Hierarchy I Numeric Nutrient Criteria for Sweetwater Branch (Alachua County):

Level II Water Quality Based Effluent Limitations for Gainesville Regional Utilities' Main Street Water Reclamation Facility and Kelly Generating Station

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1 EXECUTIVE SUMMARY

The purpose of this document is to establish Level II Water Quality Based Effluent Limitations (WQBELs) for total nitrogen (TN) and total phosphorus (TP) for the Gainesville Regional Utilities' (GRU) Main Street Water Reclamation Facility (MSWRF) and the GRU Kelly Generating Station (KGS). Portions of the report were prepared in accordance with Section 2.c.i. Action Item (9) of Administrative Order No. AO 136 NE for the Gainesville Regional Utilities' (GRU) Main Street Water Reclamation Facility (MSWRF) (FDEP Permit No. FL0027251). These WQBELs establish nutrient discharge limits for the GRU MSWRF and GRU KGS point source discharges; account for stormwater inputs; establish a site-specific interpretation of the Numeric Nutrient Criteria (NNC) in Sweetwater Branch; and protect downstream surface waters, including Paynes Prairie (an Outstanding Florida Waterbody), and Alachua Sink. The establishment of these WQBELs is an integral component of the award-winning Paynes Prairie Sheetflow Restoration Project.

Based on a series of three (3) technical reports assembled for this WQBEL analysis, **Table 1-1** provides the proposed Hierarchy 1 Numeric Nutrient Criteria (NNC)/WQBELs for Sweetwater Branch.

Table 1-1. Proposed Level II WQBELs for the GRU Mainstreet Water Reclamation Facility (MSWRF), GRU Kelly Generating Station (KGS), and Sweetwater Branch (based on wet weather years for stormwater loads). Concentration-based values are stream-wide annual geometric means.

	TN (lbs/yr)	TP (lbs/yr)	TP (mg/L)	Chlorophyll a (µg/L)
MSWRF WQBELs	182,646	11,644	-	-
KGS WQBELs	3,060	843	-	-
Stormwater Loads	29,910	3,551	-	-
Sweetwater Branch H1 NNC	**215,616**	**16,038**	**0.3**	**1.9**

1.1 EXPRESSION OF THE H1 NNC

The frequency and duration expression associated with the Hierarchy I Numeric Nutrient Criteria (NNC) for TN and TP annual load and annual geometric mean TP concentration are described as "not to be exceeded." The concentration-based site-specific chlorophyll *a* criterion for Sweetwater Branch was derived to "not be exceeded more than once in a three-year period" (derived in a similar manner to Florida's estuarine NNC). Concentration-based H1 NNC must be applied as an annual geometric mean value averaged over the entirety of Sweetwater Branch, with a minimum of four sampling events (at least one during the winter and one during the summer).

While details are explained in the following technical reports, the proposed WQBELs were designed to:

- Protect flora and fauna in Sweetwater Branch;
- Achieve the TN TMDL for Alachua Sink;
- Comply with Environmental Resource Program (ERP) TN and TP permit limits at the enhancement wetland outflow; and
- Comply with Outstanding Florida Waters (OFW) antidegradation requirements in Paynes Prairie State Park. **The OFW provision was the primary factor controlling the maximum TN and TP loadings**.

1.2 OFW Considerations

Chapter 62-302.700(1), FAC, states. "It shall be the Department policy to afford the highest protection to Outstanding Florida Waters and Outstanding National Resource Waters. 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."

Chapter 62-4.242 (2)(c). FAC, states, "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."

Therefore, the most constraining TN and TP loadings from the MSWRF to Paynes Prairie are those that were allowed by FDEP and EPA during the last NPDES permit, because those loadings represented a reduction from loadings that occurred when Paynes Prairie was designated an OFW in 1990. Note that the ERP permit also requires the discharge from the Enhancement Wetlands to achieve a TN concentration of 3 mg/L and a TP concentration of 0.3 mg/L (expressed as a 5-year rolling average).

The proposed MSWRF WQBEL load of 182,646 lb/yr TN (shown in **Table 1-1**) was based on an effluent TN concentration of 8 mg/L at the current permitted capacity of 7.5 mgd. The proposed MSWRF TP of 11,644 lb/yr was calculated based on the 2013-2016 median effluent TP concentration of 0.51 mg/L at the same current permitted capacity of 7.5 mgd. GRU plans to upgrade the MSWRF to increase flow capacity over the next 5 years but will continue to meet these proposed WQBEL loads through increased TN treatment. Additionally, the facility will continue to reduce TP at the discharge (as needed) to a maximum of 0.3 mg/L to ensure compliance with the ERP TP permit limit.

The proposed KGS WQBEL loads were based on a statistical analysis using the current permitted capacity and historical data. The stormwater loads in **Table 1-1** are based on the non-point source loads calculated by FDEP in the Alachua Sink TMDL (2006). The next section includes a demonstration that the proposed TN and TP loads would comply with OFW provisions.

1.2.1 OFW Criteria Compliance Demonstration

Table 1-2 compares the baseline OFW loads with the calculated future loads discharging from the enhancement wetland to Paynes Prairie based on the proposed WQBELs. For OFW purposes, the period of 2013 to 2016 was used to calculate the baseline nutrient loads to Paynes Prairie from the Main Street Water Reclamation Facility and Kelly Generating Station, while stormwater loads were from the FDEP TMDL document for Alachua Sink, as described above (Gao et al., 2006). At FDEP's request, nutrient data from the years 2013 to 2016, which occurred during the past permit cycle, were used for baseline conditions since they represented a period of improved water quality compared to when the OFW designation was first established in 1990.

In 1990, the MSWRF TN and TP concentrations averaged 15.1 mg/l and 3.24 mg/l, respectively. Based on the 1990 annual average concentrations and the MSWRF flow of 4.73 mgd, TN and TP loads from MSWRF alone were approximately 217,418 and 46,671 lbs/yr, respectively. The 2013-2016 baseline period values for the entire watershed in **Table 1-2** are considerably lower than the 1990 values.

For the point sources, the OFW baseline nutrient concentration data were derived from Table 7 (Dynamic Solutions, 2021), which was the QUAL2K model confirmation run (Run 529).

Table 1-2. Comparison of OFW baseline and WQBEL loads.

Parameter	MSWRF OFW Baseline	KGS (CTBD8+LVW) OFW Baseline	Stormwater (wet year) OFW Baseline	OFW Baseline Total	Future WQBEL Loads from Enhancement Wetland to Paynes Prairie (wet year lbs/yr)	Difference Between WQBEL and OFW Baseline Loads (lbs/yr)
Flow (MGD)	**7.50**	**0.505**	**-**	**-**	**-**	**-**
TP (mg/L)	**0.510**	**0.410**	**-**	**-**	**-**	**-**
TN (mg/L)	**5.27**	**1.24**	**-**	**-**	**-**	**-**
TP (lbs/yr)	**11,644**	**630**	**3,551**	**15,825**	**14,087**	**-1,738**
TN (lbs/yr)	**120,318**	**1,899**	**29,910**	**152,126**	**102,004**	**-50,122**

The OFW baseline nutrient loads from MSWRF and KGS were calculated by multiplying the 2013-2106 nutrient concentrations [provided in Table 7 (Dynamic Solutions, 2021)] by the permitted annual average daily flow for MSWRF (7.5 MGD) and the Maximum Daily Flow for KGS [0.505 MGD, see Table 31 in (Dynamic Solutions, 2021)] as shown below:

For MSWRF:

TP (lbs/yr) = 0.51 mg/L x 7.5 MGD x 8.34 x 365 = 11,644 lbs/yr

TN (lbs/yr) = 5.27 mg/L x 7.5 MGD x 8.34 x 365 =120,318 lbs/yr

For KGS:

TP (lbs/yr) = 0.41 mg/L x 0.505 MGD x 8.34 x 365 = 630 lbs/yr

TN (lbs/yr) = 1.235 mg/L x 0.505 MGD x 8.34 x 365 = 1,899 lbs/yr

The stormwater OFW baseline loads are the "wet year" values derived from the Alachua Sink TMDL document (Gao et al., 2006) as described above. The Future Loads from the Enhancement Wetland to Paynes Prairie shown in **Table 1-2** are the "wet year" loads discharging from the sheetflow distribution channel onto Paynes Prairie based on future conditions with the proposed WQBELs. The future load values in **Table 1-2** were taken from Figure 11 (Wetland Solutions, 2021) with MSWRF flows set to 12 MGD. The chosen MSWRF flow of 12 MGD is a very conservative and protective assumption since the plant is currently permitted for 7.5 MGD. The 12 MGD flow value for MSWRF was used rather than the current permitted flow of 7.5 MGD to demonstrate that the loads are still reduced compared to the baseline even if the MSWRF plant is expanded at a future date. The future TP and TN loads to Paynes Prairie are reduced by 1,738 lbs/yr and 50,122 lbs/yr, respectively as compared to the OFW baseline. Therefore, the project and associated WQBELs comply with OFW provisions.

1.3 Chlorophyll a Criteria for Sweetwater Branch

Using phaeophytin-corrected Sweetwater Branch chlorophyll *a* data from IWR run 55 (downloaded 8-1-18), data previously assembled for this report, and recent data provided by Alachua County, Annual Geometric Means (AGMs) were calculated for years with four of more data points (see **Section 3.3.2**). Using the same equation FDEP employed for promulgating estuary NNC, the 90th percentile prediction interval of the Sweetwater Branch chlorophyll *a* AGMs was calculated to be 1.9 µg/L (FDEP, 2012). An AGM of 1.9 µg/L is proposed as a site-specific chlorophyll *a* criterion for Sweetwater Branch not to be exceeded more than once in a three-year period.

Together, the above TN, TP, and chlorophyll *a* criteria constitute a Hierarchy One interpretation of the narrative nutrient criterion, which accomplishes the following:

- Creates TN and TP discharge limits for permitted discharges into Sweetwater Branch;
- Establishes a site-specific interpretation of the Numeric Nutrient Criteria (NNC) for Sweetwater Branch, including a response variable (chlorophyll *a*); and
- Protects downstream surface waters, including the Paynes Prairie OFW and Alachua Sink.

1.4 Translation of Loading-Based Criteria to Concentration-Based Values

At EPA's request, GRU has provided a translation of the loading-based criteria to concentration-based values. The Hierarchy 1 NNC will include an in-stream concentration TP limit of 0.3 mg/L to reasonably assure protection of downstream waters. Therefore, the annual geometric mean in- stream assessment criterion for TP in

Sweetwater Branch will be 0.3 mg/L, not to be exceeded in any year. As with other FDEP nutrient criteria, the criterion will be assessed as a spatial average (over the extent of Sweetwater Branch) using a minimum of four sampling events per year, with at least one event occurring in the summer months and one in the winter months. Note that the annual geometric mean default regional TP criterion is also 0.3 mg/L, although the acceptable exceedance rate is "no more than once in a three-year period".

For TN, the corresponding annual geometric mean in-stream concentration was calculated by summing the loading-based WQBELs (pounds per year, not to be exceeded) and the flows for each of the three sources considered in the WQBEL (**Table 1-3**), and then dividing the total load by the total flow. The values in **Table 1-3** were derived from information in the modeling documents for the WQBEL (Dynamic Solutions, 2021) and (Wetland Solutions, 2021).

Table 1-3. Proposed loading-based WQBELs and corresponding flows for each source demonstrated tobe effective for in-stream protection (from Dynamic Solutions, 2021 and Wetland Solutions, 2021).

Proposed WQBELS	TN (lbs/yr)	Flow (MGD)	Flow (cfs)
MSWRF (FL0027251)	182,646	7.50	11.6
KGS (FL0026646)	3,060	0.505	0.781
NPS Stormwater	29,910	3.78	5.85
Total In-Stream	**215,616**	**11.8**	**18.2**

The MSWRF flow in Table 1-3 is based on the current permitted MSWRF annual average daily flow capacity of 7.5 mgd. The corresponding in-stream nutrient concentrations are calculated below by dividing the in-stream WQBEL loads by the total stream flow:

TN (mg/L) = 215,616 lbs/yr / (18.24 cfs x 5.394 x 365) = 6.0 mg/L

Documentation of data sources and methodologies used to derive flow and nutrient concentrations for the WQBEL loads requested for Sweetwater Branch point and nonpoint sources of nutrients are presented below for MSWRF, KGS and NPS stormwater.

MSWRF: The proposed MSWRF WQBEL loads shown in Table 1-3 were calculated based on the existing NPDES permit (FL0027251) annual average daily flow of 7.5 mgd and effluent TN concentration of 8.0 mg/L.

KGS: The existing KGS NPDES permit (FL0026646) for the two KGS outfalls from (1) Cooling Tower Blowdown Unit 8 (CTBD8) and (2) Low Volume Waste (LVW) incorporate effluent limits for flow for each discharge. The NPDES permit for KGS, however, does not include effluent limits for nitrogen. Therefore, EPA's Maximum Daily Load (MDL) statistical method (EPA, 2007; EPA, 1991) was used to derive upper bound estimates to characterize KGS effluent flow rates and WQBEL loads based on paired effluent records for flow and TN concentrations (see Section 5 of the WQBEL Report under Scenario #1 with a summary of KGS data presented in Table 31).

NPS Stormwater: The WQBELs for TN load for NPS Stormwater runoff from the watershed was taken from the TMDL for Alachua Sink (Gao et al., 2006). Table 47 of the FDEP TMDL report presents TN load data developed to represent wet year conditions for watershed runoff. Section 6 of the WQBEL Report documents the data used to characterize NPS stormwater flow (5.85 cfs) for the Sweetwater Branch watershed (Wetland Solutions, 2021).

1.5 Total Phosphorus Concentration

EPA requested that FDEP include the 0.3 mg/L concentration limit for TP as a part of the H1 NNC for reasonable assurance of downstream protection and that the 0.3 mg/L TP should be applied together with the H1 TP load (if both are independently applied, both must be met). GRU has agreed to the inclusion of an in-stream annual geometric mean TP concentration limit of 0.3 mg/L as part of the H1 NNC and the stipulation that both the load-based and concentration-based criteria for TP will be applied. GRU understands that FDEP will apply a 0.3 mg/l annual geometric mean NPDES permit limit to the MSWRF discharge to ensure this concentration is met in-stream and that the WQBEL must be revised by DEP and approved by EPA before the NPDES permit limit could be revised.

1.6 Spatial Extent of the H1 NNC

Sweetwater Branch originates in downtown Gainesville, near NE 10th Ave. and NE 2nd St. The intent of the H1 NNC is to include Sweetwater Branch from its headwaters, terminating at the Sweetwater Enhancement Wetland adjacent to Paynes Prairie. The following map depicts the spatialextent of the WQBEL (**Figure 1-1**).

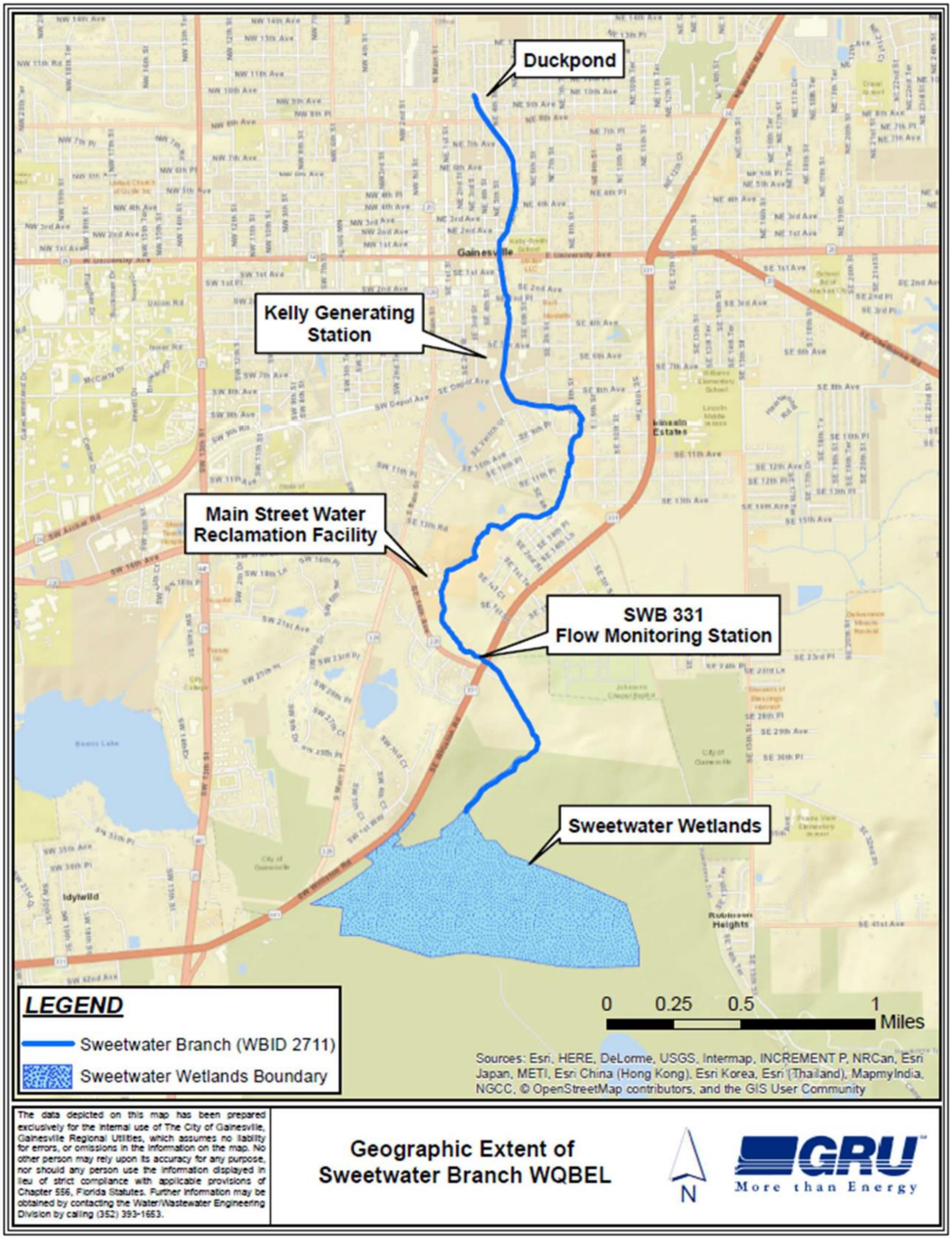

Figure 1-1. Geographic extent of Hierarchy 1 NNC site-specific criteria for Sweetwater Branch.

1.7 Major Components of the WQBEL Report

In accordance with Chapters 62-302 and 62-650, F.A.C.; § 403.061(43)(c), F.S.; and the previously accepted plan of study, the three technical reports herein present physical, chemical, and biological data; a stressor identification evaluation; and modeling that provide reasonable assurance that the proposed WQBELs and site-specific NNC are protective of Sweetwater Branch, Paynes Prairie, and Alachua Sink.

This report assembles the results of three (3) major work efforts and is organized as follows:

Sections 1-4. System Characterization, Biological Assessment, and Stressor Identification

These sections (**contained within this report**) describe the results of physical, chemical, and biological sampling at multiple locations along Sweetwater Branch to assess the condition of the creek. Biological sampling demonstrated that Sweetwater Branch flora were healthy. A stressor identification evaluation verified that while Sweetwater Branch was adversely affected by artificial channelization, habitat disturbance, and sedimentation, its flora and fauna were not being impaired due to nutrients.

Section 5. Development of Proposed WQBEL Loads and In-Stream Modeling

This is a separate document (appended after Section 4 and briefly summarized here) that describes the development of the QUAL2K in-stream model of Sweetwater Branch and the development of the proposed WQBELs (Dynamic Solutions, 2021). Several model scenarios were run through the course of the development of the proposed WQBELs. The QUAL2K water quality modeling demonstrated that the proposed WQBELs and site-specific nutrient criteria will not cause an imbalance in natural floral populations in Sweetwater Branch (Chapter 62-302.530 (48)(b), F. A. C.).

While the QUAL2K model was not run at the specific nutrient loads established in the WQBEL, a model run with higher nutrient loads was conducted and it demonstrated that loads higher than the WQBEL did not impact Sweetwater Branch (as noted in Section 1.1, the WQBEL load was limited by the OFW requirements).

A summary of the modeling scenarios is shown in **Table 1-4**.

Table 1-4. Summary of QUAL2K modeling scenarios.

Model Run	Description	MSWRF	KGS	NPS
Confirmation Run 529	Baseline (2013-2016)	Baseline 2013-2016 data	Baseline 2013-2016 data	Baseline 2013-2016 Data
Scenario #0	Existing Permits	Q=7.5 MGD, TN=8 mg/l, TP = 0.45 mg/l	Q=2.402 mgd, 95th percentile TN & TP	Same as Confirmation Run
Scenario #1	MSWRF at 9 mgd	Q=9 MGD, TN=8 mg/l, TP = 0.375 mg/l	EPA MDL method w/ 95% confidence	Same as Confirmation Run
Scenario #2	Worst case NPS	Same as Scenario #1	Same as Scenario #1	Worst-case
Scenario #3	Shade Sensitivity	Same as Scenario #0	Same as Scenario #0	Same as Confirmation Run

Scenario #4	Point Source removal	No discharge	No discharge	Same as Confirmation Run
Scenario #5	MSWRF 12 mgd buildout	Q=12 MGD, TN=8 mg/l, TP = 0.375 mg/l	Same as Scenario #1	Same as Confirmation Run
Scenario #6	MSWRF 12 mgd buildout	Q=12 MGD, TN=8 mg/l, TP = 0.3 mg/l	Same as Scenario #1	Worst-case

Section 6. Sweetwater Wetlands and Restoration Area Performance

This is a separate document (appended after Section 5 and briefly summarized here) that describes the steady state wetland model (P-k-C* model) used to demonstrate that the discharge from the Sweetwater Enhancement Wetlands would achieve the 3 mg/L TN and 0.3 mg/L TP limits specified in the Sweetwater Enhancement Wetlands Project's Environmental Resource Permit (ERP)[1] (Wetland Solutions, 2021). Additionally, this section shows that the proposed WQBELs will be protective of the downstream Paynes Prairie Sheetflow Restoration Area wetlands. As demonstrated in the approved Sweetwater Enhancement Wetlands Project design, the Sheetflow Restoration Area wetlands further attenuate nutrient concentrations to background levels prior to water entering Alachua Sink. At the proposed MSWRF WQBEL loadings, modeling demonstrates that the Sweetwater Wetlands Project will continue to achieve and maintain the Alachua Sink Total Maximum Daily Load (TMDL).

1.8 CONTEXT

A TMDL for total nitrogen has been adopted for Alachua Sink (Gao, et al., 2006). Nutrient loads to Alachua Sink originate primarily from the Sweetwater Branch watershed and the Newnan's Lake watershed. Several nitrogen sources within the Sweetwater Branch watershed were identified and include the MSWRF and KGS discharges, urban stormwater runoff, and septic tanks. The TMDL set wasteload allocations for MSWRF and KGS for total nitrogen of 40,380 lb/yr and 623 lb/yr, respectively. The wasteload allocation for NPDES stormwater requires a 45% reduction in TN based on wet period loadings calculated as part of the TMDL. The City of Gainesville, Florida Department of Transportation (FDOT), and Alachua County collectively own and maintain the MS4 urban stormwater system.

Sweetwater Branch and Paynes Prairie have been adversely affected by historic ditching and drainage activities for flood control. Upstream of Paynes Prairie, Sweetwater Branch is artificially channelized and flows through a highly urbanized area of Gainesville that was developed prior to modern stormwater regulations. As a result, the creek carries stormwater runoff and significant loads of sediment and trash that formerly deposited on Paynes Prairie prior to the Sweetwater Enhancement Wetlands Project. In addition, a ditch constructed in the 1950s had historically connected Sweetwater Branch directly to Alachua Sink, thus disrupting the natural sheetflow pattern of Sweetwater Branch onto the Prairie and increasing nutrient loads to Alachua Sink.

[1] The ERP expresses these limits as five-year rolling annual averages.

The Sweetwater Enhancement Wetlands Project (Paynes Prairie Sheetflow Restoration Project) (**Figure 1-1** and **Figure 1-3**) was developed through a multi-agency partnership as a comprehensive solution to address the above environmental concerns. The benefits of the project include:

- Improved water quality in Alachua Sink and achievement of the TMDL and NNC requirements for all nutrient sources to Alachua Sink from the Sweetwater Branch watershed;
- Restoration of hydrology to approximately 1,300 acres of wetlands in Paynes Prairie Preserve State Park and elimination of the ditch that once cut through Paynes Prairie;
- Removal of sediment, trash, and other pollutants that had been historically deposited onto the Prairie or discharged to Alachua Sink;
- Restoration of a portion of the overall water budget to Paynes Prairie Preserve State Park; and
- Creation of a city park, the "Sweetwater Wetlands Park" which includes 125 acres of high-quality wetland and wildlife habitat and a public use area for birdwatching, environmental education, and nature study.

In collaboration with FDEP, EPA, FDOT, Florida Wildlife Commission, St. Johns River Water Management District, and Alachua County, the City of Gainesville Public Works Department and Gainesville Regional Utilities completed construction of the project in 2015 at a cost of $27.5 million. The approved and completed project meets Alachua Sink TMDL and NNC requirements for sources entering Sweetwater Branch under current and anticipated future conditions.

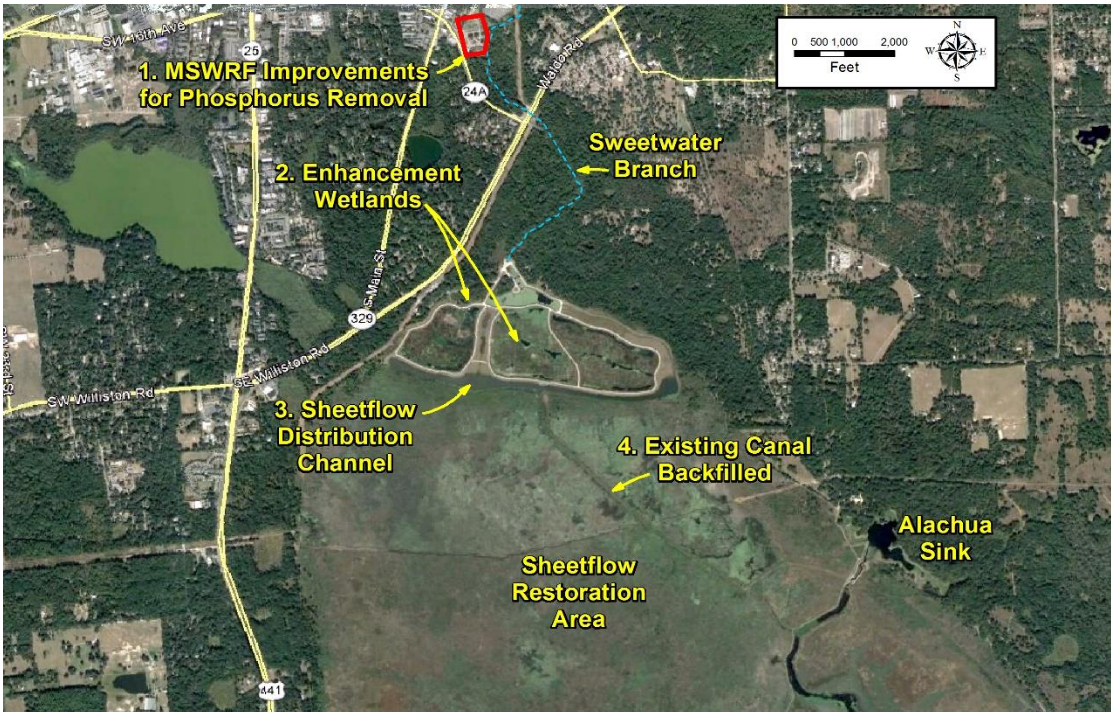

Figure 1-2. Location of Sweetwater Enhancement Wetlands Project. Note that the canal that once cut through Paynes Prairie was backfilled as part of the restoration process.

Figure 1-3. Aerial photo of the Sweetwater Enhancement Wetlands.

1.9 Basis for the Level II WQBEL

The project was located at the downstream end of Sweetwater Branch to address all nutrient sources in the Sweetwater Branch basin and to utilize land available at that location to construct the project. An integral component of the project was the establishment of WQBELs for nitrogen and phosphorus to ensure the protection of Sweetwater Branch, which contributes flow and loads to the project site.

The evidence for complying with NNC requirements in Sweetwater Branch and downstream water bodies is provided in the following section.

1.9.1 Sweetwater Branch

Sweetwater Branch has been adversely affected by channelization, habitat disruption, and sedimentation. Floral data (Rapid Periphyton Survey, Linear Vegetation Survey, and chlorophyll *a*) collected in Sweetwater Branch indicated that the evidentiary thresholds in Chapter 62-302. 531, F.A.C., were achieved. A stressor identification study concluded that fauna (as measured by the Stream Condition Index) were not impaired by nutrients. In addition, water quality modeling was performed using the QUAL2K model (Dynamic Solutions, 2019) to ensure that the proposed WQBELs would not significantly increase periphyton or chlorophyll *a* growth between the discharge and the enhancement wetland, and therefore, would not cause or contribute to imbalances in natural populations of flora and fauna (Chapter 62-302.530 (48)(b), F.A.C.). While the QUAL2K model was not run at the specific nutrient loads established in the WQBEL, a model run with higher nutrient loads was conducted and it demonstrated that loads higher than the WQBEL did not impact Sweetwater Branch (as noted in Section 1.1, the WQBEL load was limited by the OFW requirements)."

1.9.2 Sheetflow Restoration Area

Water flows from the Sweetwater Enhancement Wetlands onto the Sheetflow Restoration Area (**Figure 1-2, Figure 1-3**). Five-year rolling average TN and TP limitations of 3 mg/L and 0.3 mg/L, respectively, were established in the Environmental Resource Permit (ERP) for the project to protect water quality in the Sheetflow Restoration Area. Modeling was performed to demonstrate that discharge from the Sweetwater Enhancement Wetlands will meet these ERP effluent limits with the proposed WQBEL loads.

1.9.3 Alachua Sink

As demonstrated in the approved Sweetwater Wetlands Project design, the Sheetflow Restoration Area further attenuates nutrient concentrations to background levels prior to water entering Alachua Sink, and Alachua Sink TMDL requirements are achieved. The recent performance estimates from the P-k-C* model (**Section 6**) demonstrate that the Enhancement Wetlands (Sweetwater Wetlands Park) and Sheetflow Restoration Area have the capacity to reduce watershed nutrient concentrations to background levels, thus providing adequate protection of downstream waterbodies (Wetland Solutions, 2020). **Table 1-5** shows that the constructed Project is expected to comply with the TN load reduction required by the Alachua Sink TMDL for both dry-year and wet-year conditions. The dry-year allowable TN load, considering the WLAs for the MSWRF and KGS and the 45% reduction required for non-point sources is 55,258 lbs/yr. At a maximum MSWRF capacity of 12 MGD, the Project is estimated to discharge 53,661 lb/yr, leaving a buffer of 1,597 lbs/yr. The allowable wet-year combined

TN load is 61,114 lbs/yr, and the Project is estimated to discharge 59,493 lbs/yr, leaving a buffer of 1,621 lbs/yr (Wetland Solutions, 2020).

Table 1-5. Comparison of modeling results with TMDL requirements.

TMDL Wasteload Allocations	Dry Year TN Load (lbs/yr)	Wet Year TN Load (lbs/yr)
MSWRF	40,380	40,380
KGS	623	623
Non-Point Sources	14,255	20,111
Combined Load Allocation	**55,258**	**61,114**
Modeled TN Load to Alachua Sink, Including Enhancement Wetland and Sheetflow Restoration Area Uptake	**53,661**	**59,493**

1.10 Summary of Conclusions

Important findings are as follows:

- The required floral measures in Chapter 62-302.531, F.A.C., were achieved in Sweetwater Branch downstream of both KGS and MSWRF under current conditions;

- A stressor identification evaluation determined that hydrologic modification, habitat alteration, and sedimentation were the primary causes for Stream Condition Index failures in Sweetwater Branch, and that nutrients are not a causative agent adversely affecting the Stream Condition Index scores;

- A QUAL2K model, confirmed to 2013-2016 stream observations, predicted outcome scenarios using the proposed WQBELs for MSWRF and KGS. Modeled results under three flow conditions (low, medium, and high) and the worst case flow conditions (which are higher loads than the proposed WQBEL), resulted in only slightly higher chlorophyll *a* and periphyton levels that are still comparable to the current unimpaired floral condition in Sweetwater Branch (Dynamic Solutions, 2021). Therefore, reasonable assurance is provided that the proposed site-specific nutrient criteria for Sweetwater Branch, as articulated by the WQBELs, will not cause floral or faunal imbalances (complying with the narrative nutrient criterion in Chapter 62-302.530 (48) (b), F.A.C.);

- The Sweetwater Wetlands Project was designed to accommodate nitrogen loads from MSWRF, KGS, and nonpoint sources under buildout conditions with future growth. Modeling of the Sweetwater Wetlands for nutrient removal performance using the P-k-C* steady state model with the proposed nitrogen WQBELs for MSWRF and KGS, along with non-point source loads from both dry- and wet-weather years, demonstrated that with nutrient loadings at proposed WQBEL levels, the effluent from the Sweetwater Enhancement Wetlands will meet the 3 mg/L TN and 0.3 mg/L TP limits specified in the Sweetwater

Wetlands Project's ERP (Wetland Solutions, 2021). Therefore, the proposed criteria will be protective of the Paynes Prairie Sheetflow Restoration area wetlands downstream of the Sweetwater Wetlands.

- Because the TN and TP loads for MSWRF were based on flow and concentration conditions existing during the last approved permit cycle, the current WQBEL achieves OFW requirements.

- As demonstrated in the approved Sweetwater Wetlands Project design, additional modeling performed in conjunction with the WQBEL demonstrates that the Sheetflow Restoration Area wetlands will further attenuate TN loads to 59,493 lbs/yr (wet-weather years) prior to water entering Alachua Sink (Wetland Solutions, 2020). Accordingly, the Sweetwater Wetlands Project will continue to achieve and maintain the Alachua Sink TMDL, which allows 61,114 lbs/yr of TN during wet-weather years.

The development of WQBELs for MSWRF and KGS are integral to the Paynes Prairie Sheetflow Restoration Project. The results of these detailed analyses confirm that the proposed WQBELs for TN and TP along with conservative worst-case estimates of non-point source loads will be protective of Sweetwater Branch and downstream wetlands in the Paynes Prairie OFW and will comply with the TMDL and NNC requirements for Alachua Sink.

2 BACKGROUND

Sweetwater Branch has many sampling stations for biology and water quality (**Figure 2-1** and **Figure 2-2, Table 2-1**). The WQBELs were based upon physical, chemical, and biological data, modeling, and stressor identification analyses needed to satisfy the requirements of Chapter 62-302, F.A.C., and § 403.061(43)(c), F.S., for a Level II WQBEL to serve as a site-specific interpretation of the narrative nutrient criterion. Both KGS and MSWRF discharge to Sweetwater Branch, Alachua County.

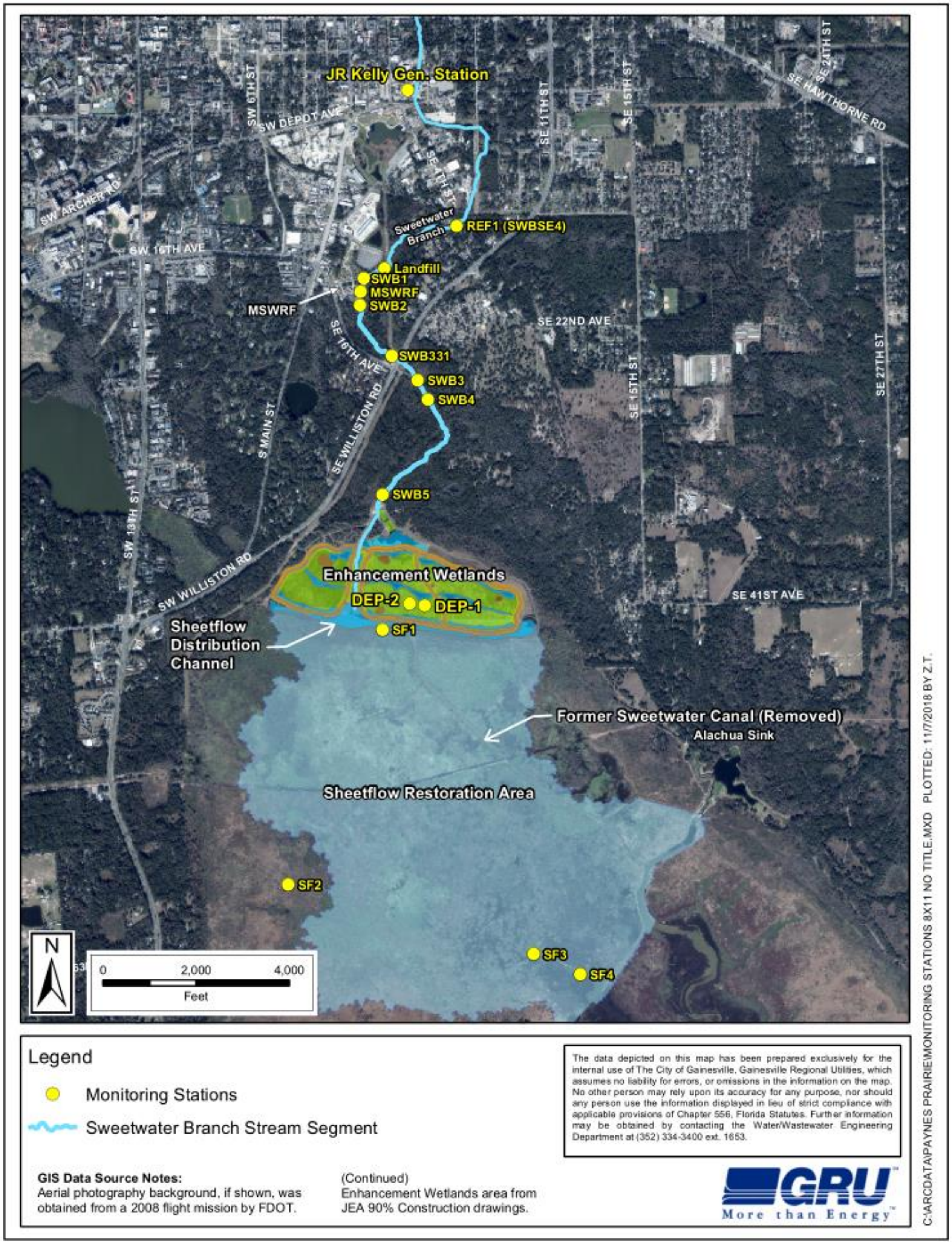

Figure 2-1. Overview map of lower Sweetwater Branch, the Enhancement Wetlands, and Paynes Prairie. Note that the Sweetwater Canal has been backfilled and sheetflow restored to Paynes Prairie.

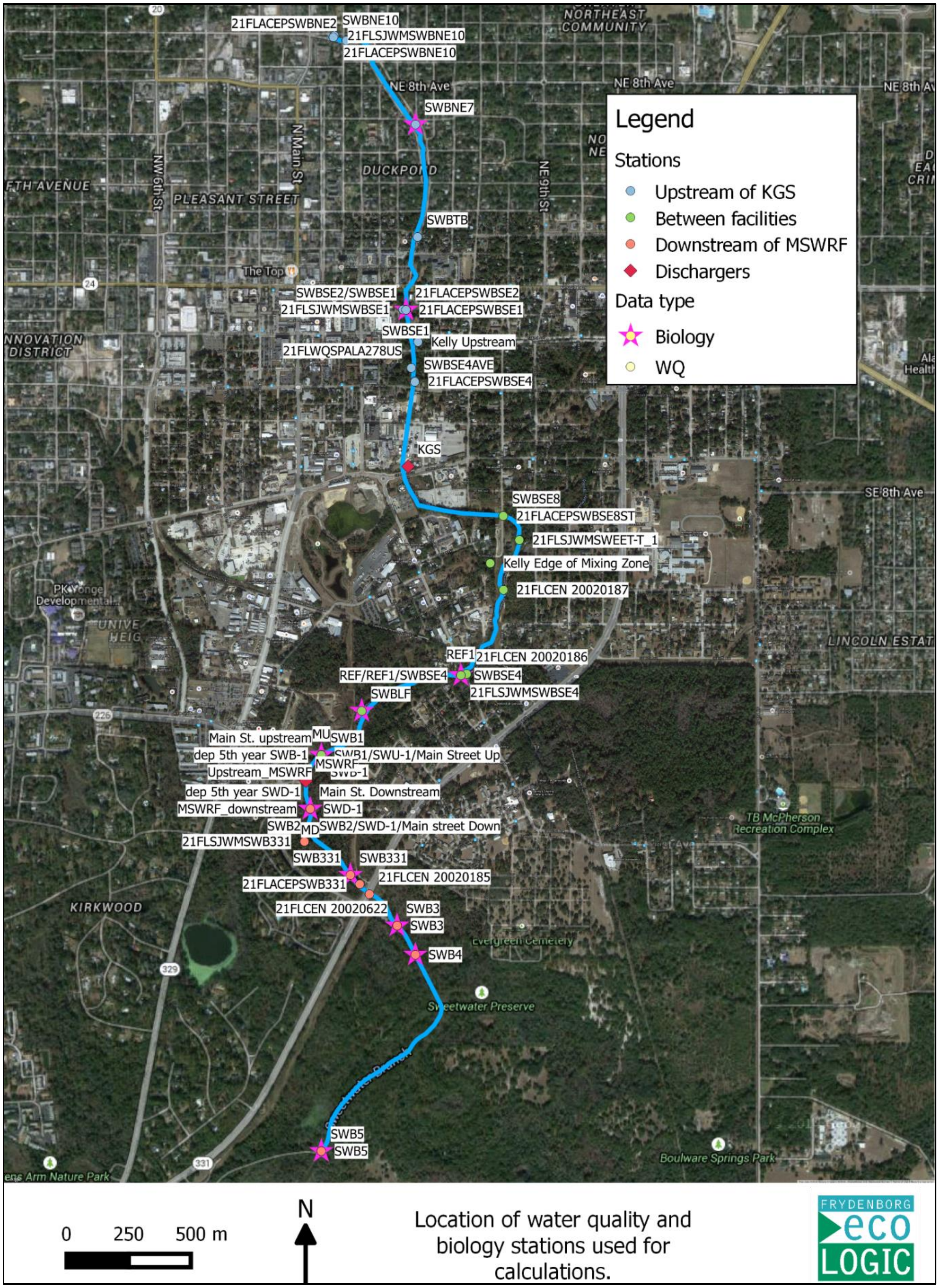

Figure 2-2. Map of the sampling stations used in this study. Stations designated with a star have both biology and water quality data, while stations designated by a circle are water quality only.

Table 2-1. Specific stations spatially grouped for analyses. Note different agencies use different names for the same sites. Data was collected by Water and Air Research (WAR), Gainesville Regional Utilities (GRU), Alachua County Environmental Protection Department, Florida Department of Environmental Protection.

