Picayune Strand Restoration Project (PSRP) Water Quality Projections With "Western Protective Levee" Feature

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PROJECT DESCRIPTION/OVERVIEW

The Picayune Strand restoration project (PSRP) is a Comprehensive Everglades Restoration Plan (CERP) project. The objective of the project is to restore the hydrological and ecological function of nearly 55,247 acres (approximately 94 square miles) of a previously drained wetland located in Southwestern Collier County. The PSRP consists of the construction of a series of pump stations, tie-back levees, spreader berms, and canal plugs to slow water flowing through the existing canals and redistribute it across the landscape (Chuirazzi and Duever, 2008). In addition, the project includes a western protection feature (levee) aimed to provide flood protection to the southwestern agricultural and residential areas (Downer et al., 2016). Implementation of this project with the additional protection feature will increase discharges to downstream Outstanding Florida Waters (OFW) within Collier-Seminole State Park and the Cape Romano – Ten Thousand Islands Aquatic Preserve through five existing culverts (TAMTOM, TMBR37, TAMBR39, TMBR40, and TAMBR49) and a new proposed structure currently referred as the New Out (**Figure 1**). Additionally, the Ten Thousand Islands regions have been assigned estuary specific Numeric Nutrient Criteria (NNC) by the Florida Department of Environmental Protection (FDEP); therefore, a concern of possible impacts to these areas resulting from the project implementation exists.

The main objectives of this analysis are to: (i) evaluate and determine the total phosphorus (TP) and total nitrogen (TN) concentrations that can be expected in the PSRP restored flows, and (ii) evaluate changes in surface flows, total phosphorus (TP) and total nitrogen (TN) concentrations before (Without project) and after (With project) restored flows through the PSRP with the western protection feature in place. Given the importance of the State Park and Aquatic Preserve water resources, this assessment was performed utilizing flow data generated from an Army Corps of Engineers (USACE) hydrologic model, and hydrologic and water quality data collected by the South Florida Water Management District (SFWMD) and Collier County.

METHODS

MONITORING STATIONS

Data from a variety of monitoring structures and stations located near and within the footprint of the PSRP were used to perform analyses described herein. The nomenclature for these stations varied with data type. **Table 1** provides a cross-walk to identify locations by their station names based on data types:

Table 1. Cross-walk providing different station nomenclature for a location based on data type.

Nomenclature of Monitoring or Modeling Location by Data Type
TAMTOM (*Water Quality*), **TAMIATOM** (*Stage*), **BR36** or US41 Culvert (*Modeling Structure*)
TMBR37 (*Water Quality and Stage*), **BR37** or Bridge 37 (*Modeling Structure*)
FAKA (*Water Quality and Flow*)
S488 (*Water Quality*), **S488_P** (*Flow*)
BC9, **BC10**, **BC11** (*Water Quality*)
COLLISEM (*Rainfall*)
BR39 or Bridge 39 (*Modeling Structure*)
BR40 or Bridge 40 (*Modeling Structure*)
New Out or New Opening (*Modeling Structure*)
Levee Culvert (*Modeling Structure*)

HYDROLOGIC DATA

Daily headwater stage (ft. NGVD29) data for TAMIATOM and TMBR37 structures located along the Tamiami Canal (US41) was evaluated for the period from January 2004 to December 2019. Stage data was used to evaluate the relationship and establish the level of connectivity between the two stations over time in response to water level changes. In addition, daily rainfall data measured at the COLLISEM meteorological station located within Collier Seminole State Park was evaluated for the period from January 2001 to December 2019. Rainfall data was compared against flow measurements reported at S488 and FAKA, as well as TP and TN concentrations measured at S488, FAKA, and TMBR49 to evaluate patterns associated with seasonal dry and wet periods. All hydrologic data were obtained from the SFWMD's DBHYDRO database (**Table 2**).

Table 2. Description of flow, stage, and rainfall, data database or DBKeys used.

DBKey	Station	Data Type	Data Description	Units
JU770	TAMIATOM (BR36)	Stage	HW Stage	ft NGVD29
S7913	TMBR37 (BR37)	Stage	HW Stage	ft NGVD29
DU533	COLLISEM	Rain	Rainfall	in
90895	FAKA	Flow	Daily Flow	cfs
38372	S488_P	Flow	Daily Flow	cfs

WATER QUALITY DATA ANALYSES

Water quality data at the monitoring locations at the periphery and within the PSRP were retrieved from the SFWMD's DBHYDRO database and obtained from Collier County. Monitoring stations, for which water quality data were retrieved, are shown in Figure 1. The data covers a period of record from October 2001 through October 2019. Monitoring periods did not overlap for all monitoring locations. Retrieved water quality data sets were stored in a Microsoft Access database.

Data from eight monitoring stations in and around the project area were used for this analysis. Three of the monitoring stations (BC9, BC10, and BC11) are located on the northern boundary of the project with two monitoring stations on the southern boundary (FAKA and TMBR49) and two stations (TAMTOM and TMBR37) on the southwestern edge along the US 41 canal. One monitoring location (S488) is located at a pump station on the Merritt Canal, approximately one mile south of the PSRP northern boundary. No water quality data were available for TAMBR39 and TMBR40 during the evaluation period (**Figure 1**).

This water quality evaluation focuses primarily on total phosphorus (TP) and total nitrogen (TN). However, additional water quality parameters were also retrieved for evaluation: specific conductance, chloride (Cl), total Kjeldahl nitrogen (TKN), and nitrate+nitrite (NOX). For a portion of the water quality data collected and analyzed by SFWMD, TKN and NOX were used to calculate TN concentrations. After June 2014, TN was directly measured by the SFWMD's analytical laboratory. TN concentrations were calculated for all Collier County data.

Data screening was performed to remove data containing qualifiers identifying potential data quality issues (e.g., H, J, K, N, O, V, Q, Y, G, or ?). Additionally, the proximity of several water quality monitoring locations (TAMTOM, TMBR37, TMBR49, and FAKA) to estuarine waters increased the possibility that these stations could be tidally influenced during certain parts of the year. Therefore, water quality samples with associated specific conductance exceeding 5,000 µS/cm or chloride values greater than 1,500 mg/L were not used in the analysis. A conservative approach was taken with nutrient concentrations reported as less than the method detection limit by setting these values to the detection limit.

Basic statistical summarization of the water quality data (TP and TN) was performed using Microsoft Excel 365, Systat 13.1 and Analyse-It 5.40.2. Distributions of nutrient concentrations were tested using the Shapiro-Wilks test in Systat 13.1. A Kruskal-Wallis test was used to compare nutrient concentrations across the eight monitoring stations. This test is a non-parametric test equivalent to the one-way analysis of variance but makes no distributional assumptions. The Dwass-Steel-Critchlow-Fligner test was used as a post hoc test to identify which monitoring stations contained statistically different data.

Trends for TP and TN data were determined using the Seasonal Mann-Kendall test from the USGS Kendall Family of Trend programs[1]. The Seasonal Mann-Kendall (SK) test (as described in Hirsch et al. 1982, Gilbert 1987, and Helsel and Hirsch 1992) is used to identify monotonic trends of the variables collected over time. Monotonic upward trends mean that the variable consistently increases over time, while monotonic downward trends mean that the variable is consistently decreasing over time. The SK test was developed by the United States Geological Survey in the 1980s to identify surface water quality trends throughout the United States (Helsel et al., 2006). Most water quality data from surface water sampling typically exhibit strong seasonal patterns. Surface water flow, rainfall, and evapotranspiration are greatly affected by seasonality and affect water quality. The SK test is a nonparametric test that does not require the data to follow a particular distribution. Additionally, the test is robust against outliers and large data gaps. The SK test was proposed by Hirsch et al. (1982) for use with 12 seasons (months). However, the SK test may also be used for other seasons, for example: a) the four quarters of the year; b) the three 8-hour periods of the day; and c) wet/dry season. For purposes of this report, months were used as seasons.

[1] https://pubs.usgs.gov/sir/2005/5275/downloads/

The following assumptions underlie the SK test:

- When no trend is present the observations are not serially correlated over time.
- The observations obtained over time are representative of the true conditions at sampling times.
- The sample collection, handling, and measurement methods provide unbiased and representative observations of the underlying populations over time.
- Any monotonic trends present are all in the same direction (up or down). If the trend is up in some seasons and down in other seasons, the SK test will be misleading.
- The standard normal distribution may be used to evaluate if the computed SK test statistic indicates the existence of a monotonic trend over time.

Hirsch and Slack (1984) develop a modification of the SK test that can be used when serial correlation is present over time. For the purpose of this document, the SK test was performed using an executable file containing the compiled FORTRAN code developed by Reckhow et al. (1993) for the Environmental Protection Agency. This code is used to compute the tau statistic, unadjusted and adjusted probability values (p-values) for the tau statistic and slope (Sen) of the observed trend. The adjusted p-value accounts for covariance caused by serial correlation. Coding in Excel was used to produce statistics (correlograms) that are used to identify potential serial correlation. Additionally, modifications to the code were made to output the intercept, as described in Helsel et al. (2006). For all statistical analyses presented herein, a significance level (α) of 0.05 was selected. Probability values (p-values) are provided for all statistical tests discussed.

Additionally, in consideration of the estuaries that will receive discharges from the PSRP, the downstream and adjacent Numeric Nutrient Regions, Blackwater River, Rookery Bay/Marco Island, and Gulf Islands) were evaluated for water quality compliance in the most recent ten water years 2009 - 2019 (**Figure 2**). The data used for this evaluation was collected by the SFWMD and is available through the SFWMD's DBHYDRO database. The annual geometric mean (AGM) for TN, TP, and chlorophyll *a* for this period was compared to the estuarine-specific criteria for each region listed in Section 62-302.532: Estuary-Specific Numeric Interpretations of the Narrative Nutrient Criterion, Florida Administrative Code (F.A.C.)[2]. Further, two stations (TTI75 and TTI75B) located at the mouth of the tidal tributaries receiving project waters (through Blackwater Creek and Mud Bay/Palm Bay) were separately evaluated for TN and TP (**Figure 2**).

[2] Rule available online at https://www.flrules.org/gateway/ruleNo.asp?id=62-302.532. Estuarine Numeric Nutrient map for the Charlotte Harbor to Florida Bay regions can be found online at: https://www.flrules.org/Gateway/reference.asp?No=Ref-05420.

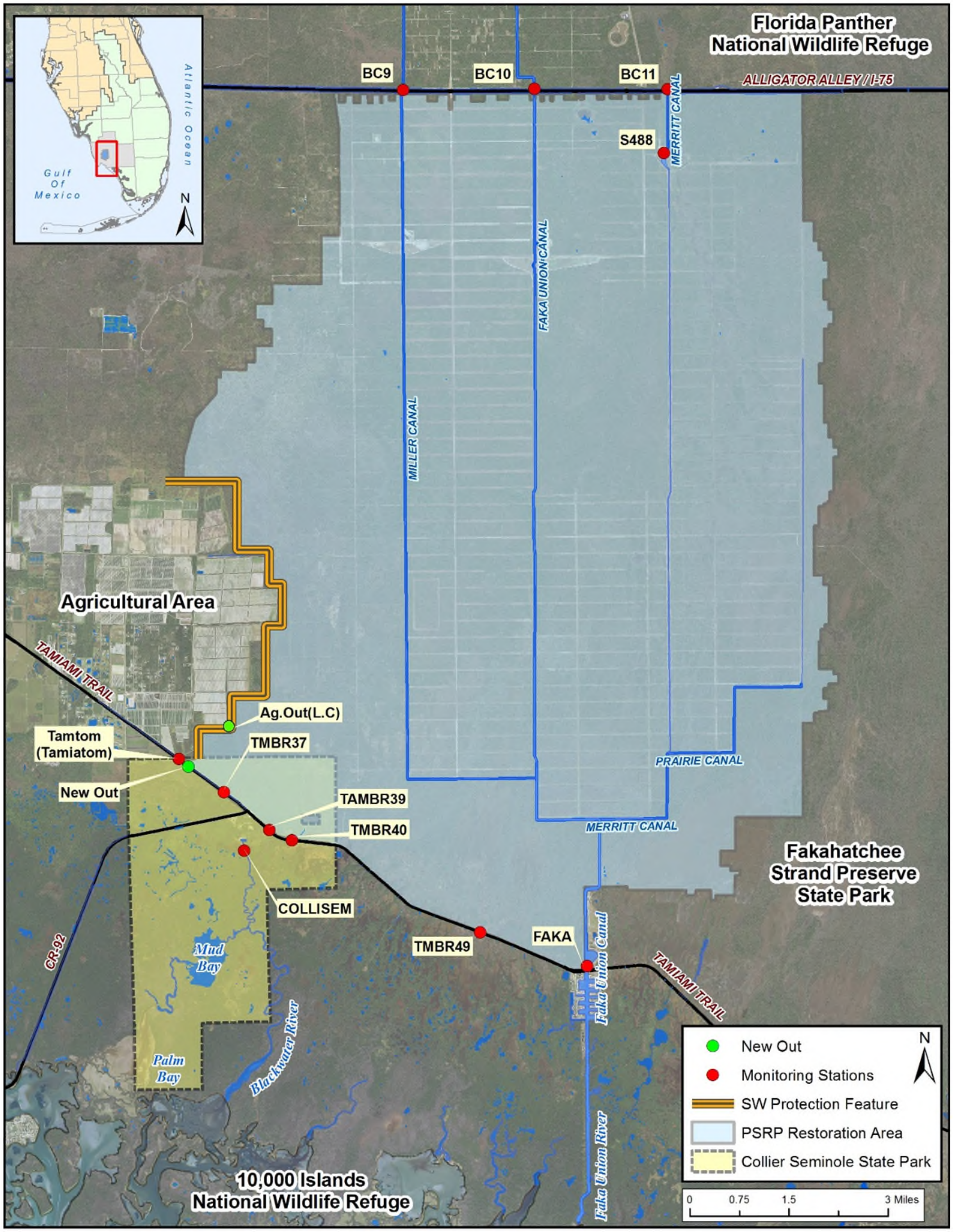

Figure 1. Map showing the Picayune Strand Restoration Project, Collier-Seminole State Park, and the location of the flow and water quality sites.

