Technical Support Document:

Derivation of the Water Quality Based Effluent Limit for Total Phosphorus in Discharges to the Everglades Protection Area

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1 Introduction

This report documents the method used to derive the Water Quality Based Effluent Limitation (WQBEL) that will be applied to all permitted discharges to the Everglades Protection Area (EPA) to assure that such discharges do not cause or contribute to exceedances of the 10 parts per billion (ppb) total phosphorus (TP) criterion (expressed as a long-term geometric mean) established under 62-302.540, Florida Administrative Code (F.A.C.). The WQBEL derivation presented herein is based on the following assumptions:

1. The WQBEL will be applied at each discharge structure. In the case of multiple discharge structures for a Stormwater Treatment Area (STA), the WQBEL will be applied to the flow-weighted mean (FWM) TP concentration across all discharge points and pump stations (including any diversions that cannot be attributed to low flow water supply deliveries or rainfall in the source basins tributary to the STAs which exceeds the maximum annual rainfall that occurred during the period of record used for deriving the WQBEL). By deriving a WQBEL applicable to the discharge points, the complexities associated with monitoring compliance in areas of the marsh not represented by the existing TP criterion assessment monitoring network are avoided and assurances are provided that all portions of the marsh are adequately protected. Application of the WQBEL proposed herein to the discharges to the EPA will not alter the monitoring required by the TP criterion rule (62-302.540, F.A.C.) in any manner.

2. Since the WQBEL is applicable to the point of discharge, changes in concentration between the discharge point and the location where the discharge enters the marsh are ignored for the purpose of this derivation. In most cases, the discharge through a canal for some distance before actually entering the EPA marsh. While in the canal, the discharge may be mixed with other water and be subject to other biogeochemical processes, which may result in increases (e.g., sediment reflux) or decreases (e.g., assimilation or adsorption) in TP concentration in the water actually entering the marsh. The changes in TP concentrations resulting from these processes are likely highly site-specific and would be difficult to evaluate.

3. For consistency with the National Pollutant Discharge Elimination System (NPDES) permits, the WQBEL derived herein is expressed as a maximum annual FWM TP concentration that is equivalent to the phosphorus criterion, which is expressed as a long-term geometric mean concentration of 10 ppb.

4. The derivation of the WQBEL is independent of antecedent phosphorus conditions in the downstream marsh receiving waters, i.e., there is no distinction between discharges to previously impacted portions of the marsh and discharges to unimpacted portions of the marsh for the purposes of this derivation.

2 Methodology: Derivation Based Upon STA Monitoring Data

2.1 *Data Handling*

The WQBEL was derived from statistical properties of STA discharges based on actual historical monitoring data for the period of record from May 1994 through April 30, 2009. The dataset utilized in the derivation of the WQBEL is the same as used in the derivation of the Technology-Based Effluent Limits (TBELs) (Nearhoof et al., 2005) except that it was expanded to incorporate more recent data as well as STA-1E and STA-3/4 data. The data for the structure G-251 discharge from STA-1West (STA-1W) were separated into two periods (Water Years 1995-2000 and Water Years 2001-2008) to recognize the change in operation between the historic Everglades Nutrient Removal (ENR) Project and the more recent full STA operation. The STA-1W data were similarly separated in the derivation of the TBEL (Nearhoof et al., 2005). In addition, due to unusual start-up problems that occurred during the early operation of STA-1East (STA-1E) that resulted in the STA not functioning typically, only data for Water Year 2007 (WY2007) (May 1, 2006-April 30, 2007) and WY2008 were used for STA-1E. For STA-6, flow and concentration measurements were taken at the G-606 structure for the period of December 1997 through February 2001 and at the G-354C and G-393B structures from March 2001 to the present. Table 1 shows the TP concentration and flow data period of records for the individual STAs.

To avoid biasing the geometric means, any TP measurements collected on days with no flow were omitted from further analyses. Additionally, for STAs 3/4 and 6 on days with negative flow, the flow was set to zero, and the TP measurements for those days were omitted from the calculation of the geometric mean. This method assures that the calculated geometric mean and the FWM are based on equivalent datasets since any TP data collected during periods of no discharge (i.e., flow less than or equal to zero) would not be factored into the FWM.

Table 1. Period of record of data for individual STAs.