Location	Site	Latitude	Longtitude	Agency/Firm	Data type
Upstream of kelly	21FLACEPSWBNE10	29.66107	-82.32348	21FLACEP	WQ
	21FLACEPSWBNE2	29.66089	-82.32298	21FLACEP	WQ
	21FLACEPSWBSE1	29.651158	-82.320501	21FLACEP	WQ
	21FLACEPSWBSE2	29.651158	-82.320501	21FLACEP	WQ
	21FLACEPSWBSE4	29.64858	-82.32013	21FLACEP	WQ
	21FLSJWMSWBNE10	29.66107	-82.32348	21FLSJWM	WQ
	21FLSJWMSWBSE1	29.65117	-82.32062	21FLSJWM	WQ
	21FLWQSPALA278US	29.64906	-82.32028	21FLWQSP	WQ
	Kelly Upstream	29.65	-82.32	KGS	WQ
	SWBNE10	29.66101	-82.32352	Alachua Co.	WQ
	SWBSE1	29.651158	-82.320501	Alachua Co.	WQ
	SWBSE4AVE	29.648554	-82.320133	Alachua Co.	WQ
	SWBTB	29.653792	-82.320018	Alachua Co.	WQ
	SWBSE2/SWBSE1	29.651158	-82.320501	Alachua Co. FDEP, Frydenborg Eco.	Biology
	SWBNE7	29.657859	-82.320106	Alachua Co.	Biology
Between facilities	21FLACEPSWBSE8ST	29.64371	-82.316459	21FLACEP	WQ
	21FLCEN 20020186	29.638	-82.31798	21FLCEN	WQ
	21FLCEN 20020187	29.64104	-82.31645	21FLCEN	WQ
	21FLSJWMSWBSE4	29.63795	-82.31822	21FLSJWM	WQ
	21FLSJWMSWEET-T_1	29.64284	-82.31579	21FLSJWM	WQ
	dep 5th year SWB-1	29.63507	-82.32402	FDEP	WQ
	Kelly Edge of Mixing Zone	29.642	-82.317	KGS	WQ
	Main St. upstream	29.63507	-82.32402	MSWRF	WQ
	MU	29.63507	-82.32402	WAR	WQ
	REF1	29.63795	-82.31822	MSWRF	WQ
	SWB1	29.63507	-82.32402	MSWRF	WQ
	SWB-1	29.63507	-82.32402	MSWRF	WQ
	SWBSE4	29.63795	-82.31822	Alachua Co.	WQ
	SWBSE8	29.64371	-82.316459	Alachua Co.	WQ
	Upstream_MSWRF	29.63507	-82.32402	Alacua Co./MSWRF	WQ
	SWBLF	29.63666	-82.32234	Alachua Co.	Biology
	SWB1/SWU-1/Main Street Up	29.63507	-82.32402	FDEP	Biology
	REF/REF1/SWBSE4	29.63795	-82.31822	Alachua Co., FDEP, Frydenborg Eco., WAR	Biology
Downstream of MSWRF	21FLACEPSWB331	29.6304	-82.32242	21FLACEP	WQ
	21FLCEN 20020185	29.63004	-82.32202	21FLCEN	WQ
	21FLCEN 20020622	29.6289	-82.32087	21FLCEN	WQ
	21FLSJWMSWB331	29.63194	-82.32472	21FLSJWM	WQ
	dep 5th year SWD-1	29.63312	-82.32448	FDEP	WQ
	Main St. Downstream	29.63312	-82.32448	MSWRF	WQ
	MD	29.63312	-82.32448	WAR	WQ
	MSWRF_downstream	29.63312	-82.32448	MSWRF	WQ
	SWB2	29.63312	-82.32448	MSWRF	WQ
	SWB3	29.628903	-82.320869	MSWRF	WQ
	SWB331	29.63073	-82.32281	Alachua Co.	WQ
	SWB5	29.62075	-82.32402	MSWRF	WQ
	SWD-1	29.63312	-82.32448	MSWRF	WQ
	SWB2/SWD-1/Main street Down	29.63312	-82.32448	FDEP, WAR	Biology
	SWB3	29.628903	-82.320869	FDEP, WAR	Biology
	SWB4	29.62785	-82.32011	FDEP	Biology
	SWB5	29.62075	-82.32402	Alachua Co., FDEP, Frydenborg Eco., WAR	Biology
	SWB331	29.63073	-82.32281	Alachua Co.	Biology
Dischargers	KGS	29.6455	-82.32041	KGS, FDEP	WQ
	MSWRF	29.63413	-82.32466	MSWRF, FDEP	WQ

2.1 PURPOSE

The purpose of this document, which follows the requirements of Chapter 62-650, F. A.C., is to provide two separate dischargers, including the Gainesville Regional Utilities (GRU) Main Street Water Reclamation Facility and the GRU Kelly Generating Station, with Level II Water Quality-Based Effluent Limitations (WQBEL) for nutrients (total phosphorus and total nitrogen). These WQBELs have determined the levels of nutrients in the point source discharges (*i.e.*, effluent nutrient limits) that result in attainment of the narrative nutrient criteria in paragraph 62-302.530(48)(b), F.A.C.

As part of demonstrating these WQBELs, a site-specific interpretation of the narrative nutrient criteria has been established for the entire extent of Sweetwater Branch.

2.2 DESCRIPTION OF FACILITY AND TREATMENT AT KELLY GENERATING STATION (KGS)

The KGS, an electric generating plant with a total nameplate rating of 195 megawatts (MW), is in downtown Gainesville, Alachua County, Florida (**Figure 2-2**). The existing facility consists of one fossil fuel-fired combined cycle unit (CC-1). The closed-loop cooling tower systems serving CC-1, designated as Cooling Tower 8, use either GRU public water supply, ground water wells, or recycled non-process industrial wastewater from onsite facilities activities as makeup water. The facility discharge may consist of the following wastewater streams: cooling tower blowdown, cooling tower overflow, low volume wastewater, storm water, and boiler blowdown. Wastewater treatment includes a low-volume wastewater treatment system, as described below. Cooling tower water may be chlorinated, and cooling tower blowdown is dechlorinated prior to discharge. Treatment processes consist of de-chlorination, pH adjustment, clarification, oil skimming, and multimedia filtration. Treated effluent from the Low Volume Wastewater Tank (Low Volume Wastes) and all other waste streams discharge to Sweetwater Branch which is designated as Class III freshwaters. Based on flow data from 1998 to 2012, discharge from the KGS Station averages 0.15 ± 0.07 MGD per year (± standard deviation, n = 15). A previous bio-assessment (FDEP, 1996) concluded that flora and fauna in the receiving waters of Sweetwater Branch appeared more affected by stormwater inputs than by the KGS effluent. Stormwater inputs to Sweetwater Branch often result in flows that exceed 10.8 MGD (20 cfs) in Sweetwater Branch (measured at Williston Road, see **Figure 3-1**). During such high flows, the KGS contribution is approximately 1.4% or less of the total stream flow.

2.3 DESCRIPTION OF FACILITY AND TREATMENT AT MAIN STREET WATER RECLAMATION FACILITY (MSWRF)

The Main Street Water Reclamation Facility (MSWRF), operated by Gainesville Regional Utilities (GRU), is a Municipal Domestic Wastewater Treatment Facility with a currently permitted discharge of 7.5 million gallons per day (MGD) (**Figure 2-2**). Pretreatment consists of two mechanical bar screens (3/4-inch opening, 4-foot width), one vortex grit removal unit (16-foot, 4-inch diameter), two grit cyclone units (18-inch screw diameter), two grit cyclone units (10-inch diameter), two grit pumps (220 gpm each), and an odor control solid bed (1,800 square feet, 48-inch media depth). The biological treatment process consists of three aeration basins (one has a volume of 1.6 million gallons (MG) and the other two, each have a volume of 1.38 MG). The biological treatment system is aerated by 11 surface aerators (3 @ 75 hp and 8 @ 60 hp). The clarification system consists of three secondary clarifiers (one @ 100-foot diameter, 10-foot side water depth; two @ 85-foot diameter, 14-foot side water depth). The filtration system consists of four filter influent pumps (4,170 gpm each), one continuously backwashed Dynasand filter system (8 @ 50-sq. ft sections, each with 4-modules with 40-inches of media depth), two air compressors (125 cfm @ 125 psig), two filter compressors (125 cfm @ 125 psig), and two filter air dryers (100 cfm each). Disinfection consists of three chlorine contact basins (0.18 MG total) and two 6,000-gallon sodium hypochlorite storage tanks, and five pumps (5 @ 7 gph and 2 @ 24.6 gph). De-chlorination is accomplished via one 2,000-gal sodium bisulfite storage tank and two peristaltic hose feed pumps (7.0 gph each). Biosolids are treated via two aerobic digesters (1.25 MG each), which are equipped with surface aerators (100 hp each), three digested sludge feed pumps (400 gpm each), one gravity sludge thickener (40 feet diameter), two gravity belt sludge thickeners (2-meter width each), three sludge thickening polymer blend/feed units, and one sludge thickening bulk storage tank (4,500 gal).

The facility is operating under an Administrative Order (AO136-NE) that formalizes a timeline to design and complete improvements and modifications to the facility.

2.4 Numeric Nutrient Criteria Requirements

The narrative nutrient criteria in paragraph 62-302.530(48)(b), F.A.C., states that “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.” The method for numerically interpreting this criterion, on a site-specific basis, is provided in Rule 62-302.531, F.A.C., using a hierarchical process. This hierarchical scheme specifies a prioritization for determining the numeric nutrient criteria that apply to a given waterbody.

The rule’s hierarchical approach gives preference to site-specific analyses that result in a numeric interpretation of the NNC. Site-specific interpretations are superior to more broadly applicable interpretations of the NNC because of the many natural factors affecting the expression of nutrient loadings on a given waterbody.

2.5 Water Quality Based Effluent Limitations

The Water Quality Based Effluent Limitation (WQBEL) process, pursuant to Chapter 62-650, F.A.C., is the mechanism for determining the levels of nutrients in a point source discharge (*i.e.*, effluent nutrient limits) that will comply with the narrative criterion in Rule 62-302.530(48)(b), F.A.C. The derivation of a Level II nutrient WQBEL is a site-specific interpretation of the NNC and is based on the highest permitted flows and the associated nutrient loads from a discharge. To serve as the interpretation of the narrative nutrient criteria, the WQBEL must provide nutrient limits for the discharge and take into account all other sources to the waterbody. Further, if downstream waters are anticipated to be potentially affected by the discharge of nutrients from an upstream facility, the potential impact must also be assessed, regardless of distance (Rule 62-302.531(4), F.A.C.). Assessments made under a nutrient total maximum daily load and basin management action plan are to be used in evaluating the impact of nutrient loadings to downstream waters (§ 403.061(43), F.S.

Revisions to a WQBEL for existing discharges are implemented through the permit renewal process and compliance schedules may be used to give permittees time to come into compliance with any new requirements pursuant to the provisions of subsection 403.088(2)(e) and (f), F.S., and subsections 62-620.610(12) and 62-

620.620(6), F.A.C. New or expanded discharges are subject to an antidegradation review, and if the discharge contains nutrients that have the reasonable potential to cause or contribute to exceedances of the nutrient standard, it will need to have a WQBEL established and provide reasonable assurance at the time the permit is issued that the WQBEL will be met. The process for renewing the GRU Main Street facility's current permit was initiated on March 19, 2015, while the permit renewal for KGS began in October 2016.

A WQBEL is recognized as the applicable interpretation of the narrative nutrient criteria if:

- The documentation for the WQBEL includes a site-specific numeric interpretation of the narrative criterion at Rule 62-302.530(48)(b), F.A.C., for the waterbody;
- The WQBEL is established pursuant to the Level II Process contained in Rule 62-650.500, F.A.C.; and
- The public notice for the WQBEL specifically states that the Level II WQBEL includes a site-specific interpretation of the narrative for the receiving waterbody.

A WQBEL may be used to establish protective levels of nutrients in a discharge if the receiving water flora are healthy but the fauna are affected by other, non-nutrient stressors. Rule 62-302.531(2)(a)1.d., F.A.C., states, "Other site specific interpretations for one or more nutrients or nutrient response variables that are formally established by rule or final order by the Department, such as a Reasonable Assurance Demonstration pursuant to Rule 62-303.600, F.A.C., or Level II Water Quality Based Effluent Limitations (WQBEL) established pursuant to Rule 62-650.500, F.A.C. To be recognized as the applicable site specific numeric interpretation of the narrative nutrient criterion, the interpretation must establish the total allowable load or ambient concentration for at least one nutrient that results in attainment of the applicable nutrient response variable that represents achievement of the narrative nutrient criterion for the waterbody. A site-specific interpretation is also allowable where there are documented adverse biological effects using one or more Biological Health Assessments, if information on chlorophyll *a* levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicate there are no imbalances in flora and a stressor identification study demonstrates that the adverse biological effects are not due to nutrients." Note that a Stressor Identification analysis is included in this WQBEL report (**Chapter** 4).

2.6 Nutrient Allocations from the FDEP Total Maximum Daily Load (TMDL)

Rule 62-302.531(4), F.A.C., requires that the "loading of nutrients from a waterbody shall be limited as necessary to provide for the attainment and maintenance of water quality standards in downstream waters." For downstream waters that are subject to a TMDL, compliance with a wasteload allocation (WLA) or if applicable, a basin management action plan (BMAP), for the downstream water constitutes reasonable assurance that a discharge does not cause or contribute to the violation of the downstream nutrient water quality standards (§ 403.061(43)(c), F.S. In the case of GRU Main Street facility and John R. Kelly Generating Station, WLAs, derived from a TMDL to protect Alachua sink, are applicable (Rule 62-304.500(19), F.A.C.). These WLAs were incorporated in the 2007 Orange Creek BMAP.

The WLAs for NPDES wastewater discharges are 40,380 lb/yr of TN for the MSWRF (FL0027251) and 623 lb/yr of TN for the John R. Kelly Generating Station (FL0026646) (Gao et al., 2006). The WLA was based on the water quality data measured from 2000 through 2004. Both a critical dry and a critical wet condition were simulated by Gao *et al.* (2006) to assess the impacts associated with point and nonpoint source discharges to Alachua Sink. In both cases, a 54.5% reduction of the point source loading from current conditions was needed to achieve the corresponding nutrient and chlorophyll targets in Alachua Sink.

In the 2006 TMDL report, the MSWRF contributed 88,748 lbs of TN during the dry year period, which is about 23% of the dry-year total TN load of 382,062 lbs discharged into Alachua Sink. During a wet year, the MSWRF also contributed 88,748 lbs of TN, which is 19% of the wet year total load of 462,457 lb/yr of TN (Gao et al., 2006).

The load from stormwater discharges permitted under the NPDES Stormwater Program (loads from MS4s) is also placed in the WLA. Based on the 2000 census, the Alachua Sink watershed includes areas that are covered by the MS4 Program, and the WLA for stormwater discharges is a 45% reduction in current loading from the MS4 (Gao et al., 2006). This percent reduction is the same percent reduction required under the load allocation (LA) for nonpoint sources.

2.7 Paynes Prairie Sheetflow Restoration Project

To address the implementation of the Alachua Sink TMDL, as required by the Orange Creek BMAP and other issues affecting Paynes Prairie, the City of Gainesville has implemented a comprehensive water quality enhancement and restoration project that will provide the following benefits (after Jones Edmunds & Wetland Solutions, 2010):

- Produce high-quality water that flows into Paynes Prairie and then to Alachua Sink and the Floridan aquifer;
- Restore the hydroperiod of over 1,300 acres of wetlands through environmental reuse of wastewater effluent and treated stormwater;
- Remove trash and debris from water discharging to Paynes Prairie (after the Sedimentation Basin and prior to entering the Enhancement Wetland);
- Reduce sediment load from Sweetwater Branch (via a Sedimentation Basin);
- Restore part of the overall water balance to Paynes Prairie;
- Create approximately 125 acres of high-quality wetland wildlife habitat;
- Create a public access area for passive recreation and research within the Sweetwater Branch Wetland Park;

- Naturally assimilate nutrients, sediments, and other pollutants to protect Paynes Prairie and the Floridan aquifer; and

- Attain the City's and FDOT's Alachua Sink TMDL reduction requirements for nitrogen in a cost-effective way.

To obtain these benefits, specific performance criteria were established for different elements of the Project (Jones Edmunds & Wetland Solutions, 2010). First, the discharge from the MSWRF would consist of a long-term average Total Nitrogen (TN) of less than 8.0 milligrams per liter (mg/L), with the annual average TN not to exceed 10.0 milligrams per liter (mg/L). The MSWRF was retrofitted for chemical phosphorus removal to provide the capability to achieve average Total Phosphorus (TP) levels as low as 0.3 mg/L at a permitted average annual daily flow of 7.5 million gallons per day (MGD). As part of a previously developed plan to minimize chemical usage and sludge disposal costs, the MSWRF originally considered operating with slightly higher effluent TP levels, utilizing the Enhancement Wetland to provide additional polishing to ensure a 5-year rolling average TP of 0.3 mg/L discharging from the Enhancement Wetland. As part of the WQBEL, GRU agreed to provide additional chemical TP removal to allow for implementation of a 0.3 mg/L TP end-of-pipe permit limit (evaluated as a 5-year rolling average).

Next, a 125-acre Enhancement Wetland was designed to treat the water from Sweetwater Branch, discharging an average TN of 3.0 mg/L, an average TP of 0.3 mg/L, with removal of suspended solids, floating trash, and debris to the maximum extent practicable before being discharged onto Paynes Prairie. Additional nutrients are naturally assimilated (via uptake and incorporation into plant tissue) in Paynes Prairie to achieve the background concentrations of 1.4 mg/L TN and 0.1 mg/L TP. Note that Paynes Prairie is an Outstanding Florida Water (OFW), and the WQBEL ensures that the indirect discharge will not significantly degrade water quality in Paynes Prairie.

Based on modeling (see below for more details) by Jones Edmunds & Wetland Solutions (2010), the enhanced wetlands and sheet flow restoration project will reduce the TN delivered to Paynes Prairie to a level that would meet the TMDL target. The treatment system was designed to satisfy the requirement for downstream protection of designated uses.

2.7.1 Assessment of Enhanced Wetland Performance in Meeting the TMDL Target

As part of the Enhancement Wetland design process, Jones Edmunds & Wetland Solutions (2010) conducted modeling to determine the effectiveness of various sized wetlands for removing and assimilating nutrients. They ultimately used an improved version of the P-k-C* model (Kadlec and Wallace 2009), which is a variation of the previously-published tanks-in-series (TIS) formulation of the first-order k-C* model (Kadlec and Knight, 1996). The P-k-C* model is based on long-term average conditions, it is widely accepted for use, has been extensively peer reviewed, has been calibrated with data from hundreds of wetlands, and is the preferred tool for sizing constructed wetlands and determining removal rate parameters from operational data (Jones Edmunds & Wetland Solutions (2010). The model incorporates the following key principles (after Jones Edmunds & Wetland Solutions 2010):

- Wetland removal processes are area-based and follow first order kinetics;
- For some parameters, internal cycling results in non-zero background concentrations (C*);
- Physical factors that influence the hydraulic efficiency of wetlands, including topography, wetland geometry, vegetation density and spatial distribution, and wind fetch lead to non-plug-flow conditions and are included in calculations; and
- Factors that describe pollutant mixtures or contaminant “weathering” are also to be included in the model.

Following the procedure of Kadlec and Wallace (2009), Jones Edmunds & Wetland Solutions (2010) accounted for stochastic variability by reviewing applicable wetland operational data and evaluating the distribution of measured outflow concentrations around the model-estimated long-term average concentration. This allowed for the calculation of factors that relate the average value (model estimate) to various confidence levels that can then determine if outflow concentrations will be in compliance with proposed permit limits. Based on this above information, which accounts for verified performance of many existing treatment wetlands, Jones Edmunds & Wetland Solutions (2010) generated the following factors as multipliers to more accurately estimate long-term average wetland outflow concentrations:

- TN – 80th Percentile = 1.31
- TN – 90th Percentile = 1.53
- TP – 80th Percentile = 1.65
- TP – 90th Percentile = 2.29

Jones Edmunds & Wetland Solutions (2010) modeled wetland performance by estimating the nutrient inputs from the MSWRF, upstream base flows (including the KGS discharge), and stormwater flows. Previous detailed performance estimates have also been conducted using measured water quality data from Sweetwater Branch at SR 331, which combines the upstream and MSWRF inputs (Wetland Solutions, 2006; Wetland Solutions, 2007).

For estimating inflow water quality to the proposed Enhancement Wetland, Jones Edmunds & Wetland Solutions (2010) assessed a range of “alternative” effluent water qualities representing several possible scenarios for the MSWRF discharge. Final nitrate concentrations and flow rates were the critical differences between the alternatives, while all options assumed chemical addition to reduce effluent TP concentrations to an average of 0.3 mg/L. Some of the alternatives evaluated are summarized below (after Jones Edmunds and Wetland Solutions (2010):

Current—The current annual average daily flow (AADF) is about 5.5 million gallons per day (MGD) or 8.5 cfs. Current effluent TN averages about 5.5 mg/L, with 4.5 mg/L as NO_3-N+NO_2-N.

Buildout (Alt. 1)—The existing plant has a maximum permitted AADF of 7.5 MGD (11.6 cfs). As influent flows reach the permitted capacity, effluent TN is expected to increase to about 8.0 mg/L, with 7.2 mg/L as NO_3-N+NO_2-N.

Buildout with Contingency (Alt. 2)—Allows for the maximum permitted AADF of 7.5 MGD, with an effluent TN of about 10 mg/L, with 9.0 mg/L as NO_3-N+NO_2-N. Note that this modeling was conducted prior to 2010 to determine the required size of the enhancement wetland, and the modeling presented in **Chapters 5 and 6** (which is a different exercise with slightly different results) represent the basis for the proposed WQBEL.

As an example (after Jones Edmunds & Wetland Solutions (2010), **Figure 2-3** and **Figure 2-4** show estimated annual average performance for TN and TP as a function of wetted treatment area for buildout with contingency conditions (Alternative 2). For a 125-acre wetland, the annual average wetland effluent TN concentration was estimated to be about 2.6 mg/L, with 80% of monthly averages less than 3.4 mg/L and 90% of monthly averages less than 4.0 mg/L. The annual average wetland effluent TP concentration was estimated to be about 0.20 mg/L, with 80% of monthly averages less than 0.33 mg/L and 90% of monthly averages less than 0.461 mg/L (Jones Edmunds & Wetland Solutions 2010). Because this modeling was conducted prior to 2010 to determine the required size of the enhancement wetland, please see the latest modeling results presented in **Chapters 5 and 6,** which represent the basis for the proposed WQBEL, for additional information.

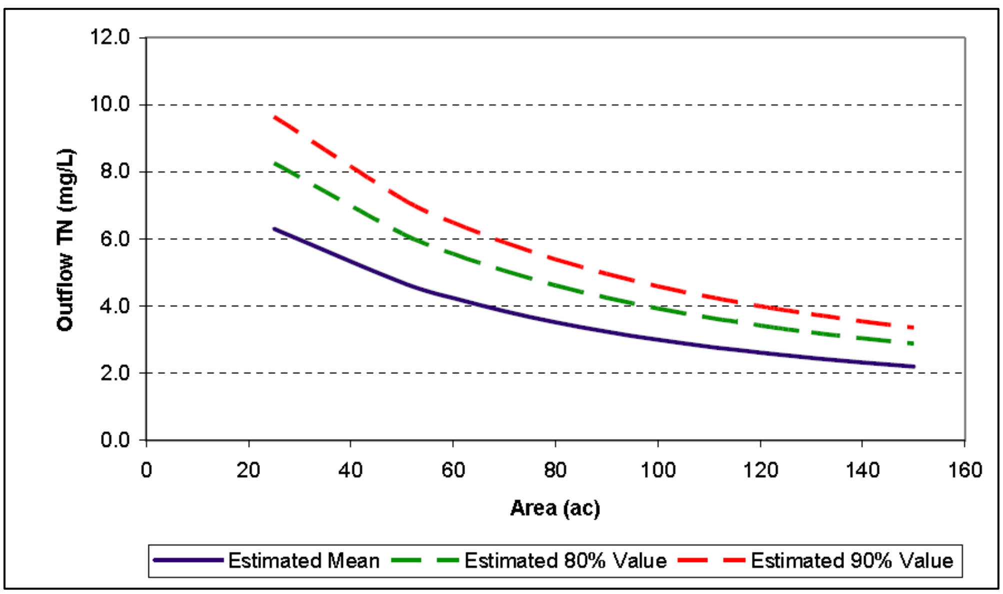

Figure 2-3. Estimated outflow Total Nitrogen as a function of wetland area – Buildout with contingency (Alt. 2) (after Jones Edmunds and Wetland Solutions (2010). The 80% and 90% factors (or multipliers) account for stochastic variability in model estimates and were derived by reviewing applicable wetland operational data and evaluating the distribution of measured outflow concentrations around the model-estimated long-term average concentrations.

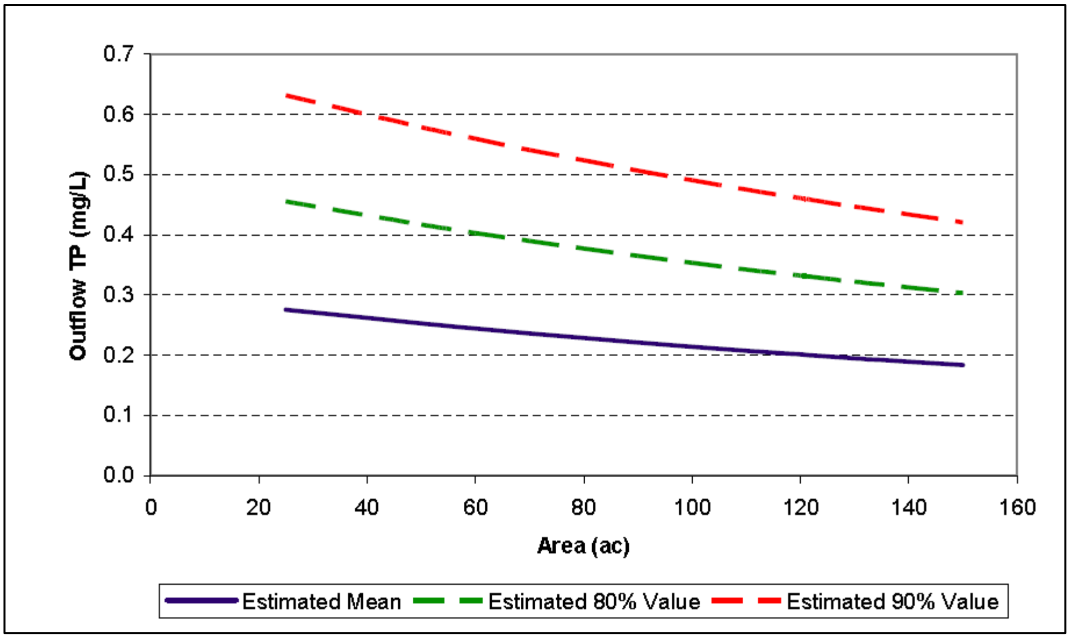

Figure 2-4. Estimated outflow Total Phosphorus as a function of wetland area – Buildout with contingency (Alt. 2) (after Jones Edmunds and Wetland Solutions (2010). The 80% and 90% factors (or multipliers) account for stochastic variability in model estimates and were derived by reviewing applicable wetland operational data and evaluating the distribution of measured outflow concentrations around the model-estimated long-term average concentrations.

Based on modeling by (Wetland Solutions, 2006), the outflow from the 125-acre enhancement treatment wetland system, under Alternative 2 (Buildout with contingency), would reduce TN load by 25,545 lbs/yr and TP load by 568 lbs/yr.

Jones Edmunds & Wetland Solutions (2010) drew the following conclusions from their analyses:

- Consistent with prior modeling efforts, a wetland area of approximately 125 acres was estimated to reduce current incoming TN loads to acceptable levels for discharge to Paynes Prairie State Park (PPSP) and partially achieve the requirements of the TMDL for Alachua Sink. Prior work (WSI 2006) showed that additional assimilation would occur within the hydrologically restored section of PPSP and that the full requirements of the TMDL would be met by the time water reaches Alachua Sink (achieving natural background concentrations of 1.4 mg L^{-1} TN and 0.1 mg L^{-1} TP before entering the sink);

- A 125-acre wetland would provide additional TP load reduction that should be beneficial in restoring desirable plant communities within PPSP;

- A 125-acre wetland would provide sufficient capacity to assimilate increased nutrient loads associated with buildout and possible future expansions of the MSWRF; and

- Limiting the peak inflow rate to 25 cfs would result in minimal bypasses of untreated water to PPSP (about 3% of the annual TN load) without creating an excessive average or maximum hydraulic loading rate to the wetland (Jones Edmunds & Wetland Solutions 2010).

2.7.2 Downstream Protection Discussion

Based on a data review, Dr. Larry White estimated that the natural background total phosphorus and total nitrogen concentrations in Paynes Prairie were approximately 0.1 mg/L and 1.4 mg/L, respectively (White, 1975). Using the k-P* model, Wetland Solutions demonstrated that these background nutrient concentrations are achieved within Paynes Prairie at various distances downstream from the Enhancement Wetland, prior to reaching Alachua Sink (**Table 2-2**). In fact, based on the recent modeling, the overall project should result in TP and TN concentrations in Paynes Prairie of approximately 0.1 mg/L (or lower) and 1.2 mg/L (or lower), respectively (Wetland Solutions, 2019).

For the median flow scenario, the results indicate that both the downstream "background" target TP (0.1 mg/L) and TN (1.4 mg/L) concentrations were estimated to be achieved approximately 4,000 feet downstream from the Enhancement Wetland distribution channel. For the low and high flow scenarios, the distance to meet the target concentrations was estimated to be 2,500 and 5,500 feet, respectively.

Wetland Solutions (2006) determined that on a long-term average basis, the total pollutant load reductions (and percent of existing average loads) due to the entire Sweetwater Branch Sheetflow Restoration Project (**including Paynes Prairie rehydration**) were estimated to be:

- Total nitrogen – 93,641 lbs/yr (73%);
- Total phosphorus – 27,133 lbs/yr (93%); and
- Total suspended solids – 152,388 lbs/yr (71%).

Note that these estimates, which were used to design and size the Enhancement Wetland, are slightly different than the estimates provided in the recent modeling presented in **Section 6** (new discharge scenarios) (Wetland Solutions, 2018). The Alachua Sink TMDL was specifically for TN, and the above information demonstrated that the TN reductions required by the TMDL would be achieved by the Enhancement Wetland. The FDEP-adopted BMAP for the Orange Creek Basin states, "Based on phytoplankton communities and the TN/TP ratio, Alachua Sink is considered nitrogen limited, meaning that the amount of nitrogen governs the growth of phytoplankton. Thus, the TMDL for Alachua Sink was expressed in terms of TN reductions to achieve water quality standards." Additionally, because Alachua Sink is a colored lake (with a long-term average color of 55.5 PCU, based upon IWR data), the upper range of the acceptable TP concentration is 0.16 mg/L. The k-P* model shows that the TP concentrations will be less than 0.1 mg/L prior to water reaching Alachua Sink (approximating background conditions), which is an additional demonstration of downstream protection.

Table 2-2. Results from the k-P* model showing predicted TN (mg/L), TP (mg/L) and TSS (mg/L) from the Enhancement Wetland at median, low and high flows, at various distances from the Enhancement Wetlands sheetflow discharge (from Wetland Solutions 2006).

Median Flow Scenario

Distance from Inlet (ft)	Cumulative Area (ac)	q (m/yr)	TP	TN	TSS
1,000	115	29.8	*0.22*	*2.03*	2.3
2,000	230	14.9	*0.16*	*1.60*	2.1
3,000	344	9.94	*0.13*	*1.38*	2.0
4,000	459	7.45	0.10	1.26	2.0
5,000	574	5.96	0.08	1.18	2.0
6,000	689	4.97	0.07	1.13	2.0
		Low Flow Scenario			
Distance from Inlet (ft)	Cumulative Area (ac)	q (m/yr)	TP	TN	TSS
1,000	115	16.4	*0.17*	*1.66*	2.1
2,000	230	8.18	*0.11*	1.29	2.0
3,000	344	5.45	0.08	1.16	2.0
4,000	459	4.09	0.06	1.09	2.0
5,000	574	3.27	0.05	1.06	2.0
6,000	689	2.73	0.04	1.04	2.0

High Flow Scenario

Distance from Inlet (ft)	Cumulative Area (ac)	q (m/yr)	TP	TN	TSS
1,000	115	41.4	*0.24*	*2.23*	2.5
2,000	230	20.7	*0.19*	*1.80*	2.2
3,000	344	13.8	*0.15*	*1.56*	2.1
4,000	459	10.3	*0.13*	*1.40*	2.0
5,000	574	8.27	*0.11*	1.30	2.0
6,000	689	6.89	0.09	1.23	2.0

2.7.3 Protection of Paynes Prairie Plant Communities

Previous studies have shown that the vegetative communities in Paynes Prairie are not sensitive to moderate levels of nutrients, and that excess desiccation, fire suppression, and grazing disturbance have historically been the main stressors to the system (White, 1975; Hall and Portier, 2002; Easterday, 1982; FDEP, 2014a). The Enhancement Wetland and filling of the Sweetwater ditch provide significant hydrologic restoration to Paynes Prairie, reducing desiccation as a stressor. It is for this reason that the FDEP convinced the Acquisition and

Restoration Council (ARC, 2009) to approve the Sheetflow Restoration Project (which it did) citing, "Water entering the 1,300-acre sheetflow restoration area will be of sufficient quality to allow the re-establishment of desirable, native wetland plant communities and wildlife habitat…. Restoring the park wetlands and cleaning up the water quality in the area have been longstanding goals of DRP (Division of Recreation and Parks), therefore the project will definitely provide a net positive benefit to the park and its conservation lands."

Cattle have been excluded from the area, eliminating excess grazing as a stressor. The State Park staff conducts prescribed burns, when appropriate, reducing fire suppression as a stressor.

Studies have been conducted that compared plant communities receiving the higher nutrient water adjacent to the historic Sweetwater Branch ditch (that once flowed through the prairie) with Paynes Prairie plant communities considered to be achieving the reference condition (White, 1975; Hall and Portier, 2002; Easterday, 1982; FDEP, 2014a). White (1975) found several plants with high Coefficient of Conservatism (C of C) scores growing in the higher nutrient waters adjacent to the former Sweetwater ditch (that historically flowed within Paynes Prairie), including *Panicum hemitomon* (5.82 C of C), *Pontederia cordata* (5.4 C of C), and *Leersia hexandra* (5.6 C of C).

Hall and Portier (2002) found no statistically meaningful differences in plant dominance between their Paynes Prairie "reference" and higher nutrient "test" plant community transects. FDEP (2014a) found that the average C of C scores across all sites in Paynes Prairie (reference and higher nutrient test sites alike) exhibited low variability, ranging from 2.23 to 2.94, and the average C of C scores were similar between reference and test sites. Note that nutrients in the Enhancement Wetland discharge are expected to be substantially lower than the nutrients adjacent to the historic ditch in Paynes Prairie. These observations indicate that the nutrients discharged from the Enhancement Wetland are protective of the Paynes Prairie flora.

2.8 Stressor Identification Study

Previous modeling (see above) has demonstrated that the additional nutrient treatment proposed to be implemented at the MSWRF coupled with the significant TN reduction provided by the Enhancement Wetlands, would fully satisfy the TMDL and protect downstream waters (Jones Edmunds and Wetland Solutions 2010) (§ 403.061(43)(c), F.S. However, it must be demonstrated that the nutrients in Sweetwater Branch (the section that is located between KGS and MSWRF and between the MSWRF discharge and the Enhancement Wetlands) would allow for protection of Class III designated uses (*i.e.,* a healthy, well balanced aquatic community). Because Sweetwater Branch is a highly physically altered water conveyance system (completely channelized by 1956), characterized by extreme hydrologic modifications and habitat limitations, there have been numerous past failures of the Stream Condition Index (SCI), both upstream and downstream of the point source discharges. Therefore, included in this report is a Stressor Identification evaluation to determine the causes of the faunal biological health issues in Sweetwater Branch (**Chapter 4**).

3 Physical, Biological, and Chemical Characterization of Sweetwater Branch

3.1 Physical Data

3.1.1 Physical Setting/System Description/Historical Perspective

Sweetwater Branch is in Alachua County, Florida, originating within the urban center of the City of Gainesville (**Figure 2-2**). This channelized, physically altered system flows to the south, through areas of residential and industrial land uses, receiving input from stormwater, the KGS and the MSWRF. The input from MSWRF is notable, as it provides approximately 5.5 (MGD) of reclaimed water to Sweetwater Branch (FDEP, 2014b). During 2012, MSWRF contributed, on average, approximately 80% of total discharge of the system (FDEP, 2014b). Beyond the MSWRF, Sweetwater Branch continues to flow south for approximately 1.3 miles, until it reaches the Enhancement Wetlands treatment system, located at the edge of Paynes Prairie (Alachua County EPD, 2007).

Prior to the development of the City of Gainesville, Sweetwater Branch was a small, intermittent stream, which received seepage and overland flow from the area's mixed pine and hardwood forests (FDEP, 2014b). Prior to the 1920s, approximately one MGD, on average, of water from Sweetwater Branch entered Paynes Prairie (west of its current location), where it would sheetflow to a wetland area known as Alachua Lake (Jones Edmunds & Associates, Inc., 2010). From the 1920s to the 1970s, Sweetwater Branch was subjected to a series of hydrologic modifications to reduce flooding in Gainesville and to allow cattle grazing on Paynes Prairie (Jones Edmunds & Associates, Inc., 2010). Among the most influential of the alterations was the complete channelization of Sweetwater Branch and the construction of the Sweetwater Canal through Paynes Prairie, which was completed by 1956 (Jones Edmunds & Associates, Inc., 2010). After 1956, Sweetwater Branch no longer discharged via sheetflow onto the Prairie, but instead, the flow was captured by the Sweetwater Canal, which conveyed the water directly to Alachua Sink and into the Floridan Aquifer (Jones Edmunds & Wetland Solutions, 2010).

Because the majority of Gainesville was urbanized prior to the implementation of modern stormwater management practices, the prevalence of impervious surfaces in the drainage basin has highly altered the timing and volume of the stormwater that enters Sweetwater Branch (FDEP, 2014a). Additionally, nutrients were identified as causing excess chlorophyll *a* production in Alachua Sink, and in 2006, a TMDL was developed identifying needed reductions in nutrients reaching the sink. To comply with the TMDL and to reestablish sheetflow to Paynes Prairie, the City of Gainesville is implementing a comprehensive restoration project. As described above, the restoration project consisted of filling in the canal connecting Sweetwater Branch to Alachua Sink and utilizing 125 acres of enhanced wetlands to effectively treat the majority of water flowing through Sweetwater Branch. Ultimately, this restoration project will provide for water with nutrient loads that will support a healthy, well balanced aquatic community in Alachua Sink, as well as provide for a significantly improved hydrologic regime for Paynes Prairie.

3.1.2 Land Use, Impervious Surfaces, and the Landscape Development Intensity Index

A land use characterization of the Sweetwater Branch watershed (WBID 2711) is provided in **Table 3-1 (**Directly Connected Impervious Area was calculated based on values in **Table 3-2** below). The dominant land use is medium density residential (2-5 dwelling units/acre), making up about 36% of the total. Other adverse human land uses (in the absence of Best Management Practices) include commercial services (17%), institutional (6%), high density residential (5%), roads and highways (3%), and other light industrial uses (3%). Given these human land uses, approximately 70% of the basin is characterized by human activities that would be expected to result in a high degree of directly connected impervious areas (DCIA) (see below).

Gao et al. (2006) discussed the importance of calculating the percent impervious area of each land use category when estimating surface runoff using the Watershed Management Model (WMM) for the Alachua Sink TMDL. Studies throughout the United States over the past 15 years have shown that annual "per acre" discharge volumes are positively related to the amount of imperviousness in a land use (WMM, 1998). During the process of calibrating the WMM for the Alachua Sink TMDL, Gao et al. (2006) adjusted the impervious and pervious runoff coefficients to fit model estimates to measured data and presented a table with the directly connected impervious area (DCIA) percentages for land use categories in the Sweetwater Branch watershed (**Table 3-1**).

Table 3-1. Land use characterization of the Sweetwater Branch watershed (WBID 2711) (Source: FDEP, 2014a, including additional analysis of Directly Connected Impervious Area).

Land use	Number of acres	Percentage of land use in watershed	Directly Connected Impervious Area (DICA) score (%)	Acres w/ DCIA
Residential, medium density - 2-5 dwelling units/acre	757.51	35.7	64.2	486.32
Commercial and services	358.73	16.9	79.5	285.19
Upland mixed coniferous/hardwood	198.08	9.3	0.5	0.99
Mixed wetland hardwoods	146.46	6.9	30	10.11
Institutional	136.9	6.4	79.5	8.84
Residential, high density - 6 or more dwelling units/acre	108.18	5.1	79.5	5.52
Roads and highways (divided 4-lanes with medians)	69.93	3.3	36.2	2.31
Cemeteries	57.1	2.7	15.4	1.54
Other light industrial	54.19	2.6	79.5	1.38
Residential, low density - less than 2 dwelling units/acre	44.95	2.1	27.9	0.95
Community recreational facilities	30.85	1.4	79.5	0.45
Electrical power transmission lines	23.17	1.1	36.2	0.25
Sewage treatment	22.21	1.0	30	0.23
Electrical power facilities	22.02	1.0	79.5	0.23
Herbaceous upland nonforested	13.54	0.6	0.5	0.09
Military	12.33	0.6	79.5	0.07
Woodland pastures	11.65	0.5	0.5	0.06
Reservoirs - pits, retention ponds, dams	11	0.5	30	0.06

Freshwater marshes	10.49	0.5	30	0.05
Lakes	10.38	0.5	30	0.05
Water supply plants	8.57	0.4	79.5	0.03
Pine flatwoods	5.25	0.2	0.5	0.01
Parks and zoos	3	0.1	27.5	0.00
Wet prairies	2.86	0.1	30	0.00
Mixed scrub-shrub wetland	1.8	0.1	30	0.00
Grand Total	2121.17	100	NA	804.75

Table 3-2. Percent directly connected impervious area (DCIA) for different land use categories (see Gao *et al.* 2006).

Land Use Categories	DCIA	Reference
Forest/rural open	0.5%	User's Manual: WMM, 1998
Urban open	15.4%	User's Manual: WMM, 1998
Agriculture	3.7%	Brown, 1995
Low-density residential	27.9%	User's Manual: WMM, 1998
Medium-density residential	64.2%	User's Manual: WMM, 1998
High-density residential	79.5%	User's Manual: WMM, 1998
Communication/transportation	36.2%	Brown, 1995
Rangeland	3.7%	CDM
Water/wetland	30.0%	Harper and Livingston, 1999

Based on the land use categories and their respective percent directly connected impervious areas, **37.94 %** of the Sweetwater Branch watershed is calculated to be impervious.

Brown and Vivas (2005) developed a Landscape Development Intensity Index (LDI) to estimate the intensity of human land use based on nonrenewable energy flow. The LDI is calculated as the percentage area within the catchment of particular types of land use multiplied by the coefficient of energy use associated with that land use, summed over all land use types in the catchment:

$$\mathbf{LDI = \sum (LDI_i * \%LU_i)}$$

Where:

LDI_i = the nonrenewable energy for a specific land use, and

$\%LU_i$ = the percentage of land area in the catchment with the specific land use.

The LDI coefficients are provided in **Table 3-3.**

Table 3-3. Landscape Development Intensity Index Coefficients.

Category	**Coefficient**
Natural System	1
Pine Plantation	1.6
Pasture	3.4

Row Crops	4.5
Residential (low)	6.8
Residential (high)	7.6
Commercial	8.0
Industrial	8.3
Commercial (high)	9.2
Business District	10.0

The LDI for the Sweetwater Branch watershed is **6.4** (FDEP, 2014a). LDI values of 2 and below are considered to represent minimally disturbed conditions. During the development of the Human Disturbance Gradient for SCI metric selection, LDI values above 3.5 were used to represent significant human influences in the watershed (Fore et al., 2007). Therefore, an LDI of 6.4 for the Sweetwater Branch basin represents remarkable adverse human effects. FDEP has had a long history of using the LDI as a tool to estimate adverse human effects from various land uses on adjacent waterbodies, such as streams, lakes, and wetlands. As part of numeric nutrient criteria development in Florida, EPA approved the use of the LDI for selection of minimally disturbed reference sites.