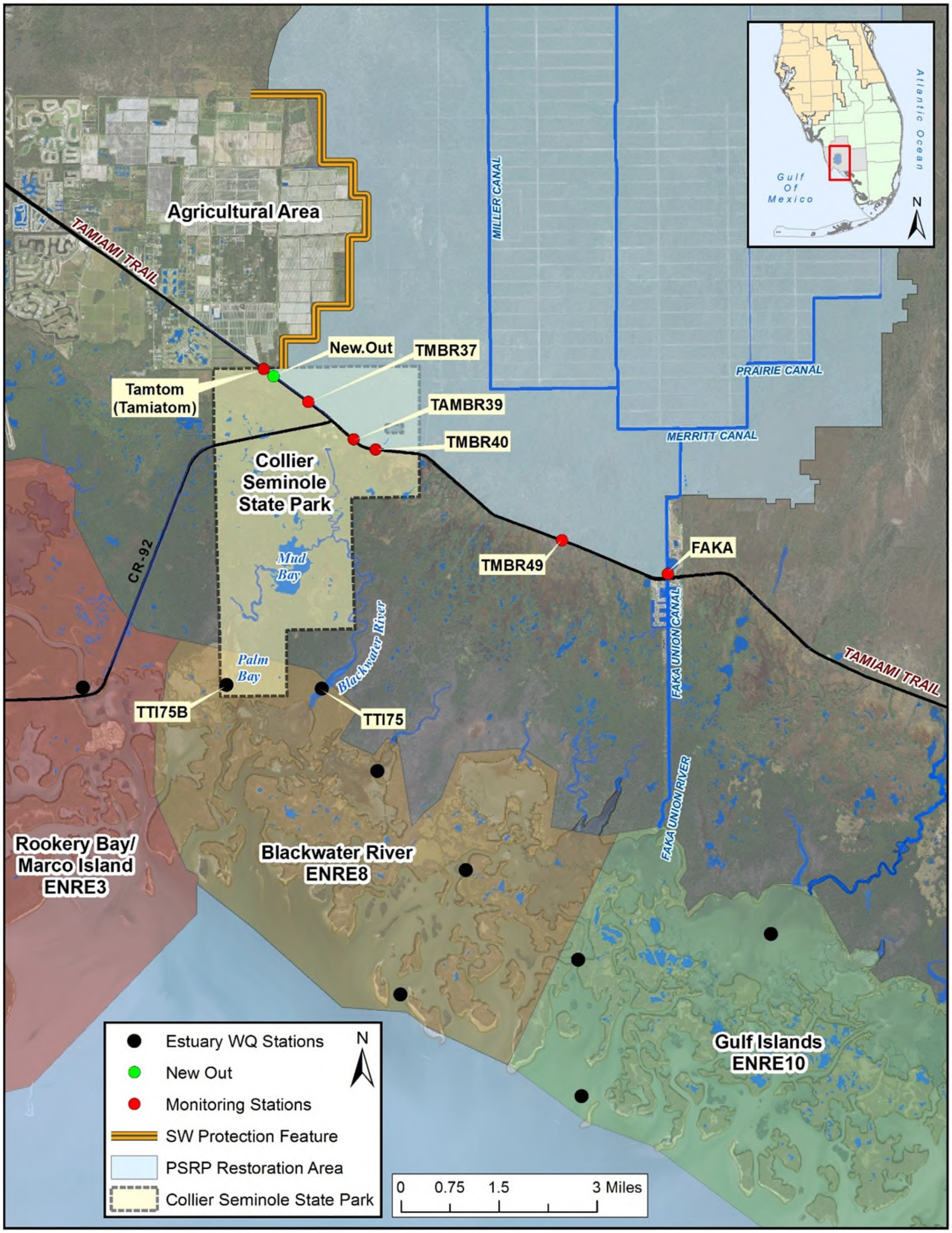

Figure 2. Map showing Estuarine Numeric Nutrient regions (Section 62-302.532(1), F.A.C.)[1] downstream of the project area discharge structures that are presented in this evaluation.

MODELED FLOW

Model Flow Scenarios

Surface water flows used in this analysis were generated from the USACE's Gridded Surface Subsurface Hydrologic Analysis (GSSHA) modeling results of the PSRP Project Model Condition 2 (Downer et al., 2016). This model has the ability to simulate the movement of water across watersheds (Weston et al., 2015). The model simulations were run for a ten-year period from 11/1/2003 to 10/31/2013 for conditions *Without project* (approximating current conditions) and *With Project* (approximating future conditions), referred to as the *Alt Project Cond2* in the model output provided by the USACE. Two subsequent model runs with project structures in place but without the restore flow were evaluated to determine the agricultural flow contribution and the existing flow (base-flow other than agricultural). These model runs are referred to as *SWPF Only* and *SWPF+New Out* (**Table 3**).

The model output included daily flows at several culverts and bridges under Highway 41. This analysis focused on structures identified in the model output as BR36 (TAMTOM), BR37 (TMBR37), New Out, BR39 (TAMBR39), and BR40 (TMBR40) delivering water to areas downstream of the southwestern region of the PSRP (**Figure 1**). Discharges from the agricultural lands (west of the PSRP) are conveyed primarily through the Tomato Road culvert and are discharged into the canal less than 100 ft. upstream of BR36 (**Figure 3**). Additional discharges from the agricultural area occur through the eastern boundary around the farmlands into the PSRP area; these flows are generated using an undetermined number of movable pumps managed by the farms, therefore actual flows can not be accurately determined. However, With the project, these flows will be redirected south along the western protection feature (for interior drainage) through a proposed culvert (Ag.Out or L.C. for levee culvert) located less than one mile north of BR37 (**Figure 3**). The levee culvert is a feature not present in the Without Project model run; this feature allows for the quantification of flows currently going over the SWPF and into the PSRP forest.

The New Out site represents a set of three combined new culverts next to each other to be constructed to aid in the delivery of water under Highway 41 from the restored areas upstream. The New Out culverts will be located approximately 1,000 ft southeast of the BR36 culvert. Note that even though the New Out currently does not yet exist, the model equations occasionally generated flows for pre-project conditions at this location on the order of 0.5-1.0 cfs. Any nonzero flows in this situation were added to the modeled flows at BR37 for the pre-project period. The daily average flows modeled for all structures were summarized into total monthly flows over the ten-year model period.

Table 3. Model run scenarios provided by the Army Corps of Engineers (USACE) showing sources of flow through inflow and outflow structures.

Model Run	Scenario	Inflow components	Agricultural Inflow	Outflows
1	Without Project	Agricultural + PSRP Existing	Tomato Road culvert	BR36+BR37+BR39+BR40
2	SWPF Only	Agricultural + PSRP Existing	Tomato Road culvert + Levee culvert	BR36+BR37+BR39+BR40
3	SWPF+New Out	Agricultural + PSRP Existing	Tomato Road culvert + Levee culvert	BR36+**NewOut**+BR37+BR39+BR40
4	Alt Project Cond2 (With Project)	Agricultural + PSRP Existing + (**Restored)**	Tomato Road culvert + Levee culvert	BR36+**NewOut**+BR37+BR39+BR40

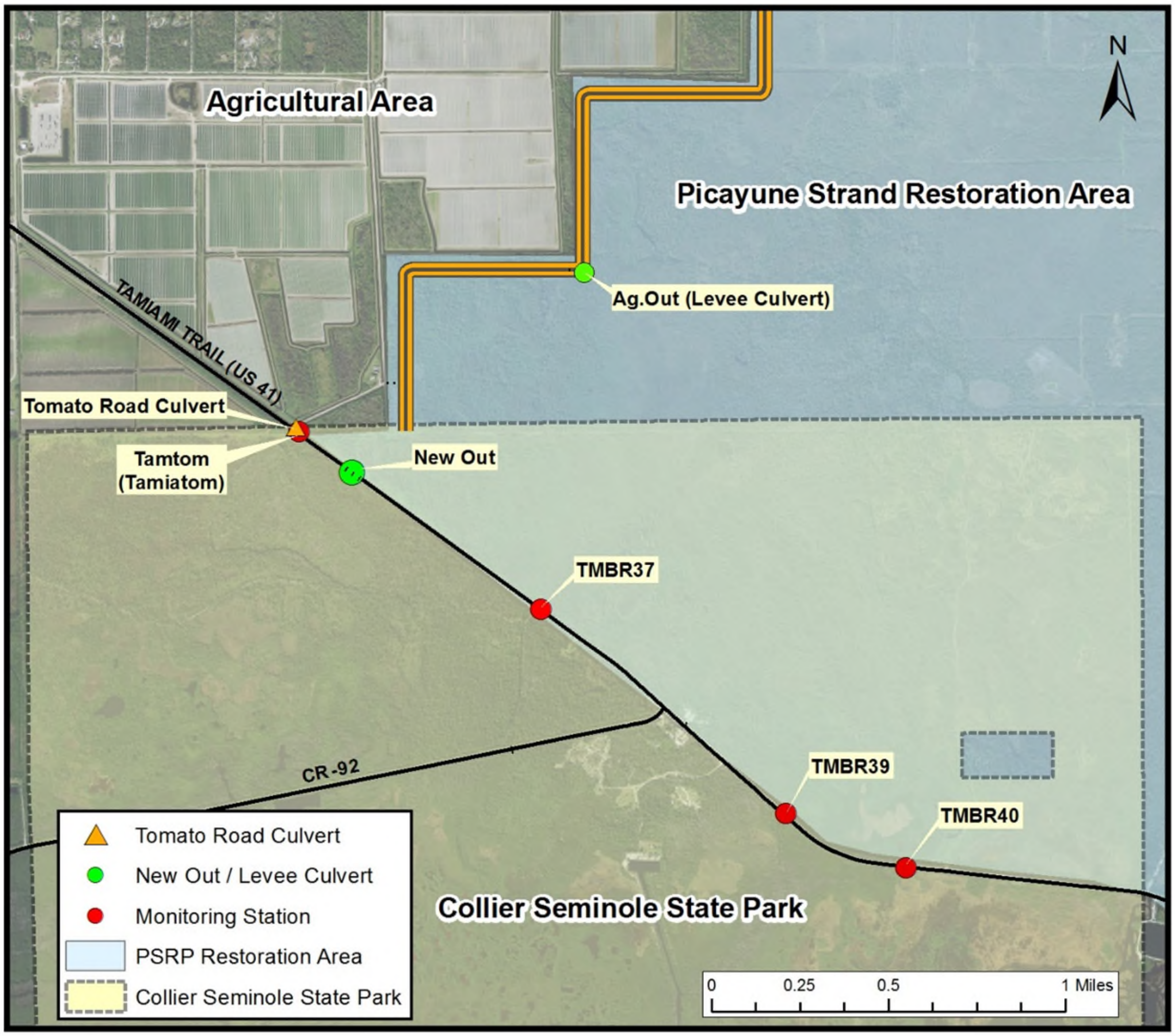

Figure 3. Map showing the Tomato Road Culvert in relation to the BR36 and New Out.

Before determining the appropriate model scenarios for the evaluation, each model output was evaluated and compared against each other to determine the level of accuracy. Model run comparisons between *SWPF Only* and the *Without Project* inflow (agricultural) volumes resulted in approximately 62% of the agricultural input missing from the *Without Project* output. Therefore, the representative without project modeled flows was selected from the *SWPF Only* model run because the *Without Project* model output did not appear to account for all agricultural flows to the Tamiami Trail (US41) culverts (**Figure 4**). Furthermore, the difference between the *SWPF Only* and the *Without Project* model run is equivalent to the unaccounted agricultural inflow *Without Project.* In contrast, comparisons between *SWPF Only* and the *SWPF+New Out*, and *Alt Project Cond2 (With Project)* agricultural inflow resulted in 4% and 2% difference respectively; these differences are consistent and representative of agricultural inputs with and without the project, particularly since increases in agricultural inputs are not expected as a result of project implementation or increase discharge by the farms. Considering that each model run is characteristically different due to new structures and features added, there is no expectation that overall inflow and outflow volumes would be the same for each model run. However, the overall inflow and outflow volume without the restored flow should be close enough so that inflows and outflows are equivalent to each other given

that agricultural inputs and the PSRP existing flow should not vary considerably between model runs for the same time period (**Figure 4**).

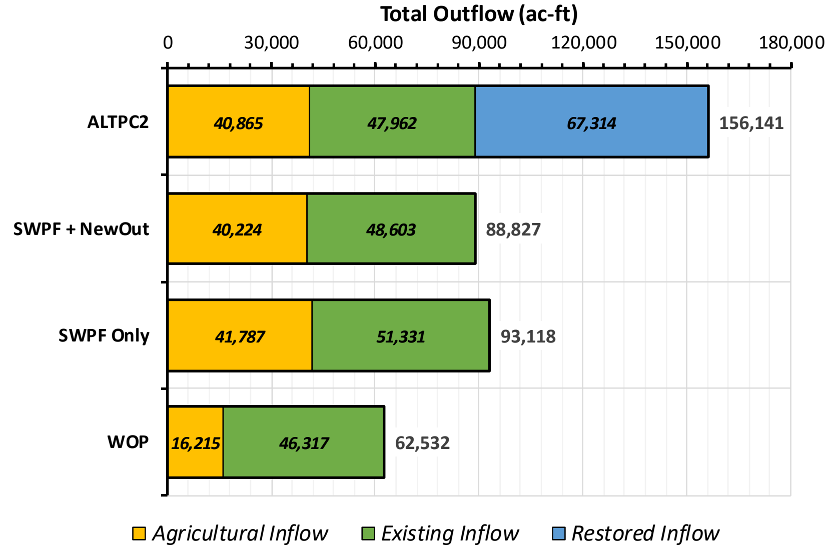

Figure 4. Comparison of total inflows and outflows for each model output covering the entire ten-year model period from 11/1/2003 to 10/31/2013.

