Numeric Interpretation of Narrative Standards for the L-28 Interceptor Canal and Big Cypress National Preserve.

Office of Ecosystem Projects

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Introduction

The federal Clean Water Act, 33 U.S.C. § 1313(c)(2)(A), and associated implementing regulations in 40 C.F.R. § 131(4)(a), assign states the primary responsibility for developing and implementing water quality standards. *Natural Res. Def. Council v. U.S. E.P.A.*, 16 F.3d 1395, 1399 (4th Cir. 1993) ("While the states and E.P.A. share duties in achieving this goal [of protecting water resources], primary responsibility for establishing appropriate water quality standards is left to the states."). Florida Department of Environmental Protection (FDEP or Department) is the state agency responsible for setting water quality standards for Florida surface waters. Fla. Stat. § 403.061(11).

Where water quality criteria are expressed narratively, such as Florida's long-standing narrative nutrient criteria, FDEP, as the responsible state agency, numerically interprets the narrative criterion on a case-by-case basis when necessary for various regulatory purposes. Because there are no numeric nutrient criteria adopted for south Florida streams and wetlands (other than the Everglades Protection Area), it is FDEP's sole responsibility to numerically interpret the narrative nutrient criteria for CERP projects such as the Western Everglades Restoration Project (WERP).[1]

The objective of this document is to outline the approach and derivation of numeric interpretations of the narrative standard for the L-28 Interceptor (L-28I) and Big Cypress National Preserve (BCNP) (**Fig 1**) for the purposes of the WERP planning effort. A component of Florida's adopted narrative nutrient criterion is "*In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.*" (paragraph 62-302.530(90)(b), Florida Administrative Code [F.A.C.]). The narrative nutrient criterion applies to all Florida surface waters with a designated use classification of either Class I, I-Treated, II or III (rule 62-302.400, F.A.C.). All waterbodies discussed in this document are classified as Class III. The designated use of Class III waterbodies is for fish consumption; recreation; and propagation and maintenance of a healthy, well-balanced population of fish and wildlife (commonly referred to as "*fishable and swimmable*").

In addition to being a Class III waters, waters within BCNP have an additional level of protection known as "Outstanding Florida Waters" (OFW). Outstanding Florida Waters designation is an antidegradation provision designed to help preserve the exceptional ecological or recreation significance of the waters relative to the water bodies' baseline condition. Baseline water quality conditions for OFWs are typically identified as the existing ambient water quality in the year prior to designation (March 1, 1979) or the year prior to the permitting action (subsection 62-302.700(8), F.A.C.).

[1] The numeric targets discussed herein are for WERP planning purposes only and are not to be considered as a formal interpretation for regulatory purposes of the narrative standard. Specific regulatory processes are required to formally adopt numeric interpretations of the narrative nutrient criteria (or OFW baselines), which were not necessary for the limited objectives of this analysis.

