituting the three closest monitoring stations (LOX6, LOX8, and LOX11) for the Clean 3, the defined relationship between average stage and geometric mean phosphorus levels improves, and is statistical significant at the 90% confidence level, but not at the 95% level of confidence. However, it should be noted that the relationship only accounts for approximately 40 percent of the observed variability with other factors (e.g., such as sampling errors, natural phenomena) accounting for the remaining 60 percent of the variability.

These findings create questions about the continued accuracy and applicability (and even the existence) of the stage-phosphorus relationship captured in the long-term equation. The fact that stage – phosphorus relationships become slightly stronger as the distance between water quality monitoring stations and stage gauges increased is not readily explainable.

Assumption 5: A model built to predict month-to-month changes in phosphorus levels could be based on a data set without month-to-month data.

The compliance equation was derived using very limited data collected at irregular intervals and at varying frequencies during the 1978 – 1983 period. The most frequent sampling interval was once every other month, but some sampling events were as much as 15 months apart (see Table 5). In addition to irregular sampling frequency, samples were also collected randomly during periods when the Rim Canal/marsh stage gradient was rising and falling at varying rates.

The irregular water quality data was then paired with the stage data to derive the compliance equation that is used to predict phosphorus levels on a monthly basis and during times of both rising and falling stage gradients between the marsh and the Rim Canal. Implicit in the decision to use the equation this way are the assumptions that month-to-month changes in phosphorus levels could be based on such irregular data and that marsh phosphorus concentrations respond quickly to changes (both rising and falling) in stage/water depth. Sampling data collected at the 14-station network since 1994 suggest that these assumptions were not justified. In the months following an excursion, phosphorus concentrations typically decrease to levels at or below the predicted concentration for the prior month. This pattern repeated itself in the September-October 2006 and October-November 2007 sampling events (see Table 2 below; WMD 161). The long-term level for September 2006 was 7.8 ppb; for the following month the measured concentration was 7.5 ppb. The long-term level for October 2007 was 7.2 ppb; for the following month, the measured concentration decreased to 7.0 ppb. These observations suggest that marsh biogeochemical processes take more than a month to stabilize after a change in ambient conditions. If so, the equation has no means to accommodate this lag time response, an observation essential to bear in mind as one attempts to interpret apparent exceedances of the long-term limit.

CONCLUSIONS

Analysis of the environmental conditions leading up to the October 2007 excursion indicate that external phosphorus loading was not a factor in the excursion. The data suggest that water quality in the Refuge is as good as or better than the 1978-1979 base period used in establishing the Outstanding Florida Water designation, represented by the adjusted geometric mean phosphorus concentration of the “Clean 3” sites. While the excursion is within the expected Type I error rate of 10% and could be explained as a false positive, further examination suggests that the excursion may be attributable to the failure of multiple assumptions underlying the Appendix B compliance methodology, most notably those relating to the continued validity and strength of the inverse stage-phosphorus relationship in the Refuge.

Under these circumstances, neither the October 2007 excursion -- nor any similar future excursions -- provide grounds to alter the Parties’ current suite of remedies.