Flow Distribution

Based on model run outputs the three different inflow components into the Collier Seminole State Park (OFW Boundary) identified as the agricultural, PSRP existing, and restored flows (**Figure 5**), were calculated for the selected model scenarios as:

$$\text{Inflow}_{\text{Agriculture}} = Q_{\text{Tomato Road}} + Q_{\text{Levee Culvert}}$$

$$\text{Outflow} = Q_{\text{BR36}} + Q_{\text{NewOut}} + Q_{\text{BR37}} + Q_{\text{BR39}} + Q_{\text{BR40}}$$

$$\text{PSRP Existing Inflow} = \text{Outflow} - \text{Inflow}_{\text{Agriculture}}$$

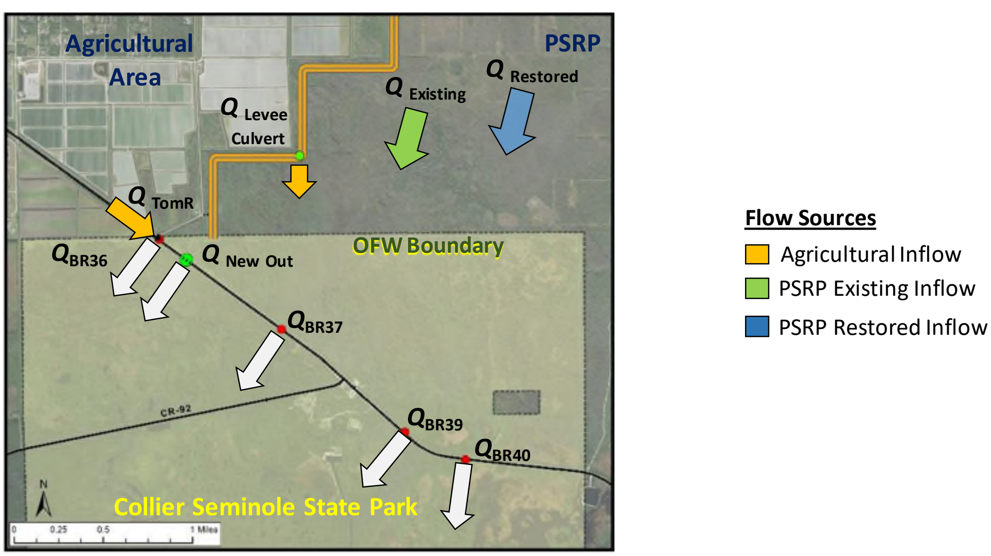

Figure 5. Map showing the different inflow sources to the Collier Seminole State Park (OFW Boundary); outflow is represented by culverts along US41.

The PSRP restored inflow component was calculated by the difference of model run *Alt Project Cond2* and *SWPF+New Out*. This approach provides a simple way to account for the total monthly volume contribution from the agricultural area, existing flow, and restored flow against the total monthly outflow so that the conservation of mass is maintained. Then, using the direct proportionality principle, proportionality constants (k) were calculated for each structure on a monthly basis as:

$$Q_{Structure} \propto Q_{Total} \text{ if } Q_{Structure} = k\,(Q_{Total}), \text{ where k is a proportionality constant}$$

$$\frac{Q_{Structure}}{Q_{Total}} = k \text{ when, } Q_{Total} \neq 0; \text{ therefore}$$

$$\frac{Q_{Structure\ (i)}}{Q_{Total}} = k_{structure\ (i)}; \sum_{i=i}^{n} k_{Structure\ (i)} = 1.00$$

Where Q_{Total} = total monthly flow across all US41 culvert structure; $Q_{Structure}$ = total monthly flow at individual US41 culvert structure; and k = proportionality constant.

Lastly, k is applied to each component to derive the correct contribution (based on the total flows passing at each structure). The allocation will maintain the mass balance (Inflows = outflows).

NUTRIENT LOAD CALCULATION

Nutrient loads *Without Project* are calculated using the modeled monthly flows for BR36, BR37, BR39, and BR40 and applying the appropriate proposed seasonal TP and TN concentrations. For this analysis, it was determined that maximum recorded nutrient concentrations were appropriate since they provide the worst-case scenario and is the most conservative approach to evaluate impacts due to project implementation. Monthly flows (Q) for each of the above structures have been parsed into the agricultural flow (A) and existing flow contributions (E) as outlined in the discussion above. Loads (TNL) at each structure are calculated as:

$$TNL_n = (Q_A \times C_A)_n + (Q_E \times C_E)_n \qquad \text{(Eq. 1)}$$

With Project flows (Q_T) are expressed as the sum of the agricultural (A), existing (E) and restored (R) flows:

$$Q_T = Q_A + Q_E + Q_R \qquad \text{(Eq. 2)}$$

Nutrient loads *With Project* are calculated using modeled monthly flows for BR36 New Out, BR37, NR39 and BR40 and applying the appropriate proposed seasonal TP and TN concentrations representing agricultural inflows, existing inflows and restored flows to the PSRP.

$$TNL_n = (Q_A \times C_A)_n + (Q_E \times C_E)_n + (Q_R \times C_R)_n \qquad \text{(Eq. 3)}$$

Annual nutrient loads (TANL) for *Without* and *With Project* are summarized as the sum of total monthly loads:

$$TANL = \sum_1^{12} TNL_n \qquad \text{(Eq. 4)}$$

FLOW-WEIGHTED MEAN NUTRIENT CONCENTRATIONS

Translating loads into flow-weighted mean (FWM) concentrations provides the best metric to gauge potential water quality influences on the receiving waters. Arithmetic averages weigh each event equally and therefore may not be representative of the actual water quality influence on the receiving waters. By determining the FWM concentration, those events with the highest inflow have a higher weight compared to those with the lowest inflows. Annual FWM concentrations for TP and TN were calculated using total annual loads and flows:

$$FWM = \frac{\sum (TANL)_i}{\sum (Q_T)_i}$$

Where Q_T is the annual flow for the i^{th} structure.

To determine the variability around the FWM concentration, a weighted standard deviation (WSD) was calculated using the equation from the National Institute of Standards and Technology (NIST 1996):

$$WSD = \sqrt{\frac{\sum_{i=1}^{n} w_i (x_i - \bar{x})^2}{\frac{(n'-1)}{n'} \sum_{i}^{n} w_i}}$$

Where n = number of observation; n' = number of non-zero observations; w_i = event weighing factor (i.e., flow); x_i = event FWM; $\bar{x}$ = annual FWM.

RESULTS

HYDROLOGIC DATA

Comparison of stage data at two existing structures (TAMIATOM and TMBR37) that convey discharges to the Collier Seminole State Park showed a strong linear relationship ($R^2 = 0.99$) suggesting a hydraulic connection between the two structures from January 2004 to December 2012. However, stage data from January 2013 to December 2019 showed significant changes in the linear relationship ($R^2 = 0.75$) and followed a second-order polynomial relationship, suggesting a possible hydraulic disconnect between both structures (**Figure 6**). The separation or disconnect of both structures suggests each structure is likely to be influenced by different sources of water (agricultural and/or existing runoff) rather than a mixing of both sources. Further investigation regarding the measurements and equipment used at these locations indicated no issues or problems associated with the instrumentation. On the other hand, historic satellite imagery suggests a gradual accumulation of vegetation along the Tamiami Canal between the two structures starting after June 2013. Recent 2019 stage data suggests an improvement in stage relationships and perhaps hydraulic connectivity between both structures; satellite imagery confirms the opening of previously obstructed segments along the Tamiami Canal that may have increased the conveyance of water.

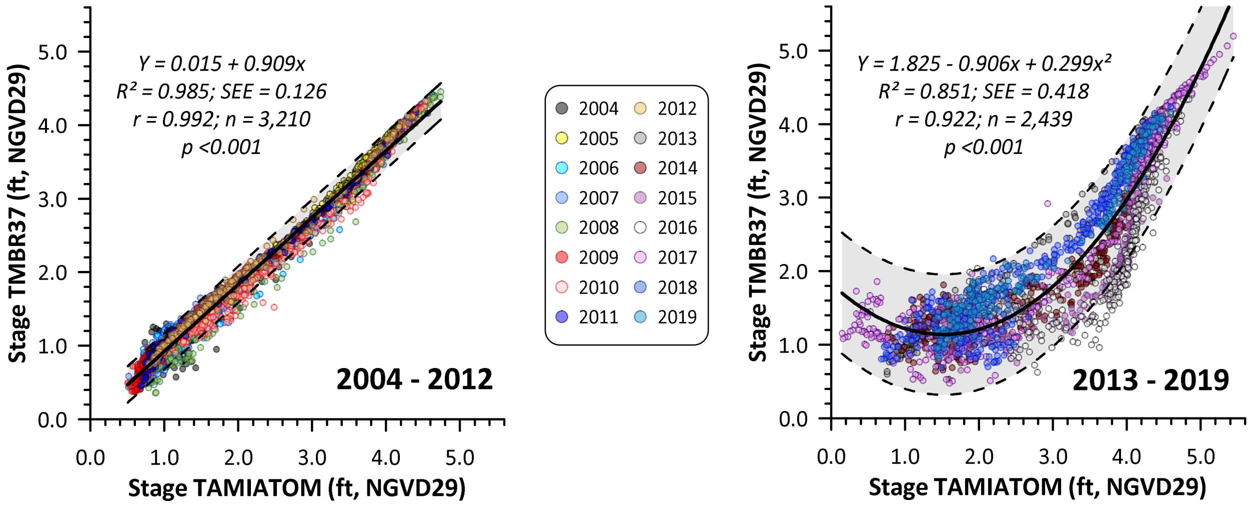

Figure 6. Scatterplot of TAMIATOM and TMBR37 stages (ft, NGVD29) from a) January 2004 to December 2012, and b) January 2013 to December 2019.

WATER QUALITY DATA

The purpose of summarizing and comparing water quality at the selected monitoring stations is to identify representative nutrient concentrations that can be used to estimate nutrient loads and concentrations that are delivered from the project area before and after flow is restored to through the wetland.

The statistical summarization of water quality data utilizes several approaches in determining the central tendencies of the data. Arithmetic averages and standard deviations can be used to provide the central tendency and variability of a data set assuming the data are normally distributed. Frequently, environmental data will follow a log-normal distribution requiring that the data are log-transformed. Under these conditions, geometric means and associated standard deviations provide an appropriate determination of central tendencies and variability. However, if the data still deviates significantly from a normal distribution after log-transformation, calculation of percentiles (25th, median, 75th, etc.) provides the best estimate of central tendencies and variabilities because no distributional assumptions are required.

Total Phosphorus

Table 4 provides statistical summarizations of TP concentrations measured at different PSRP monitoring stations. Included in the table are the statistical results of the normality test (Shapiro-Wilk) for the untransformed data and log-transformed data sets. Log-transformation of data did normalize the distribution at most monitoring stations except for TAMTOM (**Table 4**).

The station with the longest period of record (approximately 18 years) is FAKA, which is located at the southern outflow point of the project area. Generally, TP concentrations at this station ranged from <4 µg/L to 49 µg/L with a median concentration of 11 µg/L (**Table 4**). Further, water quality sampling is on-going at this monitoring station.

Stations BC9, BC10, and BC11 are inflow culverts to the PSRP and are located on the northern periphery of the PSRP. These stations have been monitored for approximately 14 years. During this period TP concentrations at these stations ranged 4 µg/L to 72 µg/L. Median TP concentrations for BC9, BC10 and BC11 are 10 µg/L, 18 µg/L, and 20 µg/L, respectively. Monitoring at these stations has not been performed since September 2015.

TAMTOM is a water quality monitoring station located at the southwestern boundary of the PSRP and has been monitored by both the SFWMD and Collier County (**Figure 3**). Water quality at TAMTOM is affected primarily by agricultural runoff conveyed through Tomato Road culvert, as well as existing base flow from the upland area.TP concentrations at TAMTOM ranged from 116 µg/L to 2,428 µg/L and had a median concentration of 276 µg/L over the more than 9 years of monitoring. This station exhibited the highest TP concentrations of all monitoring locations. TMBR37 is located less than a mile southeast of TAMTOM (Figure 1). Water quality at the TMBR37 culvert is affected by a combination of agricultural runoff from the Tomato Road culvert and existing base flows. Water quality data has been collected monthly at this location since August 2015 with TP concentrations ranging from 202 µg/L to 1,007 µg/L. TMBR37 has the second-highest TP concentrations with a median value of 251 µg/L over the period of record. TMBR49 is located at a culvert approximately 2 miles west of FAKA and over 5 miles southeast of agricultural sources. Additionally, this station receives existing base runoff passing through a wetland to the north of the structure. This station has been monitored since September 2015 with TP concentrations ranging from 6 µg/L to 28 µg/L and a median concentration of 13 µg/L. The final monitoring station summarized is located at the Merritt Pump Station (S488). Water quality sampling at this pump station started in September 2015. During the period of monitoring at this station, TP concentrations ranged from 15 µg/L to 171 µg/L with a median concentration of 38 µg/L. The discharge point for the pump station is located approximately 12 miles north of the southern boundary of the PSRP. The box plots shown in **Figure 7**, present the period of record for TP concentrations relative to each monitoring station. The box and whisker plots in this figure have been arranged to show monitoring stations with the highest to the lowest TP concentration.