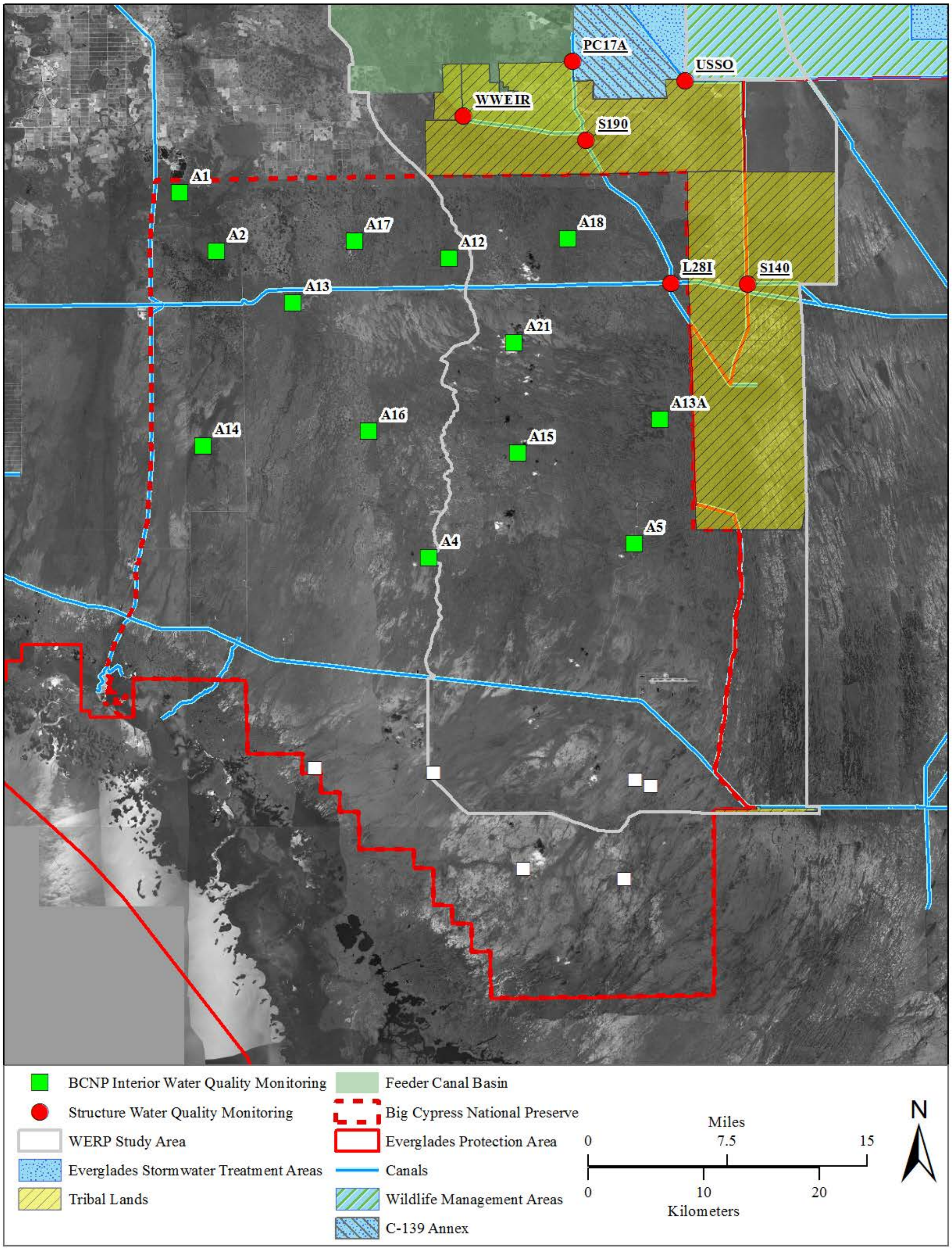

Figure 1. Region of interest relative to the Western Everglades Restoration Project (WERP), Big Cypress National Preserve (BCNP) and Tribal areas (i.e. Seminole and Miccosukee Tribes).

Approach

L-28 Interceptor Canal

The Department recently completed sample collection for the South Florida Canal Study that is intended to evaluate the aquatic life in the canals and the factors that influence the health and composition of the biological communities' present in a wide range of canals across south Florida. While none of the sites sampled during the canal study were located in or near the L-28 Interceptor (L-28I) canal or the BCNP, preliminary analysis of the study results are relevant to the derivation of nutrient targets for the L-28I and Big Cypress Preserve. Initial analyses of the macroinvertebrate data collected during the study in which all of the canal sites were grouped together indicated that measures of the macroinvertebrate community (Stream Condition Index (SCI)) were not strongly correlated to any habitat, hydrologic, or water quality variable. However, further analyses suggest that regionalization or grouping of sites with similar characteristics (water source, surrounding land use) may reveal greater information concerning the factor(s) controlling the biological community.

Sites sampled during the canal study that are most like the L-28I canal are in the C-23, C-25, C-44, L-8, and L-25 canals since they are similar in size and primarily drain a combination of natural and agricultural areas. However, TP concentrations observed for these canals are several times higher (i.e., up to 310 µg/L) than reported for the L-28I, and the canals perform poorly on the SCI. The C-44, L-8, and L-25 canals can also be strongly influenced by discharges from Lake Okeechobee. Additionally, likely differences in hydrology, management activities, and soil types between the canals can also influence water quality and biological response. Because of these important differences, it would be inappropriate to extrapolate any nutrient thresholds developed for similar sites sampled during the South Florida Canal Study to the L-28I. Further, due to the lack of biological data for the L-28I canal, it is not possible to accurately derive a site-specific numeric interpretation of the narrative nutrient criterion for the L-28I using a response-based approach.

Given these constraints, FDEP looked at other approaches to determine nutrient thresholds in the L-28I for WERP planning purposes. One approach deemed appropriate is the examination of nutrient concentrations during a baseline period, similar to an OFW analysis, but using an extended baseline period to provide a more robust data set for target derivation. To improve upon the data available for the L-28I canal prior to March 1, 1979, the baseline period was extended to include a four-water year period from 1978 to 1981 (May 1, 1977 – April 30, 1981). This approach is consistent with the establishment of OFW baseline conditions in other Everglades waterbodies such as Everglades National Park and Arthur R. Marshall Loxahatchee National Wildlife Refuge (SFWMD 1992).

During the extended baseline period, nutrient concentrations remained relatively consistent. Furthermore, after WY1981, nutrient concentrations became elevated for several years and were indicative of additional anthropogenic inputs (**Fig 2**). Annual geometric mean TP concentrations were significantly different between baseline and post-baseline periods (χ^2=5.3, df=1, ρ<0.05) although annual geometric mean TN concentrations were not significantly different between the baseline and post-baseline periods (χ^2=0.3, df=1, ρ=0.56).

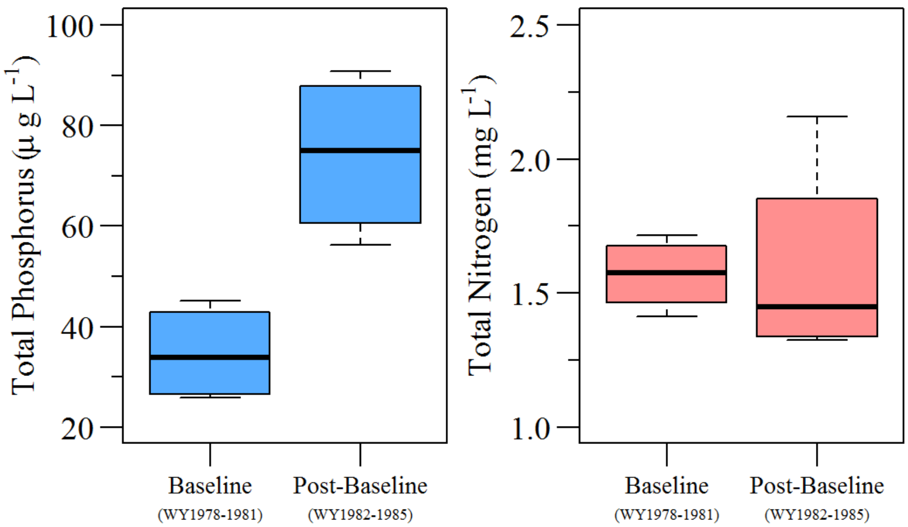

Figure 2. Boxplot of the total phosphorus and total nitrogen concentrations between the extended baseline period (WY978 – 1981) and the four years following the baseline period (post baseline WY1982 – 1985).