STA	Structure(s)	Start Date	End Date	WY
ENR	ENR	5/2/1994	4/19/2000	1995-2000
STA-1E	S-362	5/4/2006	4/30/2009	2007-2009
STA-1W	G-251, G-310	5/2/2000	4/30/2009	2001-2009
STA-2	G-335	7/5/2001	4/30/2009	2002-2009
STA-3/4	G-376B & E, G-379B & D, G-381 B & E	5/6/2004	4/30/2009	2005-2009
STA-5	G-344 A, B, C, D	7/10/2000	4/30/2009	2001-2009

STA-6	G-606, G-354C, G-393B	12-01-97 (G-606) 3/26/2001 (G-354C, G-393B)	2-26-2001 (G-606) 4-30-2009 (G-354C, G-393B)	1999-2009

2.2 Data Rescaling

Since none of the STAs are currently achieving a long-term geometric mean of 10 ppb, the existing data could not be used to directly determine the relationship between a long-term geometric mean and annual FWM TP concentrations. Therefore, the existing TP data for each STA were rescaled individually to simulate data from a hypothetical STA achieving a long-term geometric mean of 10 ppb. To accomplish the rescaling, rescaling factors were calculated in two ways. The first rescaling factor was determined as the ratio of the 10 ppb criterion divided by the arithmetic average of the annual geometric mean TP concentrations for the period of record (i.e., 10/average annual geometric mean). As described above, the annual average geometric mean TP concentrations in the STA discharges varied widely ranging from less than 20 ppb for the STA-2 discharge (G-335) to more than 100 ppb for the combined discharge from the four STA-5 discharge structures (**Table 2**). The resulting rescaling factors for the individual STAs ranged from 0.53 (10/19.0) for the STA-2 discharge (G-335) to 0.10 (10/95.4) for the combined discharge from the four STA-5 structures.

Second, the geometric mean was calculated over the entire period of record for each STA. A rescaling factor was then determined as the ratio of the 10 ppb criterion divided by the period of record geometric mean for the STA (i.e., 10/long-term geometric mean). The long-term geometric mean TP concentrations in the discharge from the STAs varied widely ranging from 18.1 ppb for the STA-2 discharge (G-335) to 95.4 ppb for the combined STA-5 discharge (**Table 2**). This exercise resulted in rescaling factors for the individual STAs ranging from 0.55 (10/18.1) for the STA-2 discharge (G-335) to 0.11 (10/90.4) for the combined STA-5 discharge.

Both rescaling factors were then applied to the individual TP measurements for that STA. Using the rescaled TP measurements and the actual flow data for the STA, annual FWM TP concentrations were calculated for the period of record for that STA. The annual FWMs calculated from the rescaled data for each individual STA were then pooled and used to evaluate the statistical relationship between a long-term geometric mean of 10 ppb and the annual FWM TP concentrations using the methodology described below.

Given the limited data available for many of the STAs, the data were pooled across all STAs to provide a better estimate of the variability in TP concentrations in the discharge of the STAs under different conditions. As described above, the data for each individual STA were rescaled prior to pooling to provide a comparable basis for combining the data across the STAs and the evaluation of the variability.

2.3 Statistical Analysis

Using the pooled rescaled dataset, the TP WQBEL for the EPA discharges (expressed as an annual FWM TP concentration limit) was then calculated separately for each rescaling method using a procedure similar to that utilized in the derivation of the TBEL (Nearhoof et al., 2005). The WQBEL estimates were derived by fitting lognormal frequency distributions to the rescaled annual FWM concentration data for the pooled STA dataset as follows:

$$m = \Sigma \ln (C_s) / N$$

$$s_y^2 = \sum_{i=1}^{k} [\sum_{j=1}^{n_i} (y_{ij} - \bar{y}_i)^2] / (N - k)$$

$$df = N - k$$

$$L_p = \exp (m + s_y t_p)$$

where,

m = log mean

y_{ij} = i^{th} annual average of the j^{th} STA

$\bar{y}_i$ = mean Ln (FWM) of the i^{th} STA

N = total number of STA years = 45

k = number of STAs = 7

s_y^2 = the pooled STA variance [Ln (FWM)]

s_y = the pooled standard deviation [Ln (FWM)]

df = degrees of freedom in s

L_p = limit concentration with exceedance probability P (ppb)

t_p = 1-tailed t statistic, significance level p

$p = 0.10$

Table 2 provides the results of the statistical derivation of the WQBEL based on the existing pooled dataset for the STA discharges using both rescaling methods.