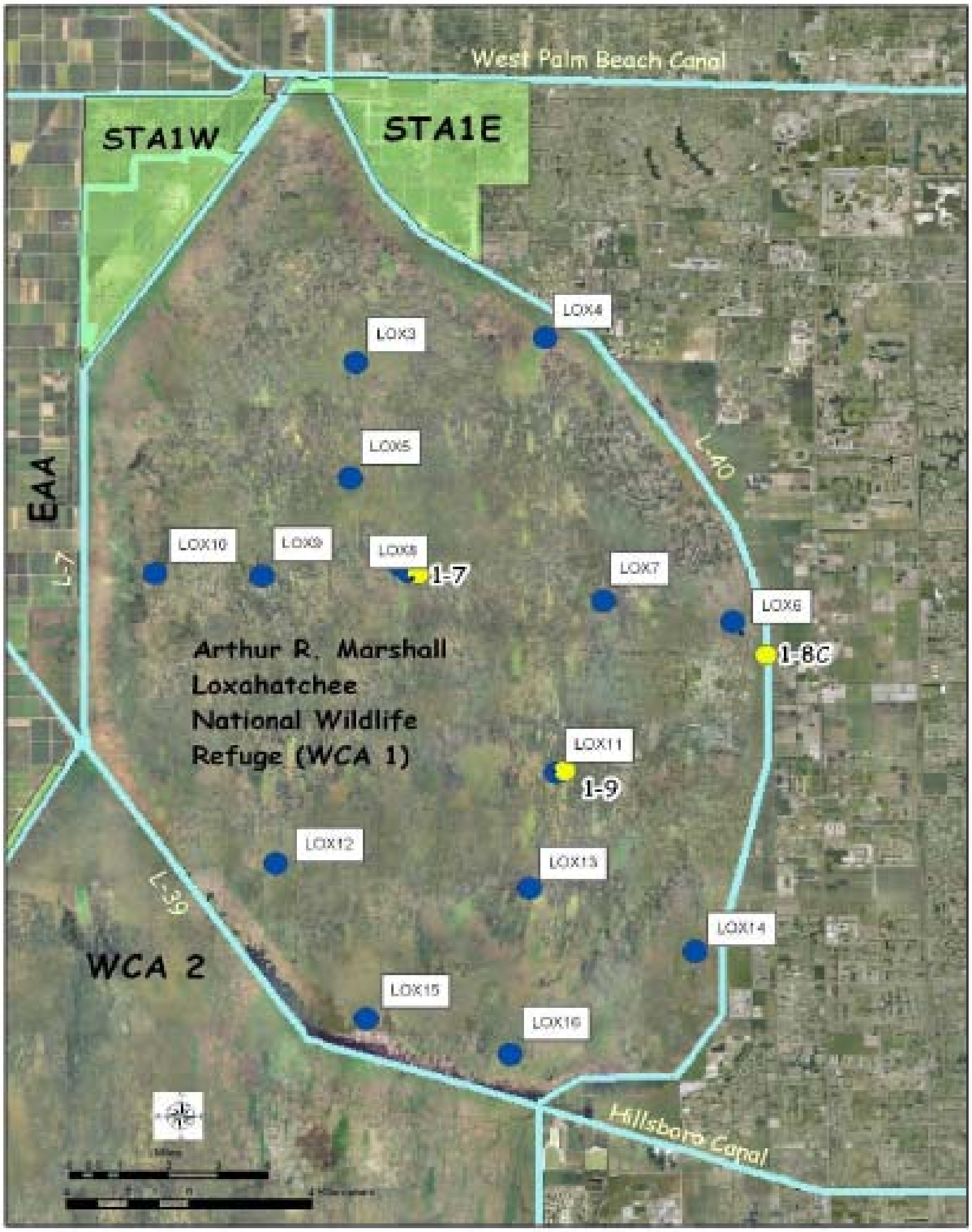

Figure 1. Map Showing the 14 TP Compliance Monitoring Stations and the Location of the Three Stage Gauges.

Table 1. Comparison of Recent TP Concentrations with the Base Period.

Period	Clean 3 TP Conc. (ppb)
1978-1983 (adjusted)	7.9
Since 2004 hurricanes (1/2005 - 11/2007)	7.3
Last 12 sampling events (9/2006 - 11/2007)	7.3

Original Clean 3 = CA1-5, CA1-6, CA1-16
Exclude dates when stage<15.42

Table 2. Summary of Refuge Phosphorus Concentrations (ppb).

Date	TP Geomean (ppb)	Long-Term Level (ppb)	Average Stage (feet)
Sep-2006	**8.2**	**7.8**	**16.96**
Oct-2006	7.5	8.6	16.74
Nov-2006	7.4	9.4	16.56
Dec-2006	5.6	11.0	16.23
Jan-2007	6.9	9.3	16.57
Feb-2007	6.2	10.4	16.34
Mar-2007	7.3	11.8	16.10
Apr-2007	*8.0*	***NA***	*15.30*
May-2007	*n/a*	***NA***	*14.68*
Jun-2007	*13.6*	***NA***	*15.37*
Jul-2007	10.4	13.5	15.86
Aug-2007	10.1	10.5	16.33
Sep-2007	8.5	9.2	16.59
Oct-2007	**8.4**	**7.2**	**17.26**
Nov-2007	7.0	7.2	17.19
Mean of last 12	7.7		

Notes: Sampling dates highlighted in yellow exceeded the long-term level.
Sampling dates highlighted in green were excluded because stage was less than 15.42 feet NGVD.

Table 3. Estimate of Increase in Ground Elevation Due to Soil Accretion.