3.1.3 Hydrologic Information

It has been established that significant alterations in a system's hydrologic regime have adverse effects on aquatic life, especially benthic macroinvertebrates and fish (EPA, 2014). Several studies have determined that 10-20% of impervious surfaces in a watershed will generally lead to failing scores on various biological indices, although implementation of stormwater Best Management Practices (*e.g.,* providing a 30 m riparian buffer of native forest, along with other structural BMPs) can help mitigate these adverse effects to some degree (Horner et al., 2004, for a review, see (EPA, 2014). Although there is a good riparian buffer zone adjacent to Sweetwater Branch south of Highway 331, the mid-and upper portions of the system are characterized by an inadequate riparian buffer, with direct stormwater discharges to the system via ditches, roads, and culverts, etc. Note that because Gainesville was largely developed prior to modern stormwater rules, BMPs have not been widely implemented in the Sweetwater Branch watershed (although some are now being implemented via the Orange Creek BMAP), meaning that adverse hydrologic effects associated with the 38% impervious surface area are largely unmitigated.

The FDEP has developed a hydrologic modification scoring method for streams to rate the degree of hydrologic changes caused by human activities. Adverse activities evaluated by the method include the presence of dredging, ditching, consumptive use of ground water, and prevalence of impervious surfaces on the landscape. This hydrologic scoring method was one component of FDEP's human disturbance gradient (HDG), which was used to select effective biological metrics for the SCI and Bioreconnaisance (BioRecon) (Fore et al., 2007). The hydrologic modification scores range from a natural hydrologic regime of 1 to an extremely altered regime of 10 (**Table 3-4**). After assessing the relevant factors in **Table 3-4**, FDEP calculated a hydrologic score of **9** for Sweetwater Branch, indicating that the flow regime is human controlled, in this case predominantly due to the amount of impervious surfaces in the watershed and the high degree of artificial channelization of Sweetwater Branch (and contributing ditches). These conditions can create water level and flow extremes that cause severe abrasion to benthic organisms, which result in "catastrophic drift," defined as extreme adverse changes in the community due to the flow regime (Paul and Meyer, 2001). Gibbens et al. (2007) identified the main hydraulic factors that influence catastrophic drift in the aquatic community, which are hydraulic stress due to rapidly changing stream velocity, bed load transport and reduction of substrate stability due to increasing shear stress, and to "sandblast-effects" due to inorganic suspended particles (*e*.g., sand).

Table 3-4. Hydrological Modification Scores and Descriptions.

Best 1-2 point	Flow regime as naturally occurs (slow and fairly continual release of water after rains), few impervious surfaces in watershed; high connectivity with ground water and surface features delivering water (*e.g.*, sandhills, wetlands; no ditches, berms)
Slight disturbance 3-4 points	Flow regime minimally changed; some water withdrawals; some wetland drainage, some impervious surfaces in watershed, some ditching
Moderately altered 5-6 points	Flow regime moderately altered; hydrograph moderately flashy (scouring after rain events with subsequent reductions in flow), groundwater pumping evident; much wetland drainage, topographic alterations reduce natural water input; more impervious surfaces throughout watershed, dams/control structures change normal water delivery schedule
Poor 7-8 points	Flow regime highly altered; hydrograph very flashy (scouring after rain events with subsequent reductions in flow, leading to stagnant or dry conditions, related to large amounts of impervious surfaces and/or ditching throughout watershed); water withdrawals & impoundments/control structures severely alter flows, large amounts of impervious surfaces
Very poor 9-10 points	Flow regime entirely human controlled; hydrograph very flashy (scouring after rain events with subsequent reductions in flow, leading to stagnant or dry conditions, related to impervious surfaces and ditching throughout watershed); water withdrawals & impoundments fundamentally alter the nature of the ecosystem

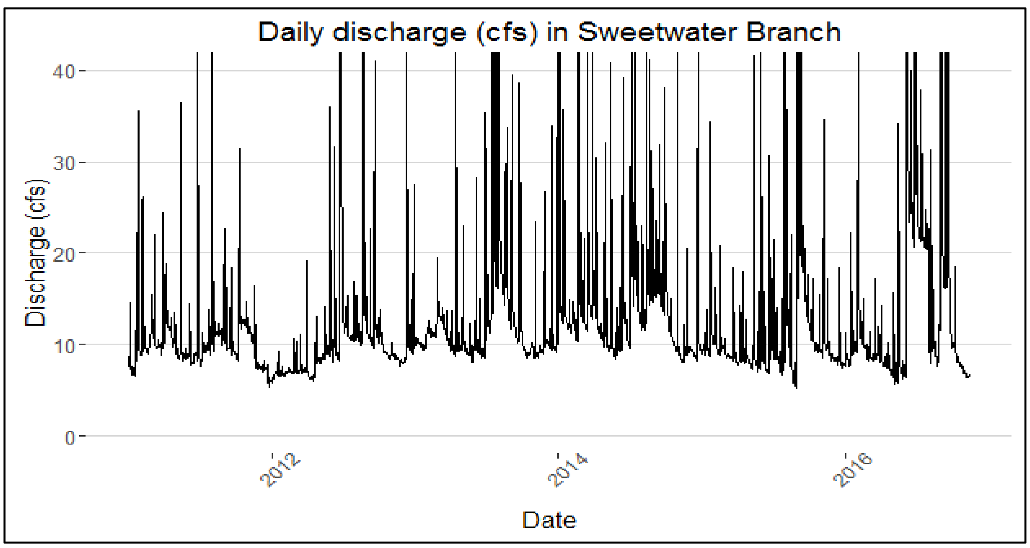

Figure 3-1. Hydrograph for Sweetwater Branch (measured at Williston Rd.) for 2012-2016 with scale truncated at 40 cfs to enable visualization of extreme discharge events (data from St. Johns River Water Management District).

Because of the above hydrologic modifications, including the high degree of impervious surfaces, the hydrograph for Sweetwater Branch is characterized by a series of extreme flow events (**Figure 3-1)**.

3.1.4 Sediment Movement in Sweetwater Branch

The sediment movement in Sweetwater Branch that is associated with storm events was studied by Jones Edmunds & Associates, Inc. (2010). They found that storm events, coupled with hydrologic modifications in the watershed, resulted in significant sediment movement (mostly sand) in Sweetwater Branch. For example, rainfall leading to a 20.3 cfs flow in Sweetwater Branch resulted in 540, 437 ft^3 of sediment transfer downstream, while a 43 cfs flow resulted in 1,401,601 ft^3 of sediment movement and subsequent deposition (Jones Edmunds & Associates, Inc. 2010). Since 2012, there have been in excess of 100 flow events that were greater than 20.3 cfs in Sweetwater Branch, indicating that extreme sediment movement is a significant issue.

3.1.5 Stream Habitat Information

The FDEP Stream Habitat Assessment consists of scoring eight parameters based on field measurements and observations, including substrate diversity, substrate availability, water velocity, habitat smothering, bank stability, degree of artificial channelization, riparian zone buffer width and riparian zone vegetation quality. Mean habitat scores in Sweetwater Branch were 60.8 points (marginal) upstream of the Kelly Generating Station (KGS), 76.9 points (marginal) between Kelly and the MSWRF discharge, and 95.2 (suboptimal) downstream of MSWRF (see **Table 3-5, Figure 3-2, Figure 3-3)**. Individual habitat components are found in **Figure 3-4**.

Table 3-5. Summary statistics for the habitat assessment scores in Sweetwater Branch at sites located upstream of KGS, between the KGS and MSWRF, and downstream from the MSWRF.

Location	Mean	Median	Min	Max	SD	n
Upstream	60.8	49.5	42	93	20.1	10
Between	76.9	86.0	48	119	23.6	15
Downstream	95.2	93.5	77	112	11.3	14

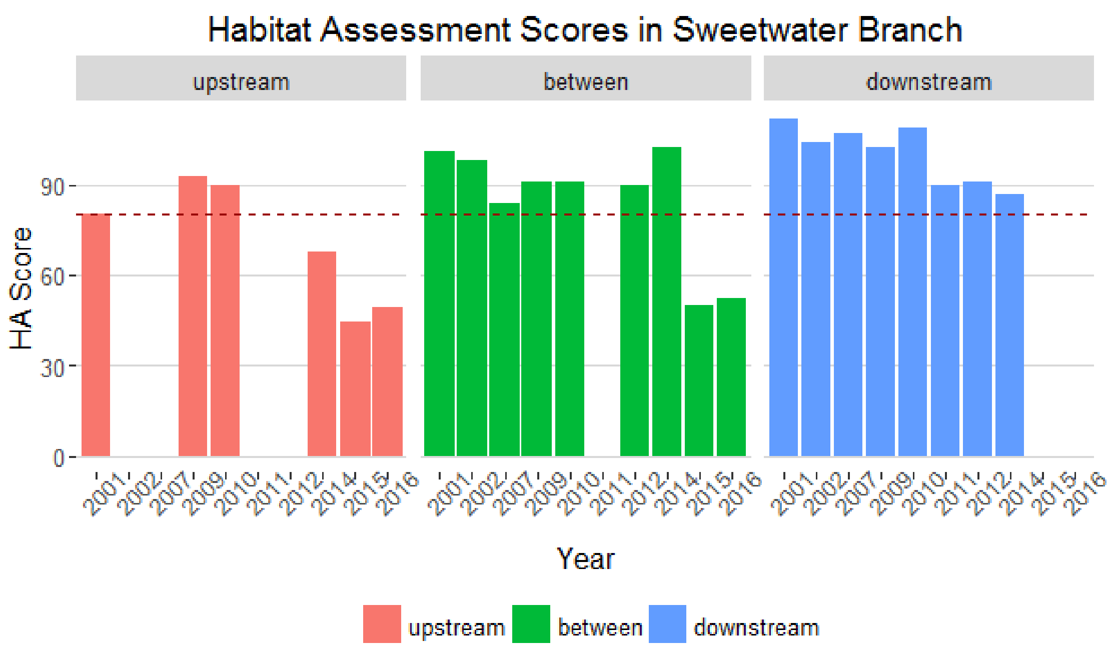

Figure 3-2. Habitat assessment scores for Sweetwater Branch by location and year. Sites with scores less than 80 (horizontal dashed line) could potentially qualify for the "ditch exception" to NNC.

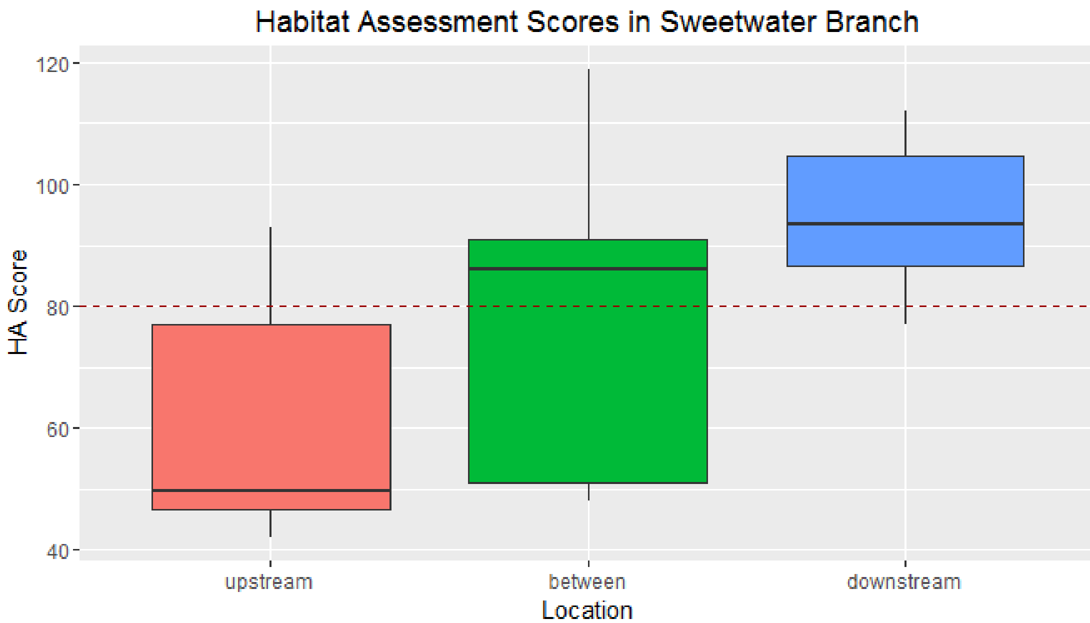

Figure 3-3. Box plots of habitat assessment scores for Sweetwater Branch by location.

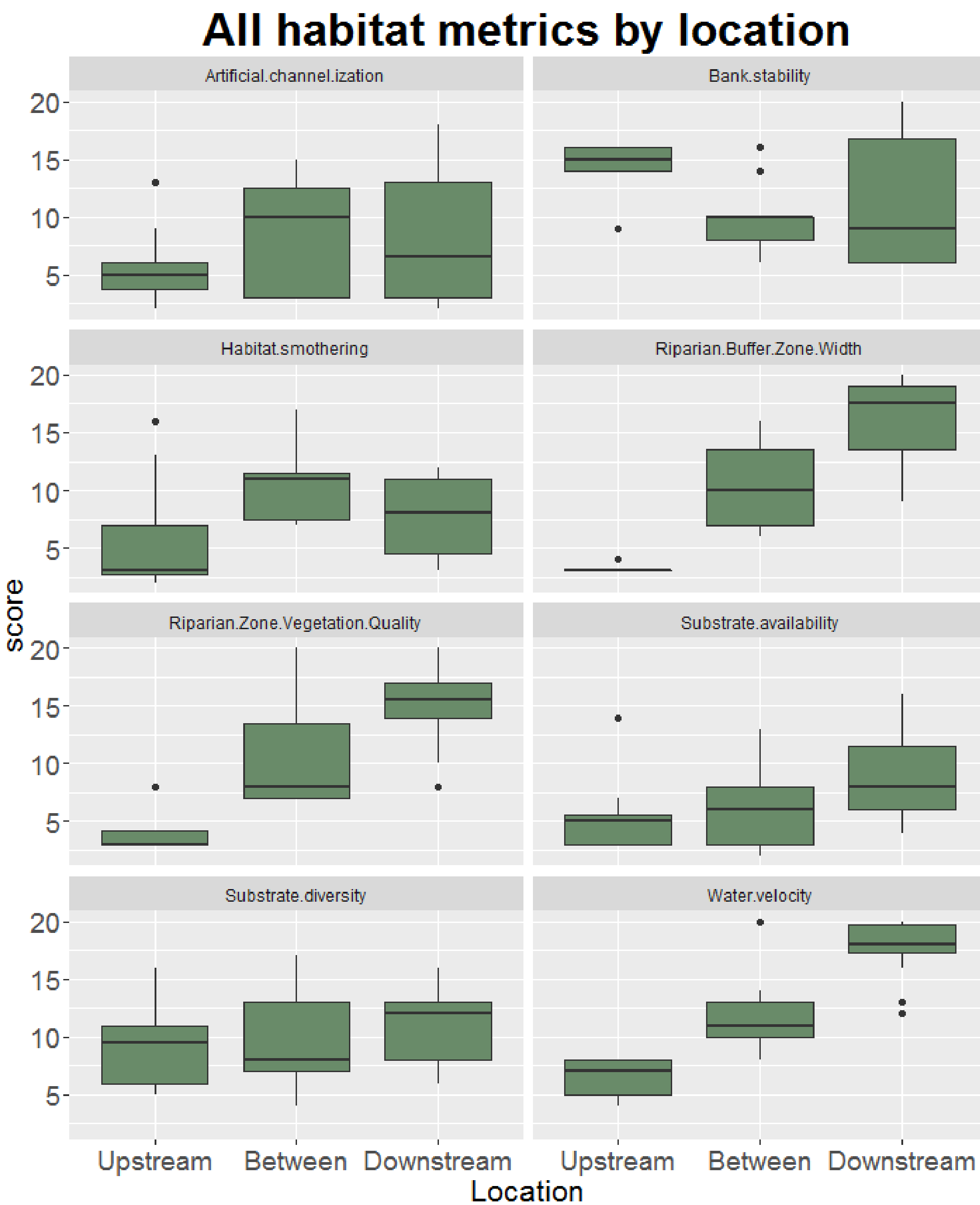

Figure 3-4. Box plot summaries of each habitat component for site locations upstream of Kelly, between Kelly and MSWRF, and downstream of MSWRF.

Photos of Sweetwater Branch taken upstream of KGS, between KGS and MSWRF, and downstream of MSWRF are found in **Figure 3-5** through **Figure 3-10**. As mentioned above, Sweetwater Branch has been entirely artificially channelized. Artificial channelization scores ranged from medians of 5 upstream of Kelly, 10 between Kelly and MSWRF, and 8 downstream of MSWRF (**Figure 3-4**). Poor channelization scores in this range are often associated with low substrate availability, habitat smothering, and scouring during rain events (**Figure 3-8)**. The low artificial channelization scores throughout the system are likely due to 1950's ditching activities, as well as from continued scouring from storm events.

Analysis of Variance conducted on Sweetwater Branch habitat assessment values, comparing scores from upstream KGS, between KGS and MSWRF, and downstream from MSWRF, determined that there were significant differences between sites (F = 9.6, p = 0) (**Table 3-6)**. Results of Tukey Honest Significant Difference post-hoc test on habitat assessment scores indicated that the upstream location was significantly lower than both the area between KGS and MSWRF, and the location downstream from MSWRF (**Table 3-7**). Note, however, that habitat at all locations was marginal or suboptimal, suggesting that habitat was a limiting factor at all locations.

Table 3-6. Results of Analysis of Variance conducted on Sweetwater Branch habitat assessment, comparing scores from upstream KGS, between KGS and MSWRF, and downstream from MSWRF.

Analysis of Variance Model	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Location	2	7052	3526	9.6	< 0.001
Residuals	36	13153	365	NA	NA

Table 3-7. Results of Tukey Honest Significant Difference post-hoc test on habitat assessment scores.

	diff	lower	upper	p adj
Between-upstream	16	-2.9	35	0.11
Downstream-upstream	34	15	54	<0.001
Downstream-between	18	0.92	36	0.04

Figure 3-5. Sweetwater Branch upstream of KGS. Note artificial channelization.

Figure 3-6. Sweetwater Branch upstream of KGS. Note the water control structure modifying natural hydrology.

Figure 3-7. Sweetwater Branch upstream of KGS. Note riparian zone infringement.

Figure 3-8. Sweetwater Branch downstream of the KGS discharge. Note high degree of artificial channelization.

Figure 3-9. Sweetwater Branch downstream of KGS during periphyton rack retrieval from the only pool found in the 100 m reach (reflecting sediment smothering).

Figure 3-10. Sweetwater Branch (1-24-14) downstream of the MSWRF, south of Williston Road, showing the high degree of artificial channelization (note lack of sinuosity).

3.2 Biological Data

A summary of biological data (including Rapid Periphyton Survey, Linear Vegetation Survey, Stream Condition Index, BioRecon, and Habitat Assessment) collected by various entities is found in **Appendix 8.3.**

3.2.1 Benthic Invertebrate Information

The BioRecon failed 2 times in 2 samplings in Sweetwater Branch upstream of the KGS. Downstream of the KGS (but upstream of MSWRF), the BioRecon failed on 3 out of 3 samplings.

The currently used Stream Condition Index (2012 version) averaged 21 (n=2) in Sweetwater Branch upstream of the KGS and 36.2 (n=5) downstream of the KGS (upstream of the MSWRF). Downstream of MSWRF, the SCI averaged 34.6 (n = 8). These average SCI scores do not achieve the minimum acceptable average score (40) for a healthy, well balanced stream (**Table 3-8, Figure 3-11, Figure 3-12**).

Table 3-8. Summary of SCI (2012 version) data for Sweetwater Branch.

Location	Mean	Median	Min	Max	SD	n
Upstream	21.0	21.0	19	23	2.8	2
Between	36.2	30.0	23	51	12.9	5
Downstream	34.6	33.5	27	45	6.2	8

In a 2008 5th Year Inspection, with sampling concurrently conducted upstream and downstream from the MSWRF, FDEP concluded that "the macroinvertebrate community in this portion of Sweetwater Branch is already suppressed by other urban influences such that the effluent did not cause further degradation of the community." The 2014 5th Year Bioassessment found that there were no violations of the biological integrity criterion (Shannon-Weaver diversity) at the Test Site, although the Control Site SCI (45) was higher than the Test Site SCI (28) (FDEP, 2014c).

Analysis of Variance (ANOVA) was conducted on the SCI scores, comparing all SCI (2012) values upstream of KGS, between KGS and MSWRF, and downstream of MSWRF (**Table 3-9**). ANOVA results show there were no significant differences in SCI scores by location (F = 2.3, p = 0.14) (**Table 3-9**).

Table 3-9. Results of Analysis of Variance conducted on the Sweetwater Branch SCI, comparing scores from upstream KGS, between KGS and MSWRF, and downstream from MSWRF.

Analysis of Variance Model	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Location	2	359	179	2.3	0.14
Residuals	12	939	78	NA	NA

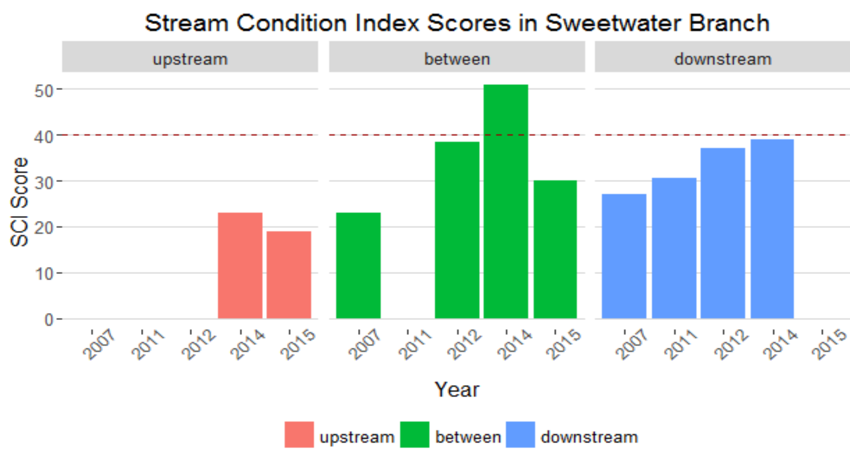

Figure 3-11. SCI scores (2012 version) for Sweetwater Branch by location and year.

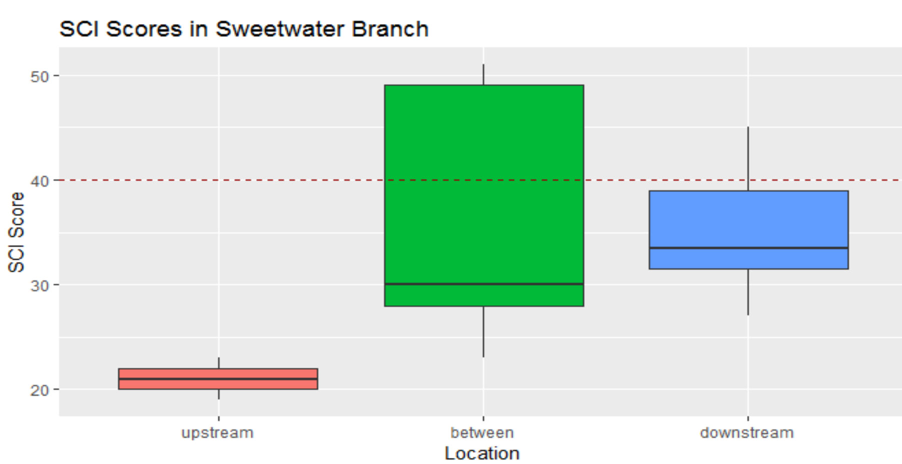

Figure 3-12. Box plots of SCI scores (2012 version) by location.

3.2.2 Linear Vegetation Survey

The LVS failed to achieve the floral evidentiary threshold for macrophytes 7 times in 7 samplings in Sweetwater Branch upstream of the KGS, likely due to the influence of urban encroachment and the accompanying sources of invasive exotic taxa. Between KGS and the MSWRF, the LVS passed all 10 times it was sampled (ten date-station combinations), with the results usually influenced by a lack of 2 m^2 of vascular plants in the water. The LVS passed 5 times and failed on two separate occasions at SWB-5 (located downstream from MSWRF near where Sweetwater Branch enters Paynes Prairie) prior to the ongoing restoration activities. Physical mitigation of this stream segment, along with continuing plant management activities, was responsible for restoring a healthy aquatic plant community at SWB-5, and subsequently, the past 3 temporally independent LVS samples achieved the NNC evidentiary thresholds. Therefore, the LVS evidentiary threshold requirement in Rule 62-302.531, F.A.C., was achieved downstream of the outfalls.

Table 3-10. Summary of LVS results for stations located on the Sweetwater Branch, comparing scores from upstream KGS, between KGS and MSWRF, and downstream from MSWRF.

Location	FLEPPC Pass	C of C Pass	Total	FLEPPC % Pass	C of C % Pass
Upstream	0	0	7	0	0.0
Between	10	10	10	100	100.0
Downstream	12	10	12	100	83.3

Prior to the construction of the Paynes Prairie sedimentation basin, station SWB-5 represented an area with extreme physical disruption due to sedimentation, with sand and debris continually depositing in the area (**Figure 3-13)**. This promoted deltaic, sand-smothered conditions where pioneer species (mainly exotic plants such as *Colocassia* and *Ruellia,* which are also common taxa at the headwaters) could outcompete other plants requiring more typical stream habitats (**Figure 3-14)**. Construction of the sedimentation basin resulted in partial physical restoration of Sweetwater Branch at SWB-5, which is now characterized by an actual stream channel with banks, with optimal water velocity, and LVS results that achieve the floristic evidentiary thresholds (**Figure 3-15**). Note that no substrate additions occurred during this restoration process, which mainly involved downcutting of the stream channel (creating banks) and water velocity improvements. Undesired aquatic vascular plants are now absent at SWB-5, and this is the direct result of the dramatically improved stream conditions associated with construction of the sedimentation basin (**Figure 3-16**), in conjunction with an exotic plant removal program conducted by the Paynes Prairie State Park staff (see below). Two temporally independent LVS samplings conducted at SWB-5 (on 1-24-14 and 4-16-14 by Frydenborg EcoLogic, and on 4-17-14 by FDEP) demonstrated that the LVS continues to achieve the evidentiary thresholds (no plants in water), confirming the success of the ongoing management activities.

The combination of physical restoration of lower Sweetwater Branch (SWB5) and active plant management provides reasonable assurance that the LVS endpoints will continue to be achieved. Paynes Prairie Preserve State Park conducts continuing management of non-native, invasive plant and animal species in accordance with the goals and priorities established in the Park's 10-year management plan. The 2013-2023 plan identifies the goal of "Remove exotic and invasive plants and animals from the park and conduct needed maintenance control." It also identifies the following specific objectives: annually treat 400 acres of exotic plant species in the park and develop and implement measures to prevent the accidental introduction or further spread of invasive exotic plants in the park. Areas within the park are prioritized for treatment based on the threat posed by specific non-native species, and sensitivity, rarity, and relative importance of the natural community or site being threatened by invasion.

Treatment of the management zones within the preserve located adjacent to the Sweetwater Branch Sheetflow Restoration Project Enhancement Wetland will continue to be a priority due to the importance of the project in restoration of hydrology within the Paynes Prairie basin marsh. Initial treatments of the wild taro, Mexican petunia, Japanese climbing fern, air potato, Chinese tallow, glossy privet, camphor tree, coral Ardisia, and Tradescantia were conducted in 2013 and 2014. Ongoing maintenance treatments of these species, and initial treatments of others detected adjacent to the project, are planned and will be conducted dependent upon funding and staffing levels within the park.

Figure 3-13. Pre-restoration photo of Sweetwater Branch at SWB-5, taken prior to construction of the sedimentation basin (photo by FDEP).

Figure 3-14. Pre-restoration photo at SWB-5 deposition delta and Colocassia (photo by FDEP).

Figure 3-15. Post-restoration photo of Sweetwater Branch at SWB-5, in January 2014. Note presence of a stream channel with banks.

Figure 3-16. Post-restoration photo of Sweetwater Branch at SWB-5, January 2014, emphasizing the recently developed (unstable) stream banks.

3.2.3 Algae and Rapid Periphyton Survey

The RPS achieved the expected floral evidentiary threshold (< 25% coverage of rank 4-6) in all 7 RPS samplings upstream of the KGS. The RPS has passed (< 25% coverage of rank 4-6) on 12 out of 13 station-date combinations between KGS and MSWRF, including during the past 3 temporally independent RPS samplings conducted by Frydenborg EcoLogic. Downstream of the MSWRF, the RPS passed during 16 of 18 samplings. Since February 2012, the RPS has passed downstream of the MSWRF on 16 station/date combinations, during four temporally independent samplings (conducted > 3 months apart). Therefore, the RPS evidentiary threshold requirement in Rule 62-302.531, F.A.C., was achieved downstream of both KGS and MSWRF.

Table 3-11. Summary of RPS results for stations located on the Sweetwater Branch, comparing scores from upstream KGS, between KGS and MSWRF, and downstream from MSWRF.

Location	Pass	Total	RPS % Pass
Upstream	7	7	100.0
Between	12	13	92.3
Downstream	16	18	88.9

3.2.3.1 Algal Community Response to Experimental Increased Nutrient Loading

A Before-After-Control-Impact Study was conducted during 2010 and 2011 to evaluate potential changes in algal species composition and abundance in response to an experimental increase in nutrient loading to Sweetwater Branch (WAR, 2011). On four separate occasions, phytoplankton and periphyton were sampled and identified to species (and variety) level at three stations, one located upstream of the MSWRF and two located downstream of the outfall. Two of the samplings occurred prior to an experimental 2 MGD increase in the MSWRF discharge, which was conducted to partially simulate the nutrient loading that would approximate a “full build-out” scenario. The experimental increase in the MSWRF discharge was accomplished by using GRU’s wastewater collection system to re-route raw wastewater flow from the Kanapaha Water Reclamation Facility to MSWRF. Two samplings occurred after the nutrient load increase to evaluate potential changes in the algal community associated with nutrient conditions that approached (but did not equal) those expected for a "full build-out" scenario. The period of increased nutrient loading began in January 2011 and continued until after the final (September 2011) algal sampling. Effluent flow and effluent nutrient concentrations that occurred during the study are found in **Table 3-12** and **Table 3-13.**

Table 3-12. Average MSWRF discharge flow and effluent nutrient concentrations for the 30 days prior to each sampling event during the WAR periphyton study. Note the receiving water (Sweetwater Branch) experienced the same flow during this time.

Sample Date	Effluent Flow (CFS)	TP (mg/L)	TN (mg/L)	Receiving Flow (CFS)
2/19/2010	10.88	-	4.84	10.89
9/21/2010	8.09	0.72	4.46	8.09
January, 2011	BACI Intervention			
3/9/11 to 3/11/11	9.11	1.09	7.38	10.95
8/24/11 to 9/24/11	12.97	1.35	5.61	12.97

Table 3-13. Data table from the WAR BACI study (WAR, 2011). Note that the actual chlorophyll units are µg/L.

Table 2. GRU Sweetwater Branch Creek Algal Study.
GRU Sweetwater Branch Water Quality Data.

Site	Date	CHLRA mg/L	Remark Code	COND µmhos	DO mg/L	NH3 mg/L	Remark Code	NO3+2 mg/L	OPO4 mg/L	pH pH units	SV cubic feet/sec.	TEMP °C	TKN mg/L	Remark Code	TPO4 mg/L	TSS mg/L	Remark Code
MU	1/14/10	0.6	U	390	6.9	0.25		0.34	0.20	6.9	1.1	14.7	0.3	I	0.37	1	U
MD	1/14/10	0.6	U	625	7.6	0.14		6.11	0.45	7.1	11.3	19.3	0.9		1.24	1	U
MU	5/26/10	1.1	U	350	8.4	0.04	I	0.30	0.23	7.1	0.4	22.4	0.6		0.84	10	
MD	5/26/10	1.1	U	400	8.1	0.08		3.06	1.17	7.2	9.7	24.1	0.8		1.29	2	I
MU	9/1/10	2.1	I	550	7.1	0.07		0.27	0.28	7.4	0.3	26.5	0.4	I	0.51	3	
MD	9/1/10	2.1	I	1,100	7.7	0.03	I	2.95	0.35	7.3	5.9	27.5	0.6		0.43	1	
MU	12/6/10	2.1	I	450	9.6	0.01	U	0.20	0.26	6.6	0.4	11.4	0.3	I	0.26	1	I
MD	12/6/10	2.1	I	635	9.6	0.01	U	4.22	1.30	7.1	10.0	16.1	0.9		1.37	1	I
MU	2/9/11	1.1	U	380	10.6	0.14		0.23	0.12	6.3	1.7	11.6	0.3	I	0.18	3	I
MD	2/9/11	1.1	U	650	10.3	0.13		6.29	0.06	7.0	13.0	16.0	0.8		0.15	1	U
MU	5/12/11	7.5		950	6.2	0.05		0.12	0.30	7.7	1.5	24.0	0.4	I	0.61	8	
MD	5/12/11	3.2	I	780	8.1	0.06		3.51	1.24	7.2	12.0	25.8	1.0		1.31	2	I
MU	8/10/11	1.1	U	450	8.0	0.04	I	0.21	0.21	8.0	0.2	26.0	0.3	I	0.20	2	I
MD	8/10/11	2.1	I	900	7.7	0.16		4.04	1.11	7.6	8.0	28.0	0.8		1.19	2	I

Abbreviations: MU - 300 feet upstream of MSWRF discharge; MD - 300 feet downstream of MSWRF discharge; CHLRA - Chlorophyll a; COND - Field Conductivity; DO - Dissolved Oxygen; NH3 - Ammonia; -NO3+2 - Nitrate plus Nitrite; OPO4 - Ortho Phosphorus; pH - Field pH ; SV - Stream Velocity; TEMP - Temperature; TKN - Total Kjeldahl Nitrogen; TPO4 - Total Phosphorus as Phosphate; TSS - Total Suspended Solids. Remark Codes: I - The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit. U - Indicates that the compound was analyzed for but not detected.

Although the Rapid Periphyton Survey was not conducted during the WAR study, Mike Hein, the investigator that carried out the study at Water and Air Research, was contacted to provide some of his qualitative observations. During the sampling, filamentous periphyton was mainly associated with the rock filled wire mesh gabion baskets located upstream from the MSWRF, while filamentous periphyton tended to be rare in the shifting sand substrate located downstream of the discharge (Hein, 2014). However, Mr. Hein stated that if filamentous periphyton was present, it would have been collected as part of the natural substrate samples.

Diatoms (Bacillariophycae) were consistently the dominant (generally >90%) group of algae collected, and no taxa potentially capable of producing toxins were observed, both pre- and post- the increased loading period (WAR, 2011). Algal density (both phytoplankton and periphyton) was low, indicating a distinct lack of nuisance conditions (WAR, 2011). For example, phytoplankton density ranged from 106 units/mL upstream of the MSWRF discharge to 1,705 units/mL downstream of the discharge during the study. While the levels increased downstream of the discharge, phytoplankton density was low throughout SWB, and the difference between upstream and downstream sites was within the variability of reference streams. For example, phytoplankton density at an FDEP reference stream (Econfina Creek) averaged 4,013 units/mL (plus or minus 3,054 units/mL) and 3,544 units/mL (plus or minus 1,748 units/mL) at two locations in the creek (FDEP, 1992). Note that these phytoplankton densities in Sweetwater Branch were associated with Annual Geometric Mean chlorophyll *a* values that complied with the reference site based expectation (<3.2 µg/L, see **Table 3-13)** (FDEP, 2013a).

Algal densities from periphytometer samplers ranged from 3,399 units/cm^2 upstream of the discharge to 7,561 units/cm^2 and 1,252 units/cm^2 at sites located downstream of the discharge (WAR, 2011). These densities are much lower than those associated with minimally disturbed, low nutrient reference site conditions in the Deerpoint Lake watershed, which ranged on average from 23,000 to 35,000 units/ cm^2 (FDEP, 1992).

Based on non-metric multidimensional scaling analyses, there were no significant differences in community composition (*i.e*., no adverse shifts or imbalances) observed when comparing the pre- with post- period of increased nutrient loading (WAR, 2011). This is partial evidence that the nutrient loading (up to 7.2 MGD and 6.6 mg/L TN) that approximated (but did not duplicate) conditions associated with a “full build-out” scenario of the MSWRF (7.5 MGD and 8 mg/L TN) would be protective of algal communities in Sweetwater Branch. This conclusion is similar to the results of a 2008 5th Year Bioassessment conducted by FDEP, which stated that “periphyton community composition did not differ between Control and Test Sites” (FDEP, 2008). To definitively address the algal issue, comprehensive modeling was conducted to evaluate the potential effects of the MSWRF and KGS discharges on phytoplankton and periphyton biomass at various nutrient loadings (see (Dynamic Solutions, 2018). The very fast travel time between the KGS and MSWRF discharges and the Enhancement Wetlands, coupled with the light-limited (shaded) conditions of Sweetwater Branch, are factors that act to mitigate the biological response to nutrient loading in the waterbody.

FDEP requested that the flow from the Kelly Power Generating facility, located upstream of the MSWRF, be characterized in relation to the 2008 5th Year Assessment. The flow from the Kelly Plant averaged 0.23 MGD for October 2007, which is significantly lower than the 6.27 MGD from the MSWRF during October 2007. The median annual flow from the Kelly Plant between 1998 and 2013 was 0.10 MGD.

During the post-loading period of the WAR study, the MSWRF averaged 7.2 MGD, compared to a 6.2 MGD average for 2010, during baseline flows from the facility. The average annual flow from KGS between 1998 and 2012 was 0.15 MGD, which is much less than the 1 MGD increase in the WAR study. The study by WAR therefore demonstrates that a substantial increase in loading by the MSWRF did not adversely affect the Sweetwater Branch algae community and lends support to the hypothesis that there may be a *de minimus* effect from the substantially lower loading from the Kelly facility.

3.3 Water Quality Data

3.3.1 Nutrients and Chlorophyll

Total nitrogen (TN), total phosphorus (TP), and phaeophytin-corrected chlorophyll a (Chlorophyll) from all available sources (GRU, Alachua County EPD, Impaired Waters Rule Database) were compiled for the period 2002-2016 (see stations in **Table 2-1**), and annual geometric means were calculated (consistent with the minimum data requirements in Chapter 62-302.531, F.A.C.) (**Table 3-14**). The data were segregated in a manner that allowed potential differences in nutrients (and the response variable) attributable to the KGS and MSWRF discharges to be determined (**Figure 3-17 through Figure 3-22**). For characterization of the upstream section, additional stations (e.g., SWBNE10) were included that are not part of the WQBEL modeling.

Table 3-14. Annual Geometric Means for TP (mg/L), TN (mg/L), and chlorophyll a (µg/L) (including the number of observations) in Sweetwater Branch, upstream of the Kelly facility, between Kelly and MSWRF, and downstream of MSWRF. Non-detects were included as half the MDL. NA means insufficient data.

Location	Year	N_TN	TN_agm	N_TP	TP_agm	N_Chla	Chla_agm
Upstream of Kelly	2002	14	0.805	15	0.105	1	NA
Upstream of kelly	2003	18	0.766	16	0.083	0	NA
Upstream of kelly	2004	8	0.442	8	0.083	0	NA
Upstream of kelly	2005	7	0.637	10	0.146	7	0.973
Upstream of kelly	2006	3	NA	4	0.135	0	NA
Upstream of kelly	2007	3	NA	3	NA	0	NA
Upstream of kelly	2008	0	NA	0	NA	0	NA
Upstream of kelly	2009	0	NA	0	NA	0	NA
Upstream of kelly	2010	0	NA	0	NA	0	NA
Upstream of kelly	2011	7	0.355	7	0.284	0	NA
Upstream of kelly	2012	8	0.589	8	0.459	0	NA
Upstream of kelly	2013	4	0.594	4	0.408	0	NA
Upstream of kelly	2014	11	0.572	11	0.099	14	1.821
Upstream of kelly	2015	15	0.464	14	0.121	13	2.035
Upstream of kelly	2016	4	0.261	4	0.135	4	1.101
Between facilities	2002	1	NA	1	NA	0	NA
Between facilities	2003	2	NA	2	NA	1	NA
Between facilities	2004	3	NA	3	NA	3	NA
Between facilities	2005	10	0.625	11	0.186	10	0.504
Between facilities	2006	8	0.786	12	0.132	9	1.438
Between facilities	2007	8	0.626	12	0.246	8	0.196
Between facilities	2008	10	0.812	12	0.356	8	2.049
Between facilities	2009	8	0.797	12	0.299	8	0.215
Between facilities	2010	9	0.748	12	0.393	8	0.548
Between facilities	2011	9	0.475	13	0.308	9	1.757
Between facilities	2012	13	0.705	13	0.488	11	1.513
Between facilities	2013	6	0.723	6	0.483	4	1.823
Between facilities	2014	23	0.668	24	0.241	13	1.700

Between facilities	2015	20	0.861	22	0.160	17	1.994
Between facilities	2016	7	0.812	7	0.180	7	2.515
Downstream of MSWRF	2002	7	3.475	7	0.749	0	NA
Downstream of MSWRF	2003	10	3.381	9	0.836	1	NA
Downstream of MSWRF	2004	3	NA	0	NA	3	NA
Downstream of MSWRF	2005	7	3.084	4	0.493	6	0.629
Downstream of MSWRF	2006	10	2.703	5	0.431	4	0.156
Downstream of MSWRF	2007	8	3.535	4	0.675	4	0.604
Downstream of MSWRF	2008	8	5.802	3	NA	8	1.293
Downstream of MSWRF	2009	8	4.101	4	0.435	7	0.410
Downstream of MSWRF	2010	8	3.205	4	0.632	7	1.052
Downstream of MSWRF	2011	8	4.022	8	0.980	8	1.689
Downstream of MSWRF	2012	23	5.700	23	0.911	28	1.208
Downstream of MSWRF	2013	6	4.429	6	0.837	6	1.057
Downstream of MSWRF	2014	8	3.423	8	0.548	4	1.579
Downstream of MSWRF	2015	8	3.993	8	0.500	4	1.985
Downstream of MSWRF	2016	3	NA	3	NA	3	NA

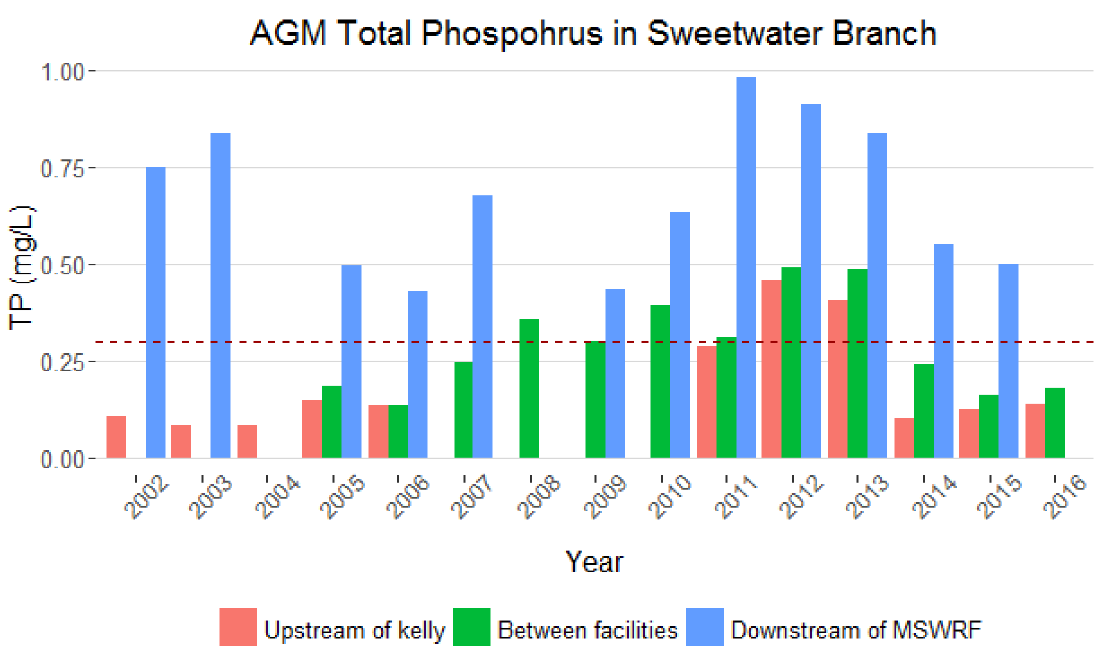

Figure 3-17. Annual Geometric Mean Total Phosphorus in Sweetwater Branch over time. "Upstream" includes stations above the Kelly power plant, "between" includes stations between Kelly and MSWRF, and "downstream" includes stations downstream of MSWRF. The horizontal dashed line indicates the regional threshold.