Table 4. Statistical summarization of TP concentrations and periods of record for eight monitoring stations located on the periphery or within the PSRP boundary. Significant statistical probabilities (p-values) are in red.

Statistics	Total Phosphorus Summary							
	FAKA	**BC9**	**BC10**	**BC11**	**TAMTOM**	**TMBR37**	**TMBR49**	**S488**
No. of Obs.	170	150	151	130	88	37	23	43
Concentrations (µg/L)								
Minimum	4	4	4	6	106	88	6	15
25th Percentile	9	7	11	14	211	202	9	23
Median	11	10	18	20	276	251	13	38
75th Percentile	15	13	27	25	411	344	15	53
Maximum	49	36	84	72	2,428	1,007	28	171
Mean	13	11	22	21	362	314	13	45
St. Deviation	7	5	15	11	306	197	6	32
St. Error	1	<1	1	1	33	32	1	5
Geometric Mean	12	10	18	19	303	274	12	37
St. Deviation	5	4	11	9	163	138	5	22
St. Error	<1	<1	1	1	17	23	1	3
Distribution Test for Untransformed Data								
Shapiro-Wilks Stat	0.816	0.873	0.826	0.851	0.581	0.735	0.905	0.770
Shapiro-Wilks p-value	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.032*	*<0.001*
Distribution Test for Log-Transformed Data								
Shapiro-Wilk Stat	0.816	0.873	0.826	0.851	0.581	0.735	0.905	0.770
Shapiro-Wilk p-value	0.018	0.144	0.223	0.381	*<0.0001*	0.170	0.505	0.064
Start Date	Oct-2001	Oct-2001	Nov-2001	Nov-2001	Nov-2009	Aug-2015	Sep-2015	Sep-2015
End Date	Oct-2019	Sep-2015	Sep-2015	Aug-2015	Aug-2019	Oct-2019	Sep-2019	Oct-2019

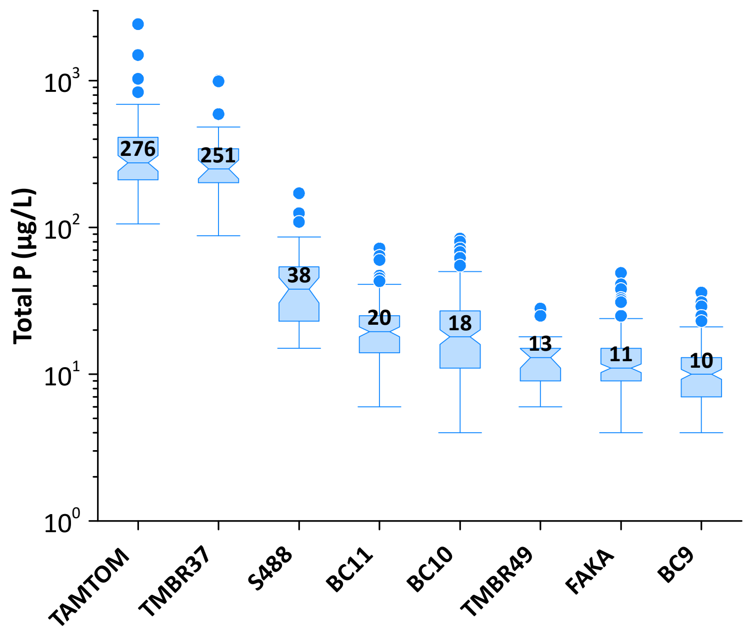

Figure 7. Notched box and whisker plots of TP concentrations measured at monitoring stations within the PSRP during the period from 2001 through 2019. Median concentrations are shown numerically for each box plot. The notches represent the 95% confidence interval around the median value. The dots represent data outside the 1.5* interquartile range.

A Kruskal-Wallis test was used to compare TP concentrations across monitoring stations. The results indicate that TP concentrations are statistically different across the monitoring network (p-value <0.001). An all-pairs comparison post hoc test was performed using the Steel-Dwass-Critchlow-Fligner test. The results indicate that the following station pairs were not statistically different from each other: TAMTOM – TMBR37 (p-value = 0.985), TMBR49 – BC9 (p-value =0.586), TMBR49 – FAKA (p-value = 0.999), FAKA – BC9 (p-value = 0.140), and BC11 – BC10 (p-value = 0.960). All the statistical results for these comparisons are provided in **Appendix A**.

Total Nitrogen

Table 5 shows the statistical summarization of TN concentrations for the PSRP monitoring network. Results for the normality test of untransformed and log-transformed TN data are also included. for the untransformed data and log-transformed data sets. Even when TN data were log-transformed, the data distributions for several stations were statistically different from normality.

The lowest TN concentrations were observed at FAKA with a period of record ranging from 0.04 mg/L to 1.65 mg/L and a median concentration of 0.46 mg/L. The highest TN concentrations were observed at TAMTOM and TMBR37, which are influenced by agricultural runoff through the Tomato Road culvert. Concentrations for these two stations range from 0.61 mg/L to 5.42 mg/L. Median TN concentrations for TAMTOM and TMBR37 are 1.59 mg/L and 1.21 mg/L respectively. TMBR49 exhibited higher TN concentrations than BC9-BC11 and S488. Overall, TN concentrations at this monitoring station ranged from 0.61 mg/L to 1.34 mg/L with a median concentration of 1.08 mg/L. This monitoring station receives surface flows via a wetland system. As a result, the higher observed TN concentrations appear to be associated with local detrital material rather than activities upstream. Lower TN concentrations measured at this station appear to be affected by rainfall events and the associated flows through the system, as will be shown further in this document. Monitoring stations located in the northern portion of the PSRP (BC9-

BC11 and S488) had comparable TN concentrations with median concentrations ranging from 0.47 mg/L at BC10 to 0.69 mg/L at S488 (**Table 5**).

Figure 8 shows the period of record concentrations relative to each monitoring station as a notched box and whisker plot. Monitoring stations in Figure 3 are arranged from those with the highest to lowest TP concentrations.

Table 5. Statistical summarization of TN concentrations and periods of record for eight monitoring stations located on the periphery or within the PSRP boundary. Significant statistical probabilities (p-values) are in red.

Statistics	Total Nitrogen Summary							
	FAKA	BC9	BC10	BC11	TAMTOM	TMBR37	TMBR49	S488
No. of Obs.	181	151	155	134	84	37	27	43
Concentrations (mg/L)								
Minimum	0.04	0.04	0.04	0.04	0.66	0.61	0.61	0.44
25th Percentile	0.39	0.48	0.36	0.44	1.33	0.83	0.92	0.60
Median	0.46	0.53	0.47	0.54	1.59	1.21	1.08	0.69
75th Percentile	0.57	0.65	0.62	0.69	1.87	1.66	1.14	0.86
Maximum	1.65	1.76	1.61	1.75	5.42	3.79	1.34	1.11
Mean	0.50	0.57	0.52	0.61	1.71	1.34	1.03	0.71
St. Deviation	0.20	0.21	0.25	0.28	0.67	0.61	0.19	0.17
St. Error	0.01	0.02	0.02	0.02	0.07	0.10	0.04	0.03
Geometric Mean	0.47	0.52	0.47	0.55	1.61	1.23	1.01	0.69
St. Deviation	0.18	0.26	0.24	0.27	0.55	0.51	0.20	0.16
St. Error	0.01	0.02	0.02	0.02	0.06	0.08	0.04	0.02
Distribution Test for Untransformed Data								
Shapiro-Wilks Stat	0.782	0.830	0.881	0.860	0.812	0.850	0.953	0.959
Shapiro-Wilks p-value	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.032*	*<0.001*
Distribution Test for Log-Transformed Data								
Shapiro-Wilk Stat	0.854	0.674	0.894	0.841	0.968	0.957	0.904	0.980
Shapiro-Wilk p-value	*<0.001*	*<0.001*	<0.001	*<0.001*	*0.035*	0.168	*0.017*	0.640
Start Date	Oct-2001	Oct-2001	Oct-2001	Oct-2001	Nov-2009	Aug-2015	Sep-2015	Sep-2015
End Date	Oct-2019	Sep-2015	Sep-2015	Aug-2015	Aug-2019	Oct-2019	Sep-2019	Oct-2019

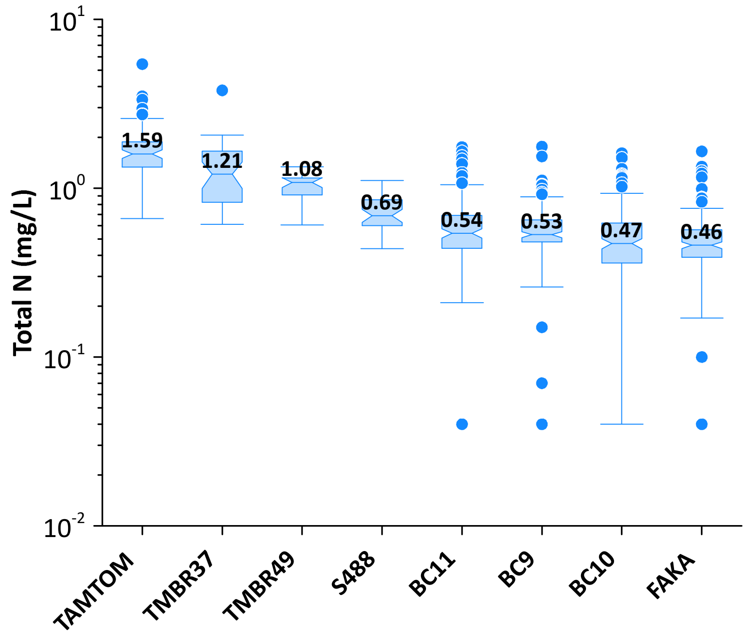

Figure 8. Notched box and whisker plots of TN concentrations measured at monitoring stations within the PSRP during the period from 2001 through 2019. Median concentrations are shown numerically for each box plot. The notches represent the 95% confidence interval around the median value. The dots represent data outside the 1.5* interquartile range.

The comparison of TN concentrations across monitoring stations in the PSRP was performed using the Kruskal-Wallis test. The results from the test show that TN concentrations are statistically different across the monitoring network (p-value <0.001). This analysis was followed by an all-pairs comparison post hoc test, Steel-Dwass-Critchlow-Fligner, to identify which stations were statistically different from each other. Based on the results from the post hoc test, the following pairs of stations did exhibit a statistical difference: TAMTOM – TMBR37 (p-value = 0.067), TMBR37 – TMBR49 (p-value =0.456), BC9 – BC10 (p-value = 0.1548), BC11 – BC9 (p-value = 0.991), and FAKA – BC10 (p-value = 0.987). All results for these tests are provided in Appendix A.

Nutrient Trend Analysis

Nutrient trends were determined using a Seasonal Man-Kendall test. Data for each parameter were averaged by year and month. For the purpose of the trends present herein, months were identified as seasons. **Figure 9** provides the results of the trend analyses for both TP and TN.

Based on the data summarized, most monitoring stations did not exhibit a significant trend over their respective periods of record for either TP or TN. Three monitoring stations had a statistically significant trend (p-value <0.05) with respect to TP concentrations. Two stations, TMBR49 and TMBR37, exhibited a significant increasing trend, while BC9 had a decreasing trend. The only station that exhibited a statistically significant trend (p-value <0.05) for TN concentrations was BC11. The observed trend suggests that concentrations have been decreasing over the period of record at this station. More detailed results from the Season Mann-Kendall analyses are available in **Appendix B**.

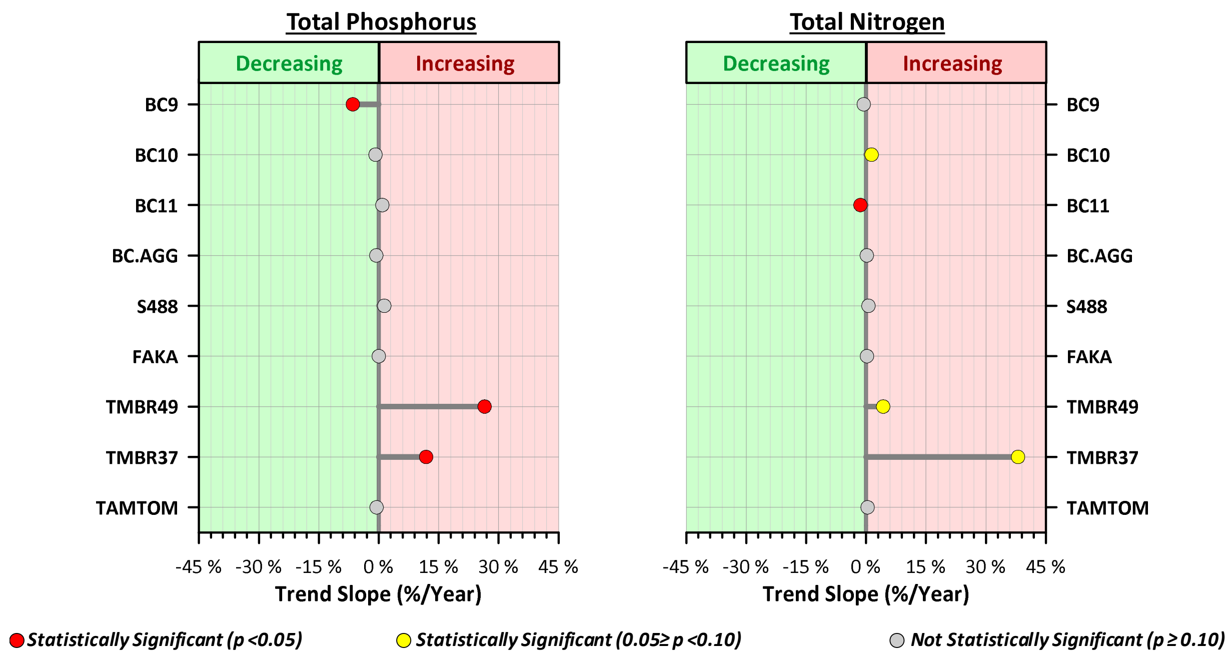

Figure 9. Trend magnitudes (expressed as percent change per year) and significance levels (α = 0.05 and 0.10) for TP and TN at each monitoring station.