Table 2. Annual geometric mean, FWM, and rescaled FWM TP concentrations at STA outflow structures.

Structure	Water Year	Annual Geometric Mean (ppb)	Original FWMC (ppb)	Rescaled FWMC (ppb)	
				Based on GM for Period of Record	Based on Average Annual GM

ENR (G-251)	1995	23.8	23.1	11.0	11.1
ENR (G-251)	1996	22.2	24.7	11.7	11.9
ENR (G-251)	1997	19.8	19.3	9.2	9.3
ENR (G-251)	1998	20.5	22.3	10.6	10.7
ENR (G-251)	1999	19.3	20.0	9.5	9.6
ENR (G-251)	2000	20.3	21.5	10.2	10.4
Averages[1]		20.8 / 21	22 / 21.8	10.5 / 10.4	10.6 / 10.5
STA-1E (S-362)	2007	43.6	70.3	25.5	28.9
STA-1E (S-362)	2008	19.5	19.5	7.0	8.0
STA-1E (S-362)	2009	19.8	21.3	7.7	8.7
Averages[1]		24.3 / 27.6	34.4 / 37	12.4 / 13.4	14.1 / 15.2
STA-1W (G-251 + G-310)	2001	31.9	36.8	7.3	7.5
STA-1W (G-251 + G-310)	2002	27.9	37.7	6.9	7.1
STA-1W (G-251 + G-310)	2003	54.0	57.0	9.9	10.3
STA-1W (G-251 + G-310)	2004	38.3	46.7	9.1	9.4
STA-1W (G-251 + G-310)	2005	68.3	92.2	18.2	18.8
STA-1W (G-251 + G-310)	2006	84.5	105.7	19.7	20.4
STA-1W (G-251 + G-310)	2007	84.1	111.4	23.5	24.3
STA-1W (G-251 + G-310)	2008	52.2	60.0	11.4	11.8
STA-1W (G-251 + G-310)	2009	29.0	34.3	6.9	7.2
Averages[1]		50.4 / 52.2	62.6 / 64.7	11.9 / 12.5	12.3 / 13
STA-2 (G-335)	2002	18.5	17.5	9.2	9.6
STA-2 (G-335)	2003	17.7	17.9	9.4	9.9
STA-2 (G-335)	2004	13.5	13.8	7.2	7.6
STA-2 (G-335)	2005	16.9	18.6	9.8	10.3
STA-2 (G-335)	2006	19.6	19.4	10.2	10.7

STA-2 (G-335)	2007	28.4	44.3	23.2	24.4
STA-2 (G-335)	2008	21.2	21.4	11.2	11.8
STA-2 (G-335)	2009	16.5	17.8	9.3	9.8
Averages[1]		18.1 / 19	20.4 / 21.3	10.7 / 11.2	11.3 / 11.8
STA-3/4 (G-376B&E, G379B&D, G381B&E)	2005	12.7	12.6	6.5	6.8
STA-3/4 (G-376B&E, G379B&D, G381B&E)	2006	23.4	23.0	12.1	12.7
STA-3/4 (G-376B&E, G379B&D, G381B&E)	2007	24.1	22.4	11.7	12.3
STA-3/4 (G-376B&E, G379B&D, G381B&E)	2008	21.1	21.4	11.4	12.0
STA-3/4 (G-376B&E, G379B&D, G381B&E)	2009	16.5	13.5	7.1	7.5
Averages[1]		18.6 / 19.6	18.5 / 18.6	9.7 / 9.7	10.2 / 10.3
STA-5 (G-344 A,B,C,D)	2001	99.8	86.9	9.4	9.9
STA-5 (G-344 A,B,C,D)	2002	76.6	78.1	7.6	8.0
STA-5 (G-344 A,B,C,D)	2003	128.8	143.2	13.9	14.7
STA-5 (G-344 A,B,C,D)	2004	107.0	101.4	12.5	13.2
STA-5 (G-344 A,B,C,D)	2005	71.0	79.2	9.3	9.8
STA-5 (G-344 A,B,C,D)	2006	95.0	93.2	10.6	11.2
STA-5 (G-344 A,B,C,D)	2007	162.6	188.4	19.5	20.6
STA-5 (G-344 A,B,C,D)	2008	77.3	97.4	10.3	10.8
STA-5 (G-344 A,B,C,D)	2009	40.9	50.1	5.2	5.5
Averages[1]		90.4 / 95.4	99.4 / 102	10.7 / 10.9	11.3 / 11.5
STA-6 (G606)	1999	20.0	22.9	8.4	11.3
STA-6 (G606)	2000	14.7	15.4	5.6	7.6
STA-6 (G606)	2001	26.7	32.2	11.9	16.0
STA-6 (G354C + G393B)	2002	16.7	16.5	6.1	8.3
STA-6 (G354C + G393B)	2003	19.2	23.9	8.8	11.8