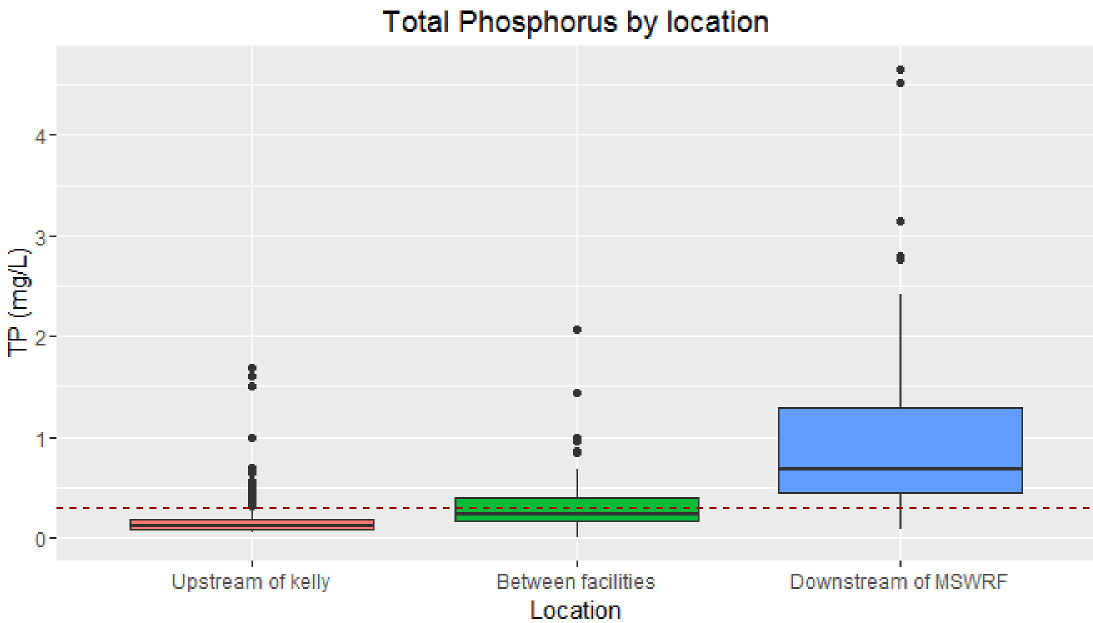

Figure 3-18. Box plots of Total Phosphorus in Sweetwater Branch by location from 2002 to 2016. "Upstream" includes stations above the Kelly power plant, "between" includes stations between Kelly and MSWRF, and "downstream" includes stations downstream of MSWRF. The horizontal dashed line indicates the regional threshold.

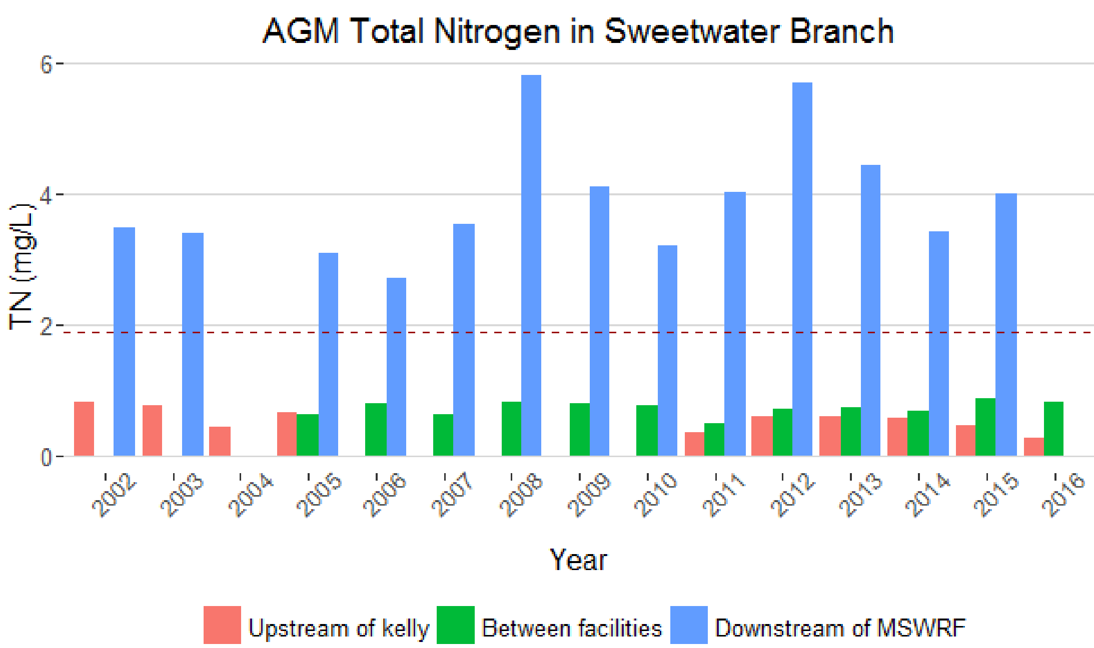

Figure 3-19. Annual Geometric Mean Total Nitrogen in Sweetwater Branch over time. "Upstream" includes stations above the Kelly power plant, "between" includes stations between Kelly and MSWRF, and "downstream" includes stations downstream of MSWRF. The horizontal dashed line indicates the regional threshold.

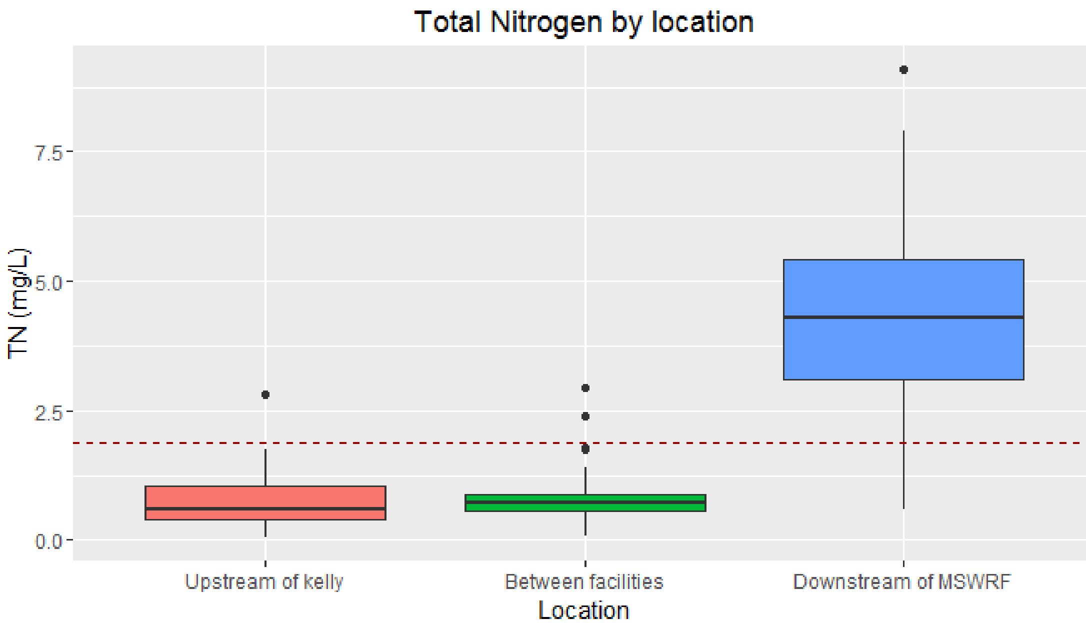

Figure 3-20. Box plots of Total Nitrogen in Sweetwater Branch by location. "Upstream" includes stations above the Kelly power plant, "between" includes stations between Kelly and MSWRF, and "downstream" includes stations downstream of MSWRF. The horizontal dashed line indicates the regional threshold.

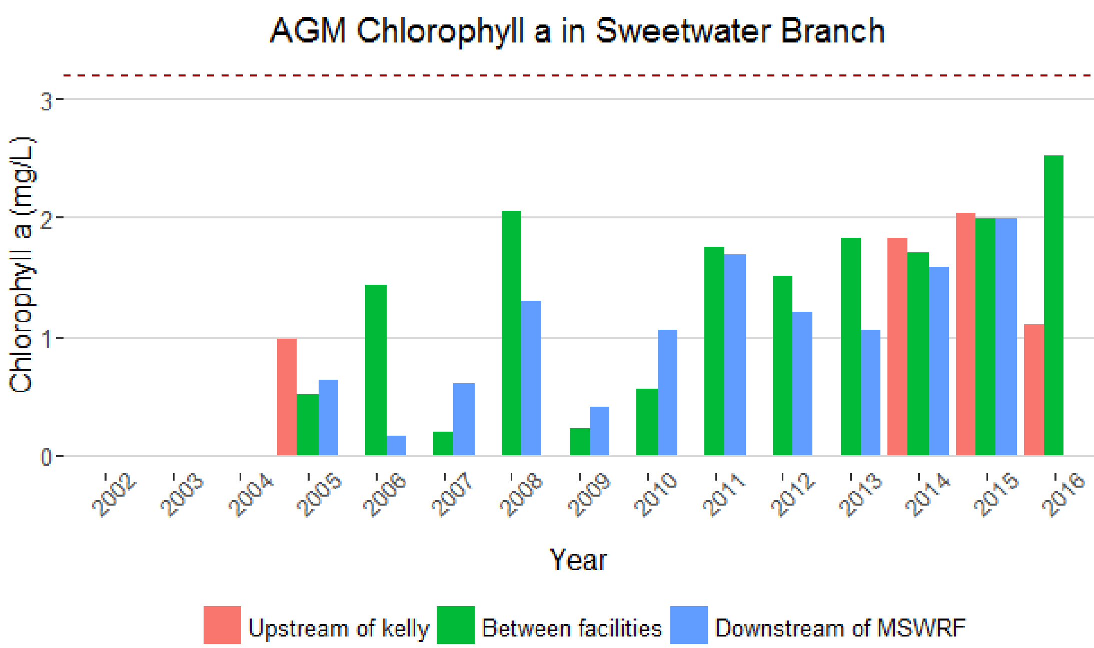

Figure 3-21. Chlorophyll a in Sweetwater Branch over time. "Upstream" includes stations above the Kelly power plant, "between" includes stations between Kelly and MSWRF, and "downstream" includes stations downstream of MSWRF. The horizontal dashed line indicates an evidentiary threshold in the NNC Implementation document.

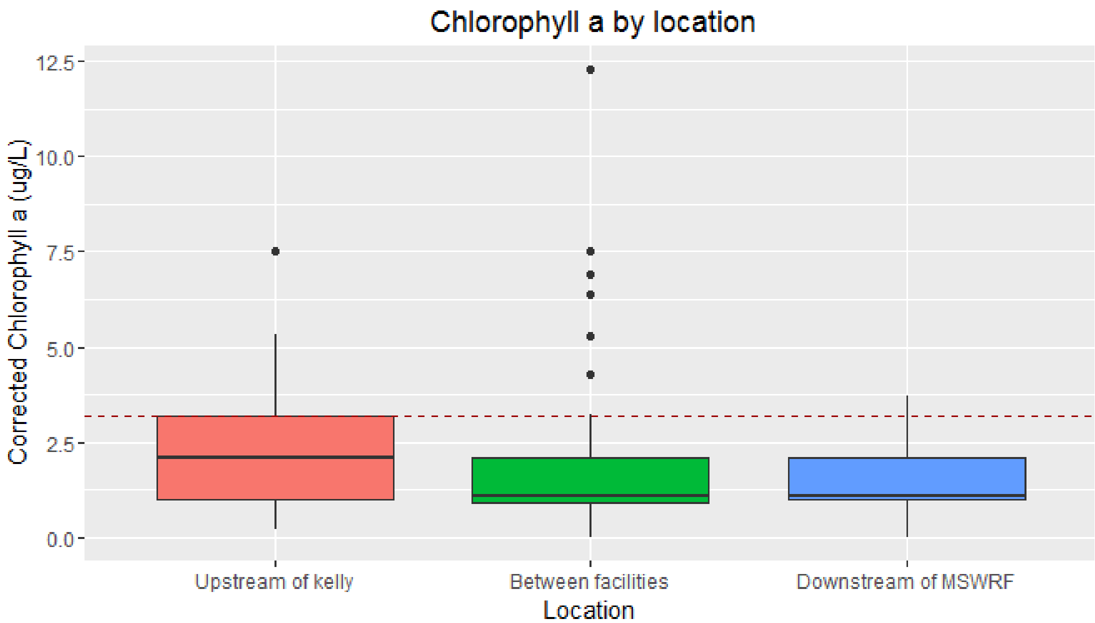

Figure 3-22. Box plots of raw chlorophyll a in Sweetwater Branch by location. "Upstream" includes stations above the Kelly power plant, "between" includes stations between Kelly and MSWRF, and "downstream" includes stations downstream of MSWRF. The horizontal dashed line indicates an evidentiary threshold in the NNC Implementation document.

TP annual geometric means exceeded the NNC threshold (0.3 mg/L) twice during the last three years downstream of the MSWRF but achieved the threshold at both other locations upstream of MSWRF in each of the past three years. Similarly, TN annual geometric means exceeded the NNC threshold (1.87 mg/L) three times during the last three years downstream of the MSWRF but achieved the threshold at both other locations upstream of MSWRF in each of the past three years. These exceedances downstream of the MSWRF constitute the reason that a WQBEL is needed for this stream section. An important biological response variable (chlorophyll *a*) was very low, both upstream and downstream from the MSWRF, consistently complying with the 3.2 µg/L evidentiary threshold discussed in the NNC Implementation Document at all locations (FDEP, 2013a).

3.3.2 Establishing Sweetwater Branch-Specific Chlorophyll Targets

Using corrected chlorophyll a data from IWR run 55 (downloaded 8-1-2018) as well as data previously assembled for this report and recent data provided by Alachua County, Annual Geometric Means were calculated for years with four of more data points **(Table 3-15**). Using the same equation FDEP employed for promulgating estuary NNC, the following equation was used to calculate the 90th percentile prediction interval of the Sweetwater Branch chlorophyll a AGMs (FDEP, 2012):

$$P.I. = e^{\left(\bar{y}+t_{(\propto,n-1)}*\sqrt{\sigma_{\bar{y}}^2+\sigma_{\bar{y}}^2/n}\right)}$$

where:

$\bar{y}$ = the mean of the log transformed data.
σ_y^2 = the variance of the log transformed data.
n = sample size (in this case the number of years).

The resulting value was **1.90 µg/L (Figure 3-23),** which is a site-specific chlorophyll a target for Sweetwater Branch not to be exceeded more than once in a three-year period.

Table 3-15. Chlorophyll means for Sweetwater Branch used for calculating the 90th percentile prediction interval.

Year	Master Parameter Code	AGM	n
1997	CHLAC	1.10	9
1998	CHLAC	0.69	27
1999	CHLAC	0.68	24
2000	CHLAC	0.87	27
2001	CHLAC	0.62	28
2002	CHLAC	0.82	23
2003	CHLAC	NA	2
2004	CHLAC	0.61	6
2005	CHLAC	0.77	28
2006	CHLAC	0.73	13
2007	CHLAC	0.29	12
2008	CHLAC	1.65	17
2009	CHLAC	0.32	16
2010	CHLAC	0.79	16
2011	CHLAC	1.44	28
2012	CHLAC	1.31	42
2013	CHLAC	1.29	14
2014	CHLAC	1.65	31
2015	CHLAC	2.06	40
2016	CHLAC	1.80	15
2017	CHLAC	1.29	4

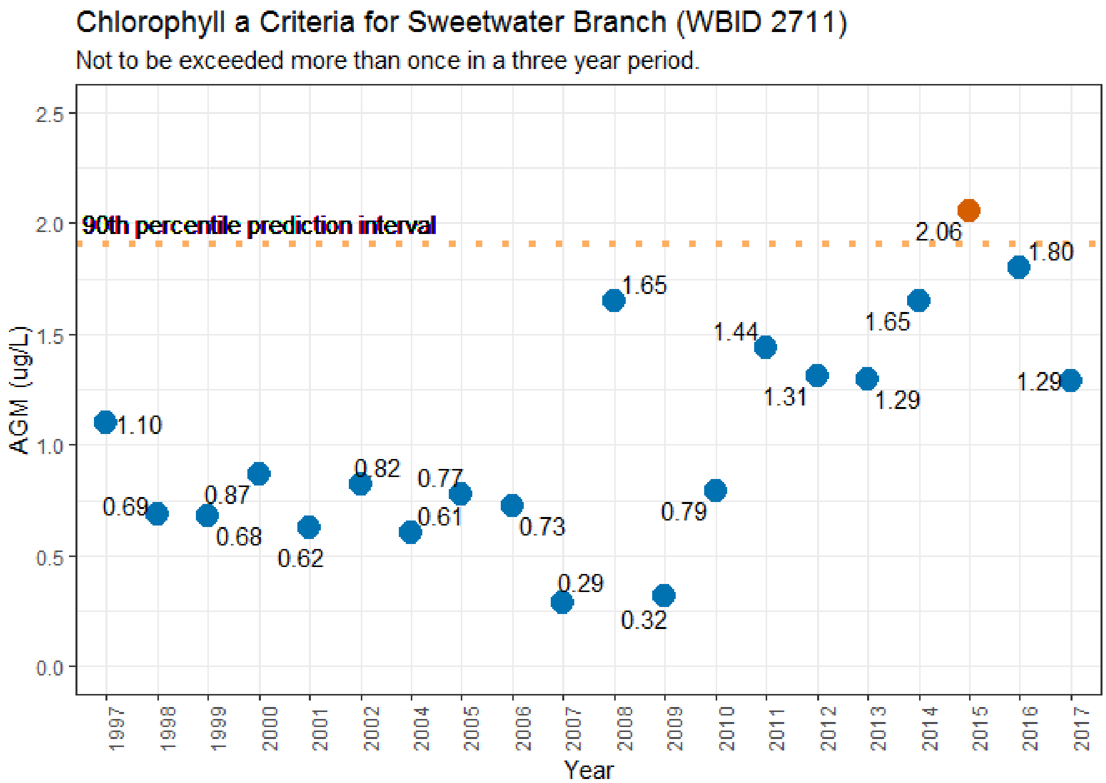

Figure 3-23. Site Specific Chlorophyll a Target for Sweetwater Branch using the 90th percentile prediction interval.

3.3.3 Metered Parameters and Other Water Quality Data

Metered parameters and other selected water quality data collected from Sweetwater Branch over time are provided and/or summarized in **Table 3-16** through **Table 3-22** and **Figure 3-24** through **Figure 3-33 f**or the time period 2002-2016. These data are provided in more detail in **Section 8** of the Appendix.

The 38% dissolved oxygen percent saturation criterion was not achieved in 22.3% of the samples upstream from the KGS, in 1.4% of the samples collected between the KGS and MSWRF but was achieved in all the samples measured downstream of the MSWRF. Overall, Sweetwater Branch did not achieve the DO criterion in 6.1% of the samples (predominantly due to the upstream location). The pH was circum-neutral throughout Sweetwater Branch.

Chapter 62-302.530(22), F.A.C., states that specific conductance shall not be increased more than 50% above background or to 1,275 µmhos/cm, whichever is greater. Specific conductance averaged 297 µmhos/cm upstream from the KGS, 451 µmhos/cm between the KGS and MSWRF, and 719 µmhos/cm downstream of the MSWRF. The water quality criterion for conductivity of 1,275 µmhos/cm was only infrequently exceeded (with a < 10% exceedance frequency), and therefore, Sweetwater Branch does not exceed the listing threshold for specific conductance. Temperature downstream of KGS was slightly lower than the upstream measurements. Ammonia was low, both upstream from KGS, between KGS and MSWRF, and downstream from MSWRF. No exceedances of either the monthly average or single sample maximum Total Ammonia Nitrogen (TAN) criterion were observed.

Table 3-16. Specific conductance in Sweetwater Branch over time (with summary statistics), upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

Location	Year	Mean	Median	Min	Max	SD	95% CI	n
Upstream of kelly	2002	330.8	334.5	285	345	16.8	10.6	12
Upstream of kelly	2003	308.8	329	113	372	64.5	31.1	19
Upstream of kelly	2004	267.1	285	153	361	72.5	37.3	17
Upstream of kelly	2005	248.6	244	96	351	81.1	62.4	9
Upstream of kelly	2006	311.5	323.5	224	381	53.7	44.9	8
Upstream of kelly	2007	297.3	334	174	384	109.7	272.5	3
Upstream of kelly	2010	318.0	318	318	318	NA	NA	1
Upstream of kelly	2011	279.3	296	169	383	69.9	53.8	9
Upstream of kelly	2012	309.6	319	189	391	60.6	43.3	10
Upstream of kelly	2013	314.7	301.2	292	351	31.7	78.9	3
Upstream of kelly	2014	305.5	320	100.9	503.8	65.8	17.6	56
Upstream of kelly	2015	294.2	302.3	136.9	636.6	74.4	19.2	60
Upstream of kelly	2016	287.1	278.1	241.6	339.9	30.6	18.5	13
Between facilities	2002	914.0	914	914	914	NA	NA	1
Between facilities	2003	427.0	427	390	464	52.3	470.1	2
Between facilities	2004	435.0	490	315	500	104.0	258.5	3
Between facilities	2005	300.5	350	100	398	109.8	66.4	13
Between facilities	2006	398.6	409	150	550	126.6	90.6	10
Between facilities	2007	478.1	500	381	550	57.3	38.5	11
Between facilities	2008	316.3	350	200	450	101.1	84.5	8
Between facilities	2009	353.8	335	210	480	89.4	74.8	8
Between facilities	2010	397.5	390	186	550	82.6	49.9	13
Between facilities	2011	552.3	507	380	950	175.9	90.4	17
Between facilities	2012	701.9	702	400	975	156.6	77.9	18
Between facilities	2013	448.7	405.8	257	675	133.4	77.0	14
Between facilities	2014	383.1	371.1	131.3	558	85.2	22.0	60
Between facilities	2015	460.5	467.8	61.3	730.1	137.1	34.0	65
Between facilities	2016	551.2	573.6	298.6	720	103.1	54.9	16
Downstream of MSWRF	2002	666.0	582	559	1131	206.9	191.4	7
Downstream of MSWRF	2003	693.2	727	409	953	166.8	100.8	13
Downstream of MSWRF	2004	811.0	809.5	501	1165	197.8	114.2	14
Downstream of MSWRF	2005	567.9	679	10.76	912	333.1	201.3	13
Downstream of MSWRF	2006	700.5	670	240	1294	316.8	191.5	13
Downstream of MSWRF	2007	707.2	667.5	410	1007	258.7	164.4	12
Downstream of MSWRF	2008	578.8	510	500	750	111.9	93.6	8
Downstream of MSWRF	2009	491.3	500	470	510	18.1	15.1	8
Downstream of MSWRF	2010	690.6	629.5	400	1100	233.7	148.5	12
Downstream of MSWRF	2011	821.4	790	650	1138	147.9	94.0	12
Downstream of MSWRF	2012	878.3	845	580	1500	198.2	98.6	18
Downstream of MSWRF	2013	719.2	680	432.7	950	190.4	176.1	7

Downstream of MSWRF	2014	694.6	722	590	750	65.7	54.9	8
Downstream of MSWRF	2015	810.5	891	503	1010	197.1	164.8	8
Downstream of MSWRF	2016	873.3	1000	600	1020	236.9	588.6	3

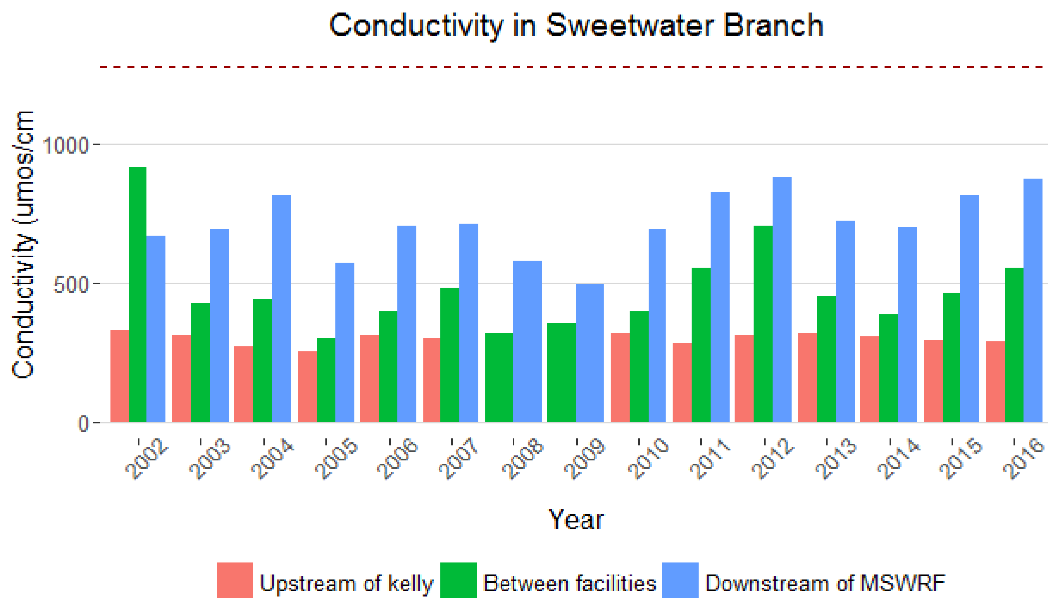

Figure 3-24. Specific conductance in Sweetwater Branch over time. Horizontal dashed line is the water quality criterion.

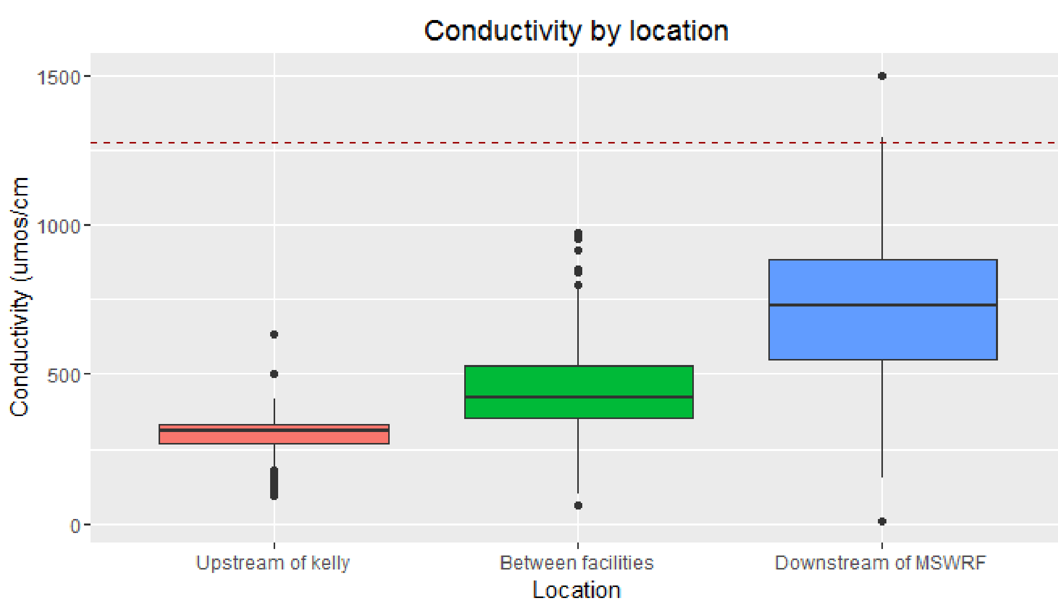

Figure 3-25. Specific conductance in Sweetwater Branch by location.

Table 3-17. Dissolved Oxygen (% saturation) in Sweetwater Branch over time (with summary statistics), upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

location	year	mean	median	min	max	sd	CI95	n
Upstream of kelly	2002	61	52	45	103	17	11	12
Upstream of kelly	2003	88	93	55	125	20	9.9	19
Upstream of kelly	2004	78	91	15	111	31	16	17
Upstream of kelly	2005	56	51	2.7	95	35	27	9
Upstream of kelly	2006	20	12	8.8	60	18	15	8
Upstream of kelly	2007	20	21	15	22	3.6	9	3
Upstream of kelly	2010	65	65	65	65	NA	NA	1
Upstream of kelly	2011	43	32	16	72	21	16	9
Upstream of kelly	2012	52	50	16	85	26	18	10
Upstream of kelly	2013	83	88	69	91	12	29	3
Upstream of kelly	2014	74	78	58	85	12	19	4
Upstream of kelly	2015	65	79	25	84	24	26	6
Upstream of kelly	2016	74	74	71	78	4.4	39	2
Between facilities	2002	89	89	89	89	NA	NA	1
Between facilities	2003	87	87	77	96	13	121	2
Between facilities	2004	88	88	84	92	3.9	9.6	3
Between facilities	2005	74	80	38	97	20	11	14
Between facilities	2006	74	67	62	108	15	9.9	11
Between facilities	2007	81	78	46	121	24	15	12
Between facilities	2008	105	105	93	115	8.3	6.9	8
Between facilities	2009	80	75	60	102	16	14	8
Between facilities	2010	86	88	68	97	11	6.4	13
Between facilities	2011	87	87	70	99	9.4	4.8	17
Between facilities	2012	86	85	70	106	9.2	4.5	18
Between facilities	2013	93	92	84	101	4.8	2.8	14
Between facilities	2014	89	89	82	98	5.3	4.4	8
Between facilities	2015	89	91	78	95	5.4	3.7	11
Between facilities	2016	90	89	84	102	7.2	9	5
Downstream of MSWRF	2002	105	111	95	111	6.8	6.3	7
Downstream of MSWRF	2003	100	100	85	117	7	4.3	13
Downstream of MSWRF	2004	102	101	88	124	8.5	4.9	14
Downstream of MSWRF	2005	90	93	70	99	10	6.1	13
Downstream of MSWRF	2006	92	95	77	98	6.8	3.8	15
Downstream of MSWRF	2007	95	94	85	107	7.1	4.5	12
Downstream of MSWRF	2008	107	107	104	110	2.3	2.1	7
Downstream of MSWRF	2009	90	86	80	109	10	8.7	8
Downstream of MSWRF	2010	92	96	83	98	6.1	3.9	12
Downstream of MSWRF	2011	97	99	85	105	6.2	4	12
Downstream of MSWRF	2012	99	99	88	107	6.7	3.1	20
Downstream of MSWRF	2013	92	93	77	102	8.3	7.7	7

Downstream of MSWRF	2014	92	91	83	103	6.9	5.8	8
Downstream of MSWRF	2015	91	92	82	99	5.9	4.9	8
Downstream of MSWRF	2016	97	94	91	106	8.1	20	3

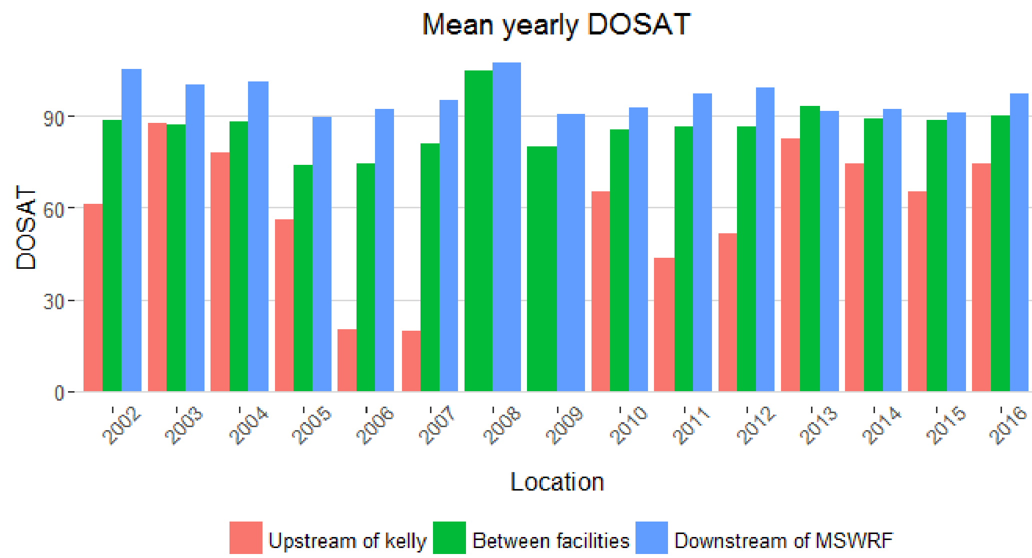

Figure 3-26. Dissolved Oxygen (percent saturation) in Sweetwater Branch over time.

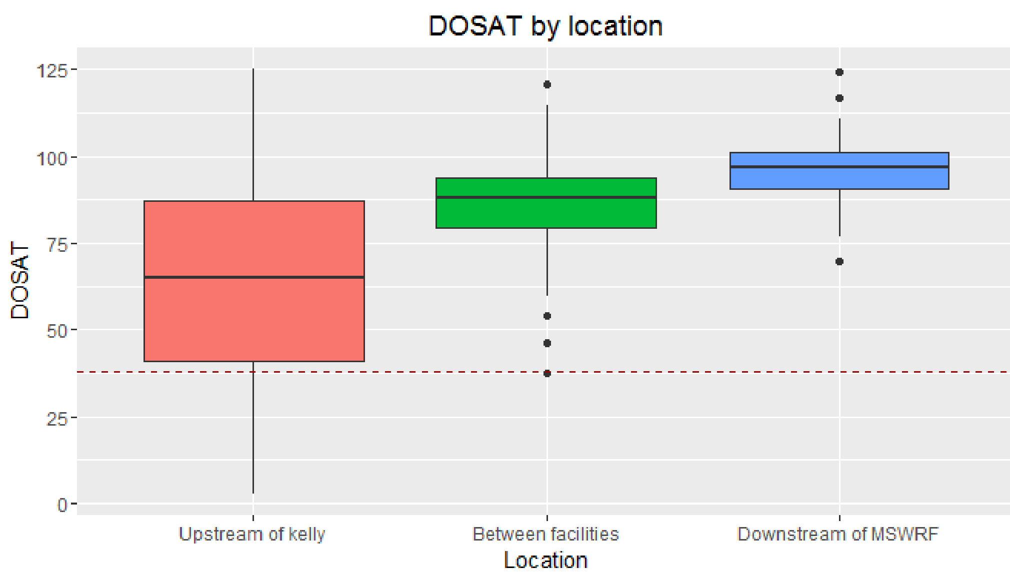

Figure 3-27. Dissolved Oxygen (percent saturation) in Sweetwater Branch by location.

Table 3-18. Number of DO exceedances (values < 38% saturation) upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

Location	Number DO Exceedances	Total Obs.	% DO Exceedances
Upstream of kelly	23	103	22.3

Between facilities	2	145	1.4
Downstream of MSWRF	0	159	0.0

Table 3-19. Number of DO exceedances (values < 38% saturation) in Sweetwater Branch between 2002 and 2016.

Number DO Exceedances	Total Obs.	% DO Exceedances
25	407	6.1

Table 3-20. Temperature (° C) in Sweetwater Branch over time (with summary statistics), upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

Location	Year	Mean	Median	Min	Max	SD	95% CI	n
Upstream of kelly	2002	21.9	23.5	16.6	24.5	3.1	1.9	12
Upstream of kelly	2003	22.1	23.4	14.2	26.4	3.9	1.9	19
Upstream of kelly	2004	22.1	19.1	16.2	31.3	5.4	2.8	17
Upstream of kelly	2005	23.4	22.2	18.7	29.6	3.8	2.9	9
Upstream of kelly	2006	23.6	25.0	17.7	26.6	3.4	2.8	8
Upstream of kelly	2007	24.7	25.0	19.0	30.3	5.6	14.0	3
Upstream of kelly	2010	9.1	9.1	9.1	9.1	NA	NA	1
Upstream of kelly	2011	22.6	20.0	18.3	28.0	4.1	3.1	9
Upstream of kelly	2012	20.5	18.4	15.6	32.3	5.4	3.8	10
Upstream of kelly	2013	21.6	21.3	15.4	27.9	6.2	15.5	3
Upstream of kelly	2014	20.3	20.1	12.1	26.5	4.4	1.2	56
Upstream of kelly	2015	21.6	21.9	14.2	27.8	3.9	1.0	60
Upstream of kelly	2016	16.3	16.3	13.1	23.1	3.0	1.8	13
Between facilities	2002	22.2	22.2	22.2	22.2	NA	NA	1
Between facilities	2003	21.3	21.3	15.9	26.7	7.6	68.4	2
Between facilities	2004	22.8	25.8	15.7	27.0	6.2	15.4	3
Between facilities	2005	20.3	20.7	14.7	24.1	3.5	2.0	14
Between facilities	2006	20.9	21.2	14.3	25.3	3.9	2.6	11
Between facilities	2007	22.3	21.5	16.6	27.5	3.4	2.1	12
Between facilities	2008	20.6	19.8	18.8	23.9	2.1	1.8	8
Between facilities	2009	17.8	19.6	7.6	26.1	7.1	5.9	8
Between facilities	2010	17.7	16.9	6.2	26.5	7.0	4.2	13
Between facilities	2011	19.7	17.8	11.6	27.6	5.3	2.7	17
Between facilities	2012	20.9	20.7	13.8	28.6	4.2	2.0	19
Between facilities	2013	20.5	20.0	15.1	28.7	4.4	2.5	14
Between facilities	2014	19.8	19.5	11.1	28.3	4.6	1.2	60
Between facilities	2015	21.5	21.9	11.9	26.6	3.9	1.0	65
Between facilities	2016	17.5	16.1	13.1	26.8	4.2	2.2	16
Downstream of MSWRF	2002	21.2	19.5	19.5	24.4	2.2	2.1	7
Downstream of MSWRF	2003	23.5	25.5	16.7	27.2	3.5	2.1	13

Downstream of MSWRF	2004	23.1	25.2	17.0	28.6	4.3	2.5	14
Downstream of MSWRF	2005	21.9	21.1	18.8	27.4	2.7	1.6	13
Downstream of MSWRF	2006	23.6	22.7	18.9	27.5	3.3	1.8	15
Downstream of MSWRF	2007	24.7	23.9	20.5	29.6	2.9	1.8	12
Downstream of MSWRF	2008	23.1	22.6	21.0	26.1	2.0	1.7	8
Downstream of MSWRF	2009	21.7	23.7	13.9	27.3	5.0	4.2	8
Downstream of MSWRF	2010	22.0	22.6	14.5	27.6	4.9	3.1	12
Downstream of MSWRF	2011	23.3	24.5	16.0	28.8	4.7	3.0	12
Downstream of MSWRF	2012	23.2	22.5	19.0	27.1	2.6	1.1	23
Downstream of MSWRF	2013	22.1	21.2	16.9	27.4	3.9	3.6	7
Downstream of MSWRF	2014	22.2	22.5	17.3	27.2	3.7	3.1	8
Downstream of MSWRF	2015	23.7	23.7	17.8	27.1	3.1	2.6	8
Downstream of MSWRF	2016	23.9	25.0	18.8	28.0	4.7	11.7	3

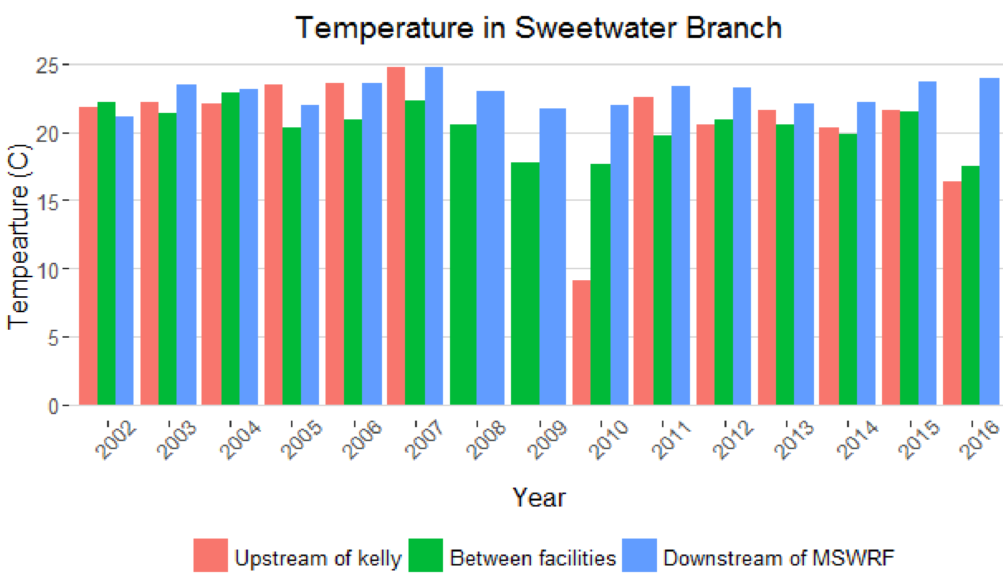

Figure 3-28. Temperature (° C) in Sweetwater Branch over time.

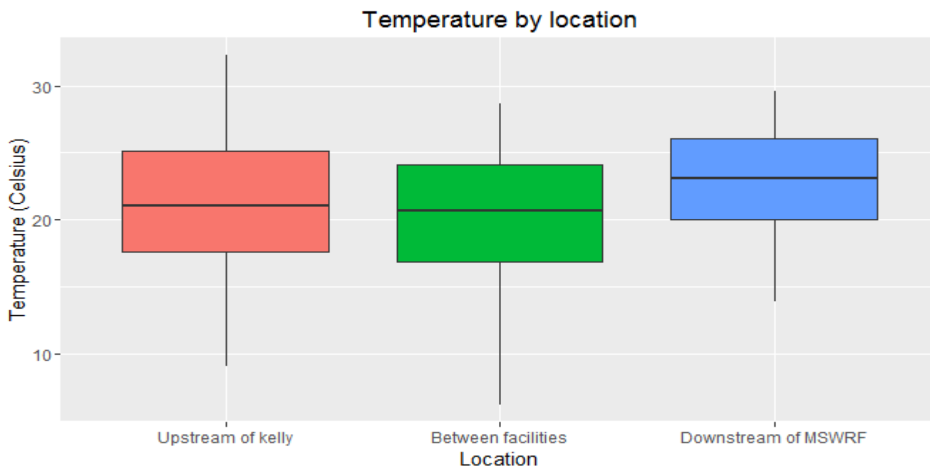

Figure 3-29. Box plots of temperature (° C) in Sweetwater Branch by location.