Potential Sources of Surface Water

The Picayune Strand Restoration Project – Basis of Design Report (Parsons 2005) indicated that the rainfall was the primary source of surface water to the PSRP and stated that:

"The shallow Water Table Aquifer, which is well connected with the canal system, responds rapidly to rainfall, the primary source of recharge. Generally, this recharge occurs after rainfall events when the canal water levels are higher than adjacent groundwater levels. Other sources of recharge are inflow from surface water bodies, such as the canals; subsurface flow from adjacent areas; and upward seepage from semi-confined deeper aquifers"

The report also indicated that mean TP concentrations from inflow monitoring locations (BC9-BC11) along the Faka Union and Merritt Canals were 15 µg/L and that estuarine TP concentrations at the outfall of the Faka Union Canal weir averaged 20 µg/L (Parsons 2005).

Additionally, stable isotopic ratios of ($^{18}O/^{16}O$) and hydrogen ($^{2}H/^{1}H$) were collected by the USGS to identify potential mixing patterns between surface water and groundwater for the Manatee Mitigation Feature that is part of the PSRP (Slone et al in progress). The partitioning of the isotopic ratios is useful in characterizing surface-groundwater mixing. Data collected included surface water samples collected immediately upstream of the Faka Union Canal Weir or FAKA. The results of the analyses performed by USGS indicate that the isotopic ratios measured at FAKA have isotopic ratios that are consistent with rainfall (Slone et al in progress).

Figure 10 presents a monthly plot of rainfall from the COLLISEM rain gauge and flows at FAKA and S488 Pump Station (S488_P). Flows at FAKA and S488_P respond to rainfall as shown in the figure. In addition, average daily flows at S488_P from 2015 through 2019 were 212 ac-ft compared to 1,084 ac-ft at FAKA or 19% of the flow at FAKA.

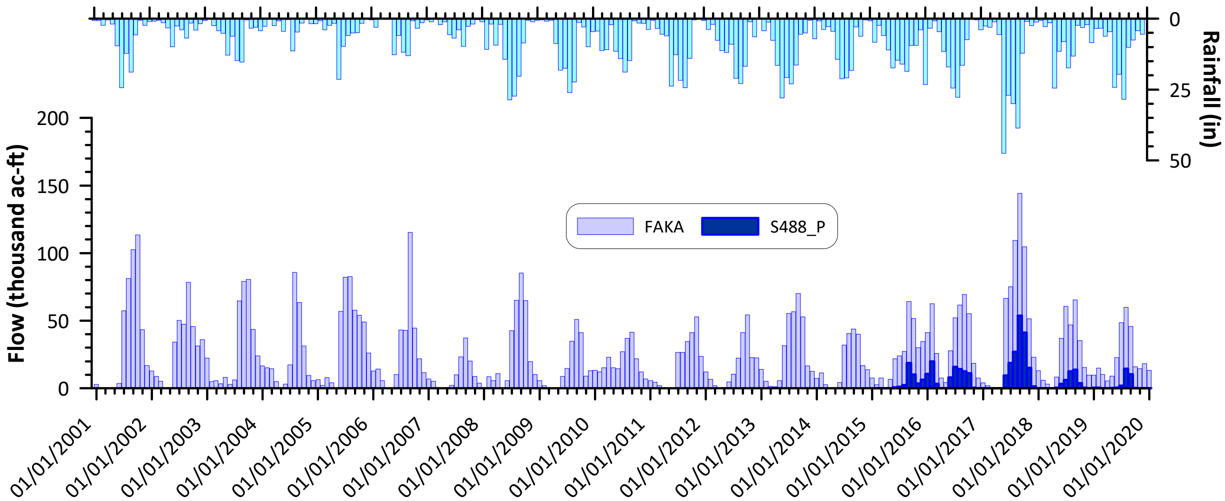

Figure 10. Monthly rainfall at COLLISEM gauge and monthly flows at S488 Pump Station and FAKA for the period from 2015 through 2019.

A comparison of daily rainfall and flows with TP and TN concentrations at FAKA, TMBR49 and S488 are provided in Figure 10. Typically, TP concentrations at S488, FAKA, and TMBR49 responded to inflow increases through the PSRP. An estimation of flow-weighted TP concentrations was performed for FAKA and S488 for the periods from January 2015 through December 2019 and January 2018 through December 2019. FAKA concentrations were approximately 5 times lower than S488 for the five-year period and 3 times lower for the most recent 2-year period (**Figure 11**). Flow-weighted TN concentrations at both monitoring stations during these two periods were 0.55 mg/L at FAKA and 0.82 mg/L at S488. While FAKA and S488 typically exhibited higher nutrient concentrations with increased flow, nutrient concentrations at TMBR49 appear to be inversely affected by rainfall and flow events. During these events, nutrient concentrations at this station decreased. These observed decreases suggest dilution from upstream sources and rainfall.

Evaluation of daily rain data from the COLLISEM meteorological station showed the seasonal variation in precipitation associated with the onset of the wet and dry season. Currently, the PSRP area flows continue to be redirected through the existing features (canals and ditches) and pumped through by the S488 pump (one of three pumps proposed for the PSRP) to the FAKA site and possibly at TMBR49. Overall, peak flow events observed at S488 and FAKA from January 2015 to December 2019 appeared to be associated with rain events following the seasonal pattern (**Figure 11**). High TP concentration peaks were observed at S488 and FAKA as a result of tropical storm Irma in September 2017. In contrast, no high TP concentrations observed at TMBR49 as a result of the storm. Overall, TP concentrations at S488 appeared to be substantially higher than those at FAKA following the tropical storm. The current ongoing work activities associated with the project at S488 and near the site have the potential to elevate TP concentrations in localized areas. Nonetheless, the materialized FWM TP concentration at FAKA appeared not to be as affected by these peaks (**Figure 11**).

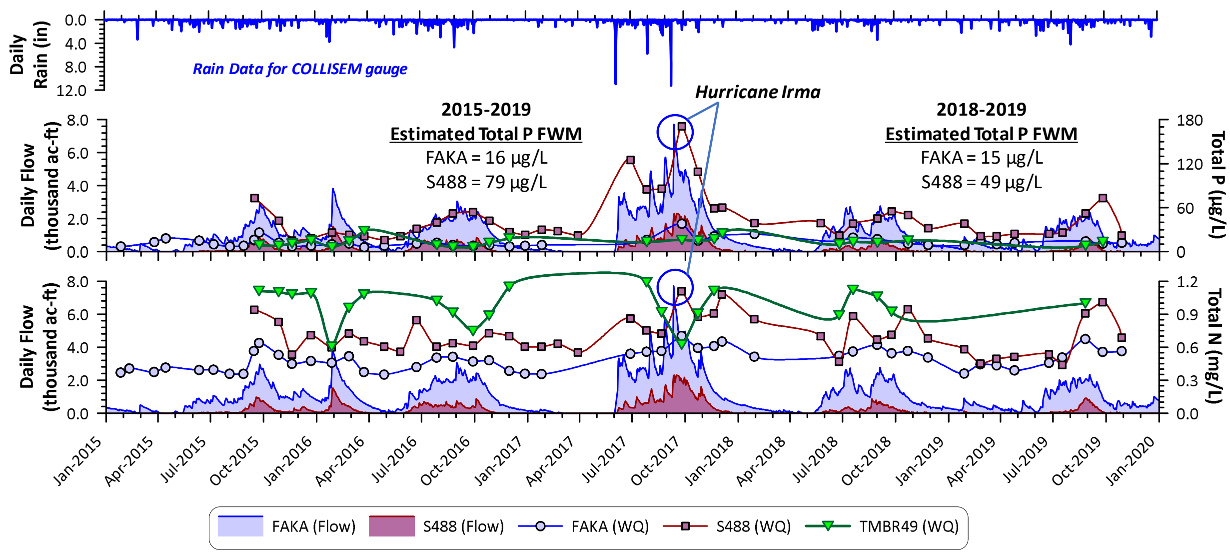

Figure 11. Daily rainfall at COLLISEM gauge and daily flows at S488 Pump Station and FAKA with TP and TN concentrations at FAKA, S488, and TMBR49 for the period from 2015 through 2019.

Proposed Nutrient Concentrations to Be Used to Characterize Loads With and Without Project

The evaluation of potential impacts by the PSRP on receiving waters will be performed following the methodology used by Restoration Strategies to estimate nutrient loads. As part of this methodology, nutrient data will be aggregated by season (i.e., month) based on empirical data collected at monitoring stations in the PSRP that are representative of concentrations passing through inflow points to the receiving waters.

A sufficiently long period of record water quality dataset exists for four monitoring stations along the southern boundary of the PSRP: TAMTOM, TMBR37, TMBR49, and FAKA. Based on statistical comparisons and analyses performed on the water quality data for these four monitoring stations, it is proposed that TP and TN data for TAMTOM and TAMBR37 be aggregated seasonally to represent agricultural inflow concentrations due to their proximity to agricultural sources. Water quality data representing the existing base and restored flows are proposed to be comprised of aggregated TP and TN data from FAKA and TMBR49. **Figure 12** and **Tables 6 and 7** show the monthly aggregations of TP and TN concentration data for agricultural inputs, existing base flow, and restored flow.

The aggregated concentrations will be used in conjunction with modeled monthly flows to estimate nutrient loads for scenarios depicting *Without Project* and *With Project* flow conditions.

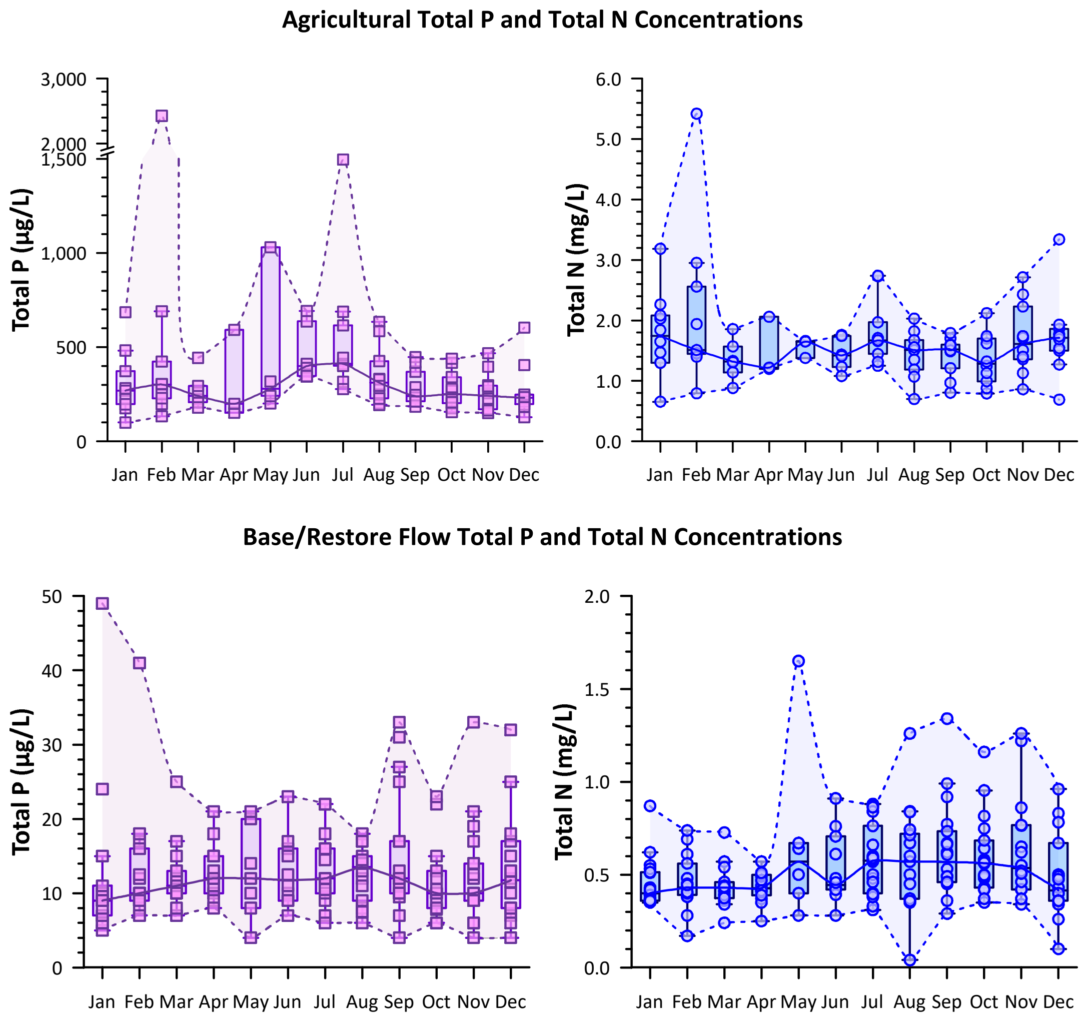

Figure 12. Box and whisker plots of TP and TN concentrations representing agricultural inflows and existing base/restored flows. The box plots show the monthly median, and the 25th, and 75th as percentiles. Squares and dots represent actual TP and TN values, as well as the minimum and maximum concentrations.

Table 6. Statistical summary of proposed seasonal agricultural nutrient concentrations based on water quality data collected at TAMTOM and TMBR37 to be used to evaluate nutrient inputs to the receiving waters for Without and With Project flow conditions.