STA-6 (G354C + G393B)	2004	12.6	11.5	4.2	5.7
STA-6 (G354C + G393B)	2005	16.1	18.5	6.7	9.0
STA-6 (G354C + G393B)	2006	35.9	28.7	10.8	14.6
STA-6 (G354C + G393B)	2007	25.6	47.7	17.4	23.4
STA-6 (G354C + G393B)	2008	72.9	41.8	17.3	23.2
STA-6 (G354C + G393B)	2009	39.5	27.7	11.3	15.2
Averages[1]		20.2 / 27.3	21.7 / 26.1	8.1 / 9.9	10.9 / 13.3

[1] Overall period of record average / Average of annual values.

Table 3. Derivation of WQBEL for TP in discharges to the EPA.

Parameter	Rescaled Based on Average Annual GM	Rescaled Based on Period of Record GM
FWM Concentration (ppb)	11.0	12.2
Ln of FWM (Ln ppb)	2.319	2.420
Significance Level	0.10	0.10
Standard Deviation of LnTP	0.405	0.405
Site Years (N)	51	51
k (sites)	7	7
Df (N – k)	44	44
One-Tailed t	1.301	1.301
90% Rejection Limit (ppb): WQBEL as maximum annual FWM TP concentration	17.2	19.1

3 Results and Discussion

The results of WQBEL derivation using both methods to rescale the existing TP measurements are very similar. The WQBEL derived from the data rescaled based on the average annual geometric mean is 17.2 ppb while a limit of 19.1 ppb was derived from the data rescaled based on the period of record long-term geometric mean (**Table 3**).

Since the evaluation to assess compliance with the TP criterion (62-302.540, F.A.C.) utilizes the arithmetic mean of annual geometric mean TP concentrations to compare to the components of the four-part measurement methodology (Payne et al., 2007), the derivation using the data rescaled based on the average annual geometric mean TP concentrations is believed to be more consistent with the application of the Florida Department of Environmental Protection's (Department) TP criterion rule, and is therefore the preferred method. This method resulted in a TP limit of 17.2 ppb, which would be rounded to 17 ppb. As indicated above, the less preferred method of rescaling the data based on the period of record geometric mean TP concentration provides a slightly higher value of 19.1 ppb. By averaging the results obtained from the two methods, a value of 18.1 ppb is obtained, which rounds to 18 ppb. Therefore, based on the analysis presented above (both the preferred method of rescaling based on the average annual geometric means and the average of the two methods), a WQBEL for TP in discharges to the EPA of 18 ppb is recommended.

In a similar but independent exercise, Walker (2005) utilized two methods to estimate the WQBEL for the STA discharges. The first method was based on the results of Dynamic Model for Stormwater Treatment Areas (DMSTA) simulations for each STA, which ranged from periods of 9 to 35 years. This method resulted in WQBEL estimates ranging from 14.3 to 16.7 ppb with an average value of 15.1 ppb. The second method utilized by Walker was similar to but much simpler than the method utilized by the Department as described above. Walker's WQBEL estimated using this method is 16.0 ppb with a standard error of 0.5 ppb. In his conclusion, Walker recommends several refinements of his analyses, many of which were incorporated into the Department's analysis presented herein.

All estimates of the WQBEL for TP in discharges to the EPA derived using multiple methods are very similar ranging from 15.1 ppb to 19.2 ppb. Therefore, based on the weight of evidence, including the Department's analysis of the existing data for the STAs rescaled based on the pooled geometric mean (a more extensive version of Walker's analysis), a TP WQBEL of 18 ppb expressed as a maximum annual FWM is recommended for incorporation into the permits for all discharges to the EPA to assure that the discharges do not cause or contribute to exceedances of the TP criterion in the downstream marsh receiving waters. Since a number of the discharge structures included in this analysis currently have a limited amount of data, the estimated WQBEL should be periodically reevaluated as additional data become available.

4 References

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