When determining stations for derivation of appropriate nutrient targets, the L-28I monitoring location was used for several reasons. First, this is the only monitoring station within Florida waters in the L-28I canal (other stations are within the Seminole Tribe of Florida). Second, the L-28I monitoring station is far removed from any immediate anthropogenic impacts. The next upstream monitoring location is the S-190, which is representative of waters of the Seminole Tribe of Florida and not of state of Florida waters. Finally, the L-28I monitoring location has the longest period of record (POR) in the region to characterize the L-28I canal dating back to WY1977.

Data for several water quality parameters, including total phosphorus (TP), orthophosphate (OP), nitrate-nitrite (NOx), total kjeldahl nitrogen (TKN), and total nitrogen (TN), were retrieved from DBhydro (my.sfwmd.gov/dbhydro) for the L28I monitoring location between May 1, 1977 – April 30, 1981. Data were screened to remove fatally qualified data, values reported below the minimum detection limit (MDL) were assigned values of one-half the MDL, and total phosphorus data (TP) were screened when ortho-phosphate (OP) was greater than TP (i.e. reversal) consistent with reversal screening conducted for evaluation of the Everglades TP rule (Rule 62-302.540, FAC; (Julian et al. 2017). Annual geometric mean (AGM) TP and TN concentrations were determined for the four-WY period to determine the OFW baseline period and derive long-term (5-year) and annual limits

Long-term (i.e. 5-year) and annual limits were derived using methods consistent with the statistical procedures performed for the establishment of numeric nutrient criteria (NNC) in the Everglades (Payne et al. 2000) and other waterbodies within the state of Florida using methods identified by Helsel and Hirsch (1992). Baseline conditions are defined as the arithmetic mean of the AGMs for the baseline period. To account for annual variability, long-term limits were set at the upper-95th

percentile of the baseline period data, which was estimated by using the arithmetic mean of the AGM concentrations, the standard deviation of the AGM concentrations, and the 95th confidence interval of the AGMs [calculated consistent with Equation 1 (Helsel and Hirsch 1992)]. Annual limits were estimated by using the arithmetic mean of natural log transformed AGM concentrations, the variance of natural log transformed AGM concentration, and the 95th prediction interval [calculated consistent with Equation 2 (Helsel and Hirsch 1992)] to estimate the upper-95th prediction interval of the baseline period data. The derived limits (long-term and annual limits) are designed to achieve the target baseline conditions within the baseline period based on the specified duration, magnitude and frequency, and are expressed as a 5-Year (long-term) and annual limits that shall not be exceeded.

Big Cypress National Preserve Interior

In addition to the L28I canal within BCNP, the BCNP interior is also considered an OFW. However, limited or no data are available for the interior portions of the BCNP to establish an OFW baseline. More recent data collected between WY1993 and 2012 were used to develop a numeric interpretation of the narrative Class III criterion to protect flora and fauna within the preserve. In lieu of historic data, a Reference Conditions approach using a biological thresholds was utilized similar to methods used to derive estuarine NNC (FDEP 2012). Achievement of the dissolved oxygen (DO) water quality criterion was used as the biological threshold in determining healthy conditions.

Data for several water quality parameters, including TP, OP, NOx, TKN, TN, DO, and temperature, were retrieved from DBhydro (my.sfwmd.gov/dbhydro) for all monitoring stations north of US-41 except A1 and A2 within BCNP between May 1, 1995 – April 30, 2012. Sites A1 and A2 were excluded *a priori* from the analysis due to information that indicates anthropogenic impacts to this region of BCNP (National Park Service, *unpublished data*). Dissolved oxygen concentrations were converted to percent saturation and evaluated against the Class III freshwater DO water quality criterion (FDEP 2013). Nutrient data were screened to remove fatally qualified data, values reported below the MDL were assigned values of one-half the MDL, and TP data were screened when OP was greater than TP (i.e. reversal) consistent with reversal screening conducted for evaluation of the Everglades TP rule (62-302.540 FAC; Julian et al. 2017). Annual GM concentrations were only computed for monitoring locations with greater than three samples per year and at least one in the wet (May – October) and dry (November – April) seasons, consistent with data screening methods for NNC development and similar to methods applied to TP rule assessment for the Everglades Protection Area. Annual GM nutrient concentrations were considered for analysis only if they achieved the data quality screening criteria and if the monitoring location achieved the DO water quality criterion. This screening methodology allows for the construction of a "*healthy*" dataset to derive water quality targets.

Similar to the derivation of the estuary NNC (FDEP 2012) and the Everglades TP rule (Payne et al. 2000), network long-term and annual limits were derived from a "*healthy*" dataset using statistical procedures outlined by Helsel and Hirsch (1992) in an effort to develop targets that would maintain the data distribution representative of healthy conditions. Typically, PORs are limited in an effort to reduce dilution of intra- and inter-annual variability, however due to the limited nature of the available data, the entire dataset was used and screened accordingly.

To account for annual variability, long-term limits were set at the upper-95th percentile of the baseline period data, which was estimated by using the arithmetic mean of the AGM concentrations across the BCNP monitoring network, the standard deviation of the AGM concentrations, and the 95th confidence interval consistent with Equation 1. Annual limits were set at the upper-95th prediction interval of the baseline period, which was estimated by using the arithmetic mean of natural log transformed AGM concentrations, the variance of natural log transformed AGM concentration, and the 95th prediction interval consistent with Equation 2 . The derived limits are expressed as a long-term network limit that shall not be exceeded in more than two out of five years (i.e. network average annual geometric mean less than or equal to the limit three of five years) and an annual limit not to be exceeded in any year.