Water Year May-Apr	14-station TP conc[1] ppb	Wet Fraction[2] %	Annual mass depostion rate $mg/m^2/yr$	Annual mass deposition metric tons/yr	New soil volume cubic meters	New soil accretion meters	Cumulative accretion inches
1979	9.66	70%	67.6	35.76	1430247	0.003	0.1
1980	10.64	70%	74.5	39.41	1576293	0.003	0.2
1981	10.14	70%	71.0	37.54	1501495	0.003	0.3
1982	10.14	70%	71.0	37.54	1501495	0.003	0.4
1983	10.14	70%	71.0	37.54	1501495	0.003	0.6
1984	10.14	70%	71.0	37.54	1501495	0.003	0.7
1985	10.14	70%	71.0	37.54	1501495	0.003	0.8
1986	10.14	70%	71.0	37.54	1501495	0.003	0.9
1987	10.14	70%	71.0	37.54	1501495	0.003	1.0
1988	10.14	70%	71.0	37.54	1501495	0.003	1.1
1989	10.14	70%	71.0	37.54	1501495	0.003	1.2
1990	10.14	70%	71.0	37.54	1501495	0.003	1.3
1991	10.14	70%	71.0	37.54	1501495	0.003	1.5
1992	10.14	70%	71.0	37.54	1501495	0.003	1.6
1993	10.14	70%	71.0	37.54	1501495	0.003	1.7
1994	7.02	70%	49.1	25.98	1039084	0.002	1.8
1995	8.88	91%	80.8	42.75	1710011	0.003	1.9
1996	6.68	91%	60.8	32.15	1286058	0.002	2.0
1997	5.94	91%	54.0	28.58	1143342	0.002	2.1
1998	8.26	91%	75.2	39.78	1591367	0.003	2.2
1999	8.38	91%	76.3	40.34	1613571	0.003	2.3
2000	10.75	91%	97.8	51.75	2070086	0.004	2.5
2001	9.94	91%	90.5	47.86	1914403	0.004	2.6
2002	9.27	91%	84.4	44.63	1785014	0.003	2.7
2003	8.17	91%	74.4	39.35	1574020	0.003	2.8
2004	8.41	91%	76.5	40.46	1618581	0.003	3.0
2005	12.13	91%	110.4	58.39	2335659	0.004	3.1
2006	7.20	91%	65.6	34.68	1387048	0.003	3.2
2007	7.90	91%	71.9	38.04	1521725	0.003	3.4
2008	8.41	91%	76.5	40.49	1619656	0.003	3.5

Notes 1. TP concentration for WY81-93 set equal to geometric mean of WY1979 and WY1980.
TP concentration for WY1994 based on January-April 1994 data.
2. From U.S. Exh. 89 (Walker rebuttal report 8/2005), page 7.

Area of Refuge (km^2) = 529
Assumed soil TP concentration (mg/kg) = 250
Assumed effective settling rate (m/yr) = 10
Assumed bulk density (g/cc) = 0.10

Table 4. Review of Previous Exceedances Using Adjusted Stage-TP Relationship.

Date	Average stage ft NGVD	Observed Geometric Mean TP Conc, ppb	Predicted Compliance Level TP Conc, ppb	Exceed-ance?	Adjust-ment ft	Adjusted[1] Predicted TP Conc ppb	Exceedance?
Oct. 2001	17.24	8.8	8.3	Yes	0.09	8.3	Yes
					0.29	9.1	No
					0.55	10.4	No
July 2002	16.82	11.2	9.7	Yes	0.09	10.2	Yes
					0.29	11.3	No
					0.55	13.1	No
Sep.2003	17.23	8.8	8.3	Yes	0.09	8.3	Yes
					0.29	9.1	No
					0.55	10.5	No
Aug. 2004	16.00	17.5	15.4	Yes	0.09	16.2	Yes
					0.29	18.4	No
					0.55	21.9	No
Sep. 2006	16.96	8.2	*Long-term: 7.7*	No	0.09	*8.0*	No
					0.29	*8.8*	No
					0.55	*10.0*	No
Oct.2007	17.26	8.4	*7.2*	Potential[2]	0.09	*7.2*	Potential[2]
					0.29	*7.7*	No
					0.55	*8.7*	No

Notes: 1. Adjusted by adding 0.08, 0.29 and 0.55 ft to the stage and recalculating the compliance level.
Adjusted interm levels shown for dates prior to September 2006.
Adjusted long-term levels are shown for September 2006 and October 2007.
2. The October 2007 excursion would have been an exceedance if the long-term levels had been in place in September 2006.