Table 3-21. pH (SU) in Sweetwater Branch over time (with summary statistics), upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

Location	Year	Mean	Median	Min	Max	SD	95% CI	n
Upstream of kelly	2002	7.2	7.3	6.4	7.6	0.3	0.2	12
Upstream of kelly	2003	7.1	7.2	6.4	7.9	0.4	0.2	19
Upstream of kelly	2004	7.2	7.3	6.8	7.5	0.2	0.1	17
Upstream of kelly	2005	7.0	6.9	6.4	7.4	0.3	0.2	9
Upstream of kelly	2006	7.0	7.1	6.7	7.2	0.2	0.1	8
Upstream of kelly	2007	7.0	7.1	6.9	7.1	0.1	0.3	3
Upstream of kelly	2010	6.9	6.9	6.9	6.9	NA	NA	1
Upstream of kelly	2011	7.3	7.4	6.8	7.5	0.2	0.2	9
Upstream of kelly	2012	7.4	7.4	7.0	8.0	0.3	0.2	10
Upstream of kelly	2013	7.5	7.5	7.5	7.6	0.1	0.1	3
Upstream of kelly	2014	7.4	7.4	7.0	7.9	0.1	0.0	56
Upstream of kelly	2015	7.4	7.4	6.8	8.1	0.2	0.1	60
Upstream of kelly	2016	7.4	7.4	7.0	7.8	0.2	0.1	13
Between facilities	2002	7.3	7.3	7.3	7.3	NA	NA	1
Between facilities	2003	7.1	7.1	7.1	7.2	0.1	0.6	2
Between facilities	2004	7.7	7.6	7.5	8.0	0.3	0.7	3
Between facilities	2005	7.3	7.4	6.7	7.8	0.4	0.2	14
Between facilities	2006	7.1	6.8	6.3	7.9	0.6	0.4	11
Between facilities	2007	7.7	7.6	7.5	8.2	0.3	0.2	12
Between facilities	2008	7.9	8.0	7.6	8.1	0.2	0.2	8
Between facilities	2009	7.2	7.3	6.5	7.5	0.4	0.3	8
Between facilities	2010	7.1	7.1	6.6	7.8	0.4	0.3	13
Between facilities	2011	7.6	7.7	6.3	8.2	0.5	0.3	17
Between facilities	2012	7.8	7.7	7.1	8.4	0.4	0.2	19
Between facilities	2013	7.6	7.4	7.2	8.2	0.4	0.2	14
Between facilities	2014	7.8	7.9	6.9	8.1	0.2	0.1	60

Between facilities	2015	7.8	7.8	7.2	8.2	0.2	0.0	65
Between facilities	2016	7.8	7.9	7.3	8.1	0.3	0.1	16
Downstream of MSWRF	2002	7.5	7.5	7.2	7.7	0.2	0.1	7
Downstream of MSWRF	2003	7.4	7.4	7.1	7.7	0.2	0.1	13
Downstream of MSWRF	2004	7.5	7.5	7.2	7.8	0.2	0.1	14
Downstream of MSWRF	2005	7.1	7.3	6.6	7.5	0.3	0.2	13
Downstream of MSWRF	2006	7.3	7.4	6.7	7.9	0.4	0.2	15
Downstream of MSWRF	2007	7.5	7.5	7.2	7.8	0.2	0.1	12
Downstream of MSWRF	2008	7.6	7.7	7.3	7.8	0.2	0.2	8
Downstream of MSWRF	2009	7.1	7.2	6.9	7.5	0.2	0.2	8
Downstream of MSWRF	2010	7.3	7.3	7.1	7.7	0.2	0.2	12
Downstream of MSWRF	2011	7.4	7.5	7.0	7.8	0.3	0.2	12
Downstream of MSWRF	2012	7.7	7.6	6.9	8.3	0.4	0.2	23
Downstream of MSWRF	2013	7.3	7.2	7.0	7.6	0.2	0.2	7
Downstream of MSWRF	2014	7.2	7.0	6.8	7.6	0.3	0.3	8
Downstream of MSWRF	2015	7.3	7.3	7.0	7.6	0.2	0.2	8
Downstream of MSWRF	2016	7.1	7.1	7.0	7.2	0.1	0.2	3

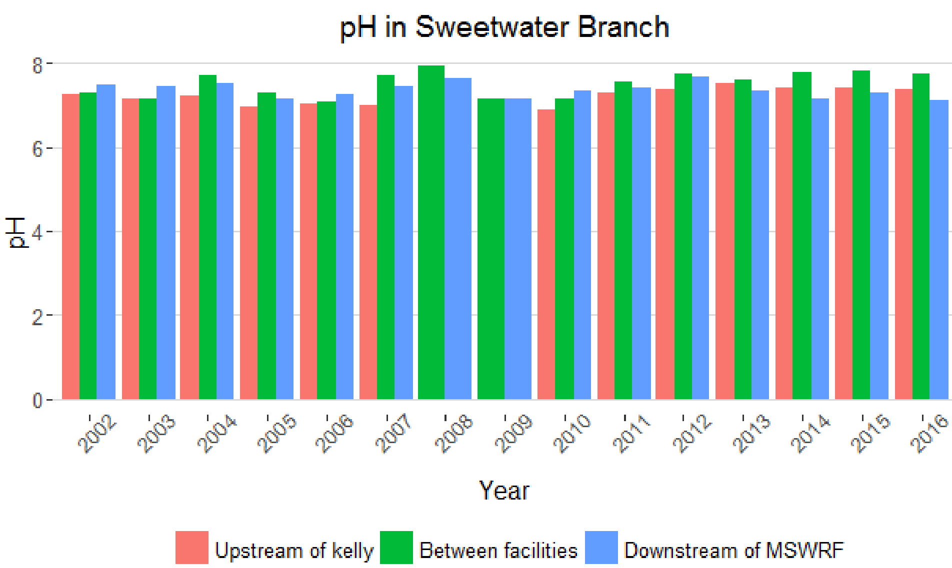

Figure 3-30. pH (SU) in Sweetwater Branch over time.

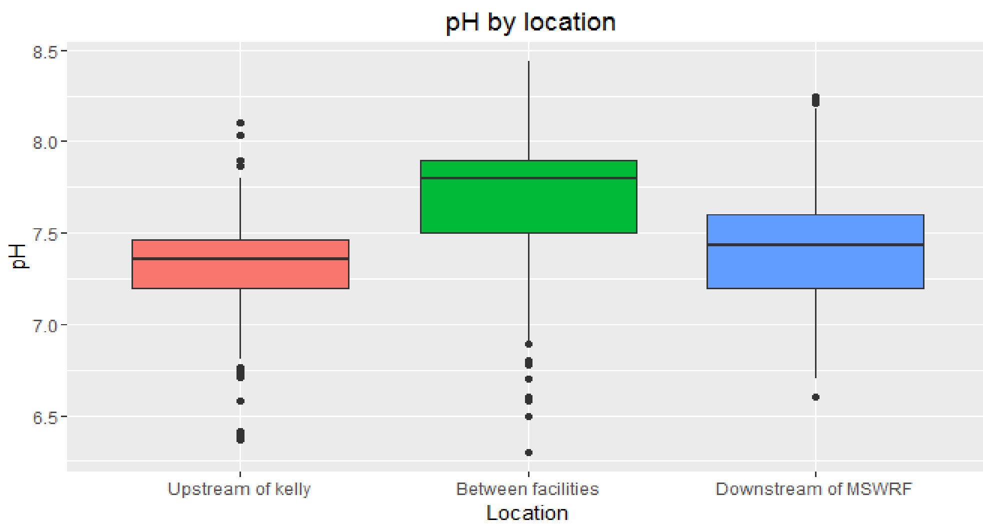

Figure 3-31. Box plots of pH (SU) in Sweetwater Branch by location, upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

Table 3-22. Total ammonia (mg/L) by location in Sweetwater Branch, showing summary statistics of stations sampled upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

Location	Mean	Median	Min	Max	SD	95% CI	n
Upstream of kelly	0.15	0.08	0.010	1.00	0.19	0.04	79
Between facilities	0.08	0.06	0.005	1.11	0.10	0.02	164
Downstream of MSWRF	0.07	0.06	0.010	0.40	0.06	0.01	144

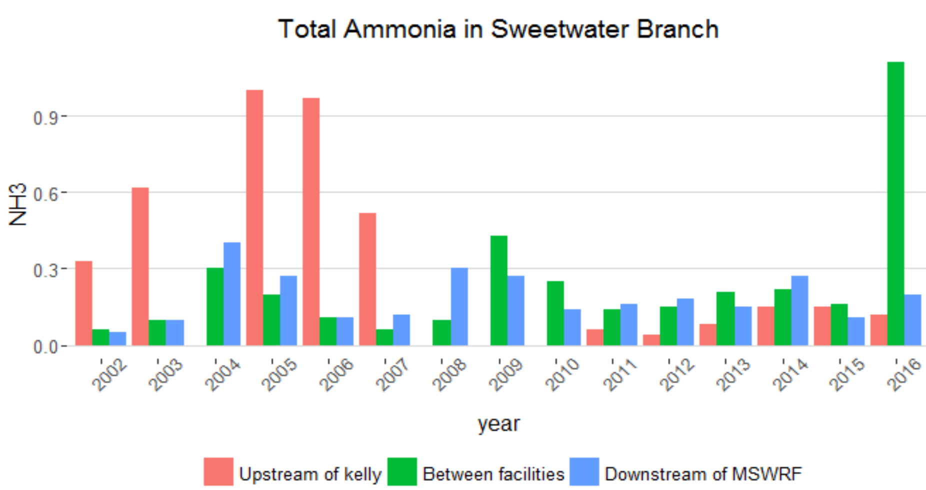

Figure 3-32. Total ammonia (mg/L) in Sweetwater Branch over time, upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

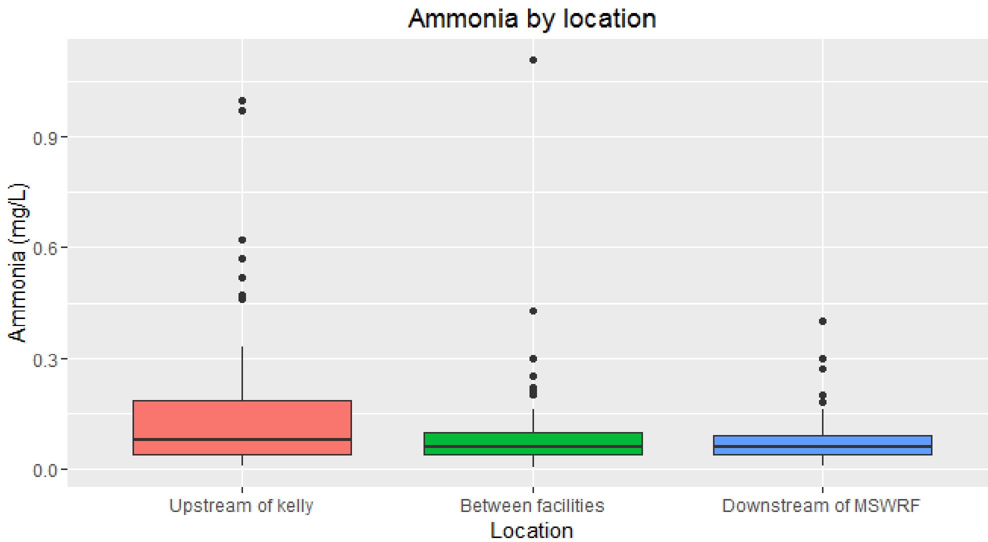

Figure 3-33. Box plots of Total Ammonia Nitrogen by location, upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF.

Table 3-23. Total Ammonia Nitrogen (TAN) criterion exceedances by location, upstream of the Kelly discharge, between Kelly and MSWRF, and downstream of the MSWRF. The TAN criterion for each sample was calculated using the FDEP formula and accompanying pH and temperature data.

Location	Pass TAN	Total Obs.	TAN Pass %
Upstream of kelly	50	50	100
Between facilities	118	118	100
Downstream of MSWRF	135	135	100

4 Stressor Identification Analysis

Chapter 3 provided a Physical, Chemical, and Biological Characterization of Sweetwater Branch. **Chapter 4** synthesizes and evaluates this information to identify the stressors causing faunal impairments. As seen below, this analysis provides reasonable assurance that nutrients, ammonia, DO, organic contaminants, toxicity, or metals are not causing faunal impairments in Sweetwater Branch; instead, the responsible stressors are hydrological modification, sediment movement, and habitat alterations. Thus, consistent with Department rules, the Stressor Identification analysis shows that the nutrient concentrations associated with the WQBEL are protective of designated uses in Sweetwater Branch.

In making this demonstration, Frydenborg EcoLogic utilized EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS, http://www.epa.gov/caddis). CADDIS provides a framework for identifying and evaluating sources of stress when multi-metric indices (such as the SCI) show impairment to biological communities (Norton et al., 2009). A main premise of CADDIS is that causal assessment is pragmatic; it connects logic with action (EPA, 2015). Using an inferential, weight-of-evidence approach, CADDIS provides a formal structure to develop explanations for impairment that are consistent with the associated data and are likely to remedy the identified biological problem (EPA, 2000). The CADDIS method compares candidate causes, weighs evidence, diagnoses and rejects implausible causes, synthesizes data, and makes conclusions (EPA, 2015). A flow chart of the CADDIS process is found in **Figure 4-1**.

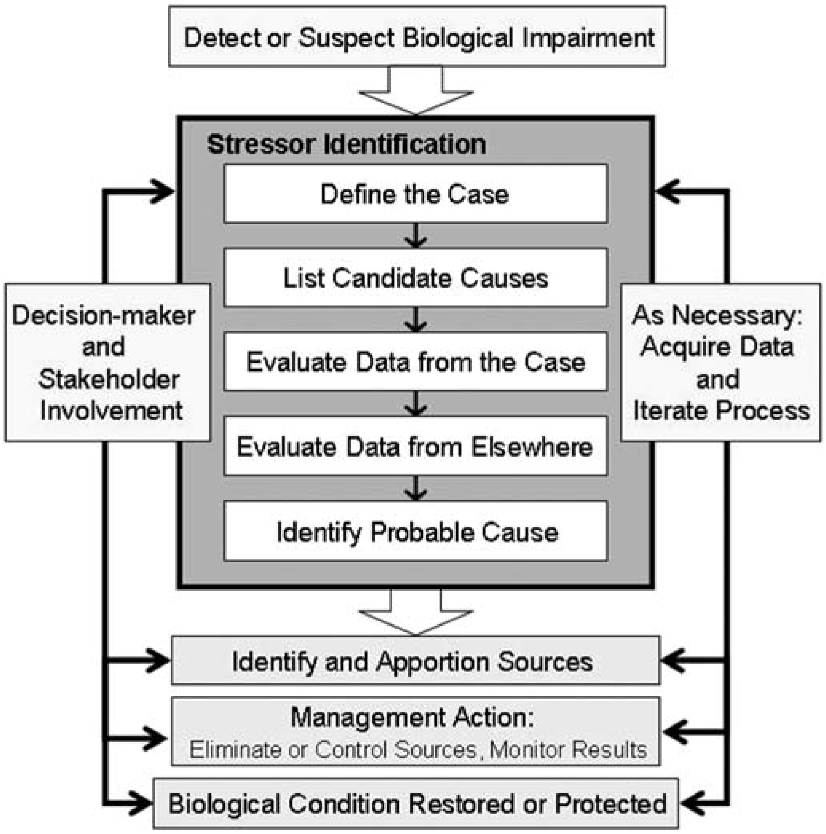

Figure 4-1. The Stressor Identification process within its broader management context (from EPA 2015).

CADDIS uses data from the subject site, along with data gathered from other studies, to focus on the site-specific stressors that mitigation efforts should be directed towards.

The CADDIS procedure involves answering two basic questions (EPA, 2000):

- Are environmental conditions or biological characteristics at a test site different from expectations?
- What is the relationship between an environmental stressor and a biological response in a particular region?

During the diagnosis process, the first step is to use data from the case to develop evidence that allows one to confidently eliminate very improbable causes or use symptoms to refute or diagnose a cause (EPA, 2015). The second goal of data evaluation is to build the body of evidence for those candidate causes that cannot be refuted or diagnosed, which will be used to identify the most probable causes (EPA, 2015). In a hypothetical example, nutrients and channelization may be eliminated as potential causes for low dissolved oxygen if no excess algal growth (and subsequent decomposition) or changes in stream morphology (and velocity regime) were observed (**Figure 4-2**) (after EPA, 2015).

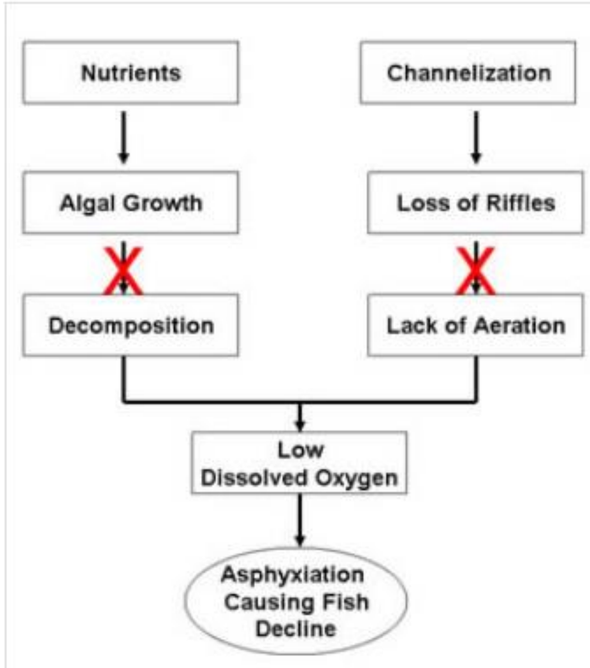

Figure 4-2. An example of eliminating two potential causes for low DO because the data did not support the conclusion (after EPA 2015).

4.1 Background on CADDIS

Sources are activities, land uses, or entities that directly or indirectly result in one or more stressors (EPA, 2015). A **candidate cause** is a hypothesized cause of a specific environmental impairment, sufficiently credible to be analyzed in a causal assessment. A candidate cause can be a proximate stressor, or the stressor directly responsible for the observed biological response (EPA, 2015). **Stressors** are any physical, chemical, or biological parameters or entities that directly or indirectly result in one or more biotic responses of concern. **Proximate stressors** (or causal agents) are directly responsible for these responses; other stressors may be indirectly responsible for these responses via their effects on proximate stressors. **Responses** are the biological results of exposure to proximate stressors (EPA, 2015).

CADDIS involves a five-step process for conducting a causal assessment (EPA, 2015):

Step 1: Define the Case. Does biological health significantly differ when comparing data upstream and downstream from a discharge (*e.g.*, in the case of the MSWRF) containing nutrients, or are other physical factors influencing the system's biological response?

Step 2: List Candidate Causes. This step involves listing likely candidates rather than focusing on a single stressor. In Sweetwater Branch, targeted factors included water quality (especially nutrients, DO, ammonia, metals, organic contaminants, toxicity, and specific conductance), physical alteration (channelization, habitat, and sediment movement), hydrologic modifications (impervious surfaces coupled with channelization), and landscape factors (LDI).

Step 3: Evaluate Data from the Case. These data are presented in **Chapter 3**, and key components analyzed here. In addition to following the CADDIS process, statistical analyses are used to assess the relationship between a stressor and a biological response variable (flora and fauna) relative to potential sources.

Step 4: Evaluate Data from Elsewhere. Data from other systems, including Florida sites collected across a disturbance gradient, are evaluated below in conjunction with information from Sweetwater Branch.

Step 5: Identify Probable Causes. These are the conclusions from the Stressor Identification analysis.

The various stressors affecting Sweetwater Branch were evaluated using the CADDIS approach as a framework, adapting the analysis to specific factors influencing the study area. Additionally, the Pollman Stressor Identification model (described below) was also used to evaluate a sub-set of the stressors (*i.e.*, conductivity and substrate diversity).

4.2 STEP 1: DEFINE THE CASE

Sweetwater Branch is an artificially channelized, hydrologically modified urban water conveyance that receives stormwater runoff and treated wastewater from a power plant (KGS) and domestic wastewater facility (MSWRF). The average Stream Condition Index (SCI) scores (macroinvertebrates) indicates unhealthy conditions upstream of KGS, between KGS and MSWRF, and downstream from MSWRF. These SCI data, in conjunction with exceedances of the regional nutrient thresholds (downstream of MSWRF), would suggest that the system currently does not meet numeric nutrient criteria unless a Stressor Identification Study determines otherwise. Upon examination of the individual ten SCI metrics, no specific set of metrics warranted additional scrutiny (all generally indicated a degraded community), making the composite SCI a good response variable. While the past three years of data downstream of the KGS discharges indicates that the regional nutrient thresholds have been achieved, the MSWRF discharge is associated with exceedances of TN and TP in Sweetwater Branch. The MSWRF is also associated with an increase in conductivity, although the water quality criterion is achieved. Other water quality parameters, including ammonia, DO, metals, organic contaminants/pesticides, and toxicity are also potential stressors to be evaluated. FDEP's conceptual nutrient model must be followed to determine if nutrient loading from the discharge still supports a healthy, well balanced community. Other factors, such as hydrologic modification, artificial stream channelization (and lack of substrate diversity), and sediment movement/smothering are noticeable stressors that also influence the system.

4.3 STEP 2: LIST CANDIDATE CAUSES

Based on "defining the case" above, hydrologic modification (related to human landuse intensity stress and imperviousness of watershed surfaces), sediment movement/scouring, habitat alterations, (including channelization and low substrate diversity), nutrients, and conductivity are the important factors to consider for a stressor identification analysis. The presence of metals, organic contaminants (including pesticides), toxicity, ammonia, and low dissolved oxygen are also potential stressors in urban environments and may be associated with point source discharges, and these were also evaluated. The potential stressors and how they could affect the SCI are graphically depicted in **Figure 4-3**.

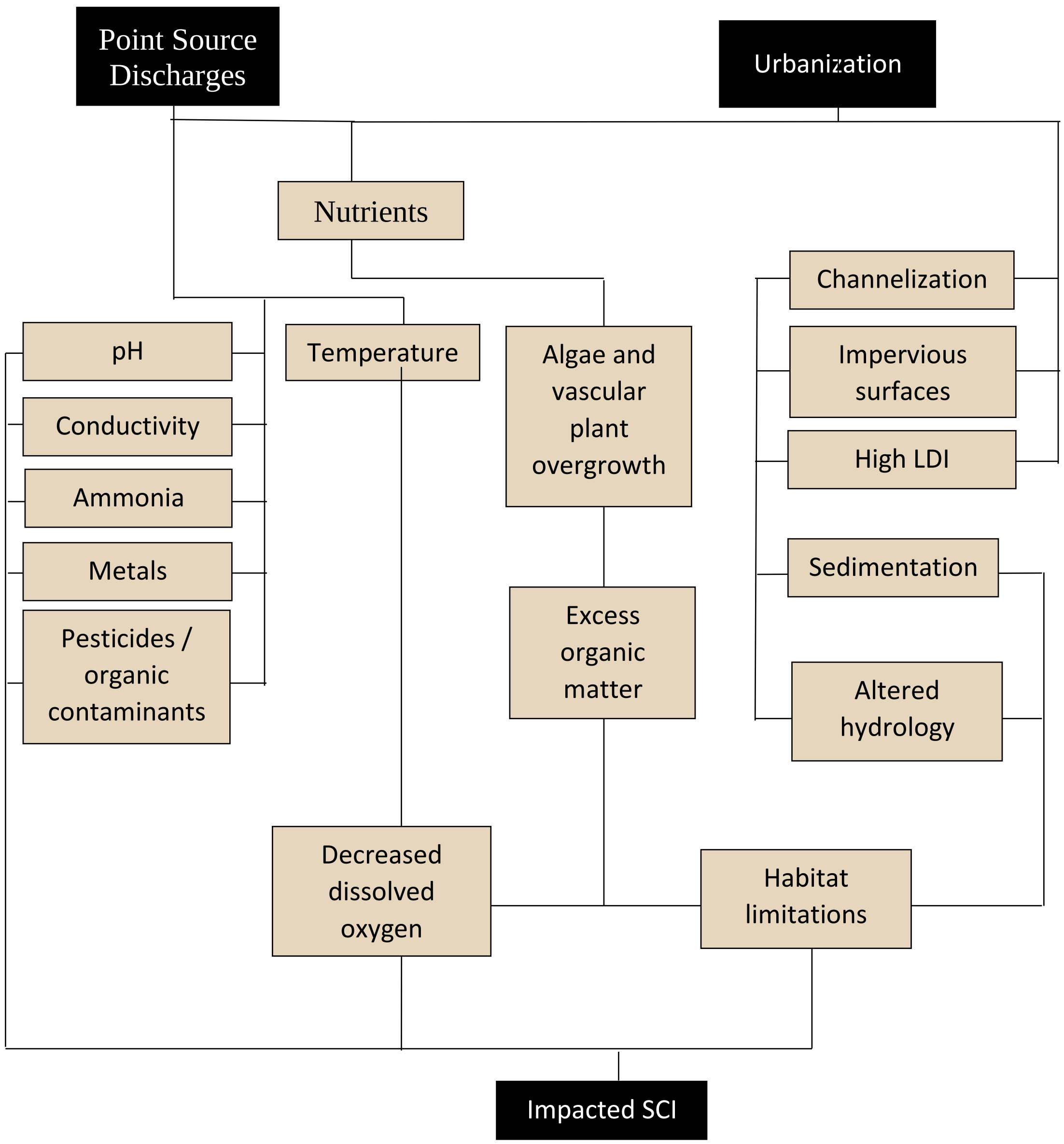

Figure 4-3. Flow chart of potential stressors in the Sweetwater Branch watershed.

4.4 Step 3: Evaluate Data from the Case

Sweetwater Branch data were extensively presented above in **Chapter 3.** This section focuses on systematically evaluating whether the exposure regime (frequency, magnitude, and duration) of potential stressors could be responsible for lowering the SCI scores. The SCI is the main focus of the analysis due to the language in Rule 62-302.531(2)(a)1.d., F.A.C., which specifically addresses a Biological Health Assessment, meaning the SCI in this case.

4.4.1 FDEP's Conceptual Nutrient Ecological Model

Because nutrients are necessary for the proper functioning of aquatic systems, and because nutrient effects may be completely mitigated by site-specific factors (water residence time, light penetration, grazers, etc.), FDEP

(2013a) stipulated that a nutrient conceptual ecological model must be followed for one to conclude that anthropogenic nutrient enrichment is responsible for SCI failures (Figure 4-4). (FDEP, 2013a) concluded that when anthropogenic nutrient loading or concentrations exceed a system's assimilative capacity, the primary response consists of changes to the primary producer communities (periphyton, phytoplankton, or vascular plants), and excess production of plant biomass. If this occurs, the enhanced floral biomass can lead to habitat loss (e.g., from excess periphyton smothering or nuisance plant biomass accumulation), food web alterations (e.g., dominance of taxa that thrive in nutrient/organic matter enriched conditions), and/or low dissolved oxygen (DO) from decomposition of plant biomass or respiration. This chain of events is ultimately reflected in meaningful biological endpoints, such as excessive algal mats, excess water column chlorophyll a, and/or excess nuisance vascular plant growth (FDEP, 2013a).

Conversely, if data show that floral health is fully supported in an aquatic system (no adverse responses consistent with the ecological model), it is reasonable to conclude that the associated nutrient regime is protective of the waterbody (FDEP, 2013a). In fact, Figure 4-4 (which FDEP adopted into Rule via the NNC Implementation Document) shows that the primary responses to excess nutrients (plant growth) must occur to elicit any secondary or tertiary responses to nutrients. Further, Rule 62-302.531(2)(a)1.d., F.A.C., states, "A site specific interpretation is also allowable where there are documented adverse biological effects using one or more Biological Health Assessments, if information on chlorophyll a levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicate there are no imbalances in flora and a stressor identification study demonstrates that the adverse biological effects are not due to nutrients." Therefore, information is first presented to explore nutrients and floral response.

4.4.2 Floral Health in Sweetwater Branch

During numeric nutrient criteria development, FDEP, in coordination with EPA, conducted a series of comprehensive statistical analyses to identify relationships between human disturbance (including nutrient enrichment) and adverse floral responses (*e.g.,* algal taxonomic composition, algal and vascular plant abundance, chlorophyll *a*, etc.) using an extensive data set collected in Florida streams (FDEP, 2013a). The relationships were statistically weak, and neither FDEP nor EPA could identify floral health/impairment thresholds associated with human disturbance or nutrient concentrations/load. Therefore, FDEP's approach was to determine whether the floral components at a given stream are consistent with the floral measures found within the EPA reference stream distribution (generally the 90th percentile, as was used to develop the nutrient thresholds). If all floral measures are within the EPA reference site distribution, FDEP, by Rule, concludes that there is a balanced floral community. Based on all potential floral outcomes associated with the conceptual model (above), FDEP evaluates the Rapid Periphyton Survey (RPS), Linear Vegetation Survey (LVS), and chlorophyll *a* data, which are assessed independently.

4.4.2.1 RPS Achieves NNC Evidentiary Thresholds at Control and Test Areas

The RPS achieved the expected floral evidentiary threshold (< 25% coverage of rank 4-6) in all 7 RPS samplings upstream of the KGS. The RPS has passed (< 25% coverage of rank 4-6) on 12 out of 13 station-date combinations between KGS and MSWRF, including during the past 3 temporally independent RPS samplings conducted by Frydenborg EcoLogic (which demonstrates compliance, since a minimum of the two most recent passing events is required). Downstream of the MSWRF, the RPS passed during 16 of 18 samplings. Since

February 2012, the RPS has passed downstream of the MSWRF on 16 station/date combinations, during four temporally independent samplings (conducted > 3 months apart). Therefore, the RPS evidentiary threshold requirement in Rule 62-302.531, F.A.C., was achieved upstream of KGS, between KGS and MSWRF, and downstream of MSWRF.

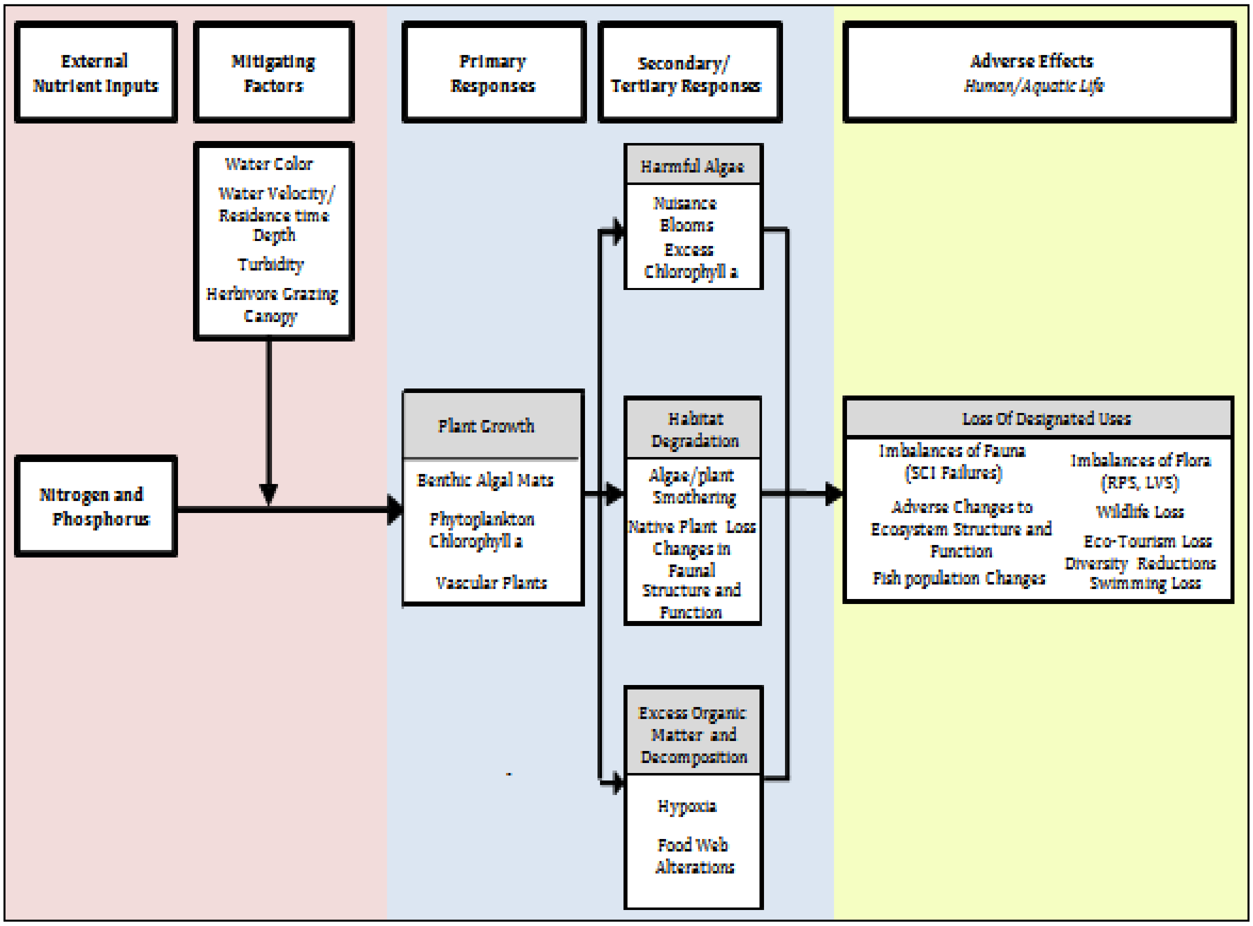

Figure 4-4. FDEP nutrient enrichment conceptual model used to assess potential adverse effects of nutrients on aquatic life and human uses in streams. Relationships between nutrients and biological responses are highly influenced by site-specific and mitigating factors.

4.4.2.2 LVS Achieves NNC Evidentiary Thresholds Except at the Control Area

The LVS failed to achieve the floral evidentiary threshold for macrophytes 7 times in 7 samplings in Sweetwater Branch upstream of the KGS (Control area), likely due to the influence of urban encroachment and the accompanying sources of invasive exotic taxa. Between KGS and the MSWRF, the LVS passed all 10 times it was sampled (ten date-station combinations), with the results usually influenced by a lack of 2 m^2 of vascular plants in the water. The LVS passed 5 times and failed on two separate occasions at SWB-5 (located downstream from MSWRF near where Sweetwater Branch enters Paynes Prairie) prior to the ongoing restoration activities. Physical mitigation of this stream segment, along with continuing plant management activities, was responsible for restoring a healthy aquatic plant community at SWB-5. Subsequently, the past 3 temporally independent LVS samples achieved the NNC evidentiary thresholds. Nutrients were not correlated with vascular plant community health (the Control area, with nutrients that achieved the regional thresholds, had the most disturbed vascular plant community, while the Test areas passed the LVS). Overall, Sweetwater Branch, downstream of both the KGS and MSWRF, achieved the LVS evidentiary thresholds in Rule 62-302.531, F.A.C.

4.4.2.3 No Adverse Changes in Algal Community Composition

A Before-After-Control-Impact Study evaluated potential changes in algal communities associated with experimental nutrient loading that approximated a "full build-out scenario." Based on non-metric multidimensional scaling analyses, there were no significant differences in community composition (*i.e*., no adverse shifts or imbalances) observed when comparing the pre- with post- period of increased nutrient loading (WAR 2011). This is partial evidence that the nutrient loading (up to 7.2 MGD and 6.6 mg/L TN) that approximated a "full build-out" scenario of the MSWRF (7.5 MGD and 8 mg/L TN) would be protective of algal communities in Sweetwater Branch. This conclusion is similar to the results of a 2008 5^{th} Year Bioassessment conducted by FDEP, which stated that "periphyton community composition did not differ between Control and Test Sites" (FDEP, 2008). The 2014 5^{th} Year Bioassessment stated, "Periphyton communities of the Test, Downstream, and Control Site samples consisted mostly of diatoms, although the Test Site contained half as many diatom taxa. The diatom community was dominated by *Nitzschia amphibia* in the Test and Downstream Site samples and by the genus *Rhoicosphenia* in the Control Site samples. No information is available currently as to the water quality tolerances and/or ecological preferences for these taxa in Florida. The Rapid Periphyton Surveys (RPS) conducted at the Test and Downstream Sites showed no evidence of nutrient enrichment in comparison with the RPS of the Control Site. Filamentous mat-forming algae were not found at any of the sampled points at the Test and Control Sites, and were found at only 6% of the sampled points at the Downstream Site" (FDEP, 2014c).

4.4.2.4 Chlorophyll a Achieves NNC Evidentiary Thresholds

Since 2002, the Annual Geometric Mean evidentiary threshold for chlorophyll (3.2 µg/L) has been consistently achieved throughout Sweetwater Branch, upstream of KGS, between KGS and MSWRF, and downstream of MSWRF. The very low chlorophyll appears to be associated with the short water residence time and stream shading. The modeling discussed in **Chapter 5** supports these observations. Downstream protection to Paynes Prairie and Alachua Sink is further ensured via the Enhancement Wetland.

4.4.3 Sweetwater Branch Floral Health Summary

Because it has been demonstrated that there are no adverse floral effects in Sweetwater Branch associated with the nutrient regime of either KGS or MSWRF, by following the process established by Chapter 62-302, F.A.C. (FDEP 2013), it is reasonable to conclude that the nutrient levels are protective of the Class III designated aquatic life use. Modeling (**Chapter 5**) demonstrates that key biological health measures would continue to be achieved at the nutrient levels associated with the WQBELs**.**

4.4.4 The FDEP Human Disturbance Gradient and the SCI

During the development of the Stream Condition Index (SCI) FDEP utilized a Human Disturbance Gradient (HDG) to select effective biological metrics. To define the HDG, FDEP converted four measures of human disturbance (Habitat Assessment score, Landscape Development Intensity Index, Hydrologic Modification score, and ammonia) to unit-less scores and summed the scores to create HDG values for each stream site used to develop the SCI (Fore et al., 2007). Three of the measures had values of 0, 1, or 2, indicating low, moderate, or high levels of human influence, respectively. One measure, hydrologic condition, had an additional value of 4 available to indicate extreme levels of disturbance**.** Thus, values for the HDG ranged from 0 (indicating minimal human disturbance) to 9 (indicating extreme disturbance). Spearman's correlations between HDG components and SCI responses are shown in **Table 4-1**. The correlation between the composite HDG and the SCI was -0.76, meaning that the SCI score is expected to be lower as human disturbance increases. By definition, the SCI responds directly to hydrologic modification, habitat disturbance, human landscape alterations (LDI), and ammonia.

Table 4-1. Correlation table of NH_3 (mg/L), hydrologic index, habitat index, LDI for the buffer, LDI for the upstream watershed, natural log of watershed size, HDG, current SCI, and old SCI for 223 stream sites (except NH_3, for which n = 214). ***Repeat visits to individual sites were averaged for each site. All values shown were significant (Spearman's r, p < 0.01) (from Fore et al. 2007).***

	NH_3	Hydro	Habitat	LDI_BF	Ln (Size)	HDG	SCI
NH_3	-	0.43	–0.45	0.39	–0.20	0.50	–0.56
Hydro	0.43	-	–0.66	0.61	–0.36	0.84	–0.71
Habitat	–0.45	–0.66	-	–0.64	0.41	–0.78	0.66
LDI_BF	0.39	0.61	–0.64	-	–0.37	0.79	–0.60
LDI_WS	0.34	0.56	–0.55	0.74	–0.28	0.70	–0.59
Ln (Size)	–0.20	–0.36	0.41	–0.37	-	–0.41	0.36
HDG	0.50	0.84	–0.78	0.79	–0.41	-	–0.76
SCI	–0.56	–0.71	0.66	–0.60	0.36	–0.76	-
Old SCI	–0.43	–0.59	0.56	–0.54	0.29	–0.69	0.86

4.4.5 Statistical Evaluation of Longitudinal Trends in Sweetwater Branch

A central step in evaluating data from the case was to determine changes (or lack thereof) in important factors, such as TP, TN, conductivity, ammonia, RPS, LVS, chlorophyll *a*, and SCI that occur in Sweetwater Branch, especially those potentially associated with the KGS or MSWRF discharges. Additionally, habitat parameters were evaluated to determine if they change from upstream to downstream in Sweetwater Branch, and the Pollman Stressor Identification model was employed to evaluate the influence of selected stressors that are included in the Pollman model.

Data were first examined for normality by visual inspection of QQ-plots and histograms (for examples, see **Figure 4-5** and **Figure 4-6**).

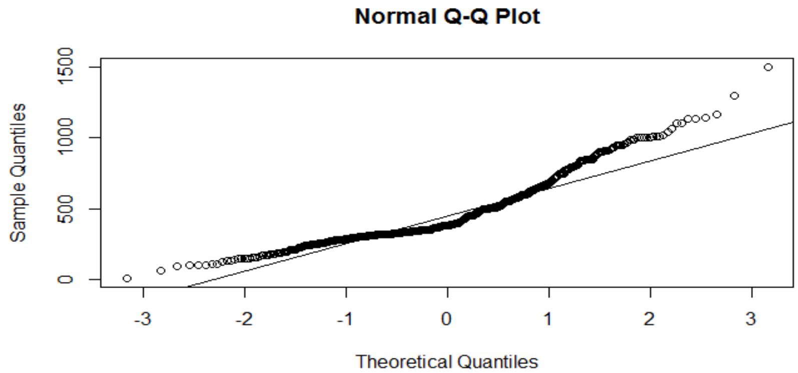

Figure 4-5. Example Q-Q plot approximating a normal distribution (conductivity).

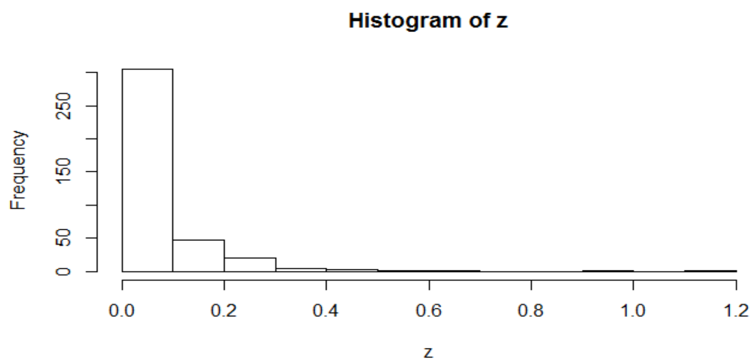

Figure 4-6. Example histogram NOT approximating a normal distribution (ammonia).

Specific conductance, pH, and DO percent saturation, SCI, habitat assessment scores, and temperature exhibited a normal distribution, and were examined via parametric Analysis of Variance. The remaining water quality and biological parameters were found to exhibit a non-normal distribution, even after data transformation attempts, and therefore, were analyzed via non-parametric tests (*i.e.*, Kruskal-Wallis rank sum test or logistic regression).

For pass/fail data (RPS, LVS), logistic regression (which is equivalent to a Chi-Squared test when there is only one independent variable) was used to compare the upstream to downstream proportion of passes vs. failures and determine if there were significant differences.

4.4.5.1 Non-Parametric Tests

A Kruskal-Wallis test was performed on the non-normally distributed data to determine if there were significant differences based on location (upstream of KGS, between KGS and MSWRF, downstream of MSWRF). A post-hoc Dunn's test with Bonferroni correction was used to examine pairwise comparisons if the Kruskal-Wallis test was found to be significant. **No significant spatial differences were found** for the following;

- Chlorophyll a (X^2 = 5.7, p = 0.06); and
- Artificial channelization score (X^2 = 0.44, p = 0.80).

TN was found to be significantly different by location ($X^2 = 232.09$, $p < 0.01$). A Dunn's post hoc test found a significant difference for upstream of KGS and downstream of MSWRF locations ($p <0.01$), and for the between facilities and downstream of MSWRF locations ($p<0.01$). No significant difference was found for upstream and between facilities ($p = 0.34$). Examining the differences from the test and the visualization presented earlier, it is apparent that downstream TN is significantly higher than the TN between facilities and is higher than the TN upstream of KGS.

TP was found to be significantly different by location ($X^2 = 151.7$, $p < 0.01$). A Dunn's post hoc test found that all three locations were significantly different from one another ($p <0.01$ for all pairwise comparisons). Downstream TP is significantly higher than the TP between facilities, and significantly higher than upstream of KGS. The TP between facilities is significantly higher than upstream of Kelly.

Although ammonia always complied with the total Ammonia Nitrogen criterion at all areas, it was found to be significantly different by location ($X^2 = 7.8$, $p = 0.02$). Ammonia was higher upstream of KGS compared to between facilities ($p = 0.04$), and to downstream of MSWRF ($p = 0.009$).

4.4.5.2 Parametric Tests

Parameters that approximated a normal distribution were first examined with a one-way Analysis of Variance (ANOVA), followed by a Tukey Honest Significant Difference (HSD) post-hoc test if significant differences were found (**Table 4-2)**.