Month	No. Obs.	Statistics						
		Minimum	25^{th}	Median	75^{th}	Maximum	IQR ($75^{th} - 25^{th}$)	Standard Error
Total P (µg/L)								
Jan	9	100	197	269	373	686	176	59
Feb	9	133	229	302	424	2428	195	65
Mar	6	180	212	241	286	443	74	30
Apr	3	152	176	199	396	592	220	127
May	4	201	231	280	496	1030	265	133
Jun	6	344	357	400	581	692	223	91
Jul	9	278	401	412	616	1496	215	72
Aug	10	194	233	312	402	634	169	54
Sep	10	185	218	240	350	447	132	42
Oct	10	156	203	251	325	439	122	39
Nov	10	151	170	241	296	468	125	40
Dec	10	128	201	231	245	604	44	14
Total N (mg/L)								
Jan	10	0.66	1.34	1.75	2.07	3.19	0.73	0.23
Feb	9	0.79	1.45	1.51	2.56	5.42	1.11	0.37
Mar	6	0.88	1.18	1.32	1.51	1.86	0.33	0.13
Apr	3	1.20	1.21	1.22	1.64	2.06	0.43	0.25
May	3	1.38	1.52	1.65	1.66	1.66	0.14	0.08
Jun	6	1.08	1.28	1.42	1.67	1.76	0.39	0.16
Jul	9	1.25	1.45	1.67	1.97	2.74	0.53	0.18
Aug	10	0.70	1.23	1.51	1.65	2.03	0.42	0.13
Sep	10	0.80	1.28	1.52	1.60	1.79	0.32	0.10
Oct	10	0.79	1.03	1.29	1.68	2.12	0.65	0.21
Nov	10	0.86	1.37	1.61	2.11	2.71	0.74	0.23
Dec	10	0.69	1.51	1.71	1.84	3.34	0.33	0.10

Table 7. Statistical summary of proposed seasonal existing base/restored flow nutrient concentrations based on water quality data collected at TMBR49 and FAKA to be used to evaluate nutrient inputs to the receiving waters for Without and With Project flow conditions.

Month	No. Obs.	Statistics						
		Minimum	25^{th}	Median	75^{th}	Maximum	IQR (75^{th} – 25^{th})	Standard Error
Total P (µg/L)								
Jan	15	5	7	9	11	49	4	1
Feb	14	7	9	10	15	41	6	2
Mar	15	7	10	11	13	25	3	1
Apr	11	8	11	12	15	21	5	3
May	7	4	9	12	17	21	8	4
Jun	10	7	9	12	16	23	7	3
Jul	16	6	10	12	16	22	6	2
Aug	16	6	9	14	15	18	6	2
Sep	17	4	10	12	17	33	7	2
Oct	15	6	9	10	13	23	5	1
Nov	17	4	9	10	14	33	5	2
Dec	16	4	8	12	16	32	8	2
Total N (mg/L)								
Jan	18	0.35	0.36	0.40	0.51	0.87	0.15	0.05
Feb	15	0.17	0.40	0.43	0.52	0.74	0.13	0.04
Mar	13	0.24	0.37	0.43	0.46	0.73	0.09	0.04
Apr	12	0.25	0.38	0.43	0.49	0.57	0.11	0.06
May	6	0.28	0.43	0.57	0.66	1.65	0.24	0.14
Jun	12	0.28	0.42	0.44	0.63	0.91	0.21	0.09
Jul	18	0.31	0.42	0.58	0.74	0.88	0.32	0.11
Aug	17	0.04	0.37	0.57	0.72	1.26	0.35	0.11
Sep	18	0.29	0.46	0.57	0.72	1.34	0.26	0.08
Oct	18	0.35	0.44	0.56	0.67	1.16	0.23	0.07
Nov	16	0.34	0.42	0.54	0.76	1.26	0.34	0.11
Dec	16	0.10	0.36	0.42	0.54	0.96	0.18	0.06

SURFACE FLOWS

Modeled flows for *With Project* and *Without Project* were derived from the model scenarios provided by the USACE. The three different inflow components (agricultural, PSRP existing, and restored flows), and the distribution of flow across all outflow culverts and bridges (US41 structures) were estimated based on the procedure described in the methods section.

A comparison of total monthly flows across all US41 structures for *With Project* and *Without Project* modeling scenarios for WY2005 to WY2013 showed minimal changes in dry-season flow volumes between the two scenarios. However, peak wet-season flow volumes were noticeably higher (sometimes more than doubled) for the *With Project* scenario (**Figure 13**). Both modeled scenarios showed distinct flow patterns associated with wet and dry season conditions consistent with regional patterns. In South Florida, surface flows typically increase gradually at the beginning of the wet season (May – June) with peak flows observed between July and September, followed by a gradual decrease near the end of October. Therefore, the bulk of the modeled flow through the US41 culverts typically is observed from June to October (**Figure 13**).

The combined flows for the BR39 and BR40 structures were comparable for the two scenarios: 69% of the total flow for *Without Project* and 70% of the total flow for *With Project*. The majority of the remaining flow is associated with BR37, 23% *Without Project* and 18% *With Project*. These three structures (BR37, BR39, and BR40) combined accounted for most of the flow passing through the US41 structures into the Collier Seminole State Park. No more than 12% of the entire flow is observed through BR36 and the New Out structure combined. A reduction of flow allocation with the project is observed at BR36 and BR37 (**Figure 14**). This reduction may be in response to increased conveyance and higher flow capacity through the New Out and the current limited flow capacity at BR36 (USACE 2020). While the flow proportionality across all structures remained consistent, the introduction of the restored flow greatly increases the total volume passing through the structures. The only exception is BR36 where flows are reduced by an average 32% (**Table 8**). While changes in stage elevation are not included as part of this analysis, it is expected that higher restored flows will result in higher stages within the project area. Consequently, the increase in stage will reduce head and tailwater head differences at the Tomato Road culvert thus limiting flows through this structure as observed in the modeled flow results.

Based on model outputs and the flow distribution described in the methods section, the overall WY2005 to WY2013 total flow volume for agricultural and existing flow inputs were comparable for *Without* and *With Project* scenarios. Slight differences between model output are within acceptable error, considering that each model run is characteristically different and independent from others (**Table 9**). Therefore, there is no expectation that overall inflow and outflow volumes would be the same for each model run. Under the current condition (*Without Project*), total agricultural discharges for WY2005 to WY2013 accounted for nearly 45% (39,176 ac-ft) of the total flow across the US41 structures. While the agricultural volume under the *With Project* scenario (37,856 ac-ft) is comparable to the *Without Project* volume, it only accounts for 27% of the total flow (which includes restored flows) across the US41 structures. Finally, the restored flow (58,963 ac-ft) *With Project* accounts for 41% of the total flow across the US41 structures (**Figure 15**).

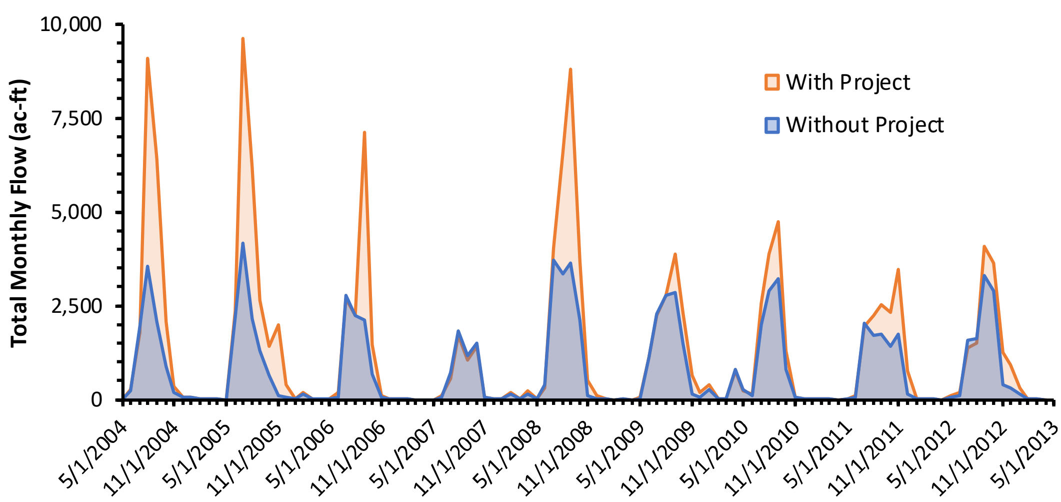

Figure 13. Comparison of estimated total monthly flows (ac-ft) *Without Project* and projected flow *With Project* for WY2005 to WY2013.

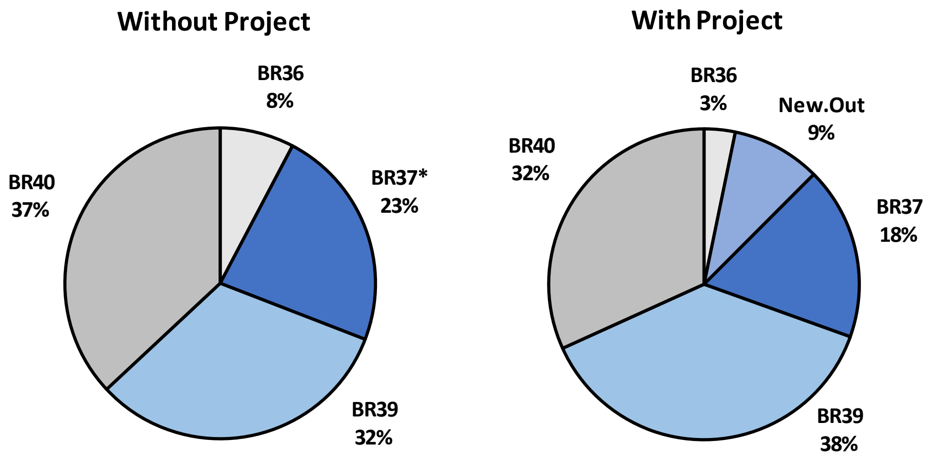

Figure 14. Comparison of *Without Project* and *With Project* percent distribution of flow across the US41 culverts; percentages are estimated using the total flow across each structure for WY2005 to WY2013.

Table 8. Change in total flow volume (ac–ft) across individual US41 culverts *Without* and *With Project* for YW2005 to WY2013; based on the sum of monthly flow volumes.

	BR36	New Out	BR37	BR39	BR40
Without Project Total Flow (ac-ft)	6,739	--	20,201	28,109	32,261
With Project Total Flow (ac-ft)	4,587	13,210	25,573	53,731	45,211
***With Project* % Change** in Total Flow	-32%	--	27%	91%	40%

Table 9. Comparison of model output total flows and model differences Without Project (SWPF Only model run) and With Project (ALT2P model run) for YW2005 to WY2013.

	Without Project			***With Project***	
Flows Compared	**SWPF Only**	**SWPF + New Out**	**Model Output Difference**	**ALT2P**	**Overall *With Project* % Change**
Agricultural inflow	39,176	37,856	-3%	37,856	-3%
PSRP Existing inflow	48,134	45,493	-6%	45,493	-6%
PSRP Restored inflow	---	---	---	58,963	
All US41 Culvert outflow	87,310	83,349	-5%	142,313	39%

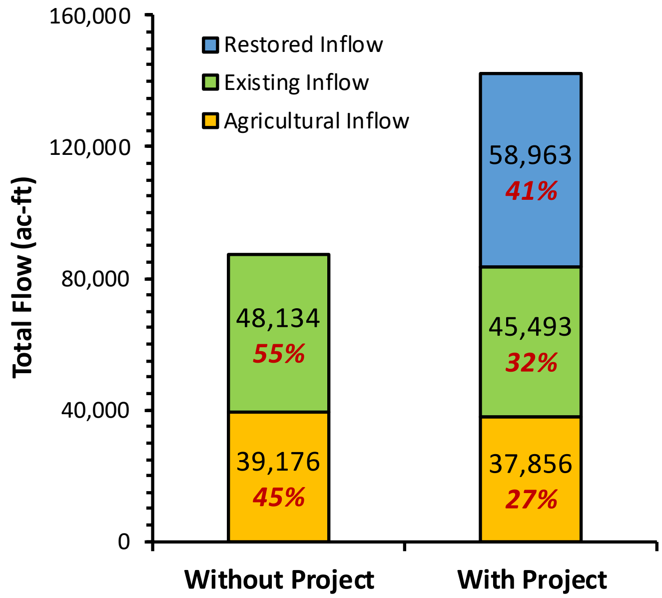

Figure 15. Comparison of aggregated monthly total volumes for the different inflow sources (agricultural, PSRP existing, and restored) for WY2005 to WY2013.

FLOW-WEIGHTED MEAN CONCENTRATIONS

Annual FWM concentrations were estimated based on nutrient load calculations as described in the methods section. The maximum TP and TN concentration proposed for use in the modeling effort (**Tables 6 and 7**) were used to estimate monthly nutrient loads. The use of maximum TP and TN concentration is considered as the most conservative approach to evaluating potential water quality impacts resulting from the project implementation. The estimated *With Project* and *Without Project* FWM TP and TN concentrations were compared against the existing ambient water quality provided by FDEP. The existing ambient water quality were derived by FDEP following the procedure outlined in Section 62-302.700 of the Florida Administrative Code (FAC) for Outstanding Florida Water (OFW)[3] which established the baseline data for this project as the water year 2019 (the year prior to the permit application) and the TAMTOM (BR36) location as representative of water flowing into OFW (FDEP 2020). While the baseline is presented as an annual geometric mean, it is assumed that the relationship between annual geometric means and flow-weighted means is 1:1 (FDEP 2020).