Table 5. Excerpt from 1992 Everglades SWIM Plan Appendix E (Note: "Stations CA1-5, 6 & 16" refer to stations LOX5, LOX6 and LOX16).

TABLE 10. CALCULATION OF LONG TERM PHOSPHORUS LIMITS FOR LOXAHATCHEE NATIONAL WILDLIFE REFUGE 10% REJECTION LIMIT ON 14-STATION GEOMETRIC MEAN [tp] ppb ADJUSTED TO 1978-79 BASELINE FOR ANY GIVEN MEAN STAGE

Statistical Analysis of Stations CA1-5,6 & 16 geometric mean:

yymm	base year	Geometric Mean [tp] ppb	S Stage (ft)	Log Linear Fitted [tp]	Predicted Long Term Mean at Stage S	10% Rejection Limit [tp]
7806	1	15.4	15.70	9.2	9.2	14.8
7808	1	6.0	15.98	7.9	7.9	12.6
7810	1	5.2	16.46	6.1	6.1	9.9
7812	1	7.2	16.63	5.6	5.6	9.1
7905	1	7.7	15.42	10.7	10.7	17.5
7908	0	13.4	15.60	15.1	9.7	15.7
7910	0	5.6	17.11	6.7	4.3	7.3
8002	0	9.2	15.91	12.8	8.2	13.2
8007	0	15.6	15.53	15.7	10.1	16.4
8009	0	12.8	16.03	11.9	7.7	12.3
8012	0	14.2	15.59	15.1	9.8	15.8
8204	0	25.9	15.46	16.3	10.5	17.1
8212	0	13.2	16.45	9.5	6.1	9.9
8307	0	11.5	15.77	13.8	8.9	14.3

Geometric mean = 7.9

ON THE NATURAL LOG SCALE:

$R^2 = .62224$

Standard error of estimate: $s = .31131$

Fitted [tp] $= 2.35 - .4380(\text{base} - .36) - .541156(S - 15.97)$

$= a + b \cdot (\text{base}) + c \cdot S$

$= 11.1553 - .4380 \cdot (\text{base}) - .541156 \cdot S$

Standard errors: ± 2.7173 $\pm .1745$ $\pm .170359$

Adjusted [tp] $= (a + b) + c \cdot S$

$= 10.7172 - .541156 \cdot S$

Standard errors: ± 2.7359 $\pm .170359$

$$\text{Upper Limit} = \text{Adjusted [tp]} + t\sqrt{[s^2 + s^2/n + \text{var}(b) \cdot (1 - .36)^2 + \text{var}(c) \cdot (S - 15.97)^2 + 2 \cdot \text{cov}(b,c) \cdot (1 - .36) \cdot (S - 15.97)]}$$

$$\text{Log Limit} = 10.7172 - .541156 \cdot S + 1.372 \cdot \sqrt{[7.5819 - .9310 \cdot S + .02902216 \cdot S^2]}$$

Figure 2a. Annual Phosphorus Loads Entering the Refuge (WY1979-WY1999).

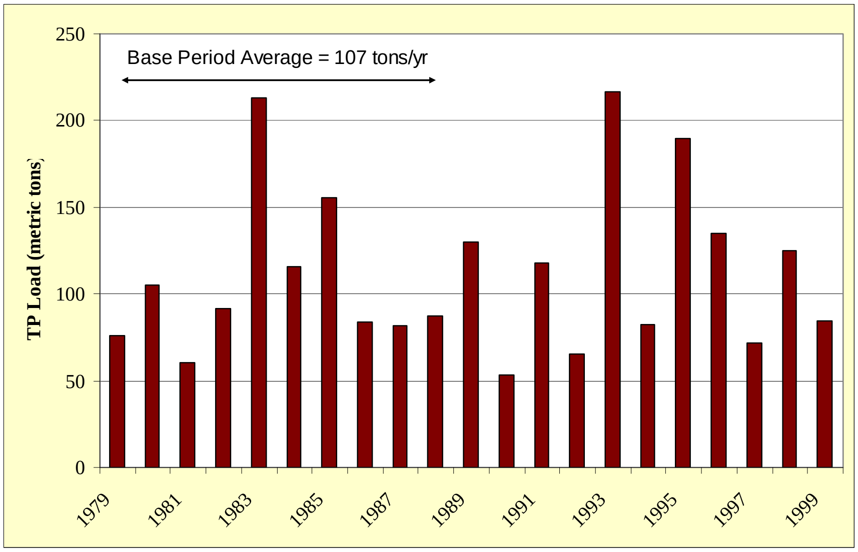

Figure 2b. 12-Month Rolling Average Inflows to the Refuge (January 2000 – November 2007).