The SCI (2012) data exhibited **no significant spatial differences** ($F = 2.3$, $p = 0.14$).

Temperature was significantly different by location ($F = 20$, $p < 0.001$). Downstream of the MSWRF was significantly greater in temperature when compared to the areas upstream of Kelly ($p = 0.002$) and between Kelly and MSWRF ($p <0.001$).

Specific conductance ($F = 335.7$, $p < 0.001$) increased from upstream of Kelly to the area between Kelly ($p < 0.001$) and MSWRF ($p < 0.001$) and conductivity again increased downstream of MSWRF ($p < 0.001$).

pH ($F = 65.15$, $p < 0.001$) was significantly higher between Kelly and MSWRF when compared to the areas upstream of Kelly ($p < 0.001$) and downstream of the MSWRF ($p < 0.001$).

DO percent saturation ($F = 42.33$, $p < 0.001$) was significantly higher between facilities and downstream of MSWRF ($p < 0.001$) and was significantly greater downstream of MSWRF compared to Upstream of KGS ($p < 0.001$).

Habitat Assessment scores ($F = 9.6$, $p < 0.001$) increased from upstream of Kelly to the area between Kelly and MSWRF ($p = 0.04$) and habitat scores again increased downstream of MSWRF) $p < 0.001$).

Table 4-2. ANOVA results.

Parameter	Upstream Kelly	ANOVA Group Between Kelly and NSWRF	Below MSWRF	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Temperature	b	b	a	2	725	363	20	< 0.001
Conductivity	c	b	a	2	16339189	8169595	335.7	< 0.001
pH	b	a	b	2	15.07	7.536	65.15	< 0.001
DO % Saturation	b	a	a	2	18709	9355	42.33	< 0.001
SCI	a	a	a	2	186	93	2.3	0.14
Habitat Assessment	c	b	a	2	7052	3526	9.6	< 0.001

4.4.5.3 Logistic Regression and Multiple Comparison of Logits Tests

For pass/fail data (LVS, RPS), logistic regression was used to compare sites located upstream of KGS, between facilities, and downstream of MSWRF. The advantage of using logistic regression over a Chi Squared test is that linear contrasts may be used to compare specific levels of the treatment if there are significant differences found by the overall test.

Results showed that there were **no significant spatial differences** in RPS (**Table 4-3**).

Table 4-3. Analysis of deviance table from Logistic Regression on RPS data.

Analysis of Deviance Table	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
NULL	NA	NA	37	21	NA
location	2	1.4	35	20	0.5

While the initial logistic regression on LVS data suggested that LVS may be different by location ($X^2 = 25.11$, $p < 0.001$), subsequent analysis using Multiple Comparison of Logits indicated no significant spatial differences due to the large standard errors associated with the results (**Table 4-4**).

Table 4-4. Results of Multiple Comparison of Logits analysis.

	Location	LS mean	SE	df	Asymp. LCL	Asymp. UCL	Group
2	Between	-21	5607	NA	-11010	10969	1
3	Downstream	-1.6	0.77	NA	-3.1	-0.09	1
1	Upstream	21	6701	NA	-13114	13155	1

4.4.5.4 Other Stressors

Scant data were available for metals, organic contaminants (including pesticides) and toxicity. Statistical analysis was not attempted. Instead, data were evaluated as potential stressors to Sweetwater Branch by comparing values to water quality criteria in Chapter 62-302 F.A.C., which were achieved.

4.4.6 Effect of MSWRF on Nutrients and Conductivity

As shown by the Kruskul-Wallis test, Annual Geometric Mean TP and TN were significantly higher downstream of the MSWRF when compared with data upstream from KGS and between KGS and MSWRF. Specific conductance increased significantly between the area upstream of KGS to the area between KGS and MSWRF and increased again downstream of MSWRF. While TN and TP exceeded the regional nutrient thresholds, specific conductance was in compliance with the water quality criterion throughout Sweetwater Branch. These parameters can be thought of as potential stressors that could influence Sweetwater Branch downstream of the discharge. However, identifying biological responses directly attributable to these factors is the goal of a stressor evaluation process. The biological responses are presented in subsequent sections.

4.4.7 Floral Responses in Sweetwater Branch Attributable to the MSWRF Discharge

Based on the results of non-parametric Kruskal-Wallis tests (above), there were no statistically significant spatial changes in Annual Geometric Mean chlorophyll in Sweetwater Branch. Additionally, results from Logistic Regression and Multiple Comparison of Logits indicated that there were no significant spatial differences in RPS or LVS scores in Sweetwater Branch. Therefore, the increased TN, TP, and conductivity associated with the discharge did not elicit any statistically significant biological responses. This is consistent with the above findings that all floral measures achieved the evidentiary thresholds specified in Rule 62-302.531, F.A.C., and is strong evidence to conclude that characteristics of neither the KGS nor MSWRF discharges (*e.g.*, nutrients and conductivity) are having adverse floral effects in Sweetwater Branch.

4.4.8 Faunal Response in Sweetwater Branch Attributable to the Discharge

A one-way ANOVA (above) indicated that the SCI (2012) data exhibited **no significant spatial differences** ($F = 2.3$, $p = 0.14$). Therefore, the increased TN, TP, and conductivity associated with the discharge **did not elicit any statistically significant faunal response**.

The Stream Condition Index (2012 version) averaged 21 (n=2) in Sweetwater Branch upstream of the KGS and 36.2 (n=5) downstream of the KGS (upstream of the MSWRF). Downstream of MSWRF, the SCI averaged 34.6 (n = 8). Although these average SCI scores do not achieve the minimum acceptable average score (40) for a healthy, well balanced stream, there were no statistically significant decreases in the SCI scores from upstream to downstream of either facility, despite the increased TN, TP, and conductivity.

For TN or TP to have adverse effects on faunal health, the biological responses must be consistent with FDEP's Nutrient Ecological Model. As seen above, there were no statistically significant changes in any floral response associated with either discharge, and **all floral evidentiary thresholds were met downstream of both the KGS and MSWRF discharges**. This is clear evidence that nutrients cannot be considered causative agents that adversely affect the SCI scores, *sensu* the FDEP model. Therefore, the evidence indicates that nutrients are not adversely affecting fauna in Sweetwater Branch.

However, as seen in **Chapter 3** above, there are other significant (non-nutrient) anthropogenic stressors that could adversely affect the fauna of Sweetwater Branch, including hydrologic modification (including landscape use intensity stress and impervious surfaces), sedimentation (sand movement and deposition), and habitat alterations (including artificial channelization). Evidence is presented below to appropriately identify the (non-nutrient) factors most influential in causing the observed faunal deficiencies, which occur both upstream and downstream from both discharges.

4.4.9 Hydrologic Modifications

The significant hydrologic modifications of Sweetwater Branch are discussed in **Chapter 2**. FDEP calculated a hydrologic score of **9** for Sweetwater Branch, indicating that the flow regime is human controlled, in this case predominantly due to the amount of landscape intensity stress, impervious surfaces in the watershed, and the high degree of artificial channelization of Sweetwater Branch (as well as contributing culverts and ditches). Because of the hydrologic modifications, the hydrograph for Sweetwater Branch is characterized by a series of extreme flow events (see Figure in **Chapter 3**). The correlation between the SCI and hydrologic modification score (-0.71, from the SCI development data set) indicates that hydrologic modification exerts a significant negative influence on the Sweetwater Branch SCI scores.

4.4.10 Sedimentation

Jones Edmunds & Associates, Inc. (2010) found that storm events in Gainesville, coupled with hydrologic modifications in the watershed, resulted in significant sediment movement (mostly sand) in Sweetwater Branch. There is an annual mean of 45,900 ft^3 of sediment movement and subsequent deposition in the system (Jones Edmunds & Associates, Inc., 2010). Consequently, the median Habitat Smothering score upstream of the KGS was in the poor range (3), while the median smothering scores between KGS and MSWRF and downstream of the MSWRF were 11 (suboptimal) and 8 (marginal), respectively. This means that throughout Sweetwater Branch, generally more than 25% of the substrates were affected by sand smothering and that the expected number of pools (1 to 2 for every 12 m of stream width) was not achieved, thereby reducing the habitats for benthic macroinvertebrate colonization (FDEP, 2014b). Accordingly, the median substrate availability score upstream of the KGS was 5 (poor), while median substrate availability scores between KGS and MSWRF downstream of the MSWRF were 7 and 8, respectively (marginal) (FDEP, 2014b).

4.4.11 Habitat/Artificial Channelization Stress

Mean habitat scores in Sweetwater Branch were 60.8 points (marginal) upstream of the Kelly Generating Station (KGS), 76.9 points (marginal) between Kelly and the MSWRF discharge, and 95.2 (suboptimal) downstream of MSWRF.

The Habitat Assessment score was also used when developing the SCI and BioRecon (Fore et al., 2007). For the statewide SCI data set, Spearman's Correlation Coefficient between Habitat Assessment and the SCI ($p < 0.01$) was **0.66**, meaning that habitat stress is another factor adversely affecting invertebrates in Sweetwater Branch. The average HA scores in Sweetwater Branch upstream of Kelly, between Kelly and MSWRF, and downstream of

Kelly were 60.8, 76.9, and 95.2, respectively. The increase in overall habitat scores downstream of MSWRF was caused by the presence of a better riparian zone buffer in that area. A Habitat Assessment score of less than 80 received 2 points on the HDG while scores between 80 and 104 received 1 point on the HDG. Particularly noteworthy in Sweetwater Branch is the low artificial channelization scores throughout the system, with median values of 5, 10, and 6 reported for upstream of Kelly, between Kelly and MSWRF, and downstream of MSWRF, respectively. Artificial channelization works in conjunction with extreme hydrologic events to enable scouring of habitat and to move (and deposit) sediment, while limiting available substrates for colonization (FDEP, 2014d). This suggests that channelization is a significant stressor throughout Sweetwater Branch, and is somewhat more influential upstream of KGS and downstream of the MSWRF.

4.4.12 Metals, Organic Contaminants (including pesticides), Toxicity, Ammonia, and Dissolved Oxygen

In 2014, metals and a full suite of potential organic contaminants (including pesticides) were sampled and analyzed by FDEP for the MSWRF effluent and for Sweetwater Branch, both upstream and downstream of the discharge (FDEP, 2014c). Metals were either not detected or complied with water quality standards at all locations. Similarly, no organic contaminants (including pesticides) were detected in the three 2014 locations sampled, complying with water quality criteria. In 2008 and 1996, metals and a full suite of potential organic contaminants (including pesticides) were sampled and analyzed by FDEP for the MSWRF effluent (no receiving water samples were taken during these dates) (FDEP, 2008)(FDEP, 1996). Again, metals were either not detected or they were present in concentrations that complied with water quality standards, and no organic contaminants were detected. This is evidence that metals and organic contaminants (including pesticides) are not causing the observed stress to the macroinvertebrate community downstream of MSWRF. FDEP also performed chronic toxicity tests on the MSWRF effluent in 1996, 2008 and 2014. During these tests, no acute or chronic toxicity was observed to either the fish or invertebrate test organisms.

In 1992 and 1996, metals and a full suite of potential organic contaminants (including pesticides) were sampled and analyzed by FDEP for the KGS effluent (no receiving water samples were taken during these dates) (FDEP, 1996) FDEP, 1992). Again, with one exception, metals were either not detected or they were present in concentrations that complied with water quality standards, and no organic contaminants were detected. In 1992, copper was present in one of the KGS discharges, but sampling at the edge of the mixing zone did not occur, therefore, compliance could not be definitively determined (KGS currently uses agents to minimize leaching of copper from pipes). FDEP also performed toxicity tests on the KGS effluent. During these tests, no toxicity was observed to either the fish or invertebrate test organisms. This is evidence that metals and organic contaminants (including pesticides) are not causing the observed stress to the macroinvertebrate community downstream of KGS.

Ammonia concentrations are low in Sweetwater Branch upstream of the KGS, between KGS and MSWRF, and downstream of the MSWRF discharge. No exceedances of either the monthly average or single sample maximum Total Ammonia Nitrogen (TAN) criterion were observed in Sweetwater Branch (**Table 3-23**). Therefore, ammonia is not a stressor.

The 38% dissolved oxygen percent saturation criterion was not achieved in 22.4% of the samples upstream from the KGS, in 1.4% of the samples collected between the KGS and MSWRF, and in 0% of the samples downstream of the MSWRF (**Table 3-19**). Therefore, while low DO may occasionally influence the community upstream of KGS, low DO is not a stressor between KGS and MSWRF and downstream of MSWRF.

4.5 Step 4: Evaluate Data from Elsewhere, and Compare to Study Area

4.5.1 Hydrologic Stress

EPA (2014) documented case studies that conclusively link urbanization and increased watershed imperviousness to hydrologic impacts on streams. Existing reports and case studies provide strong evidence that urbanization negatively affects streams and results in problems such as loss of habitat, increased temperatures, sedimentation, and loss of fish populations (EPA, 2014; Moore and Palmer, 2005). Based on the land use categories and their respective percent directly connected impervious areas, **37.94 %** of the Sweetwater Branch watershed is calculated to be impervious, which would be associated with low benthic macroinvertebrate taxa richness, a critical component of the SCI (see **Figure 4-7**).

During development of the SCI, Hydrologic Modification Scores from 8-9 scored 2 points (with 0 being associated with minimally disturbed conditions) on the Human Disturbance Gradient. Spearman's Correlation Coefficient between the Hydrologic Modification Score and the SCI ($p < 0.01$) was **-0.71**, meaning that low SCI scores (below 40) would generally be expected based on the strong correlation with the high Hydrologic Modification Score (9) for the Sweetwater Branch watershed (Fore et al., 2007).

The LDI was another component of FDEP's human disturbance gradient (HDG), which was used to select effective biological metrics for the SCI and Bioreconnaisance (BioRecon) (Fore et al., 2007). The LDI would be expected to assess, in part, the hydrologic modification of the watershed. Spearman's Correlation Coefficient between the LDI and the SCI ($p < 0.01$) was **-0.60**, meaning that low SCI scores (below 40) would be expected based on the strong correlation with the high LDI (**6.4**) for the Sweetwater Branch watershed (Fore et al., 2007). During development of the SCI, an LDI score above 3.5 received 2 HDG points. As part of a Tiered Aquatic Life Use analysis, Fore (2006) assembled data from 126 Florida sites collected across a Human Disturbance Gradient and conducted change point analysis between the LDI and SCI (**Figure 4-8**). A change point was detected at SCI = 44 and a second point was detected at SCI = 18.3. The first change point was associated with median LDI values shifting from approximately 1.6 to approximately 2.8. The second change point, representing very impaired conditions, was associated with a shift in the LDI from 2.8 to 4.9. Note the Sweetwater Branch LDI value, at 6.4, is quite elevated, and the change point analysis suggests that the median SCI score at this level would be near 20. The observed SCI values averaged 21 (n=2) upstream of the KGS, 36.2 (n=5) downstream of the KGS, and 34.8 (n = 8) downstream of MSWRF.

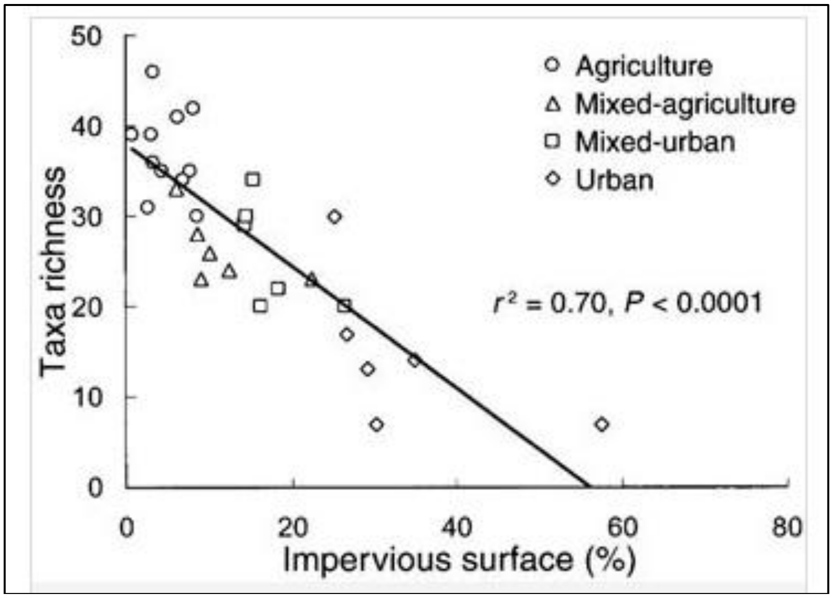

Figure 4-7. Relationship between total macroinvertebrate richness and % impervious surface cover in 29 headwater Maryland streams sampled in 2001. Taxa richness declined linearly with increasing impervious cover (from Moore and Palmer 2005).

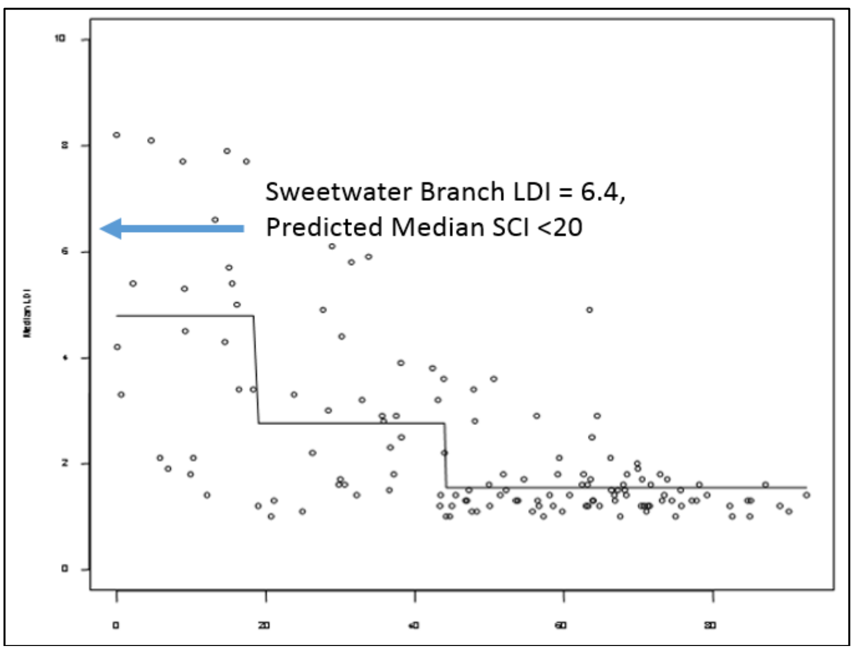

Figure 4-8. Change point analysis for SCI (x-axis) regressed against LDI (after Fore 2006).

4.5.2 Sedimentation

Excessive sediments (suspended or deposited and bedded) can adversely affect aquatic biota and lead to biological impairment. In EPA's conceptual sediment model, sediments are the direct cause of biological impairments, understood in context with the hydrology, geology, and geomorphology of the system (EPA, 2015). Many types of channel alteration (*e.g.,* channel straightening, separating from a floodplain) cause increased water velocity and discharge that forcefully mobilize streambed sediments, resulting in stream channels that lack stable geometries and leading to increased bank erosion. During storms, flows increase, and the force of the water is stronger when it is restricted to a channel rather than dissipated over a floodplain. Also, the full burden of sediments is carried rather than being deposited on land in the floodplain. The increased supply of sediments moves with the flowing water as suspended sediments or is pushed across the streambed creating an unstable habitat, which can scour the bed. When the flow diminishes, sediments are deposited, changing the type of substrate, filling interstitial spaces and pools, and covering plants, animals, and substrate with material. These deposited and bedded sediments change the habitat making it unsuitable for the original inhabitants (EPA, 2015).

High suspended sediment concentrations can adversely affect aquatic biota by four main pathways: (1) impairment of filter feeding, by filter clogging or reduction of food quality; (2) reduction of light penetration and visibility in the stream, which may alter interactions between visually-cued predators and prey, as well as reduce photosynthesis and growth by submerged aquatic plants, phytoplankton, and periphyton; (3) physical abrasion by sediments, which may scour food sources (e.g., algae) or directly abrade exposed surfaces (e.g., gills) of fishes and invertebrates; and (4) increased heat absorption, leading to increased water temperatures. Deposited and bedded sediments may lead to biological impairment by three main pathways: (1) increased coverage by fine particles, which can alter benthic habitats (e.g., increasing fine substrate habitats favored by burrowing insects and tolerated by nest cleaning fishes, or reducing deeper pool habitats) and bury relatively sessile taxa and life stages (e.g., fish eggs); (2) clogging of interstitial spaces, leading to reduced interstitial flows and habitats; and (3) reduction of substrate size, leading to reduced substrate diversity and stability (EPA, 2015; EPA, 2014).

4.5.3 Habitat Alterations/Channelization

Alterations of physical habitat, including changes in the structural, geomorphic, or vegetative features of stream channels, can adversely affect aquatic organisms (EPA, 2015). Many human activities and land uses can lead to myriad changes in in-stream physical habitat. Urbanization may contribute to increased sedimentation (e.g., via increased erosion) and changes in discharge patterns (e.g., via increased stormwater runoff), as well as lead to decreases in streambank habitat and instream cover, including large woody debris) (EPA, 2015; Norton et al., 2009).

Direct alteration of stream channels also can influence physical habitat by changing discharge patterns, changing hydraulic conditions (water velocities and depths), creating barriers to movement, and decreasing riparian habitat. These changes can alter the structure of stream geomorphological units (EPA, 2015).

Typically, physical habitat degradation results from reduced habitat availability (e.g., decreased snag habitat) or reduced habitat quality (e.g., increased habitat smothering). Decreases in habitat availability or substrate diversity may contribute to decreased condition, altered behavior, increased mortality, or decreased reproductive success of aquatic organisms; ultimately, these effects may result in changes in population and community structure and ecosystem function (EPA, 2015; EPA, 2014).

Artificial channelization and habitat modification are very plausible causes for the observed biological effects in Sweetwater Branch.

4.5.4 Ammonia, Dissolved Oxygen, Metals, Organic Contaminants (including pesticides), and Toxicity

Due to its toxicity to biota, FDEP adopted an Total Ammonia Nitrogen criterion (EPA, 2013). Studies have shown that excess ammonia in the discharge of sewage treatment plants causes shifts in the macroinvertebrate communities between upstream and downstream locations (*e.g.,* Monda and Saiki, 1994). Mesocosm and microcosm studies have confirmed the detrimental effect of ammonia to stream macroinvertebrates (*e.g.,* Hickey et al., 1999; Berenzen et al., 2001). However, the consistently low ammonia levels found throughout Sweetwater Branch indicate that ammonia is not a plausible stressor.

FDEP conducted an extensive investigation to revise the dissolved oxygen criteria for Florida's lakes, streams, and marine waters (FDEP, 2013b). The previous standard for freshwaters was based on data collected from a statewide monitoring study during 2005 and 2006, and later supplemented with additional data in 2010. These data revealed a significant relationship between Florida's Stream Condition Index and DO, and a new water quality criterion was developed to ensure that DO would be sufficient for waterbodies to pass the SCI. FDEP independently confirmed that minimally disturbed waterbodies (natural background conditions) were characterized by a DO regime that would be maintained by the new DO criteria, which are also protective of threatened and endangered species. For the region of the state that Sweetwater Branch is located, the DO criterion is 38% saturation, not to be exceeded more than 10% of the time (**Figure 4-9**). This level was consistently achieved in Sweetwater Branch between KGS and MSWRF and downstream from MSWRF, meaning DO is not a plausible stressor attributable to the discharges.

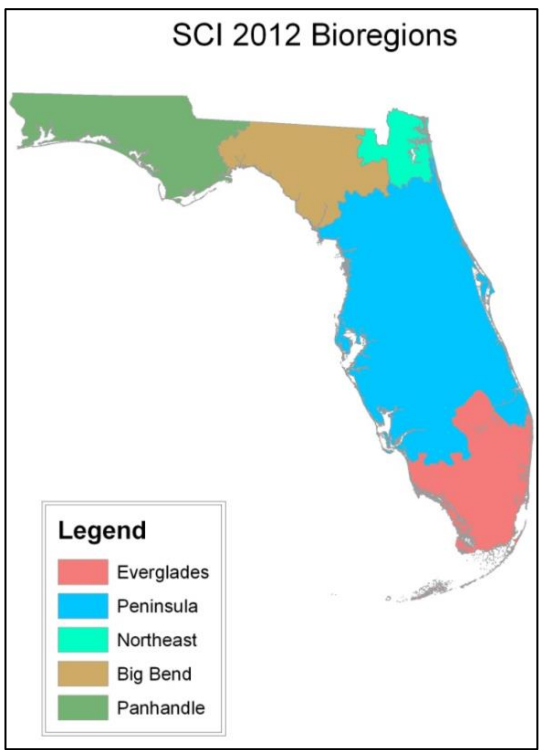

Figure 4-9. Bioregions for the SCI, which correspond with applicable DO regions in Florida.

Based on a plethora of information from EPA, FDEP has adopted water quality criteria that address a full suite of potentially toxic metals and organic contaminants (including pesticides). These criteria were derived primarily using laboratory toxicity data and calculated to protect the most sensitive species from acute and chronic effects, thus ensuring full protection of aquatic life uses.

The results of five comprehensive, temporally independent analyses of a full suite of metals and organic contaminants of the KGS and MSWRF effluents showed that water quality criteria were consistently achieved, meaning metals and organics are not plausible stressors.

FDEP has long-adopted criteria designed to prevent acute and chronic toxicity in waters of the state. FDEP toxicity tests of the KGS and MSWRF effluents consistently show compliance with toxicity criteria, meaning toxicity is not a plausible stressor.

4.5.5 Human Disturbance Gradient: Combined Effects of Ammonia, Hydrologic Modification, Habitat, and LDI

The Human Disturbance Gradient used for development of the SCI consisted of ammonia, Hydrologic Modification, Habitat Assessment, and LDI, with higher HDG points associated with more human stress. In Sweetwater Branch downstream of the MSWRF, ammonia averaged 0.07 mg/L (receiving 0 HDG points, not an adverse factor), the average habitat assessment scored 95 points (receiving 1 point on the HDG), the hydrologic modification score was 9 (receiving 2 HDG points), and the LDI was 6.4 (receiving 2 points on the HDG). Therefore, the total HDG score for Sweetwater Branch downstream of the MSWRF is 5 points. When the HDG was regressed against the SCI, an HDG score of 5 would be expected to score below 20 on the SCI. The observed average SCI values in three reaches of Sweetwater Branch (upstream to downstream) were 21, 32, and 29, respectively (**Figure 4-10**).

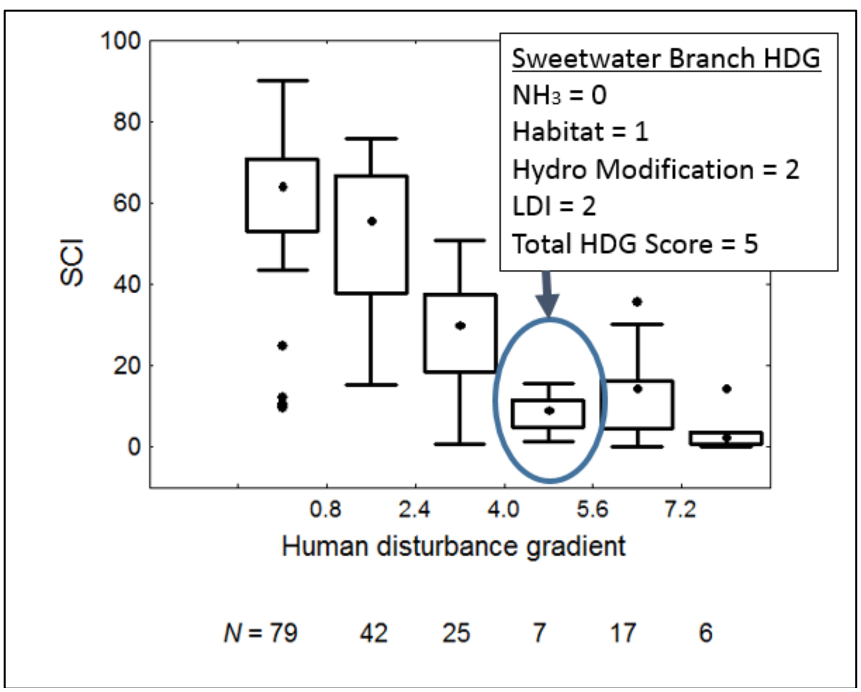

Figure 4-10. Box and whisker plots of SCI vs. the Human Disturbance Gradient (HDG) at 176 sites (after Fore et al. 2007). With an HDG score of 5, Sweetwater Branch SCI scores are predicted to be below 20.

4.5.6 Pollman Stressor Identification Model: Evaluating Nutrients and Conductivity

Dr. Curt Pollman developed a Stressor Identification Model that includes excess TKN, excess temperature, specific conductance, dissolved oxygen, substrate diversity, water velocity, and artificial channelization as input variables to predict an SCI score. Development of the model included the input variables in **Table 4-5,** and is especially useful when the list of candidate stressors is limited to the factors in the table. The most recent version of the model (2012) was employed to evaluate the effect of conductivity and substrate diversity on the SCI scores.

Table 4-5. List of water quality variables and habitat scores used in development of the Pollman Stressor Identification Model (from Pollman 2012).

Water Quality	Habitat Scores
NH_3	Artificial channelization
Color	Substrate availability
Specific conductance (field)	Substrate diversity
NO_2-NO_3	Water velocity
pH	Habitat smothering
Temperature	Riparian vegetation quality
TKN	Riparian buffer width
TP	Bank stability
Turbidity	

4.5.6.1 Accuracy of Pollman Model in Predicting SCI scores in Sweetwater Branch

The Pollman model over-predicted the median SCI score in Sweetwater Branch by 9 points, meaning that stressors not accounted for by the model were also influencing the invertebrate community (**Figure 4-11**). Due to the appearance of unequal variances, a Welch's paired t-test was performed on the differences in the observed vs. predicted SCI data and the results confirmed that the over-prediction was statistically significant ($t = -3.2$, $p = 0.01$).

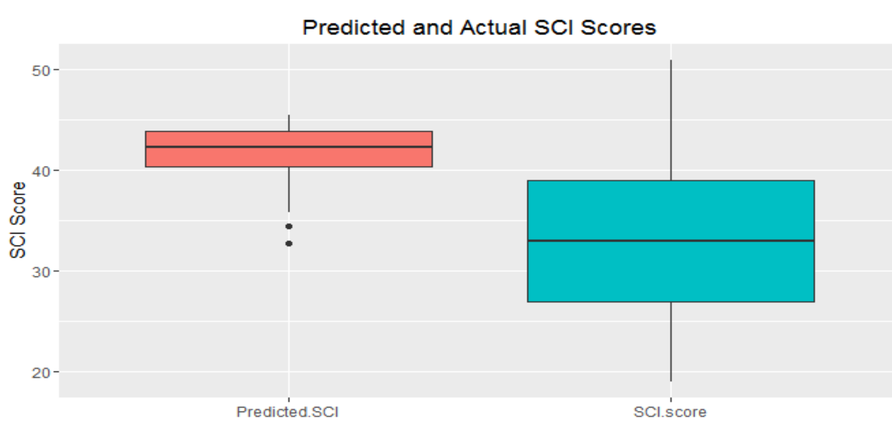

Figure 4-11. Box plots of observed SCI scores (median = 34, n = 13, blue box) in Sweetwater Branch vs. the SCI scores predicted by the Pollman model (median = 42, n = 13, red box).

Figure 4-12 shows an example of typical output from the model using data from the MSWRF Test Site in 2014. In the example, the observed vs. predicted SCI score is depicted and potential changes to the score related to excess TKN are evaluated via the response curve. The model shows TKN at the Test Site to be approximately 0.5 mg/L higher than what would be expected to occur based on color (measured in PCU) alone. However, it would be projected by the model that an SCI score of 42 would occur at the existing TKN regime. It should be noted that there is no known **direct mechanism** for TKN to exert adverse effects on the invertebrate community without the intermediate step of excess plant biomass production, which would then cause habitat smothering, excess organic matter accrual, and subsequent low DO (which did not occur in Sweetwater Branch). The CADDIS approach requires a causal mechanism be present to identify stressors. In **Figure 4-13**, the influence of low substrate diversity, which is known to reduce macroinvertebrate health, is plotted. In this case, the model shows that moderate increases in substrate diversity would be expected to result in modest improvements in the SCI, which would be supported by a causal mechanism. In the example, a perfect Substrate Diversity score (20) at the Sweetwater Test Site would theoretically result in an SCI score of 55, even if the intensity of all the existing stressors remained the same.

Figure 4-11 shows box plots of the all the observed vs. predicted SCI values (n=13), indicating that factors other than those accounted for in the Pollman model are affecting Sweetwater Branch.

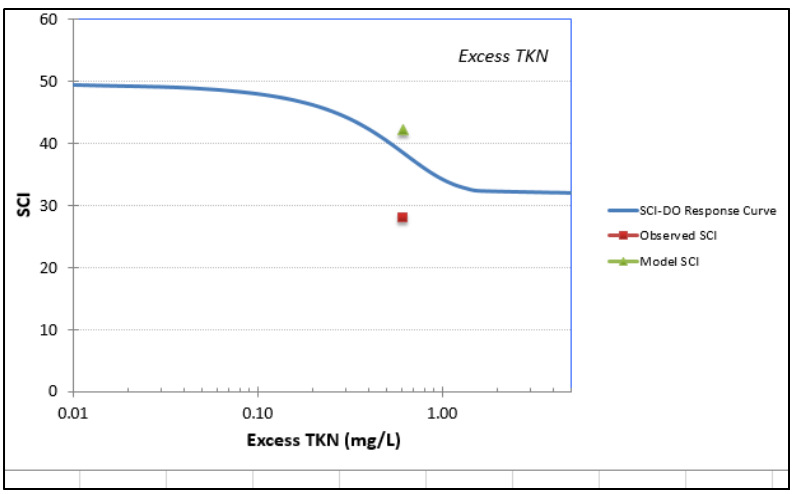

Figure 4-12. Example of the Pollman Model output for the observed vs. predicted SCI score related to the influence of excess TKN at the Sweetwater Branch Test Site in 2014.

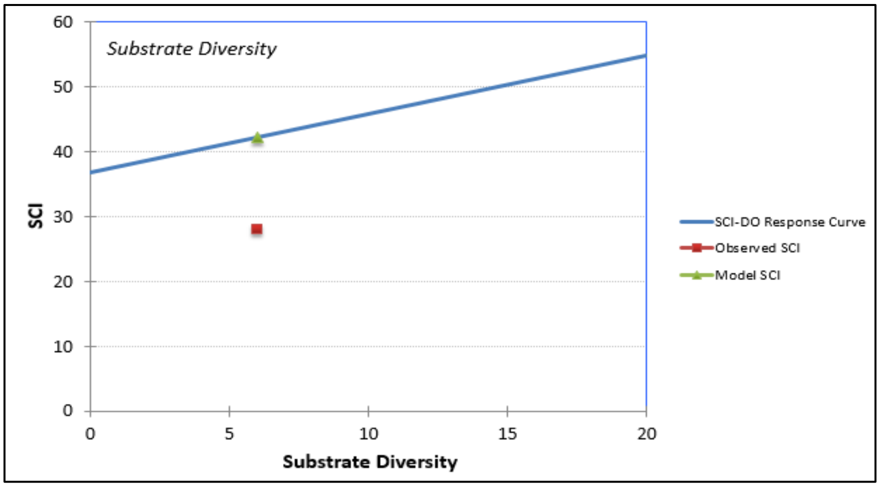

Figure 4-13. Example of the Pollman Model output for the observed vs. predicted SCI score related to the influence of Substrate Diversity at the Sweetwater Branch Test Site in 2014.

The Pollman Model predicted that 13 of 15 SCI scores would be 40 or higher in Sweetwater Branch (**Figure 4-11**, right-hand box plot). If the model accurately accounted for all the stressors in Sweetwater Branch, a healthy, well balanced community should be present. If this condition were true, a stressor identification study would be unnecessary.

However, the Pollman model does not directly account for hydrologic modification (associated with human landuse intensity stress and imperviousness of watershed surfaces and ditching) or sediment movement/scouring, and explains only 46% of the variability in the SCI scores (Pollman, 2012). As shown above, human land use intensity, hydrologic modification, habitat disturbance, and sedimentation are significant stressors in the Sweetwater Branch watershed. The influence of these factors is the likely reason the Pollman model tended to over-predict the SCI scores in Sweetwater Branch. However, the model may still be used to assess the relative influence of factors that are incorporated into the model calculations. Two factors of interest, including specific conductance and substrate diversity, were evaluated with the Pollman model.

4.5.6.2 Use of Pollman Model to Assess the Influence of Conductivity and Substrate Diversity

During development of the WQBEL Plan of Study, FDEP expressed concern that specific conductance may be a stressor affecting the invertebrate community in Sweetwater Branch, and suggested that the Pollman Model be employed to assess the hypothesis that specific conductivity was an important adverse factor. Specific conductance averaged 297 µmhos/cm upstream from the KGS, 451 µmhos/cm between the KGS and MSWRF, and 719 µmhos/cm downstream of the MSWRF. We explored the use of the Pollman Model and discovered that observed and predicted SCI scores may be 40 (healthy) or higher at many sites with conductivity values similar to those observed in Sweetwater Branch. For example, the conductivity in Beaver Creek (a tributary of the Ochlockonee River in Leon County that receives the Arvah Hopkins Power Plant discharge) was 691 µmhos/cm when it passed the SCI with an actual score of 46 in 2014 (FDEP, 2014e). The Pollman model, at the measured conditions, predicted an SCI score of 47 (**Figure 4-14**). An arrow was drawn on the graph to show where the modeled specific conductance curve intersected the standard passing SCI score of 40. Based on the Pollman model equation (where the curve intersected 40), Beaver Creek would continue to pass the SCI as the conductivity approached 1,300 µmhos/cm. Using this same approach, other examples of this phenomenon (see **Appendix A** for graphs) include:

- The Mid-County WWTP Test Site, where the Pollman Model equation predicts a passing SCI at 1,300 µmhos/cm conductivity. The actual SCI was 41 at 608 µmhos/cm (FDEP, 2010);
- The Mosaic South Ft. Meade Test Site, where the Pollman Model equation predicts a passing SCI at 1,300 µmhos/cm conductivity. The actual SCI was 35 at 1,354 µmhos/cm (FDEP, 2011); and
- The CF North Pasture Test Site, where the Pollman Model equation predicts a passing SCI at 1,100 µmhos/cm conductivity. The actual SCI was 69 at 385 µmhos/cm (FDEP, 2006).

Many of the stressors affecting Sweetwater Branch (*e.g*., hydrologic extremes, sedimentation, and significant channelization) were not present at the sites shown above as examples of passing SCI scores associated with elevated conductivity. These observations, as well as the statistically significant over-prediction of the SCI scores in Sweetwater Branch (by the Pollman model), suggest that factors other than those included in the Pollman Model are influencing the biological communities in Sweetwater Branch. However, the Pollman Model may still be used to examine the relationships between stressors that are incorporated into the model and for "scenario" exploration.

As indicated earlier, the average specific conductance in Sweetwater Branch increased from 451 µmhos/cm between KGS and MSWRF to an average of 719 µmhos/cm downstream of the MSWRF discharge. Because the highest conductivity was observed downstream of MSWRF, additional analyses concerning effects on conductivity on SCI scores were conducted on data collected downstream of MSWRF. Using the data for SWB-5, collected by FDEP on 4-17-14, the Pollman model predicted that the SCI score would be 45.5, which is close to the actual SCI score of 45. With all other variables remaining constant, the input conductivity value to the model was replaced with 451 µmhos/cm (the average upstream value) to assess how conductivity would affect the SCI score. Substituting this conductivity value resulted in the model predicting an SCI score of 46.9 (approximately 2 points higher than using the actual conductivity value) (**Table 4-6)**.

Table 4-6. Output from Pollman model for SWB-5 (collected by FDEP on 4-17-14), with conductivity adjusted to 451 µmhos/cm (the average upstream conductivity value).

Variable Name	Variable Value
Sample ID	
Name	SWB-5, cond adj
Bioregion (number)	3
Year	2014
Month	4
Latitude (decimal degree)	29.6
Observed SCI	45
Predicted SCI	46.92200623
Color	18
Specific conductance	451
TKN	0.68
Dissolved Oxygen	8.2
Temperature	19.2
Substrate diversity	11
Water velocity	18
Artifical channelization	11

Additionally, the Pollman model was run for MSWRF Control and Test Sites (collected by FDEP in 2007 and 2014) to determine the effects of conductivity and substrate diversity on the SCI scores (see **Figure 4-15** through **Figure 4-24,** also see **Appendix A** for input values).

The median substrate diversity score measured in Sweetwater Branch was 8 (range 4-14) between KGS and MSWRF and 12 (range 6-14) downstream of MSWRF. It was hypothesized that a moderate adjustment to the substrate diversity score input (by 5 points, representing an addition of a single substrate type, such as leaf packs) to the Pollman model would increase the predicted SCI score. This was systematically conducted for individual station/date combinations, and the results are found in **Figure 4-15** through **Figure 4-24**).

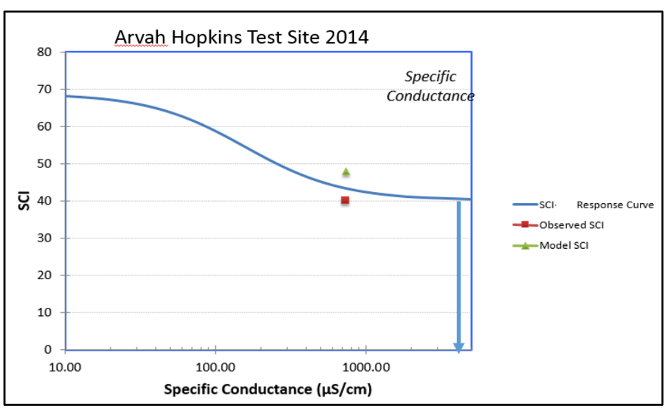

Figure 4-14. For the Arvah Hopkins Downstream Site (sampled 2014), the equation associated with the Pollman Model predicts a passing SCI at ~1,300 µmhos/cm conductivity. The actual SCI was 46 at 691 µmhos/cm conductivity.

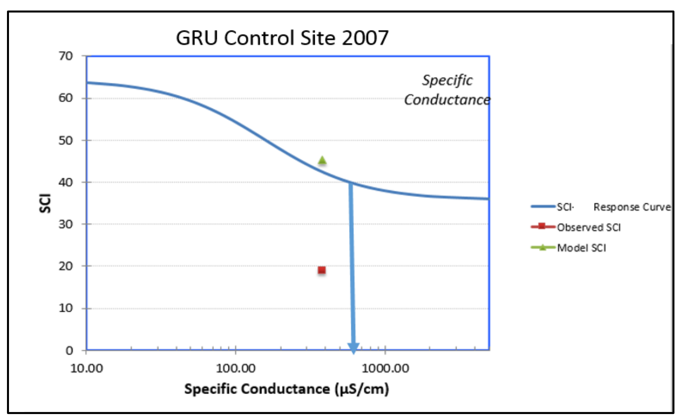

Figure 4-15. At the MSWRF Control Site (sampled in 2007), the equation associated with the Pollman Model predicts passing the SCI at 600 µmhos/cm conductivity. The actual SCI was 23 at 381 µmhos/cm, but the Pollman Model predicted an SCI score of 45.