Data sufficiency

The numeric interpretations of the narrative criterion for the L-28I Canal and BCNP were derived using the same prediction interval method recommended by the department for Type III SSAC calculations (FDEP, 2011). The document, titled *Development of Type III Site Specific Alternative Criteria for Nutrients,* is adopted by reference into Rule 62.302.800, F.A.C., and was previously reviewed and approved by U.S. EPA. This document recommended that the prediction interval approach only be used when there are at least four years of data. The numeric interpretations for both L-28I and BCNP were based on at least four years of data. In fact, the data used to derive the target concentrations for BCNP exceeded this minimum with 11 and 12 years for TN and TP, respectively. Furthermore, the NNC that were previously adopted by the department and expressed as annual geometric means were based on minimum sample sizes of at least four samples per year. The data sets for the L-28I and BCNP exceed this minimum annual size. Annual sample sizes for the L-28I were between 11 and 26 samples, while the sample sizes ranged from 5 to 26 for BCNP. Thus, the data used to develop numeric interpretations for L-28I and BCNP meet sufficiency requirements previously applied by the department for purposes of NNC development.

$$Long\ Term\ Avg.Geomean = m + s \times \frac{t_p}{\sqrt{N}} \qquad \text{Equation 1}$$

m Arithmetic Mean of annual geometric mean concentrations.
s Standard deviation of annual geometric mean concentrations.
t_p Student t-statistics.
N Number of Water Years used in the analysis.

$$Annual\ Geomean = e^{\left(\bar{y} + t_p\sqrt{\sigma^2 + \frac{\sigma^2}{NYR}}\right)} \qquad \text{Equation 2}$$

$\bar{y}$ Mean of natural log-transformed AGM.
σ^2 Variance of natural log-transformed AGM.
t_p Student t-statistics.
NYR Number of Station-Water Years used in the analysis.

$$Y_i = \mu + \delta_{yr} + \delta_s + \delta_{sd} \qquad \text{Equation 3}$$

Y_i Natural log network annual average concentration on year i
μ Natural log of the long-term geometric mean
δ_{yr} Year effect (mean = 0, standard deviation = σ_{yr})
δ_s Site effect (mean = 0, standard deviation = σ_s)
δ_{sd} Replicate error (mean = 0, standard deviation = σ_{sd}

Results

L-28 Interceptor Canal

Annual geometric mean concentrations observed at the L-28I monitoring location ranged from 21.9 µg/L to 34.4 µg/L and 1.28 mg/L to 1.54 mg/L for TP and TN, respectively, during the baseline period (**Table 1 and Fig 3**). The overall mean AGM TP concentration during the baseline period was 27.7 µg/L, and the overall standard deviation was 6.10 µg/L, resulting in a long-term limit of 35 µg/L, not to be exceeded. The overall mean AGM TN concentration during the baseline period was 1.37 mg/L, with an overall standard deviation of 0.14 mg/L, which resulted in a long-term limit of 1.53 mg/L, not to be exceeded (**Table 2**).

Annual limits for TN and TP within the L28I canal were derived from natural log (i.e. Ln) transformed AGM data observed during the baseline period. The overall natural log transformed geometric mean concentrations were 3.3 µg/L and 0.312 mg/L for TP and TN, respectively. The overall variance of natural log transformed geometric mean concentrations were 0.049 µg/L and 0.010 mg/L for TP and TN, respectively. Using these data in conjunction with equation 2 (above), the annual limit based on the 95th prediction interval is 49 µg/L and 1.77 mg/L for TP and TN, respectively, which shall not be exceeded (**Table 2**).

Table 1. Annual geometric mean and standard error of geometric mean (SE_{GM}) total phosphorus and total nitrogen concentrations for the L-28I water quality monitoring stations during the baseline period.

WY[1]	Samples Per Year (NYR)	Total Phosphorus (µg/L) Geometric Mean	Total Phosphorus (µg/L) SE_{GM} [2]	Total Nitrogen (mg/L) Geometric Mean	Total Nitrogen (mg/L) SE_{GM} [2]
1978	11	21.9	2.8	1.28	0.12
1979	26	31.4	3.4	1.24	0.16
1980	24	34.4	5.5	1.42	0.11
1981	17	23.3	3.1	1.54	0.11

[1] Florida Water Year (May – April)

[2] $SE_{GM} = GM \times \frac{\sigma_{log}}{\sqrt{N-1}}$ (Norris 1940)