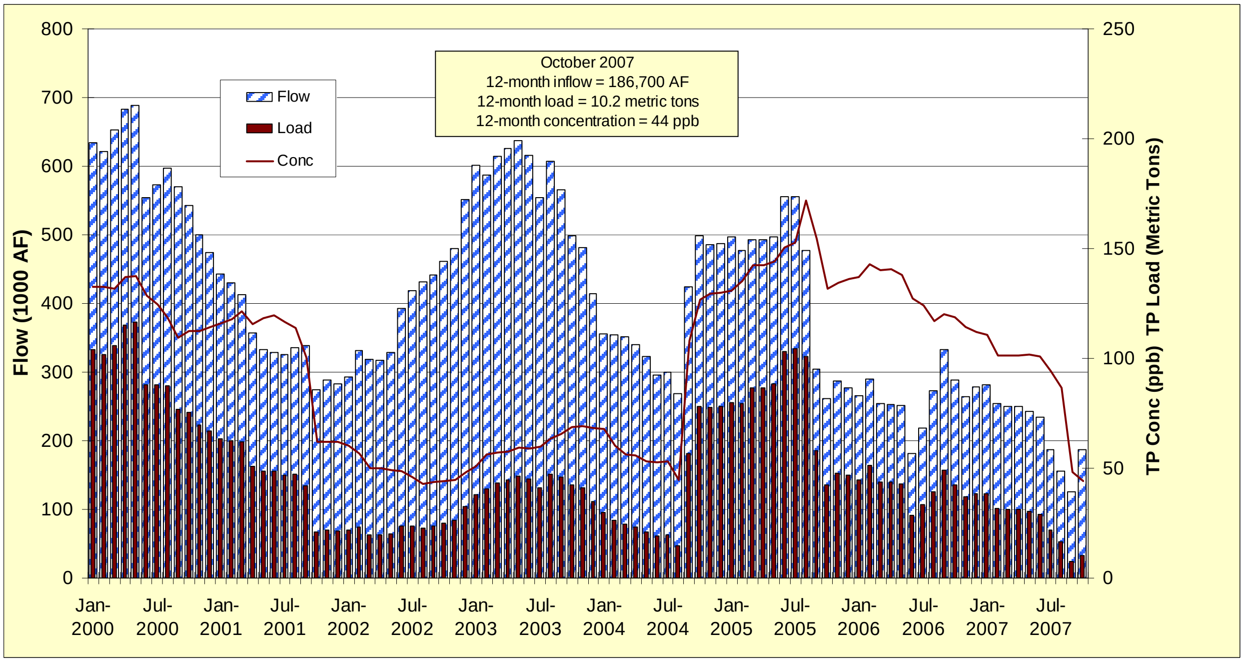

Table 6. Comparison of TP Concentrations at Clean 3 Sites.

Period	Original Clean 3 TP Conc. (ppb)	Clean 3 TP Conc. (ppb)
1978-1983 (adjusted)	7.9	7.9
Since S-6 Diversion (6/2001 - 11/2007)	8.0	7.0
Since 2004 hurricanes (1/2005 - 11/2007)	7.3	7.0
Last 12 sampling events (9/2006 - 11/2007)	7.3	6.7

Original Clean 3 = CA1-5, CA1-6, CA1-16
Exclude dates when stage<15.42

Table 7. Summary of Stage-Phosphorus Regression Analyses.