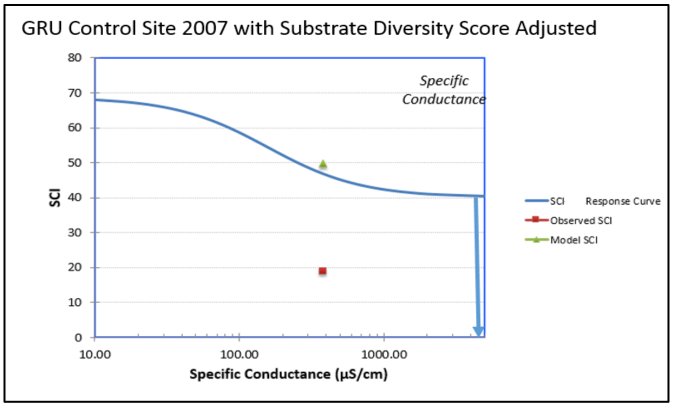

Figure 4-16. The MSWRF Control Site (sampled in 2007) with the Substrate Diversity score adjusted to 16 (a 5-point increase). The equation associated with the Pollman Model predicts a passing SCI at >1,300 µmhos/cm conductivity. The actual SCI was 23, but the predicted SCI score was 50 if substrate diversity were improved.

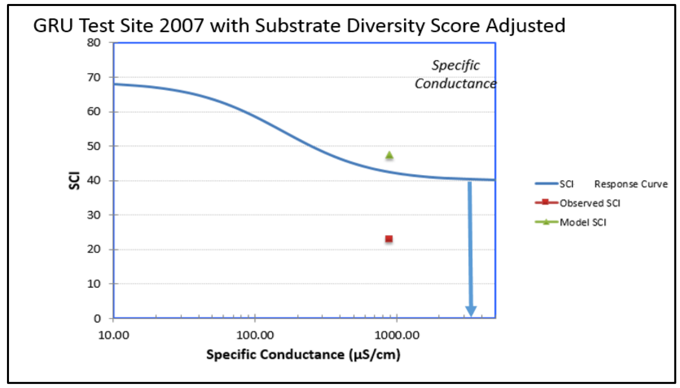

Figure 4-18. The MSWRF Test Site (2007) with Substrate Diversity adjusted to 18 (a 5-point increase). The equation associated with the Pollman Model predicts a passing SCI at >1,200 µmhos/cm conductivity. The actual SCI was 27 at 888 µmhos/cm but was predicted to be 47 if substrate diversity were improved.

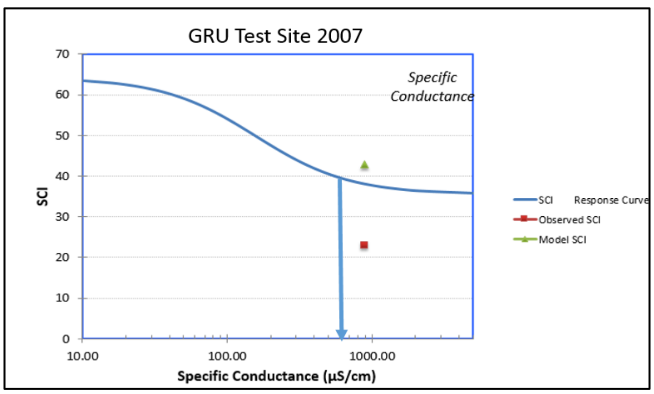

Figure 4-17. At the MSWRF Test Site (sampled in 2007), the equation associated with the Pollman Model predicts a passing SCI at 600 µmhos/cm conductivity. The actual SCI was 27 at 888 µmhos/cm conductivity, but the Pollman Model predicted an SCI score of 42.

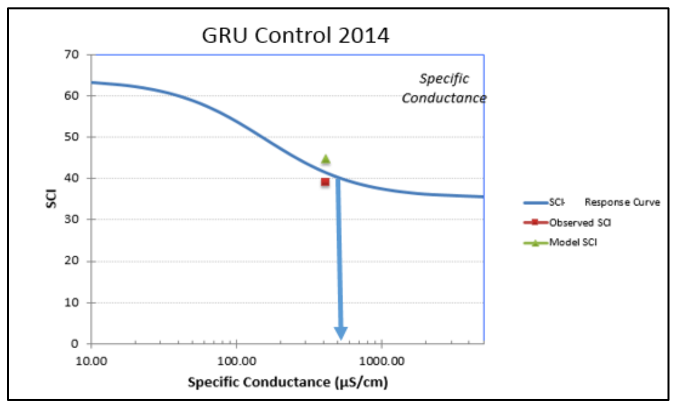

Figure 4-19. At the MSWRF Control Site (sampled in 2014), equation associated with the Pollman Model predicts a passing SCI at 500 µmhos/cm conductivity. The actual SCI was 51 at 414 µmhos/cm, and the Pollman Model predicted an SCI score of 45.

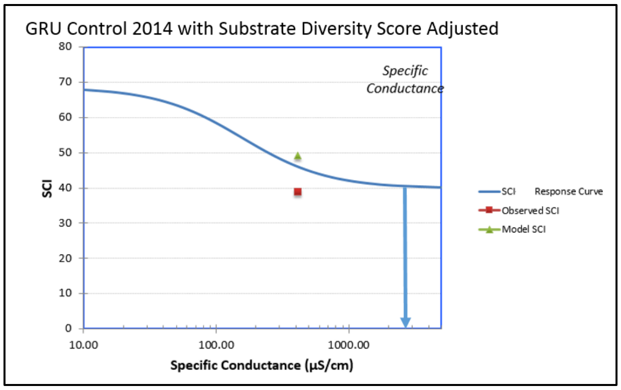

Figure 4-20. The MSWRF Control Site (sampled 2014) with the Substrate Diversity Score adjusted to 13 points (a 5-point increase). The equation associated with the Pollman Model predicts a passing SCI at ~1,200 µmhos/cm conductivity. The actual SCI was 51 at 414 µmhos/cm but predicted to be 49 if substrate diversity were improved.

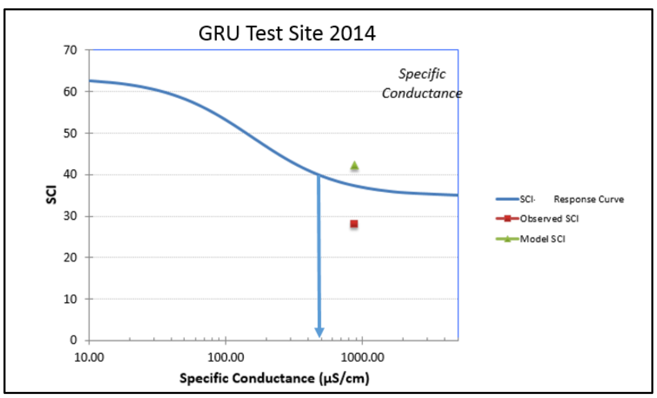

Figure 4-21. At the MSWRF Test Site (sampled in 2014), the equation associated with the Pollman Model predicts a passing SCI at 500 µmhos/cm conductivity. The actual SCI was 33 at 879 µmhos/cm, but the Pollman Model predicted an SCI score of 42 at 879 µmhos/cm.

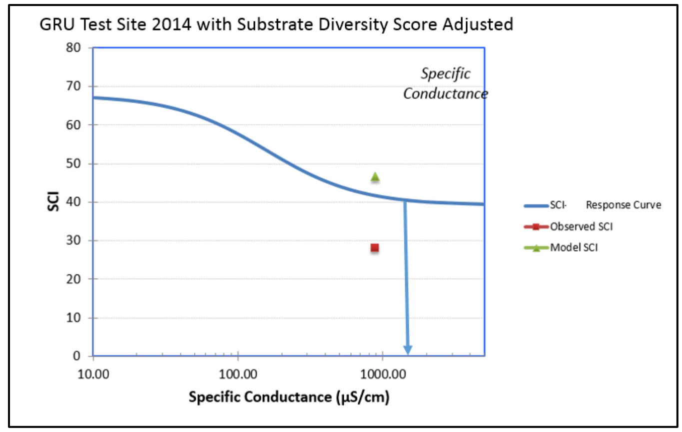

Figure 4-22. The MSWRF Test Site (2014) with the Substrate Diversity Score adjusted to 11 (a 5-point increase). The equation associated with the Pollman Model predicts a passing SCI at 1,050 µmhos/cm conductivity. The actual SCI was 33 at 879 µmhos/cm but predicted to be 47 if substrate diversity were improved.

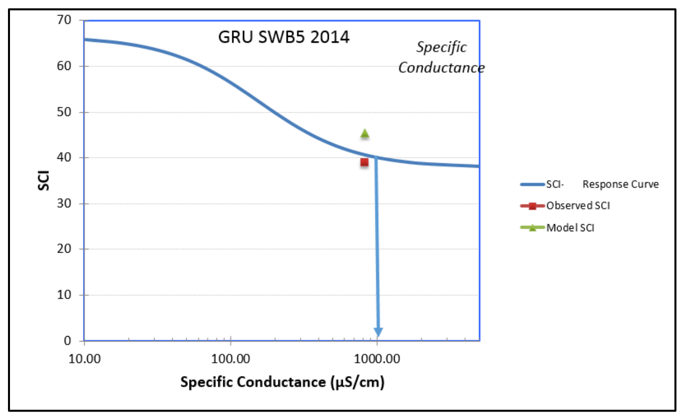

Figure 4-23. At the MSWRF Downstream Test Site (located near the new sedimentation basin and sampled in 2014), the equation associated with the Pollman Model predicts a passing SCI at 1000 µmhos/cm conductivity. The actual SCI was 45 at 827 µmhos/cm, and the Pollman Model predicted an SCI score of 46.

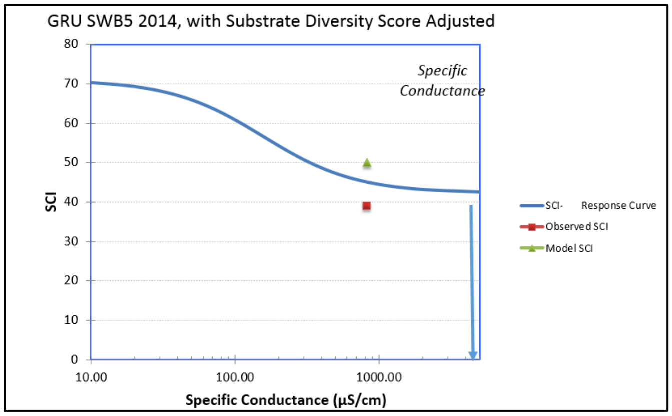

Figure 4-24. GRU Downstream Test Site (2014), with Substrate Diversity adjusted to 16 (a 5-point increase). The equation associated with the Pollman Model predicts a passing SCI at >1,300 µmhos/cm conductivity. The actual SCI was 45 at 827 µmhos/cm but predicted to be 50 if substrate diversity were improved.

Table 4-7. Specific conductance, actual SCI, and predicted SCI (Pollman model) for sites collected and analyzed by FDEP downstream of the MSWRF.

Location	Analyzing Agency	Site name	Date	Actual SCI score	Predicted SCI	Conductivity During SCI Sample
Downstream MSWRF	FDEP	SWB2	10/29/2007	27	42.4	888
Downstream MSWRF	FDEP	SWB3	10/18/2011	34	44.2	720
Downstream MSWRF	FDEP	SWB4	10/18/2011	27	42.9	720
Downstream MSWRF	FDEP	SWB3	2/21/2012	34	43.7	400
Downstream MSWRF	FDEP	SWB5	2/21/2012	39	32.8	400
Downstream MSWRF	FDEP	SWB5	9/11/2012	39	42.1	611
Downstream MSWRF	FDEP	SWB2	4/17/2014	33	42.3	879
Downstream MSWRF	FDEP	SWB5	4/17/2014	45	45.5	827
Mean				**35**	**42**	**681**

Specific conductance, actual SCI, and predicted SCI (Pollman model) for sites collected and analyzed by FDEP downstream of the MSWRF are summarized in **Table 4-7**. Based upon actual conditions in Sweetwater Branch, downstream of MSWRF, the Pollman Model predicts an average SCI score of 42 at a conductivity of 681 µmhos/cm, which is similar to the fourteen-year average conductivity of 719 µmhos/cm measured downstream of MSWRF. Based on the information in **Figure 4-15** through **Figure 4-24**, when Substrate Diversity was adjusted upward by 5 points (adding a single habitat), the Pollman Model predicts routine passing SCI scores in Sweetwater Branch at conductivities of over 1,200 µmhos/cm. Note that the water quality standard for specific conductance is a maximum of 1,275 µmhos/cm in predominantly freshwater systems, meaning that Sweetwater Branch complies with the standard. Therefore, as seen by both the unaltered model output, when the model was adjusted for a decrease in conductivity, and when the model was adjusted for a moderate increase in substrate diversity, the existing conductivity range in Sweetwater Branch does not appear to be a significant stressor to the invertebrate community.

While addition of another habitat type would be predicted to improve the biological conditions in Sweetwater Branch, it should be noted that the original channelization (and habitat removal) occurred prior to the Clean Water Act, to provide for flood control in the City of Gainesville. Due to the extreme hydrologic disturbance in the watershed, physical addition of some habitat types, such as leaf packs, may not be practical, because this substrate type would be scoured away during even minor to moderate rain events. Addition of some habitat types, such as large woody debris, may potentially exacerbate flooding, which could result in adverse human health and economic effects. Therefore, physical habitat addition may be inconsistent with the historic and current use of Sweetwater Branch.

4.6 Step 5: Identify Probable Causes

Explanation of the types of evidence used for CADDIS is shown in **Table 4-8**. EPA (2015) suggested scoring the potential causative stressors according to **Table 4-9** (an example shown for causal pathway). EPA then suggests following a decision guide for evaluating Stressor ID evidence (**Table 4-10)**.

Following EPA (2015) recommendations, a table specific to Sweetwater Branch was compiled to assess potential stressors according to a variety of evidence types. These included spatial/temporal co-occurrence, evidence of exposure or biological mechanism, causal pathway, stressor-response relationships from the field, manipulation of exposure, laboratory tests of site media, temporal sequence, verified predictions, and symptoms (see **Appendix 8).**

Because all floral metrics complied with Rule 62-302.531, F.A.C., (downstream of the discharges) and because there were no statistically significant changes in floral metrics associated with the discharges, TN and TP were ruled out as potential stressors. The KGS and MSWRF discharges were not associated with any significant changes in SCI scores (which averaged < 40 throughout Sweetwater Branch, including upstream of any point source discharge), meaning factors other than the NPDES discharges were responsible for the lower-than-expected SCI scores.

Rule 62-302.531(2)(a)1.d., F.A.C allows a site specific nutrient interpretation, even with failing SCIs, as long as floral metrics indicate no imbalances in flora and a stressor identification study demonstrates that the adverse biological effects are not due to nutrients. This chapter has systematically demonstrated that nutrients are not causing the low SCI scores in Sweetwater Branch, and that the responsible stressors are hydrologic modification, sediment movement, and habitat alterations. Direct empirical evidence (*e.g.,* SCI passing at conductivities exceeding 800 µmhos/cm in Sweetwater Branch) and use of Dr. Pollman's model indicated that specific conductance was not a significant stressor to the invertebrate community.

Explanations for the types of evidence used for the CADDIS evaluation are shown in **Table 4-8**, and a summary of the information and the interpretation of the influence of each candidate stressor in Sweetwater Branch is shown in **Table 4-11**.

The probable causes and supporting evidence for the observed SCI impairments in Sweetwater Branch are summarized in **Appendix 8.**

Table 4-8. Explanation of the types of evidence used for CADDIS (from EPA 2015).

Types of Evidence that Use Data from the Case	
Type of Evidence	The Concept
Spatial/Temporal Co-occurrence	The biological effect must be observed where and when the cause is observed and **must not** be observed where and when the cause is absent.
Evidence of Exposure or Biological Mechanism	Measurements of the biota show that relevant exposure to the cause has occurred, or that other biological mechanisms linking the cause to the effect have occurred.
Causal Pathway	Steps in the pathways linking sources to the cause can serve as supplementary or surrogate indicators that the cause and the biological effect are likely to have co-occurred.
Stressor-Response Relationships from the Field	*As* exposure to the cause increases, intensity or frequency of the biological effect increases as exposure to the cause decreases, intensity or frequency of the biological effect decreases.
Manipulation of Exposure	Field experiments or management actions that increase or decrease exposure to a cause must increase or decrease the biological effect.
Laboratory Tests of Site Media	Controlled exposure in laboratory tests to causes (usually toxic substances) present in site media should induce biological effects consistent with the effects observed in the field.
Temporal Sequence	The cause must precede the biological effect.

Verified Predictions	Knowledge of a cause's mode of action permits prediction and subsequent confirmation of previously unobserved effects.
Symptoms	Biological measurements (often at lower levels of biological organization than the effect) can be characteristic of one or a few specific causes.
Types of Evidence that Use Data from Elsewhere	
Type of Evidence	The Concept
Stressor-Response Relationships from Other Field Studies	At the impaired sites, the cause must be at levels sufficient to cause similar biological effects in other field studies.
Stressor-Response Relationships from Laboratory Studies	Within the case, the cause must be at levels associated with related biological effects in laboratory studies.
Stressor-Response Relationships from Ecological Simulation Models	Within the case, the cause must be at levels associated with effects in mathematical models simulating ecological processes.
Mechanistically Plausible Cause	The relationship between the cause and biological effect must be consistent with known principles of biology, chemistry, and physics, as well as properties of the affected organisms and the receiving environment.
Manipulation of Exposure at Other Sites	At similarly impacted locations outside the case sites, field experiments or management actions that increase or decrease exposure to a cause must increase or decrease the biological effect.
Analogous Stressors	Agents similar to the causal agent at the impaired site should lead to similar effects at other sites.
Evaluating Multiple Types of Evidence	
Type of Evidence	The Concept
Consistency of Evidence	Confidence in the argument for or against a candidate cause is increased when many types of evidence consistently support or weaken it.
Explanation of the Evidence	Confidence in the argument for a candidate cause is increased when a post hoc mechanistic, conceptual, or mathematical model reasonably explains any inconsistent evidence.

Table 4-9. Scoring for potential causative stressors.

Finding	Interpretation	Score
Data show that all steps in at least one causal pathway are clearly present.	This finding *very strongly supports* the case for the candidate cause, because it is improbable that all steps occurred by chance.	**+++**
Data show that all steps in at least one causal pathway are present.	This finding *strongly supports* the case for the candidate cause, because it is improbable that all steps occurred by chance; it is not convincing because these steps may not be sufficient to generate sufficient levels of the cause.	**+ +**
Data show that some steps in at least one causal pathway are present.	This finding *somewhat supports* the case for the candidate cause.	**+**
Data show that the presence of all steps in the causal pathway is uncertain.	This finding *neither supports nor weakens* the case for the candidate cause.	**0**
Data show that there is at least one missing step in each causal pathway.	This finding *somewhat weakens* the case for the candidate cause but is not strongly weakening because it may be due to temporal variability, problems in sampling or analysis, or unidentified alternative pathways.	**-**

Finding	Interpretation	Score
Data show, with a high degree of certainty, that there is at least one missing step in each causal pathway.	This finding *convincingly weakens* the case for the candidate cause, assuming critical steps in each pathway are known, and are not found at the impaired site after a well-designed, well-performed, and sensitive study.	- -
Data show, with a high degree of certainty, that there is clearly at least one missing step in each causal pathway.	This finding very *convincingly weakens* the case for the candidate cause, assuming critical steps in each pathway are known, and are not found at the impaired site after a well-designed, well-performed, and sensitive study.	- - -

Table 4-10. Decision making guide for evaluating Stressor ID evidence. Adapted from EPA CADDIS, 2015.

Situation	Status	Code
Cause refuted by indisputable evidence	Refuted	R
Cause of impairment identified by diagnostic symptoms	Diagnosed	D
Cause of impairment refuted by diagnostic symptoms	Refuted	R
All evidence supports the case for the cause, evidence for three or four characteristics of causal relationships	Probable	P
All evidence weakens the case for the cause, evidence against three or four characteristics of causal relationships	Unlikely	U
All evidence supports the case for the cause, evidence for only one or two characteristics of causal relationships	Probable with low confidence	PL
All evidence weakens the case for the cause, evidence against one or two characteristics of causal relationships	Unlikely with low confidence	UL
Some evidence supports and some weakens the case for the cause	Unlikely with low confidence	UL
Insufficient evidence to make a determination	No evidence	NE
Not applicable	Not applicable	NA

Table 4-11. Conclusions regarding the influence of each candidate stressor on low SCI scores in Sweetwater Branch.

Stressor	Explanation	CADDIS Conclusion
TN and TP	There are no adverse floral effects in Sweetwater Branch associated with the nutrient regime, and by following the process established by Chapter 62-302, F.A.C. (FDEP 2013), it is reasonable to conclude that the nutrient levels are protective of the Class III designated aquatic life use. Further, there were no statistically significant changes in flora or SCI scores associated with either discharge. Modeling demonstrated that the floral community would be protected at the nutrient levels associated with the **WQBELs.**	**R (Refute)**
Ammonia	Ammonia is low in Sweetwater Branch and no sample exceeded FDEP's chronic Total Ammonia Nitrogen criterion.	**R (refute)**
DO	The DO percent saturation data between KGS and MSWRF and downstream of MSWRF exceeded the DO criterion in only 1.4% and 0% of the samples, respectively, meaning DO consistently complied with water quality standards downstream of the discharges. DO was lower upstream of KGS and could have influenced communities there.	**– –**

Metals/toxicity	Metals were sampled and toxicity tests performed in 1992, 1996, 2008 and 2014, at one or both point source discharges and either were not detected or were present in concentrations that complied with water quality standards. No acute or chronic toxicity was observed to either the fish or invertebrate test organisms.	**– – –**
Organics/pesticides/ toxicity	No organic contaminants or pesticides were detected in samples collected in 1992, 1996, 2008 and 2014 at one or both point source discharges. No acute or chronic toxicity was observed at either discharge in either the fish or invertebrate test organisms during the same time period.	**– – –**
Specific Conductance	Using existing conditions in Sweetwater Branch, the Pollman Model predicts average SCI scores of 42 at a concurrently measured average conductivity of 681 µmhos/cm, downstream of the MSWRF. This conductivity downstream of the MSWRF approximates the fourteen-year average conductivity of 719 µmhos/cm measured there. When the conductivity of a site downstream of the MSWRF was substituted with the average upstream conductivity value, the Pollman model predicted an SCI increase of only 2 points (from 45 to 47 points). When Substrate Diversity was adjusted upward by 5 points (adding a single habitat), the Pollman Model predicts passing SCI scores in Sweetwater Branch at conductivity greater than 1,200 µmhos/cm. Therefore, as seen by both the unaltered model output and when the model was adjusted for a decrease in conductivity and an increase in substrate diversity, the existing conductivity range in Sweetwater Branch does not appear to be a significant stressor to the invertebrate community.	**–**
Excess Plant Biomass	There are no adverse floral effects in Sweetwater Branch associated with the nutrient regime, and by following the process established by Chapter 62-302, F.A.C. (FDEP 2013), it is reasonable to conclude that the nutrient levels are protective of the Class III designated aquatic life use. The vascular plants were disturbed only at the upstream control site, where nutrients achieved the regional thresholds.	**R (refute)**
Hydrologic Modification (related to Landscape Intensity Stress and Impervious Surfaces)	Based on the land use categories and their respective percent directly connected impervious areas, **37.94 %** of the Sweetwater Branch watershed is calculated to be impervious, which would be associated with low benthic macroinvertebrate taxa richness, a critical component of the SCI. High LDI values are associated with greater impervious surfaces and hydrologic alterations. Spearman's Correlation Coefficient between the LDI and the SCI ($p < 0.01$) was **-0.60**, meaning that low SCI scores (below 40) would be expected based on the strong correlation with the high LDI (**6.4**) for the Sweetwater Branch watershed. Spearman's Correlation Coefficient between the Hydrologic Modification Score and the SCI ($p < 0.01$) was **-0.71**, meaning that low SCI scores would generally be expected based on the strong correlation with the high **Hydrologic Modification Score (9)** for the Sweetwater Branch watershed.	**+++**
Adverse Habitat Alterations	Spearman's Correlation Coefficient between Habitat Assessment and the SCI ($p < 0.01$) was **0.66**, indicating a strong correlation. The average HA scores in Sweetwater Branch upstream of Kelly, between Kelly and MSWRF, and downstream of Kelly were 61, 77, and 95 (out of 160), respectively, demonstrating that habitat stress is adversely affecting invertebrates in Sweetwater Branch.	**+++**
Sedimentation	There is an annual mean of 45,900 ft^3 of sediment movement and subsequent deposition in the Sweetwater Branch (Jones Edmunds 2010). Consequently, the average Habitat Smothering score downstream of the MSWRF was in the marginal range (7.8) and the average substrate availability score was in the marginal range (with 7.7 points).	**+++**
Human Disturbance Gradient: Combined Effects of Hydrologic Modification, Habitat, and LDI	Using Sweetwater Branch downstream of the MSWRF as an example, ammonia averaged 0.07 mg/L (receiving 0 HDG points, meaning no adverse influence from ammonia), the average habitat assessment scored 95 points (receiving 1 point on the HDG), the hydrologic modification score was 9 (receiving 2 HDG points), and the LDI was 6.4 (receiving 2 points on the HDG). Therefore, the total HDG score for Sweetwater Branch downstream of the MSWRF is 5 points. When the HDG was regressed against the SCI, an HDG score of 5 would be expected to score below 40 on the SCI. The observed average SCI values in	**+++**

	Sweetwater Branch upstream of KGS, between KGS and MSWRF, and downstream of the MSWRF were 21, 36, and 35, respectively.	

5 QUAL2K MODELING TO ESTABLISH THE WQBELS

Section 5 consists of a separate "stand-alone" document (**Section 5**) that is part of the WQBEL demonstration. A brief description of the chapter and the citation is presented here. Modeling was conducted by Dynamic Solutions (Dynamic Solutions, 2021) to establish the Water Quality Based Effluent Limitations for both facilities discharging to Sweetwater Branch, including accounting for stormwater inputs. The QUAL2K model, which was developed by Dynamic Solutions (Dynamic Solutions, 2019) and calibrated to data collected within the upper and lower reaches of Sweetwater Branch, provides a technically credible water quality model framework for assessing the potential effects of two separate NPDES discharges, including the Kelley Generating Station (KGS) and Main Street Water Reclamation Facility (MSWRF), on water quality and biological conditions in the stream. The model was developed to incorporate the interactions of physical transport, point and nonpoint source inputs, nutrients and effluent loading from KGS and the MSWRF on water quality and biological distributions including nutrients, phytoplankton and periphyton biomass in upper and lower Sweetwater Branch. The QUAL2K model was used as a reliable quantitative modeling tool to support establishment of the Level II Water Quality Based Effluent Limitations (WQBEL) for nutrients for both KGS and MSWRF. The results of the QUAL2K model were used to develop a Hierarchy I interpretation of Numeric Nutrient Criteria for Sweetwater Branch (Dynamic Solutions, 2021).

6 MODELING TO DEMONSTRATE DOWNSTREAM PROTECTION

Section 6 consists of a separate "stand-alone" document (**Section 6**) that is part of the WQBEL demonstration. A brief description of the chapter and the citation is presented here. Wetland Solutions (Wetland Solutions, 2021) conducted modeling to assess downstream protection of the proposed WQBELs. Modeling of the Sweetwater Enhancement Wetlands for nutrient removal performance using the P-k-C* steady state model with the proposed nitrogen WQBELs for MSWRF and KGS, along with worst-case non-point source loads, demonstrated that with nutrient loadings at proposed NNC levels, the effluent from the Sweetwater Enhancement Wetlands will meet the 3 mg/l TN and 0.3 mg/l TP limits specified in the Sweetwater Wetlands Project's Environmental Resource Permit (ERP), and the proposed criteria will be protective of the Paynes Prairie Sheetflow Restoration area wetlands downstream of the Sweetwater Wetlands, and Alachua Sink (Wetland Solutions, 2021).

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8 APPENDICES

8.1 WQ DATA

Data were compiled from IWR, Alachua Co., GRU, and FDEP. Duplicates were removed and data were sorted by location and year prior to analysis.

WQ_compiled_data
_Sweetwater.csv

8.2 NUTRIENT DATA

Data were compiled from IWR, Alachua Co., GRU, and FDEP reports, spreadsheets, and databases. Duplicates were removed and data were sorted by location and year prior to analysis. Chlorophyll data, when needed, were converted to ug/L from mg/L prior to analysis.

nutrient_compiled_
sweetwater.csv

8.3 BIOLOGY DATA

Data were compiled from IWR, Alachua Co., GRU, and FDEP reports, spreadsheets, and databases. Duplicates were removed based on sample date, time, and latitude/longitude.

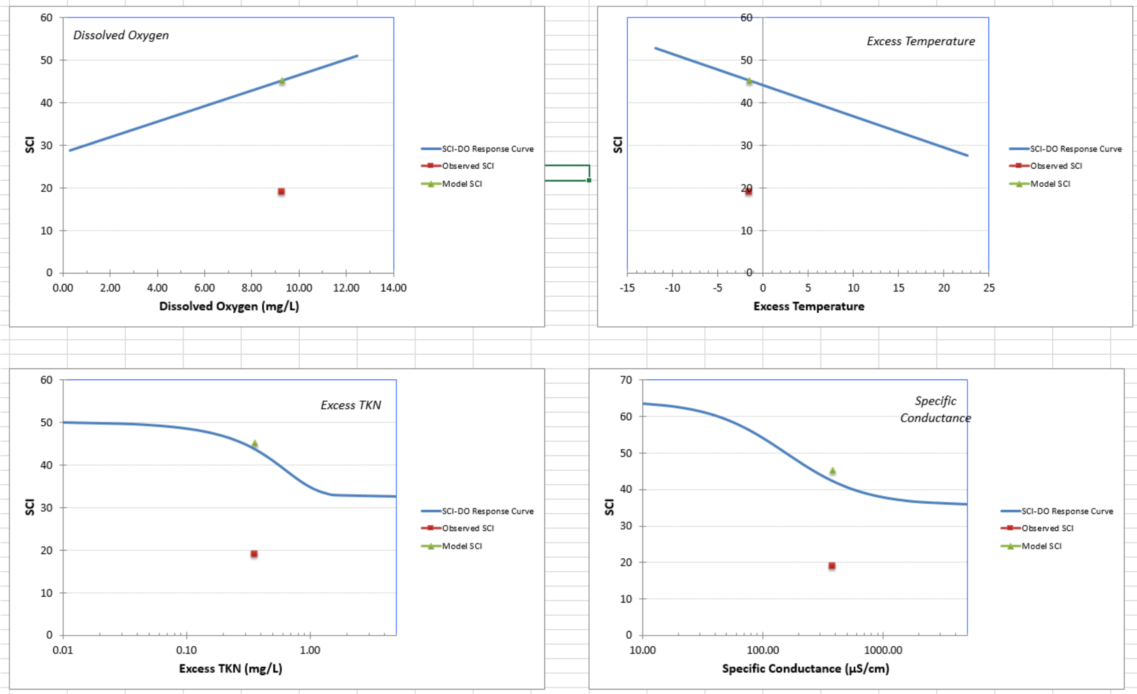
bio_data_compiled_
sweetwater.csv

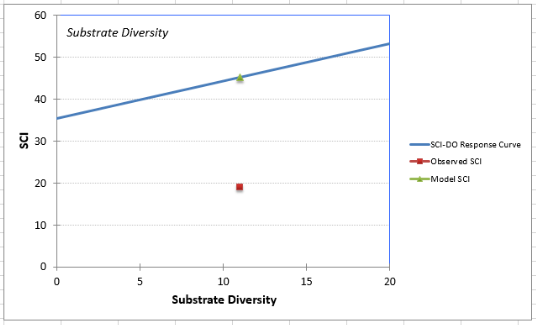
8.4 ADDITIONAL STRESSOR IDENTIFICATION INFORMATION

8.4.1 GRU Data Input for Pollman Model.

Location	Agency	Site name	Date	Latitude	**SCI score**	**Predicted SCI**	Color	Conductivity	DO (mg/L)	TKN	Channelization	Sub diversity	Velocity	Temperature
up	FrEcol	SWBSE2	4/16/2014	29.6323	**23**	**40.8**	25	189	6.48	0.17	9	11	8	22.13
up	FDEP	SWB1	10/29/2007	29.6323	**23**	**45.3**	25	381	9.3	0.43	4	11	13	19.9
up	FDEP	REF1	2/21/2012	29.6323	**49**	**40**	25	790	7	0.3	15	11	10	13.75
up	FDEP	REF1	9/11/2012	29.6323	**28**	**41.8**	25	611	7.4	0.62	13	8	12	18.8
up	FDEP	SWB1	4/17/2014	29.6323	**51**	**44.7**	39	414	8.3	0.47	10	8	14	16.9
down	FDEP	SWB2	10/29/2007	29.63113	**27**	**42.4**	25	888	8.6	1.8	13	13	19	23.4
down	FDEP	SWB3	10/18/2011	29.63113	**34**	**44.2**	7.9	720	7.92	0.78	3	12	18	17.79
down	FDEP	SWB4	10/18/2011	29.63113	**27**	**42.9**	9.8	720	7.92	0.835	3	12	17	17.79
down	FDEP	SWB3	2/21/2012	29.63113	**34**	**43.7**	10	400	7.23	0.62	3	11	20	13.75
down	FDEP	SWB5	2/21/2012	29.63113	**39**	**32.8**	10	400	7.23	0.62	3	7	12	13.75
down	FDEP	SWB5	9/11/2012	29.63113	**39**	**42.1**	10	611	7.39	0.62	3	12	13	18.8
down	FDEP	SWB2	4/17/2014	29.63113	**33**	**42.3**	9	879	8.6	0.64	10	6	20	20.5
down	FDEP	SWB5	4/17/2014	29.63113	**45**	**45.5**	18	827	8.2	0.68	11	11	18	19.2

8.4.2 SWB1 (Control) 10-29-07: Pollman model output.




Substrate Diversity
SCI
Substrate Diversity
SCI-DO Response Curve
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Model SCI
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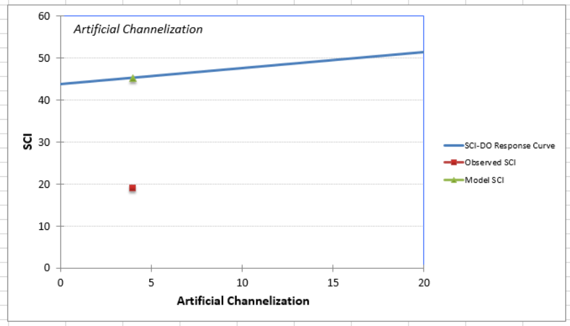
Artificial Channelization
SCI
Artificial Channelization
SCI-DO Response Curve
Observed SCI
Model SCI
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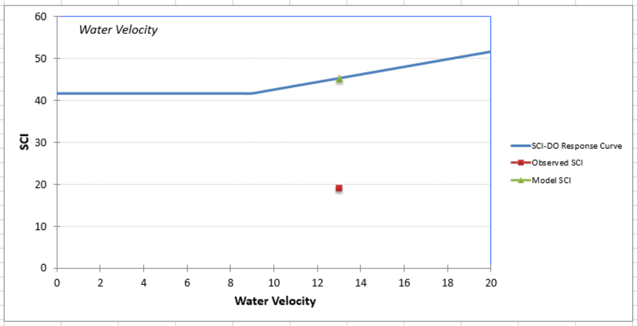
Water Velocity
SCI
Water Velocity
SCI-DO Response Curve
Observed SCI
Model SCI
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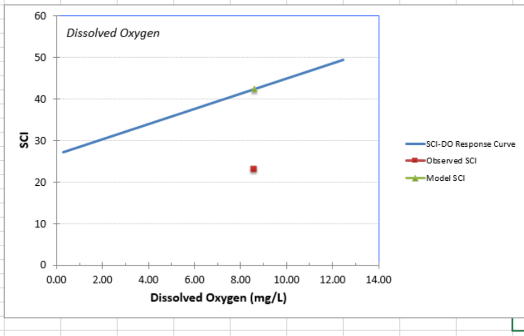
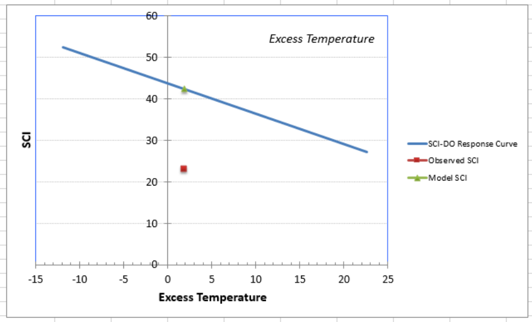
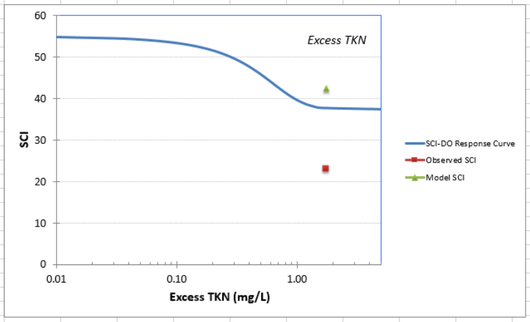
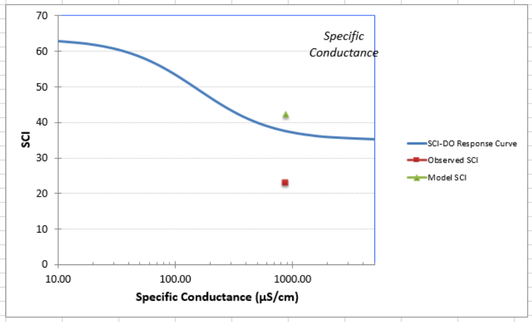
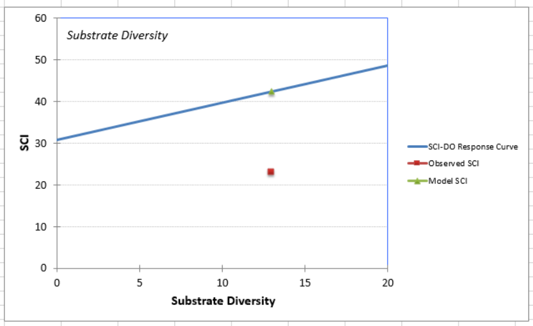
8.4.3 SWB2 (Test) 10-29-07: Pollman model output.

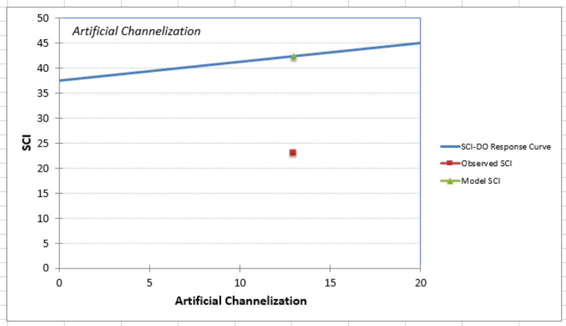


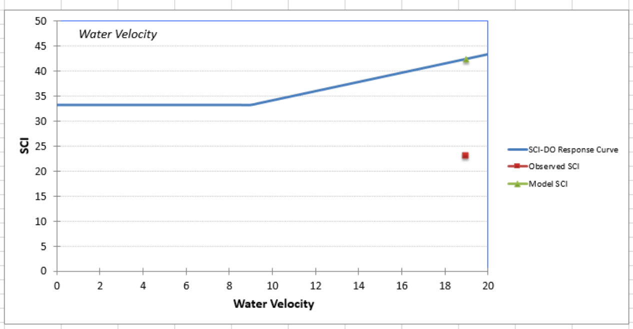




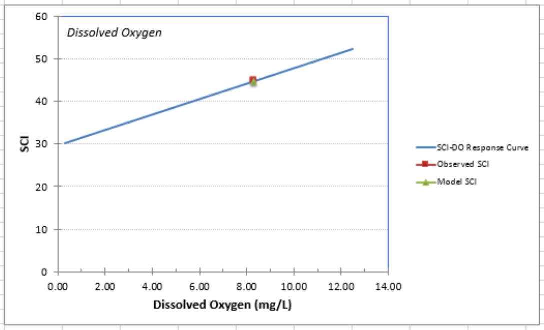


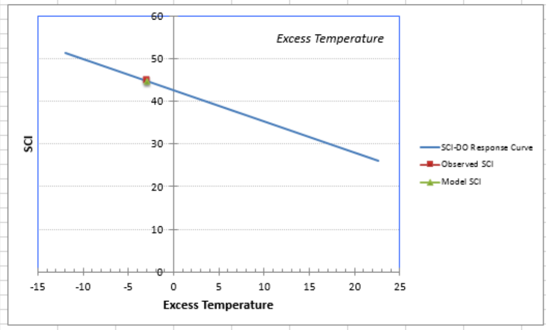


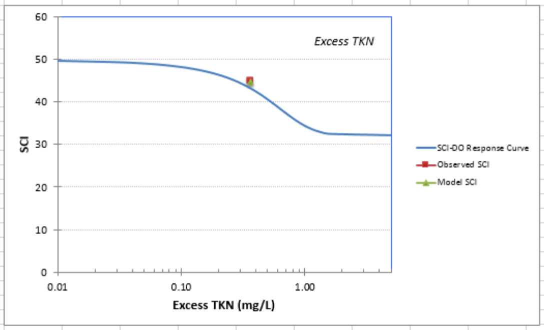


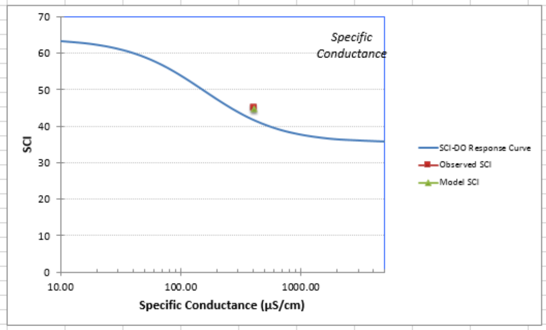


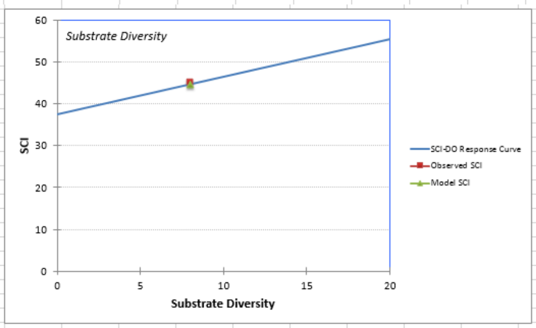
8.4.4 SWB1 (Control) 4-17-14: Pollman model output.