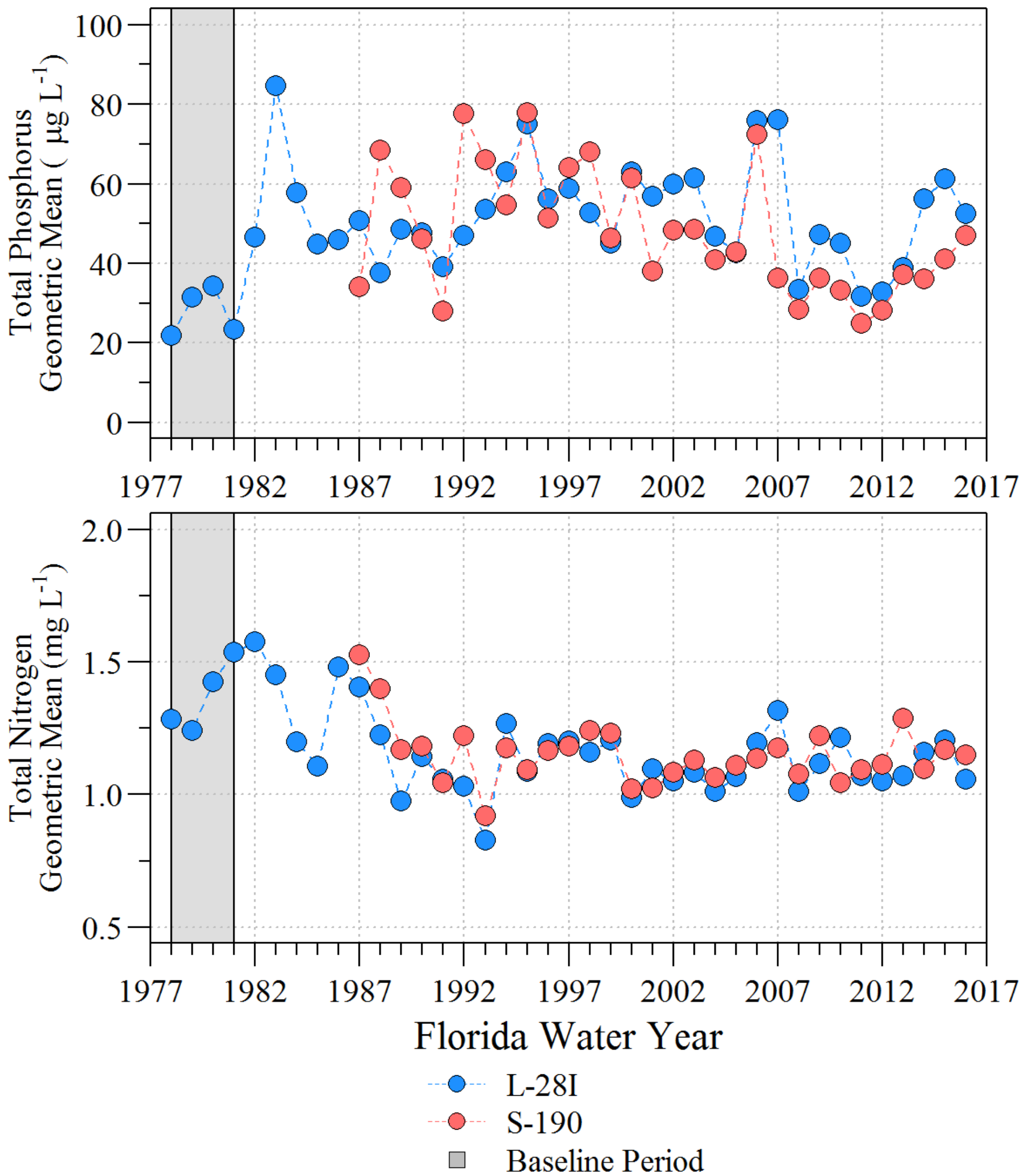

Figure 3. Annual Geometric Mean Total Phosphorus and Total Nitrogen concentration for L-28I and S-190 relative to the baseline. Note: Only the L-28I monitoring location was used to derive limits for the L-28I canal, S-190 is included for reference purposes.

Table 2. Statistical results of the long-term and annual total phosphorus and total nitrogen limits for L-28I canal.

Long-term (5-Year)	**Statistic**	**Total Phosphorus (µg/L)**	**Total Nitrogen (mg/L)**
Arithmetic Mean of Annual Geometric Mean:	*m*	27.7	1.37
Standard Deviation of Annual Geometric Mean:	*s*	6.10	0.14
Number of Water Years, N:	*N*	4	4
Deg. of Freedom (*Df* = N-1):	*Df*	3	3
Confidence Interval Probability:	*1-tail ρ*	0.05	0.05
Student-t Statistic:	*tp*	2.353	2.353
$\text{Long} - \text{term Avg. Geomean} = \text{m} + \text{s} \times \frac{\text{t}_\text{p}}{\sqrt{\text{N}}}$	*5-Year Limit*	35	1.53
Annual	**Statistic**	**Total Phosphorus (µg/L)**	**Total Nitrogen (mg/L)**
Mean Ln(Geometric Mean):	$\bar{y}$	3.3	0.312
Variance Ln(Geometric Mean):	σ^2	0.049	0.010
$\sum(No. of\ water\ years\ per\ station)$:	*NYR*	4	4
Number of Stations:	*NS*	1	1
Deg. of Freedom (*Df=NYR-NS):*	*Df*	3	3
Prediction Interval Probability	*1-tail ρ*	0.05	0.05
Student-t Statistic	*tp*	2.353	2.353
$\text{Annual Geomean} = \text{e}^{\left(\bar{\text{y}} + \text{t}_\text{p}\sqrt{\sigma^2 + \frac{\sigma^2}{\text{NYR}}}\right)}$	*Annual Limit*	49	1.77

Big Cypress National Preserve Interior

A total of 31 AGM concentrations across 14 years were used to derive long-term and annual limits for TP within BCNP interior natural areas. Fewer AGM concentrations were available for TN during the same period. Several monitoring locations did not pass either the DO screening or the seasonal screening criteria (**Fig 4, 5 and 6**). Annual geometric mean concentrations ranged from 3.6 µg/L to 25.0 µg/L and 0.55 mg/L to 1.38 mg/L for TP and TN, respectively, within BCNP during the assessment period (**Table 3 and Fig 4**). The overall mean AGM TP concentration during the POR was 9.6 µg/L, and the overall standard deviation was 5.75 µg/L. The overall mean AGM TN concentration during the baseline period was 0.91 mg/L, with an overall standard deviation of 0.17 mg/L. Using these data in conjunction with equation 1 and a 95^{th} confidence interval, the resulting long-term limits are 13 µg/L and 1.00 mg/L for TN and TP, respectively (**Table 4**), which shall not be exceeded more than two out of five years (i.e. average annual geometric mean shall be less than or equal to the limit three of five years).

The overall natural log transformed geometric mean concentrations across the monitoring network were 2.1 µg/L and -0.116 mg/L for TP and TN, respectively. The overall variance of natural log transformed geometric mean concentrations were 0.31 µg/L and 0.035 mg/L for TP and TN, respectively. Inputting these data into equation 2 using a 95^{th} prediction interval, the annual network limit is 21 µg/L and 1.24 mg/L for TP and TN, respectively, which shall not be exceeded (**Table 4**).