[3] Outstanding Florida Waters
62-302.700 FAC
(1) "… No degradation of water quality, other than that allowed in subsections 62-4.242(2) and (3), F.A.C., is to be permitted in Outstanding Florida Waters and Outstanding National Resource Waters, respectively, notwithstanding any other Department rules that allow water quality lowering."
(8) For each Outstanding Florida Water listed under subsection 62-302.700(9), F.A.C., the last day of the baseline year for defining the existing ambient water quality (paragraph 62-4.242(2)(c), F.A.C.) is March 1, 1979, unless otherwise indicated. Where applicable, Outstanding Florida Water boundary expansions are indicated by date(s) following "as mod." under subsection 62-302.700(9), F.A.C. For each Outstanding Florida Water boundary which expanded subsequent to the original date of designation, the baseline year for the entire Outstanding Florida Water, including the expansion, remains March 1, 1979, unless otherwise indicated.
62-4.242(2)
(a) "No Department permit or water quality certification shall be issued for any proposed activity or discharge within an Outstanding Florida Waters, or which significantly degrades, either alone or in combination with other stationary installations…"
(c) "For the purpose of this section the term "existing ambient water quality" shall mean (based on the best scientific information available) the better water quality of either (1) that which could reasonably be expected to have existed for the baseline year of an Outstanding Florida Water designation or (2) that which existed during the year prior to the date of a permit application. It shall include daily, seasonal, and other cyclic fluctuations, taking into consideration the effects of allowable discharges for which Department permits were issued or applications for such permits were filed and complete on the effective date of designation."

Comparison of estimated annual FWM TP concentrations entering the Seminole Collier Park for WY2005 to WY2013 indicates that a considerable reduction in FWN TP may be expected as a result of *With Project* implementation. Based on FDEP proposed annual baseline TP of 310 ± 50 µg/L (GM ± SE_{GM}), most annual FWM TP concentrations *With Project* appeared below the baseline year range (**Figure 16**). The only exception is WY2008, which appears to be affected by low flow conditions extending from a severe drought. As a result, both *Without Project* and *With Project* scenarios exhibited high FWM TP concentrations for this water year (**Figure 16 and 17**).

Estimated annual FWM TN concentrations for both the *With* and *Without Project* scenarios during WY2005 – WY2013 were lower than the 2.18 ± 0.21 mg/L (GM ± SE_{GM}) baseline determined by FDEP. While the differences in FWM TN concentrations between the two scenarios were not as pronounced as TP, *Without Project* concentrations were slightly higher those for *With Project* (**Figure 17**). Summary tables for each parameter and each water year summarizing annual flows, loads and FWM concentrations are provided in **Appendix C**.

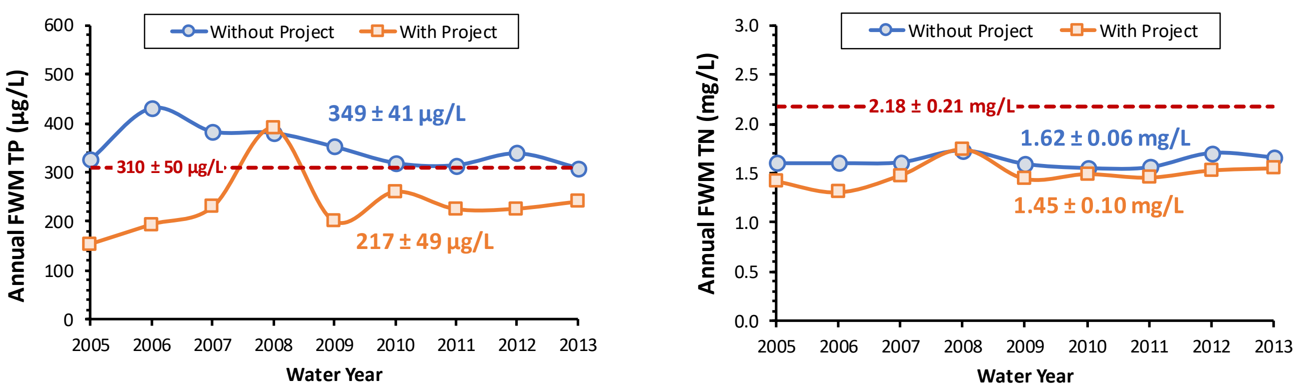

Figure 16. Annual FWM TP and TN concentrations *With* and *Without Project* for WY2005 to WY2013 compared against FDEP baseline WY 2019 values (GM ± SE_{GM}).

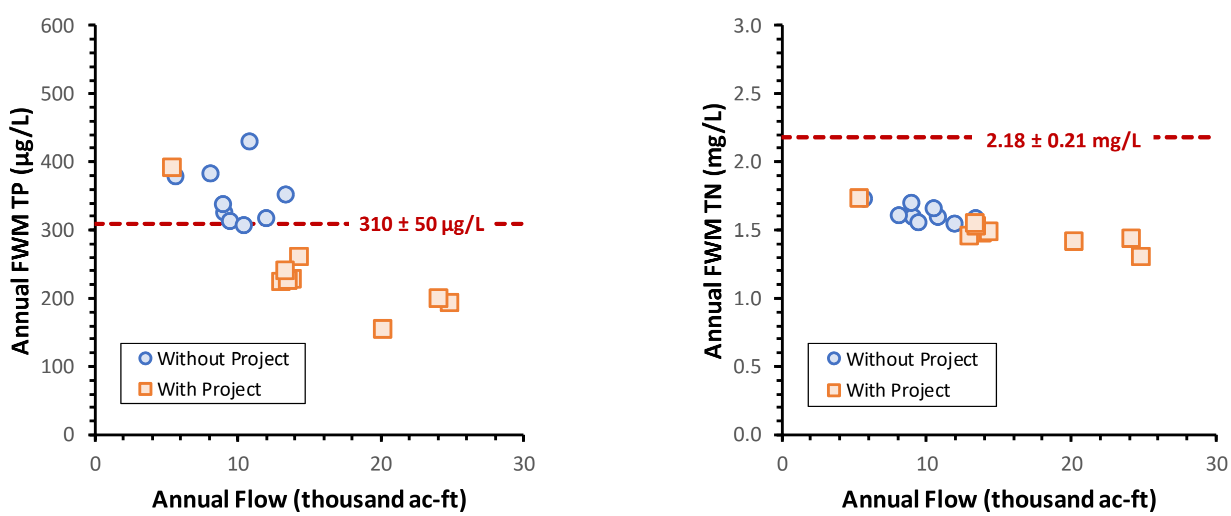

Figure 17. Scatterplot of annual flows, and FWM TP and TN concentrations *With* and *Without Project* for WY2005 to WY2013 compared against FDEP baseline WY 2019 values (GM ± SE_{GM}).

PRESENT CONDITIONS IN RECEIVING ESTUARINE REGIONS

The PSRP project implementation will directly increase discharges to the Collier-Seminole State Park and these volumes are ultimately expected to flow into the Cape Romano – Ten Thousand Islands Aquatic Preserve, primarily into the regions known as Rookery Bay/Marco Island, Blackwater River, and Gulf Islands. These regions have assigned estuary NNC by FDEP as listed in Section 62-302.532, F.A.C. (**Table 10)**. The criteria are calculated from all available data in a region and are expressed as an annual geometric means (AGM) not to be exceeded more than once in a three-year period. A comparison of the recent ten water years (2009 - 2019) AGM for TN, TP, and Chlorophyll *a* with the corresponding NNC for each of the regions, shows TN consistently exceeding the criteria. In contrast, TP annual concentrations exceeded the criteria less than four times, while and Chlorophyll *a* did not exceed the criteria (**Table 11**). Prior to reaching the estuary regions, most of the project flows will likely be directed through the Mud Bay/Palm Bay, and the Blackwater River tidal creeks (**Figure 2**). Evaluation of two monitoring stations (TTI75 and TTI75B) within these tidal creeks shows that both TN and TP have been above the criteria for most years (**Figure 18**). However, as indicated by modeling results, reduction in TP and TN concentrations are expected. Therefore, project waters (restored flow) discharged to these areas are not expected to adversely impact the tidal creeks or the estuarine regions.

Table 10. FDEP Established Numeric Nutrient Criteria (Section 62-302.532(1), F.A.C.)

Estuary Segment Code	Region (sub-paragraph)	Total N mg/L	Total P mg/L	Chlorophyll *a* µg/L
ENRE3	Rookery Bay/Marco Island (e)(3)	0.3	0.046	4.9
ENRE8	Blackwater River (e)(8)	0.41	0.053	4.1
ENRE10	Gulf Islands (e)(10)	0.44	0.038	3.4

Table 11. Review of NNC Annual Geometric Means for the Ten Thousand Islands Region for Water Years 2010-2019. NNC criteria excursions are indicated by red italics.

Water Year (WY)	Total Phosphorus, TP (mg/L)			Total Nitrogen, TN (mg/L)			Chlorophyll-*a*, Chla (µg/L)		
	Rookery Bay/Marco Island	Blackwater River	Gulf Islands	Rookery Bay/Marco Island	Blackwater River	Gulf Islands	Rookery Bay/Marco Island	Blackwater River	Gulf Islands
	ENRE3	ENRE8	ENRE10	ENRE3	ENRE8	ENRE10	ENRE3	ENRE8	ENRE10
2010	0.043	0.048	0.033	*0.41*	*0.49*	*0.44*	*5.20*	*4.20*	2.80
2011	*0.048*	*0.059*	*0.041*	*0.43*	*0.55*	*0.52*	3.60	3.90	3.40
2012	*0.049*	*0.059*	*0.039*	*0.44*	*0.56*	*0.52*	*5.90*	*4.90*	*4.40*
2013	0.045	*0.054*	0.037	*0.43*	*0.52*	*0.49*	4.60	3.60	3.00
2014	0.046	0.051	0.034	*0.40*	*0.50*	*0.46*	3.90	3.20	3.20
2015	0.042	0.045	0.031	*0.37*	*0.44*	0.41	4.40	3.60	3.20
2016	0.039	0.048	0.032	*0.52*	*0.55*	*0.59*	4.40	*4.60*	*4.00*
2017	0.040	0.047	*0.044*	*0.31*	0.37	0.41	2.40	3.20	3.10
2018	0.044	0.052	0.034	*0.39*	*0.48*	*0.45*	3.50	*4.40*	2.20
2019	*0.047*	*0.064*	0.038	*0.43*	*0.53*	*0.51*	3.40	2.40	2.40

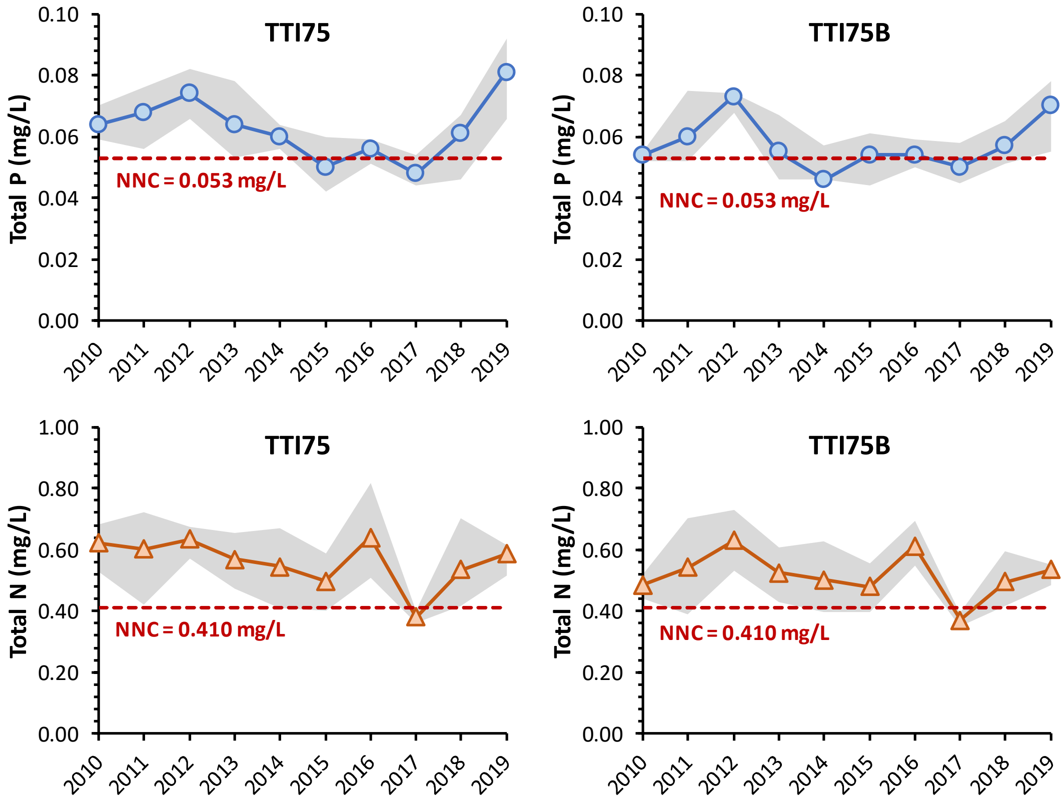

Figure 18. Total phosphorus (TP) and total nitrogen (TN) Annual geometric mean, and Numeric Nutrient Criteria (NNC) in mg/L for the closest two stations (TTI75 and TTI75B) receiving waters from the Blackwater River tributaries. Shaded area indicates the interquartile Range (25th to 75th Percentiles).

CONCLUSION

The main objectives of this analysis were to determine the possible impacts with respect to TP and TN concentrations that can be expected with the proposed PSRP restored flows. The assessment of potential impacts was performed by evaluating changes in surface flows, and TP and TN concentrations prior to project implementation (*Without Project*) and after project completion (*With Project*). An assessment of nutrient concentrations in relation to established NNC in estuarine areas was also conducted. This report summarizes findings based on model outputs of surface water flows generated by the USACE; and water quality data available at each of the structures and monitoring stations within the project area. The three different inflow components (agricultural, PSRP existing, and restored flows) into the Collier Seminole State Park were estimated from the model outputs.