LOX8 TP versus 1-7 stage (6/1978 – 07/1983)

Ln (TP) = -0.279 Stage – 0.588 Base + 14.647 r^2 = 0.216 p = 0.261

LOX11 TP versus 1-9 stage (6/1978 – 07/1983)

Ln (TP) = -0.352 Stage – 0.485 Base + 8.219 r^2 = 0.331 p = 0.133

LOX6 TP versus 1-8C stage (6/1978 – 07/1983)

Ln (TP) = -0.229 Stage – 0.474 Base + 6.201 r^2 = 0.151 p = 0.408

LOX5 TP versus 1-7 Stage (06/1978-07/1983)

Ln(TP) = -0.660 Stage – 0.488 Base + 13.153 r^2 = 0.426 p = 0.062

LOX16 TP versus 1-9 Stage (06/1978-07/1983)

Ln(TP) = -0.843 Stage – 0.445 Base + 15.849 r^2 = 0.493 p = 0.020

where Base is the time adjustment variable

Only the LOX16 relationship is significant with stage and detrending variable (Base).

Geometric Mean TP (LOX6, LOX8 and LOX11) versus Mean Stage (1-7, 1-9, 1-8C)

Ln (TP) = -0.502 Stage – 0.511 Base + 10.71 r^2 = 0.415 p = 0.052

Figure 3. A Summary of Geometric Mean Phosphorus Concentrations at the 14 Compliance Sites in the A.R.M. Loxahatchee National Wildlife Refuge from 1999 to November 2007. A Significant Trend of Decreasing TP Concentrations is Evident.

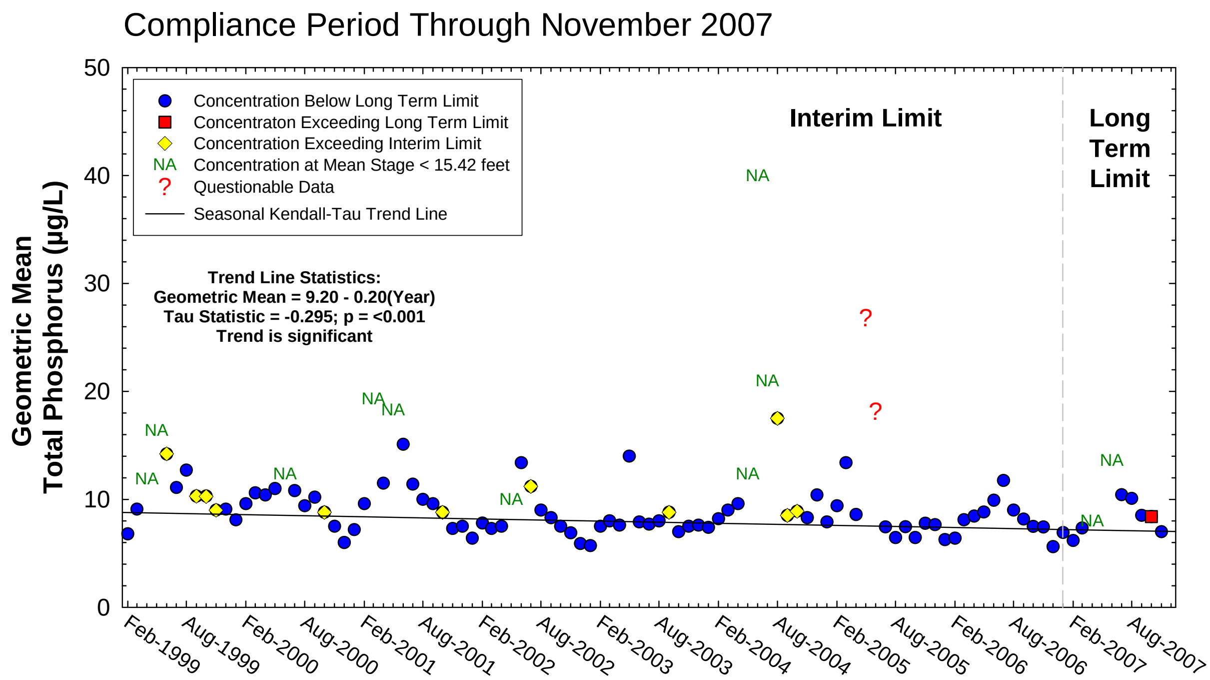

Figure 4. Time Plot from January 1978 through January 1984 Showing the Difference in Stage Elevations between the Canal and Marsh as a Measure of Potential Water Movement. Grayed-Out area Between 0.2 and -0.2 Feet Indicates an Area of Uncertainty Regarding Water Movement. The Yellow Dots Show When Sampling Events Occurred for the Baseline Data Set.