To determine the Type-I error rates associated with different evaluations of the proposed limits, a Monte Carlo analysis was done using values presented in **Table 5.** The estimated exceedance probabilities at a long-term concentration of 13 µg/L and 1.00 mg/L TP and TN, respectively varied between 0.17 and 0.75. The 3:5-year exceedance frequency was determined to be the more sensitive of the three metrics assessed. Therefore, the proposed limit for TP should be expressed as long-term network limit of 13 µg/L that shall not be exceeded more than twice in a five-year period and an annual network limit of 21 µg/L that shall not be exceeded in any year. The proposed limit for TN should be expressed as long-term network limit of 1.00 mg/L that shall not be exceeded more than twice in a five-year period and an annual network limit of 1.24 mg/L that shall not be exceeded in any year.

Table 3. Annual geometric mean total phosphorus and total nitrogen concentrations used in deriving target, long-term and annual limits for Big Cypress National Preserve interior natural areas. Only data that passed the screening protocol are presented.

Station ID	WY	Annual Geometric Mean Concentration Total Nitrogen (mg/L)	Total Phosphorus (µg/L)
BCWQA5	1996	0.77	14.4
BCWQA5	1998	---	18.6
BCWQA5	2000	0.80	17.8
BCWQA5	2002	---	11.3
BCWQA5	2004	0.94	9.9
BCWQA5	2006	0.98	11.5
BCWQA13A	2006	0.84	3.9
BCWQA13A	2007	1.15	5.6
BCWQA13A	2008	1.13	3.8
BCWQA13A	2009	0.89	4.5
BCWQA13A	2010	1.07	3.6
BCWQA21	2006	0.89	4.8
BCWQA21	2010	0.82	3.8
BCWQA13	1998	0.91	6.7
BCWQA13	2000	0.70	13.5
BCWQA13	2003	0.78	6.5
BCWQA13	2004	0.66	7.3
BCWQA4	1996	---	7.6
BCWQA4	1998	---	9.2
BCWQA4	2000	0.55	9.3
BCWQA4	2003	0.96	16.7
BCWQA3	1997	1.38	25.0
BCWQA3	1998	1.05	6.0
BCWQA3	2000	---	10.5
BCWQA3	2003	0.77	6.2
BCWQA3	2004	0.92	7.3
BCWQA3	2006	0.83	5.1
BCWQA3	2009	0.95	6.0
BCWQA3	2010	0.96	5.4
BCWQA12	1997	0.89	23.7
BCWQA17	2003	0.93	11.6