Water quality (TP and TN concentrations) applied to the PSRP existing and restored flow were derived from the seasonal aggregation of the FAKA and TMBR49. While TP and TN concentrations from the agricultural area were derived from TAMTOM and TMBR37 sites. In both cases, maximum concentrations were used as metrics for evaluating possible water quality impacts resulting from project implementation. The use of maximum seasonal concentrations is viewed as a conservative approach to determine potential impacts to downstream areas.

Based on model results of calculated flows through the five structures evaluated (BR36, BR37, New Out, BR39, and BR40), flows to the downstream areas (Collier-Seminole State Park and down to the Cape Romano – Ten Thousand Islands Aquatic Preserve) will increase by as much as 39% most of it generated by the restored flow *With Project*, and considering that increase in agricultural discharges are not expected as a result of project implementation. The majority of the modeled flow *With Project* (70%) and *Without Project* (69%) across the US41 structures will remain through the eastern most structures BR39, and BR40. *With Project*, total flows through BR36 (TAMTOM) will be reduced by 32%, this is likely due to increased conveyance and higher flow capacity through the New Out set of culverts and the limited flow capacity at the BR36 culvert.

Taking into account flow and nutrient concentrations, the overall FWM TP and TN concentrations across all US41 structures are expected to be lower *With Project*. Based on the baseline proposed by FDEP, the project restored flow results in improved water quality by lowering and maintaining FWM TP concentrations below the baseline. Similarly, the restored flow does not show an increase in the FWM TN concentrations, which already below the baseline FWM TN concentrations. Rather, FWM TN concentrations are further improved *With Project*.

Finally, the evaluation of the downstream areas indicated that the estuarine regions have not been meeting the assigned NNC for TN and some excursions have occurred for TP and Chlorophyll *a* during the past ten years. Based on data derived from modeled flows and nutrient concentrations associated *With Project* implementation, it is expected that discharges to Collier-Seminole State Park will be of improved water quality for both TP and TN. It is also expected that TP concentrations in the tidal tributaries receiving project waters (through Blackwater Creek and Mud Bay/Palm Bay) and within the Ten Thousand Islands nutrient region will improve overall, while TN concentrations will likely improve or remain approximately at current levels. Therefore, water quality degradation is not expected with the increased discharges to the downstream areas of the PSRP project.

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APPENDIX A

Statistical Comparison of Total P and Total N Concentrations Between PSRP Water Quality Monitoring Stations

Table A-1. Kruskal-Wallis test results for total P between water quality monitoring stations

Total P by Station	No. Obs.	Rank Sum	Mean Rank
BC9	150	31,116	207
BC10	151	60,666	402
BC11	130	56,560	435
FAKA	170	43,247	254
S488	43	24,967	581
TAMTOM	51	36,391	714
TMBR37	37	26,210	708
TMBR49	23	6,235	271
H statistic	405.95		
X^2 approximation	405.95		
DF	7		
p-value	<0.0001		

Table A-2. Steel-Dwass-Critchlow-Fligner all pairs comparisons for total P between water quality monitoring stations

Comparisons	Hodges-Lehmann location shift	Simultaneous 95% CI	0	p-value
TAMTOM - BC9	264	236 to 305		<0.0001
TAMTOM - TMBR49	263	210 to 377		<0.0001
TAMTOM - FAKA	262	234 to 299		<0.0001
TAMTOM - BC10	256	222 to 294		<0.0001
TAMTOM - BC11	255	222 to 296		<0.0001
TMBR37 - BC9	241	200 to 325		<0.0001
TMBR37 - FAKA	240	199 to 323		<0.0001
TMBR37 - TMBR49	239	191 to 332		<0.0001
TMBR37 - BC10	236	193 to 312		<0.0001
TAMTOM - S488	235	190 to 305		<0.0001
TMBR37 - BC11	234	192 to 313		<0.0001
TMBR37 - S488	219	166 to 301		<0.0001
S488 - BC9	24	16 to 34		<0.0001
S488 - TMBR49	22	12 to 39		<0.0001
S488 - FAKA	22	15 to 32		<0.0001
TAMTOM - TMBR37	***21***	***-57 to 98***		***0.9931***
S488 - BC10	15	9 to 26		<0.0001
S488 - BC11	15	8 to 26		<0.0001
BC11 - BC9	9	6 to 11		<0.0001
BC10 - BC9	8	5 to 11		<0.0001
BC11 - FAKA	7	5 to 10		<0.0001
BC11 - TMBR49	7	2 to 12		0.0006
BC10 - FAKA	6	3 to 9		<0.0001
BC10 - TMBR49	6	0 to 13		0.0310
TMBR49 - BC9	***2***	***-1 to 5***		***0.5859***
TMBR49 - FAKA	***1***	***-3 to 4***		***0.9993***
FAKA - BC9	***1***	***0 to 3***		***0.1397***
BC11 - BC10	***1***	***-2 to 4***		***0.9597***

H0: θ = 0
The shift in location between the distributions of the populations is equal to 0.
H1: θ ≠ 0
The shift in location between the distributions of the populations is not equal to 0.

Reject the null hypothesis in favor of the alternative hypothesis at the 5% significance level.

Do not reject the null hypothesis at the 5% significance level.

Table A-3. Kruskal-Wallis test results for total P between water quality monitoring stations

Total P by Station	No. Obs.	Rank Sum	Mean Rank
BC9	137	45,084	329
BC10	142	38,947	274
BC11	120	41,689	347
FAKA	161	39,643	246
S488	43	19,894	463
TAMTOM	83	56,477	680
TMBR37	37	23,278	629
TMBR49	23	13,621	592
H statistic	345.40		
X^2 approximation	345.40		
DF	7		
p-value	<0.0001		

Table A-4. Steel-Dwass-Critchlow-Fligner all pairs comparisons for total N between water quality monitoring stations

Comparisons	Hodges-Lehmann location shift	Simultaneous 95% CI	0	p-value
TAMTOM - FAKA	1.110	0.98 to 1.25		<0.0001
TAMTOM - BC10	1.090	0.96 to 1.24		<0.0001
TAMTOM - BC9	1.037	0.90 to 1.18		<0.0001
TAMTOM - BC11	1.017	0.87 to 1.17		<0.0001
TAMTOM - S488	0.891	0.71 to 1.10		<0.0001
TMBR37 - FAKA	0.750	0.52 to 1.08		<0.0001
TMBR37 - BC10	0.740	0.49 to 1.05		<0.0001
TMBR37 - BC9	0.680	0.45 to 1.02		<0.0001
TMBR37 - BC11	0.660	0.40 to 0.98		<0.0001
TAMTOM - TMBR49	0.570	0.34 to 0.81		<0.0001
TMBR49 - FAKA	0.562	0.46 to 0.67		<0.0001
TMBR37 - S488	0.556	0.23 to 0.92		<0.0001
TMBR49 - BC10	0.550	*0.42 to 0.67*		<0.0001
TMBR49 - BC9	0.489	0.38 to 0.60		<0.0001
TMBR49 - BC11	0.470	0.33 to 0.60		<0.0001
TAMTOM - TMBR37	0.350	0.02 to 0.67		0.0309
TMBR49 - S488	0.350	0.19 to 0.48		<0.0001
TMBR37 - TMBR49	*0.220*	*-0.11 to 0.63*		*0.4596*
S488 - FAKA	0.215	0.14 to 0.30		<0.0001
S488 - BC10	0.205	0.11 to 0.30		<0.0001
S488 - BC9	0.137	0.05 to 0.22		<0.0001
S488 - BC11	0.132	0.03 to 0.23		0.0030
BC11 - FAKA	0.080	0.03 to 0.14		0.0001
BC9 - FAKA	0.080	0.03 to 0.12		<0.0001
BC11 - BC10	0.070	0.01 to 0.14		0.0243
BC9 - BC10	0.060	0.01 to 0.12		0.0194
BC10 - FAKA	*0.010*	*-0.04 to 0.07*		*0.9975*
BC11 - BC9	*0.010*	*-0.05 to 0.07*		*1.0000*

H0: θ = 0
The shift in location between the distributions of the populations is equal to 0.
H1: θ ≠ 0
The shift in location between the distributions of the populations is not equal to 0.

Reject the null hypothesis in favor of the alternative hypothesis at the 5% significance level.

Do not reject the null hypothesis at the 5% significance level.

APPENDIX B

Seasonal Kendall Results for Total P and Total N using Period of Record Monthly Data PSRP Trends determined using USGS Seasonal Kendall Program

Table B-1. Total P Seasonal Kendall-tau Analyses

Season Kendall-tau Results		FAKA	BC9	BC10	BC11	BC.AGG	TAMTOM	TMBR37	TMBR49	S488
Kendall's tau:	***tau (τ)***	0.026	-0.353	-0.060	0.085	-0.058	-0.016	0.451	0.545	0.082
Sum of Seasonal Differences:	***S***	30	-306	-53	55	-52	-5	23	12	5
Approximation of z-Statistic:	***z***	0.438	-5.724	-0.957	1.23	-0.921	-0.142	2.496	2.104	0.432
Intercept:	b_0	11	13.33	19.36	18.25	17.42	284.2	192.2	7.167	36.75
Slope (Sen):	b_1	0.000	-0.444	-0.143	0.167	-0.100	-1.500	23.500	2.333	0.500
Probability Value:	***p***	0.661	<0.001	0.338	0.219	0.357	0.887	0.013	0.035	0.666
Adjusted Probability Value:	**p (adj)**	0.801	0.009	0.465	0.471	0.556	0.920	0.102	0.176	0.827
Use Adjusted p-value [p(adj)]:		N	Y	N	N	N	N	N	N	Y
Total Number of Years		19	15	15	15	15	11	5	5	5
Total Number of Records		228	180	180	180	180	132	60	60	60
Number of records with Data		168	151	151	130	153	88	37	23	43
Percent Missing		26%	16%	16%	28%	15%	33%	38%	62%	28%
p-values Adjusted for Serial Correlation:		*0.661*	***0.009***	*0.338*	*0.219*	*0.357*	*0.887*	***0.013***	***0.035***	*0.827*

Table B-2. Total N Seasonal Kendall-tau Analyses

Season Kendall-tau Results		FAKA	BC9	BC10	BC11	BC.AGG	TAMTOM	TMBR37	TMBR49	S488
Kendall's tau:	***tau (τ)***	0.046	-0.073	0.11	-0.137	0.027	0.031	0.667	0.394	0.016
Sum of Seasonal Differences:	***S***	60	-64	102	-96	26	9	34	13	1
Approximation of z-Statistic:	***z***	0.798	-1.157	1.79	-2.027	0.434	0.298	3.769	1.726	0
Intercept:	b_0	0.449	0.5547	0.4287	0.5936	0.5258	1.555	0.555	0.9738	0.677
Slope (Sen):	b_1	0.0010	-0.0030	0.0060	-0.0070	0.0010	0.0060	0.2620	0.0430	0.0040
Probability Value:	***p***	0.4251	0.2471	0.0734	0.0427	0.6643	0.7653	0.0002	0.0843	1.0000
Adjusted Probability Value:	**p (adj)**	0.4816	0.2925	0.2133	0.1382	0.7572	0.8307	0.0710	0.1505	1.0000
Use Adjusted p-value [p(adj)]:		N	Y	N	N	N	N	Y	Y	N
Total Number of Years		19	19	15	15	15	15	11	5	5
Total Number of Records		228	228	180	180	180	180	132	60	60
Number of records with Data		168	179	151	155	134	157	84	37	27
Percent Missing		26%	21%	16%	14%	26%	13%	36%	38%	55%
p-values Adjusted for Serial Correlation:		*0.661*	0.482	0.247	0.073	***0.043***	0.664	0.831	0.071	0.084

APPENDIX C

Table C-1. Total Annual Flows, P Loads and FWM TP Across All Structures

Water Year	Overall *Without Project*			Overall *With Project*		
	Flow ac-ft	Load Kg	FWM µg/L	Flow ac-ft	Load Kg	FWM µg/L
2005	8,969	3,613	327	20,163	3,835	154
2006	10,776	5,740	432	24,789	5,926	194
2007	8,008	3,793	384	13,834	3,915	229
2008	5,623	2,643	381	5,358	2,586	391
2009	13,329	5,806	353	24,083	5,962	201
2010	11,897	4,684	319	14,314	4,603	261
2011	9,372	3,634	314	12,983	3,609	225
2012	8,919	3,731	339	13,460	3,753	226
2013	10,418	3,976	309	13,329	3,959	241
Mean	***9,701***	***4,180***	***349***	***15,813***	***4,239***	***217***
St. Dev.	*2,247*	*1,043*	*41*	*6,155*	*1,099*	*49*

Table C-2. Total Annual Flows, N Loads and FWM TN Across All Structures

Water Year	Overall *Without Project*			Overall *With Project*		
	Flow ac-ft	**Load Kg**	**FWM mg/L**	**Flow ac-ft**	**Load Kg**	**FWM mg/L**
2005	8,969	17,733	1.60	20,163	35,263	1.42
2006	10,776	21,323	1.60	24,789	40,025	1.31
2007	8,008	15,935	1.61	13,834	25,246	1.48
2008	5,623	12,010	1.73	5,358	11,474	1.74
2009	13,329	26,266	1.60	24,083	42,889	1.44
2010	11,897	22,830	1.56	14,314	26,311	1.49
2011	9,372	18,077	1.56	12,983	23,325	1.46
2012	8,919	18,765	1.71	13,460	25,354	1.53
2013	10,418	21,393	1.66	13,329	25,471	1.55
Mean	***9,701***	***19,370***	***1.62***	***15,813***	***28,373***	***1.45***
St. Dev.	*2,247*	*4,155*	*0.06*	*6,155*	*9,595*	*0.10*