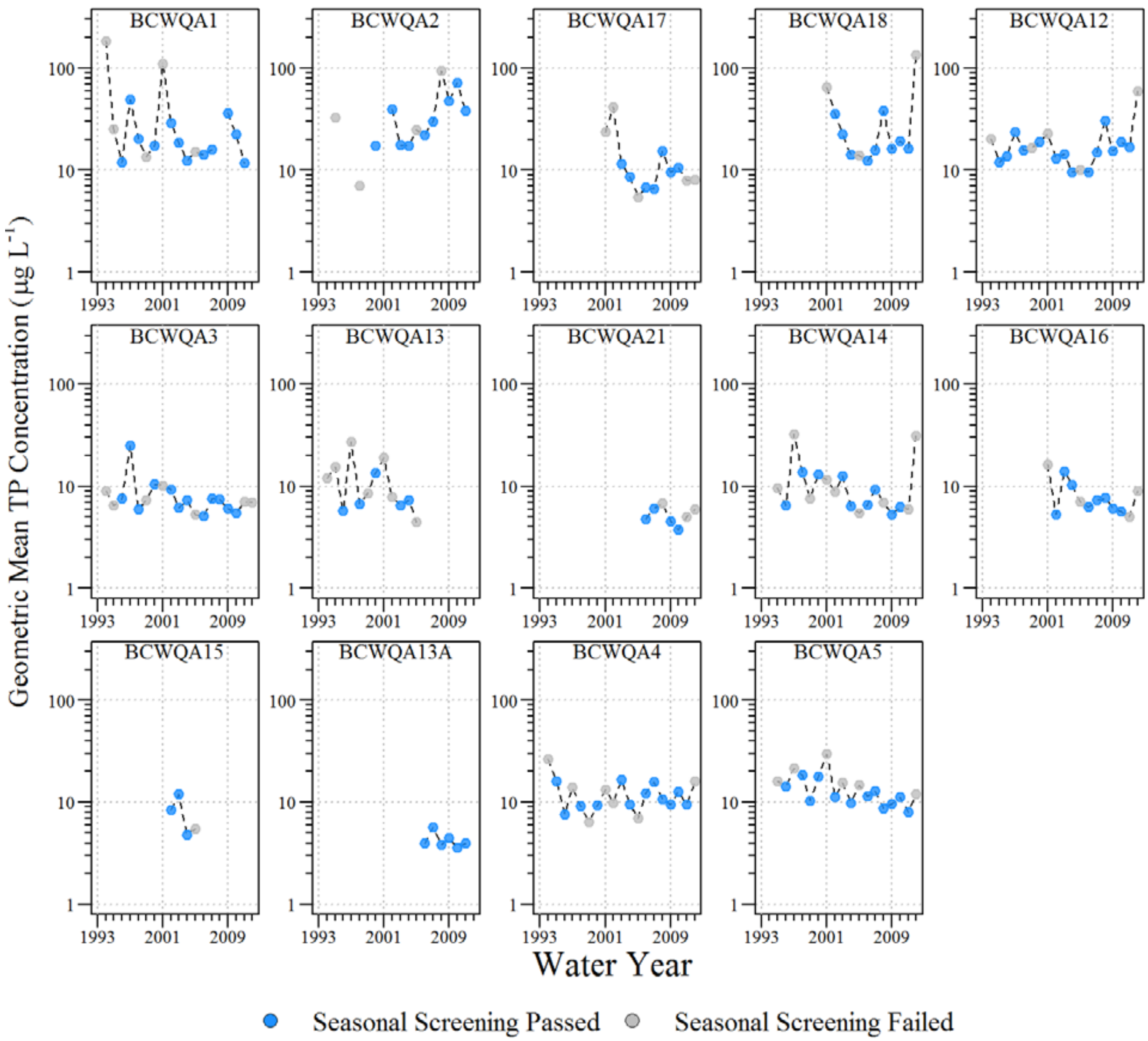

Figure 4. Period of record Big Cypress National Preserve geometric mean total phosphorus concentrations between Florida Water Year (May – April) 1994 and 2010 for monitoring locations north of US-41. Seasonal screening criteria includes years must have greater than three samples per year and at least one in the wet and dry season per monitoring location.

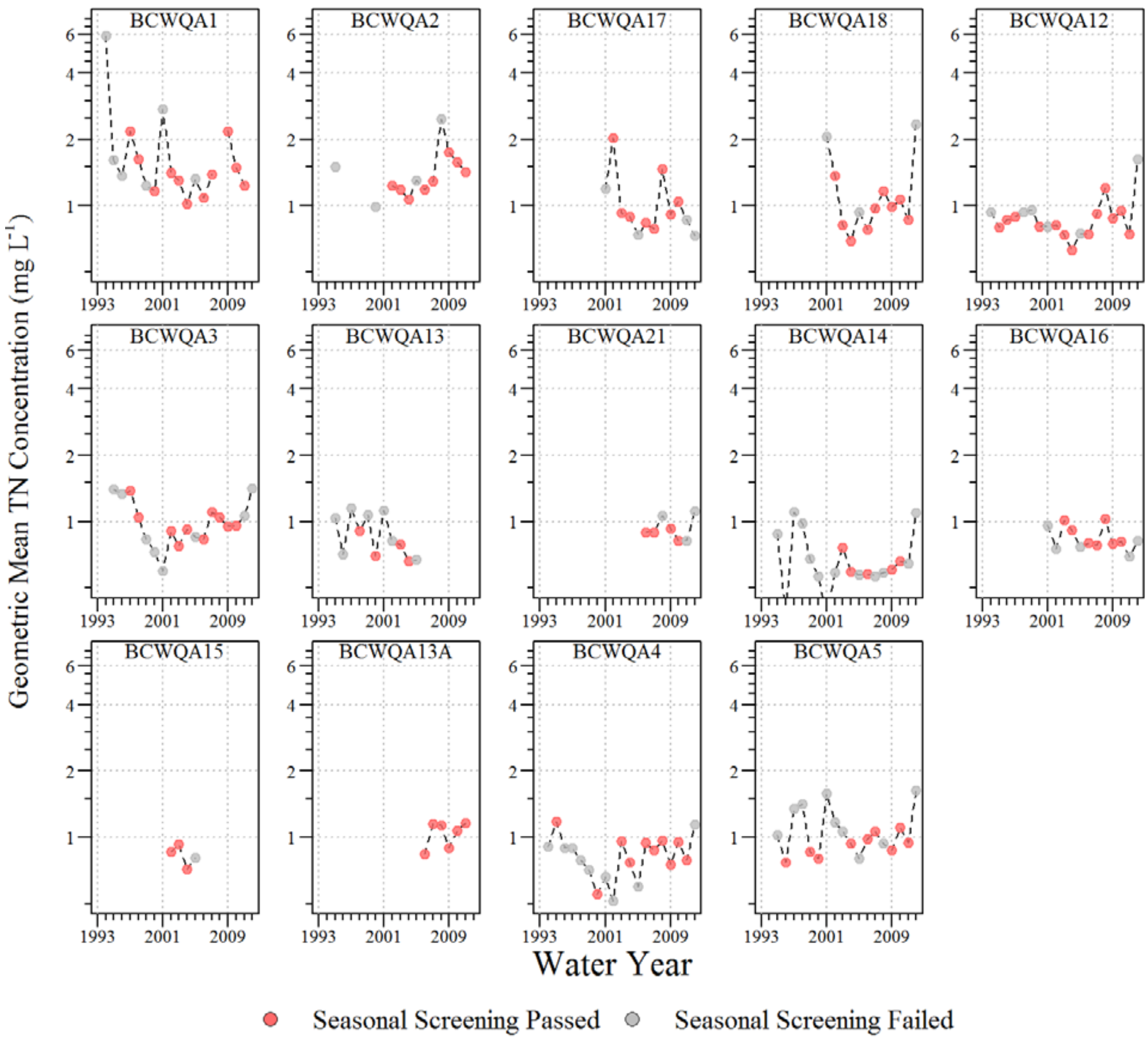

Figure 5. Period of record Big Cypress National Preserve geometric mean total nitrogen concentrations between Florida Water Year (May – April) 1994 and 2010 for monitoring locations north of US-41. Seasonal screening criteria includes years much have greater than 4 samples per year and at least one in the wet and dry season per monitoring location.

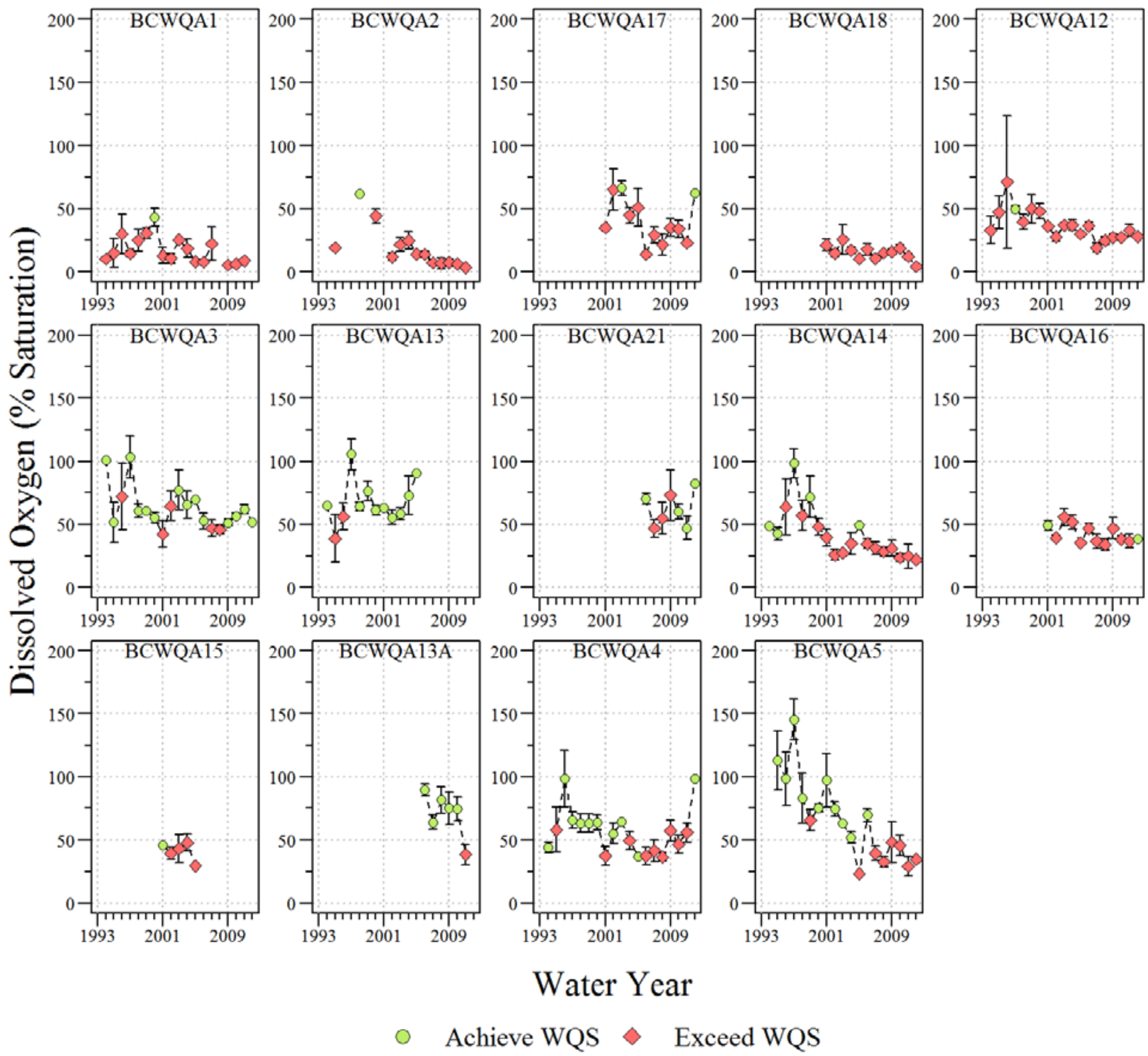

Figure 6. Period of record annual mean dissolved oxygen concentrations relative to class III water quality standard (WQS) within Big Cypress National Preserve between Florida Water Year (May – April) 1994 and 2010 for monitoring locations north of US-41.

Table 4. Statistical results of the long-term and annual total phosphorus and total nitrogen limits for Big Cypress National Preserve (BCNP) interior.

Long-term (5-Year)	**Statistic**	**Total Phosphorus (µg/L)**	**Total Nitrogen (mg/L)**
Arithmetic Mean of Annual Geometric Mean:	*m*	9.5	0.91
Standard Deviation of Annual Geometric Mean:	*s*	5.75	0.17
Number of Water Years, N:	*N*	12	11
Deg. of Freedom (*Df* = N-1):	*Df*	11	10
Confidence Interval Probability:	*1-tail ρ*	0.05	0.05
Student-t Statistic:	*tp*	1.80	1.812
$\text{Long-term Avg. Geomean} = m + s \times \frac{t_p}{\sqrt{N}}$	*5-Year Limit*	13	1.00
Annual	**Statistic**	**Total Phosphorus (µg/L)**	**Total Nitrogen (mg/L)**
Mean Ln(Geometric Mean):	$\bar{y}$	2.1	-0.116
Variance Ln(Geometric Mean):	σ^2	0.31	0.035
$\sum(\textit{No. of water years per station})$:	*NYR*	31	26
Number of Stations:	*NS*	8	8
Deg. of Freedom (*Df=NYR-NS):*	*Df*	23	18
Prediction Interval Probability	*1-tail ρ*	0.05	0.05
Student-t Statistic	*tp*	1.714	1.734
$\text{Annual Geomean} = e^{\left(\bar{y} + t_p\sqrt{\sigma^2 + \frac{\sigma^2}{NYR}}\right)}$	*Annual Limit*	21	1.24

Table 5. Monte Carlo model parameters used to evaluate the proposed Big Cypress National Preserve long-term limits for total phosphorus and total nitrogen. These data are estimated from the dataset used to derive the proposed limits.

Value	**Total Phosphorus**	**Total Nitrogen**
Long-term Limit	13	1.00
Number of Sites	8	8
δ_{yr}	5.83	0.173
δ_s	3.05	0.150
δ_{sd}	9.47	0.327

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