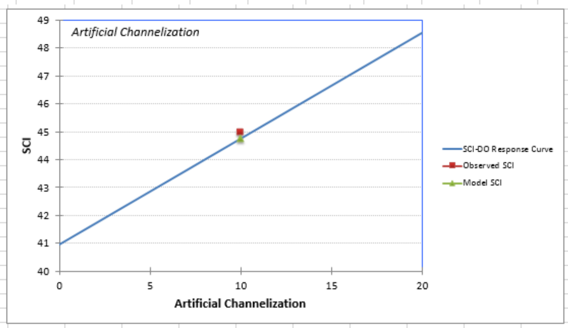


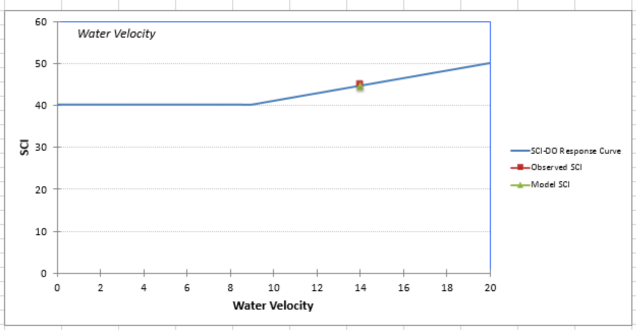




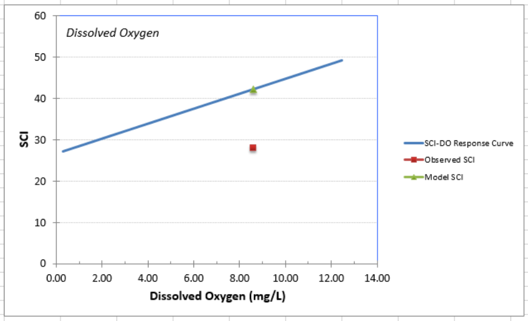


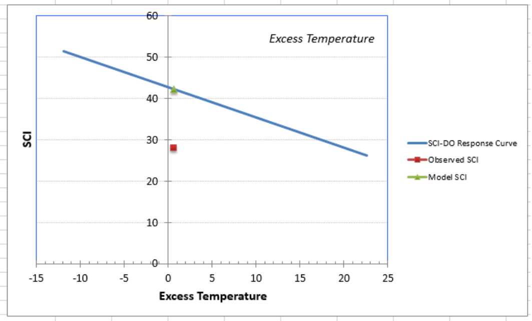


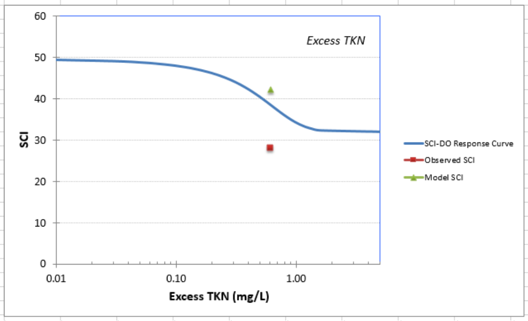


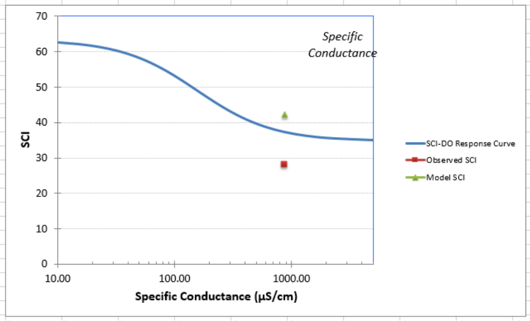


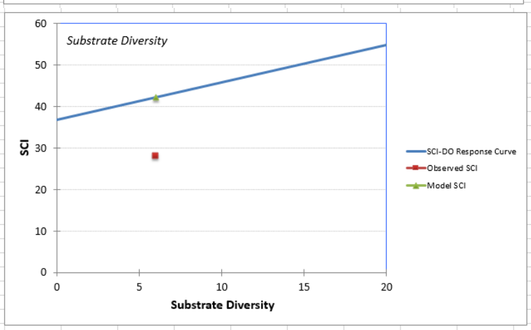
8.4.5 SWB2 (Test) 4-17-14: Pollman model output.

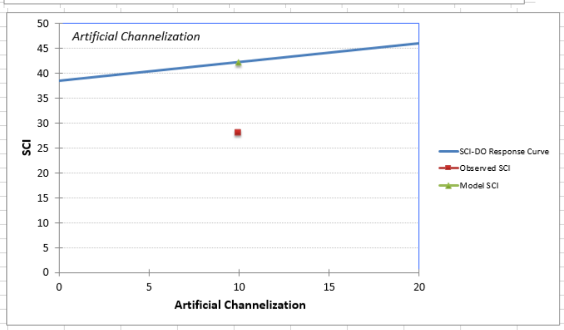


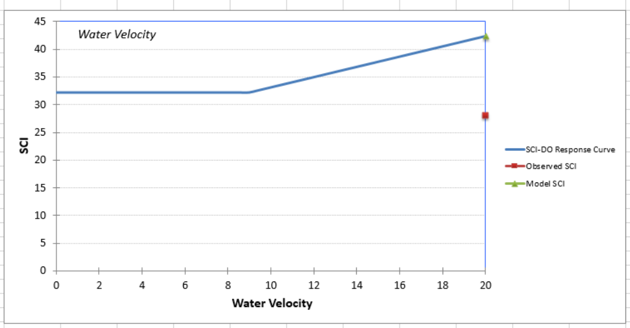






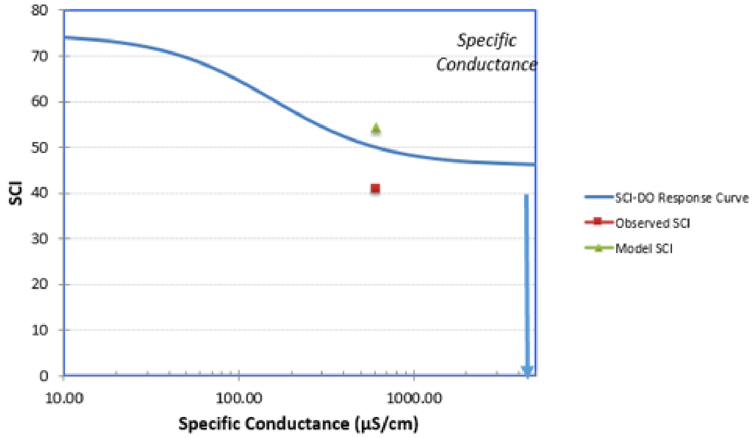






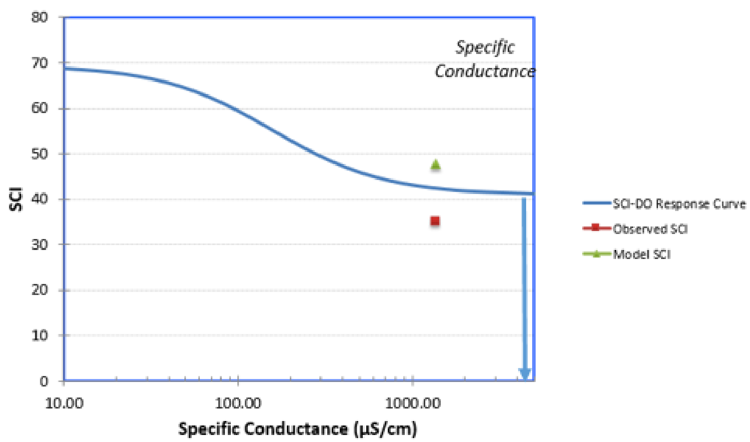
8.4.6 Mid-County WWTP, Pollman Specific Conductance model output.

Mid-County WWTP Test Site: Pollman Model Predicts Passing SCI at 1300 umhos/cm conductivity. Actual SCI 41 at 608 umhos/cm.



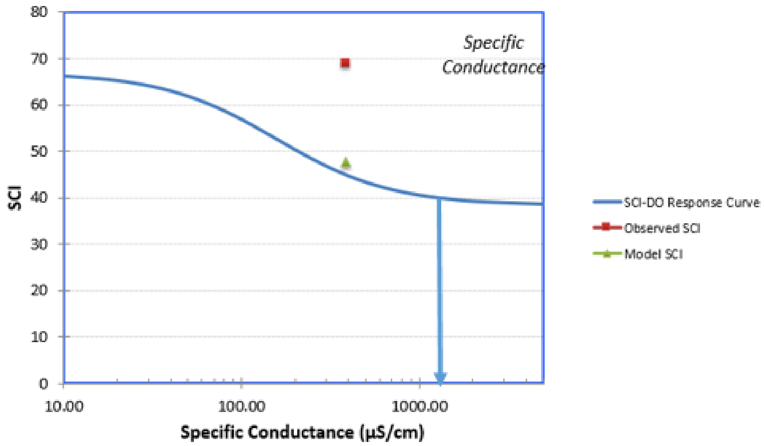
8.4.7 Mosaic South, Ft. Meade, Pollman Specific Conductance model output.

Mosaic South Ft. Meade Test Site: Pollman Model Predicts Passing SCI at 1300 umhos/cm conductivity. Actual SCI 35 at 1354 umhos/cm.



8.4.8 CF North Pasture Test Site, Pollman Specific Conductance model output.

CF North Pasture Test Site: Pollman Model Predicts Passing SCI at 1100 umhos/cm conductivity. Actual SCI 69 at 385 umhos/cm.



8.5 Evaluation Tables for Stressor ID Reasoning

8.5.1.1 *Data from the Case*

TP/TN		
Spatial/Temporal Co-occurrence	---	High nutrients downstream did not result in high biomass. Floral metrics of NNC achieved.
Evidence of Exposure or Biological Mechanism	---	High nutrients downstream did not result in high biomass. Floral metrics achieved.
Causal Pathway	--	Lack of plant overgrowth to cause DO drop or habitat smothering. Observed plants and DO inconsistent with FDEP nutrient model.
Stressor-Response Relationships from the Field	--	No response observed. Flora achieve evidentiary thresholds. No differences up and downstream
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	NE	
Verified Predictions	---	Expected increased biomass with high nutrients did not occur
Symptoms	---	Symptoms of enrichment not observed (NO high chlorophyll, plant overgrowth, or DO limitations)

NH3		
Spatial/Temporal Co-occurrence	---	Ammonia complied with chronic toxicity based WQ standard.
Evidence of Exposure or Biological Mechanism	---	Toxicity not possible based on low concentrations
Causal Pathway	---	Stressor not present
Stressor-Response Relationships from the Field	---	Stressor not present
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	NE	
Verified Predictions	NE	
Symptoms	---	Chronic toxicity not possible based on concentrations, so no symptoms

DO		
Spatial/Temporal Co-occurrence	---	DO complies with criterion downstream of both discharges
Evidence of Exposure or Biological Mechanism	---	DO is higher than WQ standard
Causal Pathway	--	DO is higher than WQ standard
Stressor-Response Relationships from the Field	---	Stressor (low DO) not present

Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	NE	
Verified Predictions	NE	
Symptoms	---	None observed

Excess plant biomass		
Spatial/Temporal Co-occurrence	---	Floral metrics comply with WQ standards downstream of both effluents
Evidence of Exposure or Biological Mechanism	---	Floral metrics comply with WQ standards downstream of both effluents
Causal Pathway	--	No plant overgrowth
Stressor-Response Relationships from the Field	---	No cause effect from nutrients or changes in the plant biomass. More disturbance in vascular plants where NNC thresholds are achieved.
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	--	Rare occurrences of overgrowth in past no longer present. No increase associated with either discharge.
Verified Predictions	--	Plants do not produce excess biomass as expected with excess nutrients
Symptoms	--	No imbalance in flora present downstream of discharges. Meets evidentiary thresholds. Vascular plants more disrupted where NNC thresholds achieved due to physical disturbance.

Habitat and channelization		
Spatial/Temporal Co-occurrence	+	Channelization poor throughout system, SCI degraded at both up and down due to overall suboptimal habitat
Evidence of Exposure or Biological Mechanism	+++	High levels of channelization results in pulsed flow and low habitat availability and substrate diversity.
Causal Pathway	++	Habitat essential for macroinvertebrate presence
Stressor-Response Relationships from the Field	++	Low SCI scores and low habitat co-occurring
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	NE	No undisturbed before state
Verified Predictions	++	SCI calibrated based on relationship, in part, between habitat and SCI
Symptoms	++	Channelization and low habitat scores evident, visually obvious

Metals/toxicity		
Spatial/Temporal Co-occurrence	---	Not detected up, down, or in effluents at levels above WQ standards
Evidence of Exposure or Biological Mechanism	---	Not detected up, down, or in effluents at levels above WQ standards

Causal Pathway	---	Not detected up, down, or in effluents at levels above WQ standards
Stressor-Response Relationships from the Field	---	Cannot have response without presence in system
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	---	Toxicity tests as part of 5-year permit cycles found no toxicity
Temporal Sequence	NE	
Verified Predictions	---	WQ standards based on prediction that being above standard could lead to a problem, but protective if below
Symptoms	--	None observed, no metals in system

Organics/pesticides/toxicity		
Spatial/Temporal Co-occurrence	---	Not detected up, down, or in effluents at levels above WQ standards
Evidence of Exposure or Biological Mechanism	---	Not detected up, down, or in effluents at levels above WQ standards
Causal Pathway	---	Not detected up, down, or in effluents at levels above WQ standards
Stressor-Response Relationships from the Field	---	Cannot have response without presence in system
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	---	Toxicity tests as part of 5-year permit cycles found no toxicity
Temporal Sequence	NE	
Verified Predictions	---	WQ standards based on prediction that being above standard could lead to a problem, but protective if below
Symptoms	--	None observed, no organics/pesticides in system

Conductivity		
Spatial/Temporal Co-occurrence	-	Conductivity increases moving upstream to downstream, but average SCI did not statistically change
Evidence of Exposure or Biological Mechanism	-	No change in SCI, which can respond to conductivity, upstream to downstream
Causal Pathway	-	No statistically significant decrease in SCI corresponding to increase in conductivity
Stressor-Response Relationships from the Field	-	No decrease in SCI corresponding to increase in conductivity
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	NE	
Verified Predictions	-	Curt Pollman model shows SCI should pass at existing levels of conductivity
Symptoms	-	Failing SCI, but not due to “salt tolerant” organisms, and was already failing upstream of both discharges

Hydrology		
Spatial/Temporal Co-occurrence	++	Entire system is hydrologically impaired, and failing SCI scores throughout

Evidence of Exposure or Biological Mechanism	+++	Scouring present, extreme hydrograph
Causal Pathway	++	Impaired hydrology is present in conjunction with low SCI scores, lack of habitat and proper flow
Stressor-Response Relationships from the Field	0	No non-hydrologically modified section to compare
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	NE	No undisturbed before state
Verified Predictions	++	High correlation between hydrologic modification and SCI scores
Symptoms	++	Scouring and smothering present, extreme hydrograph

Sediment		
Spatial/Temporal Co-occurrence	+	Sediment smothering present throughout system, where SCI scores low
Evidence of Exposure or Biological Mechanism	+++	Hydrology and habitat/channelization lead to increased sedimentation in the system. Lack of pools and habitat smothering observed.
Causal Pathway	+++	Lack of pools and habitat smothering
Stressor-Response Relationships from the Field	0	No non -smothered section
Manipulation of Exposure	NE	
Laboratory Tests of Site Media	NE	
Temporal Sequence	NE	No undisturbed before state
Verified Predictions	+	SCI calibrated, in part, based on sedimentation/habitat smothering leading to low SCI score
Symptoms	+	Lack of pools and habitat smothering

8.5.1.2 *Data from Elsewhere*

TP/TN		
Mechanistically Plausible Cause	--	Nutrients can cause excess biomass, which lowers DO, impacting fish/inverts. Excess nutrients are present at site but no nutrient responses.
Stressor-Response Relationships from Other Field Studies	--	FDEP and EPA conducted analyses on a statewide data set and were unable to find a cause-effect relationship for streams. No nutrient response is observed at this site.
Stressor-Response Relationships from Laboratory Studies	-	Lab studies demonstrate increasing nutrients can lead to plant overgrowth. Studies also show low levels of nutrients can cause overgrowth when grazers are excluded. However, no nutrient response observed in Sweetwater Branch.
Stressor-Response Relationships from Ecological Simulation Models	--	Levels of nutrients present can result in increased plant growth in other stream systems but are site specific. No nutrient response observed at this site.
Manipulation of Exposure at Other Sites	--	Everglades mesocosms show effects of TP, but the studies are not applicable to streams, such as Sweetwater branch. Additionally, no nutrient response is observed for this site.
Analogous Stressors	0	Iron addition studies in the open ocean showing addition of iron when limited will cause producer blooms, but not applicable to stream systems. No nutrient response is observed at this site and no analogous stressors applicable to ditches were found.

NH3		
Mechanistically Plausible Cause	--	Lab toxicity studies. Fish/inverts lack ability to convert to carbamoyl phosphate for entrance into urea cycle. Must excrete directly. However, NH3 not present at site above wq criterion.
Stressor-Response Relationships from Other Field Studies	--	Field studies have verified effects of ammonia toxicity, but levels are well below water quality criterion in this case
Stressor-Response Relationships from Laboratory Studies	--	Lab toxicity studies demonstrate harm of ammonia, but ammonia levels comply with water quality standards
Stressor-Response Relationships from Ecological Simulation Models	--	Levels of NH3 would not cause an impact to the biological community
Manipulation of Exposure at Other Sites	--	When excess ammonia is present, species health is greatly improved by removing individuals from exposure, but water quality standards are achieved for the discharges
Analogous Stressors	NA	

DO		
Mechanistically Plausible Cause	--	Macroinvertebrates/fish dependent on enough DO present. However, DO levels achieve criterion downstream of discharges.
Stressor-Response Relationships from Other Field Studies	--	Studies show minimum thresholds required for different species but DO below discharges is well above minimums.

Stressor-Response Relationships from Laboratory Studies	--	Lab studies show minimum thresholds required for different species, but DO below discharges is well above minimums.
Stressor-Response Relationships from Ecological Simulation Models	--	Levels of DO would not cause an impacted biological community except for the control area, where nutrients are low.
Manipulation of Exposure at Other Sites	--	Other previously DO limited sites are improved when DO is increased but DO is above established WQ thresholds downstream of discharges.
Analogous Stressors	NA	

Excess plant biomass		
Mechanistically Plausible Cause	--	Nutrients can cause excess biomass, which lowers DO, impacting fish/inverts. However, no excess algal or plant growth present except occasionally, at both high and low nutrient sites, and sites fail SCI with no excess biomass present (indicating other stressors).
Stressor-Response Relationships from Other Field Studies	--	FDEP and EPA could not find a cause-effect relationship in Florida streams with nutrients and biomass because other factors often more influential (light, grazers, etc.).
Stressor-Response Relationships from Laboratory Studies	NE	Manipulative stream nutrient dosing experiments on Florida streams have not been done to our knowledge. Studies of this nature in Everglades not directly applicable.
Stressor-Response Relationships from Ecological Simulation Models	0	Levels of nutrients present can result in increased plant growth in other stream systems, but modeling in Sweetwater Branch showed no adverse effects from nutrients.
Manipulation of Exposure at Other Sites	-	Plant management that is ongoing and active at other sites does not necessarily cause an increase in SCI due to presence of other stressors, but sometimes does. Excess vegetation and algae are not present in Sweetwater Branch.
Analogous Stressors	NA	

Habitat and channelization		
Mechanistically Plausible Cause	++	Habitat limitations and channelization of stream cause degradation to macroinvertebrate communities. Habitat limitations and channelization are present throughout system.
Stressor-Response Relationships from Other Field Studies	++	The development of the SCI documents the extensive evaluation of various stressors on the macroinvertebrate community. The habitat and channelization scores at SWB predict a lower SCI.
Stressor-Response Relationships from Laboratory Studies	+	Straightening of a stream and removal of habitat shown to decrease organism health and presence. Both of these limitations are present in SWB.

Stressor-Response Relationships from Ecological Simulation Models	+	Curt Pollman's model demonstrates that improving habitat and reducing channelization slightly should lead to improved SCI scores with all other variables remaining constant.
Manipulation of Exposure at Other Sites	+	Supplying enough habitat and reducing channelization improves the macroinvertebrate community (phosphate mitigation studies). Habitat is limiting in SWB and channelization is present, and there is no practical solution without causing flooding in Gainesville
Analogous Stressors	NA	

Metals/toxicity		
Mechanistically Plausible Cause	--	Lab toxicity studies, many mechanistic studies show metals can cause toxic effects. However, water quality standards are achieved in discharge, up, and downstream.
Stressor-Response Relationships from Other Field Studies	--	FDEP, EPA, and scientific literature. Shown to affect mayflies for example. However, water quality standards are achieved for the discharge, up, and downstream.
Stressor-Response Relationships from Laboratory Studies	--	Lab toxicity studies. Shown to effect mayflies for example. However, water quality standards are achieved for the discharges, up and downstream.
Stressor-Response Relationships from Ecological Simulation Models	--	Water quality standards are achieved for the discharges.
Manipulation of Exposure at Other Sites	--	When excess metals are present, biology is improved by removing them, but water quality standards are achieved for the discharges, up, and downstream.
Analogous Stressors	NA	

Organics/pesticides/toxicity		
Mechanistically Plausible Cause	--	Lab toxicity studies and many mechanistic studies show pesticides/organics can cause toxic effects. However, not present in SWB.
Stressor-Response Relationships from Other Field Studies	--	Response documented, but no pesticides/organics detected in SWB.
Stressor-Response Relationships from Laboratory Studies	--	Lab toxicity studies, but no pesticides/organics detected in SWB.
Stressor-Response Relationships from Ecological Simulation Models	--	Levels of pesticides/organic pollutants would not cause an impacted biological community.
Manipulation of Exposure at Other Sites	--	When excess organics/pesticides are present, biology is greatly improved by removing them, but water quality standards are achieved in the discharges.

Analogous Stressors	NA	

Conductivity		
Mechanistically Plausible Cause	+	SCI was developed for freshwater streams, so freshwater organisms will be eliminated/reduced by excess conductivity, resulting in failing SCI. Conductivity is somewhat elevated, but not above water quality standards
Stressor-Response Relationships from Other Field Studies	-	Other SCI sites pass at similar and/or higher levels of conductivity in Florida
Stressor-Response Relationships from Laboratory Studies	0	Lab studies show that high levels of conductivity can affect freshwater organisms. However, conductivity present in system is lower than these studies and complies with criterion.
Stressor-Response Relationships from Ecological Simulation Models	--	Curt Pullman's model shows that passing SCI can still be achieved in sites at current and often greater levels of conductivity (>1300 µmhos/cm)
Manipulation of Exposure at Other Sites	NE	Not aware of field conductivity mesocosms.
Analogous Stressors	NA	

Hydrology		
Mechanistically Plausible Cause	++	Unnatural hydrology impacts macroinvertebrates, and hydrology of system is severely human impacted.
Stressor-Response Relationships from Other Field Studies	++	Studies show that as impervious surfaces go up, biology decreases in stream due to impacted hydrology. The amount of impervious surfaces in this system predicts an impacted biology.
Stressor-Response Relationships from Laboratory Studies	++	Studies showing invert response to very low or very high-water velocity, as occurs with hydro modification.
Stressor-Response Relationships from Ecological Simulation Models	++	Studies pre and post dam removal show improved biology when hydrology improves. Kissimmee river restoration studies also confirm.
Manipulation of Exposure at Other Sites	+	Hydrologic improvements (adding flood plains to ditches, removing impervious surfaces, etc.) reduce the stress on systems and improve biology. Also see Kissimmee River studies.
Analogous Stressors	NA	

Sediment		
Mechanistically Plausible Cause	++	Excessive sedimentation limits available habitat and natural pools, decreasing macroinvertebrate community. Excess sedimentation is present.
Stressor-Response Relationships from Other Field Studies	++	Sedimentation and smothering at similar levels as this site often leads to a failing SCI at other sites in Florida. Studies also show that excessive sediment movement cause "sand blast" effects on inverts.

Stressor-Response Relationships from Laboratory Studies	++	Lab sediment manipulations show adverse effects on invertebrates.
Stressor-Response Relationships from Ecological Simulation Models	++	EPA sediment models used to reduce sediment for TMDL achievement.
Manipulation of Exposure at Other Sites	+	Sediment removal at other sites when coupled with mitigating the root cause of the original sedimentation leads to a return of pools and increased habitat availability. Extreme sedimentation is present.
Analogous Stressors	NA	

Sweetwater Branch Level II Water Quality-Based Effluent Limits Report

Section 5 – Joint Report

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UPDATED: March 24, 2021

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List of Acronyms

1d or 1d (x)	One-dimensional spatial distribution
AFDW	Ash-Free-Dry-Weight (periphyton biomass)
BIN1	Sweetwater Branch: Low flow conditions less than the 25th percentile flow
BIN2	Sweetwater Branch: Medium flow conditions between 25th to 75th percentile flow
BIN3	Sweetwater Branch: High flow conditions greater than the 75th percentile flow
BIN9	Sweetwater Branch: Flow condition for all stream discharge rates
BOD	Carbonaceous + nitrogenous forms of biochemical oxygen demand
BOD5	Carbonaceous + nitrogenous forms of biochemical oxygen demand, 5-day
C:CHL	Carbon-to-Chlorophyll-a ratio
C:DW	Carbon-to-Dry Weight ratio
CBOD	Carbonaceous biochemical oxygen demand, ultimate
CBOD(fast)	QUAL2K state variable for labile organic matter
CBOD(slow)	QUAL2K state variable for refractory organic matter
CBOD5	Nitrogen inhibited carbonaceous form of biochemical oxygen demand, 5-day
CBODU	Carbonaceous biochemical oxygen demand, ultimate
cfs	Discharge rate as cubic feet/sec
Chl or Chl-a	Chlorophyll-a (phytoplankton and periphyton biomass)
cms	Discharge rate as cubic meters/sec
CTBD8	Cooling Tower Blowdown, Unit 8, Kelly Generating Station
CTBD8+LVW	Combined flow, load and flow-weighted equivalent concentration for CTBD8 & LVW
DEP	Florida Department of Environmental Protection
DMR	Discharge Monitoring Reports
DO	QUAL2K State Variable for Dissolved Oxygen
DOC	Dissolved Organic Carbon
DSLLC	Dynamic Solutions, LLC
FDEP	Florida Department of Environmental Protection
GRU	Gainesville Regional Utilities
IWR	Impaired Waters Rule (Florida Dept. Environmental Protection Database)
JEA	Jones Edmunds & Associates
KGS	John R. Kelly Generating Station, Gainesville, Florida
K_n	QUAL2K Half-saturation constant for Nitrogen (phytoplankton and periphyton)
K_N	Nitrification rate
K_p	QUAL2K Half-saturation constant for Phosphorus (phytoplankton and periphyton)
LVW	Low Volume Waste, Kelly Generating Station
MDL	Maximum Daily Load
MGD	Discharge rate as million gallons/day
MSWRF	Main Street Water Reclamation Facility, Gainesville, Florida
N	Nitrogen
NH4	QUAL2K State Variable for Ammonia-N
NNC	Numeric Nutrient Criteria

NO3NO2	QUAL2K State Variable for Nitrate/Nitrite-N
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
ORG-C	Organic Carbon
ORG-N	QUAL2K State Variable for Organic Nitrogen
ORG-P	QUAL2K State Variable for Organic Phosphorus
P	Phosphorus
PIM	QUAL2K State Variable for Inorganic Suspended Solids (Particulate Inorganic Matter)
PO4	Dissolved Orthophosphate-Phosphorus
POC	Particulate Organic Carbon
POM	QUAL2K State Variable for Organic Suspended Solids (Particulate Organic Matter)
PS	Point source
Q	Discharge rate
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SOD	Sediment Oxygen Demand
SR331	State Road 331, Gainesville, Florida
SRP	QUAL2K State Variable for Inorganic Phosphorus (Soluble Reactive Phosphate)
SU	Standard Units for QUAL2K State Variable for pH
TKN	Total Kjeldahl Nitrogen (Total Organic Nitrogen + Ammonia-Nitrogen)
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
WAR	Water and Air Research, Gainesville, Florida
WQBEL	Level II Water Quality-Based Effluent Limitations

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5.0 Modeling Analyses to Determine the WQBEL

Sweetwater Branch is a small stream located in Alachua County in Gainesville, Florida. Ata The upper and lower reaches of the stream, located within the Ocklawaha watershed (USGS Catalog Unit 03080102), receives runoff from an urbanized 3 square mile catchment of Central Gainesville. Sweetwater Branch is ~3.7 miles (5.9 km) in length and Rosewood Branch, the only major tributary to Sweetwater Branch, is approximately 0.9 miles (1.45 km) long. The watershed is characterized by a mean land surface elevation of 180 feet National Geodetic Vertical Datum of1929 (NGVD29) in the upper basin at NE 10th Avenue with elevation decreasing to 59 feet NGVD29 at Paynes Prairie. NPDES dischargers to Sweetwater Branch include two facilities owned and operated by Gainesville Regional Utilities (GRU). The John R Kelly Generating Station (KGS) is a steam electric power generating facility (NPDES ID=FL0026646) that discharges to upper Sweetwater Branch 0.45 miles (0.72 km) upstream of the confluence of Sweetwater Branch with Rosewood Branch. The Main Street Water Reclamation Facility (MSWRF) is a municipal wastewater treatment plant (NPDES ID=FL0027251) that discharges to lower Sweetwater Branch 0.87 miles (1.4 km) downstream of the confluence of Sweetwater Branch with Rosewood Branch. Figure 1 shows a map of the Sweetwater Branch study area with key landmarks.

Beginning in 2014, Dynamic Solutions, LLC developed, confirmed, and applied a QUAL2K water quality model of Sweetwater Branch in Gainesville, Florida under three separate projects for Gainesville Regional Utilities (DSLLC, 2015; 2016; 2017; 2020). Findings from these projects provide the scientific basis needed to establish Level II Water Quality-Based Effluent Limitations (WQBEL) for nutrients (total phosphorus and total nitrogen) for the KGS coal-fired power plant and the MSWRF municipal wastewater treatment facility. The WQBEL provides effluent nutrient limits for the KGS and MSWRF point source discharges that are expected to attain compliance with Florida's nutrient water quality standards. The Florida Department of Environmental Protection (FDEP) requires an evaluation of the in-stream water quality impacts, including the ecological impacts of effluent discharges on stream phytoplankton and periphyton biomass, resulting from NPDES-permitted flows and nutrient loading from the KGS power plant and the MSWRF wastewater effluent discharge to Sweetwater Branch for establishing their respective WQBEL.

The WQBEL approach allows for the establishment of effluent limitations that are determined by FDEP to be protective of the water quality conditions and ecological resources of the stream. With technical support provided by the results of the QUAL2K model for assessments of the water quality and ecological impacts of a worst case condition scenario, GRU will provide reasonable assurance to FDEP that water quality standards will be met in Sweetwater Branch, and that the export of nutrients from Sweetwater Branch and the reduction of nutrients within the Enhancement Wetland Area and Paynes Prairie, will result in compliance with Florida DEP's Total Maximum Daily Load (TMDL) for Total Nitrogen determined for Alachua Sink (Gao et al., 2006).

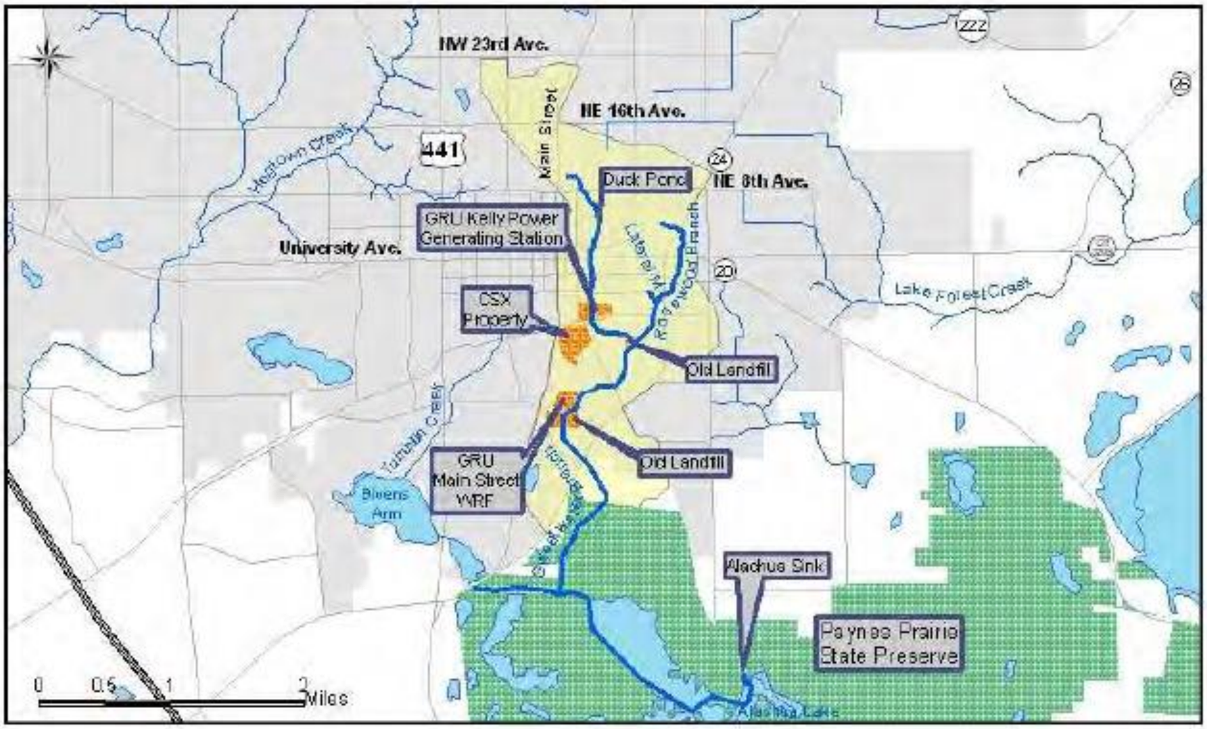


Figure 1 Sweetwater Branch watershed and notable landmarks Source: (Alachua County EPD, 2007)

QUAL2K. The QUAL2K model was selected as being the most cost-effective and appropriate public domain water quality model for establishing the WQBEL for Sweetwater Branch. QUAL2K is designed to assess the water quality impact of point and nonpoint source loading, including alternative streamflow and nutrient loads, on a wide range of water quality interactions including nutrients, water column phytoplankton and benthic algae. The QUAL2K model developed for Sweetwater Branch is shown to provide a technically credible framework for modeling the interactions of physical forcing, stream flow, nutrients, and effluent loading from the KGS and MSWRF effluent discharges on the accumulation and distribution of phytoplankton and periphyton biomass in Sweetwater Branch. The QUAL2K model was developed as a quantitative tool to support establishment of the Level II WQBEL for nutrients for GRU's J.R. Kelly Generating Station (KGS) and Main Street Water Reclamation Facility (MSWRF).

Part 1. In the first part of the project (DSLLC, 2015), the QUAL2K model was developed to include a spatial domain defined by the lower reaches of Sweetwater Branch. The upstream boundary was defined by the confluence of Sweetwater Branch and Rosewood Branch and the downstream boundary was defined by the outflow of Sweetwater Branch into the Enhancement Wetland Treatment project. The purpose of the first modeling study was to evaluate the water quality and biological impacts of the NPDES point source discharge from the MSWRF to Sweetwater Branch. Nonpoint source runoff from urban runoff and baseflow was implicitly included in the model in the specification of the upstream boundary inflow. Downstream of the SR331 gage, nonpoint source loading to Sweetwater Branch was represented in proportion to the estimated drainage area of the lower reaches as 20% of the urban runoff loads of total nitrogen estimated for the Sweetwater Branch watershed in Florida DEP's 2006 TMDL report for Alachua Sink. The estimate of nonpoint source nitrogen loading from the urban land uses of the lower reaches of the stream was added to the simulated export of the total nitrogen load from the downstream outlet of the model domain to derive an estimate of the total nitrogen load delivered to the enhancement wetland. The model was confirmed for three different hydrologic flow conditions using observed meteorological, flow, water quality and biological data compiled for the period from 1998-2012. The period from 1998-2012 was selected to represent effluent loading prior to the upgrade of the MSWRF for phosphorus removal and reductions of phosphorus loading from GRU's John R. Kelly Generating Station (KGS).

Part 2. In the second part of the project, the QUAL2K model domain was extended to add the upper reaches of Sweetwater Branch to the model domain (DSLLC, 2016). The purpose of the second modeling study was to evaluate the water quality and biological impacts of the effluent discharge from the KGS. The spatial domain was extended upstream into the upper reaches of Sweetwater Branch to define a new upstream boundary located a short distance downstream from the Duck Pond weir. The downstream boundary, defined by the outflow from Sweetwater Branch into the Enhancement Wetland Treatment project, was unchanged from the first modeling study. Data compiled for the second model included meteorological data, stream flow, water quality and biological data, NPDES effluent flow and effluent quality data from both KGS and MSWRF, point source tributary inflow from Rosewood Branch, and nonpoint source inflow within the upper and lower reaches of the stream including the reaches of the lower stream below the SR331 gage. The model was confirmed for three different hydrologic flow conditions using data compiled for the period from January 2013 through March 2016. The modeling analysis addressed the impact of effluent discharges from both the KGS and MSWRF outfalls to represent effluent conditions after upgrade of the MSWRF and reductions of phosphorus loading from GRU's KGS coal-fired power plant. Based on predicted nutrient outflow from Sweetwater Branch, methodologies were applied to assess the expected nutrient removal in the Enhancement Wetland Treatment area and Paynes Prairie to estimate the expected nutrient loading exported from Sweetwater Branch to Alachua Sink.

Part 3. In the current third phase of the project (DSLLC, 2017; 2020), the QUAL2K stream model was setup and confirmed to data collected during 2013-2016 and was applied to an assessment of the predicted water quality and biological impact of proposed effluent flow and nutrient loading from the KGS and MSWRF under possible build-out conditions for the City of Gainesville. Upstream boundary flow conditions, representative of baseflow and overland runoff conditions, are based on pooled data from 2004-2016. Upstream boundary water quality data were compiled for the period from 1998-2016 to derive water quality boundary conditions considered to be representative of urban stormwater runoff in this area of Gainesville. The confirmed model was also applied for assessment of the impact of worst-case stormwater flow and loading conditions under the proposed effluent flow and loading scenario for KGS and MSWRF. Predicted stream model results for nutrient export from Sweetwater Branch were then used to provide input flow and nutrient loading data to the wetland model (Wetland Solutions, 2006a, 2006b) that has been developed to represent nutrient removal processes within the Enhancement Wetland Treatment area and Paynes Prairie and the expected nutrient loading exported from Sweetwater Branch and the wetland to Alachua Sink.

5.1 Introduction

The purpose of the project is to provide the Gainesville Regional Utilities (GRU) John R. Kelly Generating Station (KGS) and Main Street Wastewater Reclamation Facility (MSWRF) with the scientific basis needed to establish Level II Water Quality-Based Effluent Limitations (WQBEL) and Numeric Nutrient Criteria (NNC) for nutrients (total phosphorus and total nitrogen). These individual WQBELs will determine effluent nutrient limits for the KGS and MSWRF point source discharges that are expected to attain compliance with Florida's water quality standards. For establishment of a WQBEL, Florida DEP requires an evaluation of the in-stream water quality impacts, including the ecological impacts on stream phytoplankton and periphyton, resulting from NPDES-permitted flows and nutrient loading from effluent discharges to Sweetwater Branch from the KGS coal-fired power plant and the MSWRF. In separate reports, Dynamic Solutions, LLC prepared assessments of the water quality and biological impacts of the existing effluent flow and loading from the MSWRF (DSLLC, 2015) and the KGS (DSLLC, 2016). In the third phase of the project, DSLLC evaluated the predicted water quality and biological impacts of proposed effluent scenarios for KGS and MSWRF and worst-case conditions for stormwater runoff (DSLLC, 2017; 2020).

Section 5 of the Joint WQBEL report presents data sources, model setup, and confirmation of the model based on observed streamflow, effluent loading and ambient water quality conditions in Sweetwater Branch. Data were compiled for model setup and confirmation for the period from 2013-2016 to represent current existing ambient stream conditions, nonpoint source runoff, operating conditions and effluent discharges from the KGS and MSWRF. This period was selected to provide a focus for an evaluation of the water quality and biological impacts of changes in nutrient loading to Sweetwater Branch. In 2013, upgraded phosphorus removal processes were installed to improve effluent quality from the Main Street Wastewater Reclamation Facility and in 2012 treatment processes were modified to reduce phosphorus loading from the KGS.

The confirmed model was applied to assessments of the predicted water quality and biological impact of proposed effluent flow and loading from the KGS and MSWRF under possible build-out conditions for the City of Gainesville. The confirmed model is also applied to an assessment of the impact of worst-case stormwater flow and loading conditions under the proposed effluent flow and loading scenario for KGS and MSWRF. The QUAL2K modeling assessment presented in this report includes a summary of data sources, model setup, model confirmation, and application of the confirmed model to assessments of proposed effluent flow and loads from the KGS and MSWRF.

5.2 QUAL2K MODEL

QUAL2K, a public domain model supported by the U.S. Environmental Protection Agency, simulates the steady-state transport and fate of water quality constituents in a one-dimensional stream (1D) network of one or more headwaters and depth-averaged stream/river channel reaches. Channel hydraulic properties are represented as non-uniform, steady-state flow conditions. External loading of water quality constituents can be assigned as (a) point sources from tributaries or NPDES wastewater discharges and (b) nonpoint source diffuse inputs from watershed runoff. State variables of the QUAL2K model (Table 1) include flow, water temperature, suspended sediments, nutrients, dissolved oxygen, carbonaceous biochemical oxygen demand (CBOD), alkalinity, specific conductance, phytoplankton and benthic algae (periphyton). The representation of periphyton is essential for modeling the impact of nutrient sources in shallow streams and rivers such as Sweetwater Branch. The QUAL2K model framework, unlike the predecessor QUAL2E model (Brown & Barnwell, 1987), incorporates an advanced sediment flux model (Di Toro, 2001) to internally link organic matter deposition from the water column to the sediment bed to model sediment-water fluxes of dissolved oxygen and nutrients. In addition, the QUAL2K model updates some of the QUAL2E scientific representations of water quality interactions, incorporates several new features and provides a user-friendly interface. QUAL2K uses Excel as the graphical user interface for model input, model runs, and display of model results. A description of the theory, assumptions, state equations, and kinetic interactions of the QUAL2K model is given in Chapra, Pelletier, and Tao (2012).

Table 1- State Variables in QUAL2K Model

State Variable	Units
Stream flow	$m^3 sec^{-1}$
Water temperature	Deg C
Conductivity	µmhos
Inorganic Suspended Solids (Particulate Inorganic Matter, PIM)	mg/L
Dissolved Oxygen	mg/L
Slow reacting CBOD	mg/L
Fast reacting CBOD	mg/L
Organic Nitrogen, Total	µg /L
Ammonia-Nitrogen	µg/L
Nitrate+Nitrite-Nitrogen	µg/L
Organic Phosphorus, Total	µg/L
Inorganic Phosphorus (Soluble Reactive Phosphate, SRP)	µg/L
Phytoplankton (Chlorophyll-a)	µg/L
Phytoplankton (Nitrogen)	µg/L
Phytoplankton (Phosphorus)	µg/L
Organic Suspended Solids (Detritus, Particulate Organic Matter, POM)	mg/L

State Variable	Units
Pathogens (not modeled)	cfu/100mL
Alkalinity	mg CaCO3/L
pH	Standard Units
Bottom Algae Biomass (Chlorophyll-a)	mg Chl m^{-2}
Bottom Algae Biomass (Nitrogen)	mg N m^{-2}
Bottom Algae Biomass (Phosphorus)	mg P m^{-2}
General Constituent 1,2,3 (not modeled)	mg/L

Data requirements for setup of the QUAL2K model include the following types of data:

- Channel geometry for reach segmentation and hydraulics
- Streamflow
- Upstream headwater boundary conditions for streamflow and water quality
- Point source flow and effluent quality
- Diffuse nonpoint source flow and water quality
- Meteorological, light, and heat data
- Kinetic coefficients, stoichiometric constants, and model parameters

Data requirements for confirmation of the QUAL2K model include the following types of observed data:

- Streamflow
- Stream depth and stream velocity
- Stream monitoring data for water temperature and water quality
- Stream monitoring data for phytoplankton and periphyton biomass

The input data items listed above were compiled and processed to represent conditions for the 2013-2016 time period used for setup and confirmation of the QUAL2K model of the upper and lower reaches of Sweetwater Branch.

5.3 Data Sources

As described above, types of data required for setup of the QUAL2K stream model include channel geometry, streamflow, NPDES point source effluent records, ambient water quality records, and biological surveys of phytoplankton and periphyton biomass in Sweetwater Branch.

Channel reaches and model segments for the QUAL2K model of Sweetwater Branch were defined using stream survey data collected in 2001-2002 by Jones Edmunds & Associates (JEA, 2010) to characterize geomorphic and stream conditions of the upper and lower reaches of Sweetwater Branch. Additional information regarding channel configuration and geometry for the upper stream reaches was provided by Frydenborg Ecologic (Russell Frydenborg, personal communication, 2016).

Hydraulic data are available for water depth, streamflow and velocity from the Alachua County Gainesville Creeks project and other county projects in the watershed (Robin Hallbourg, 2018). Electronic files with velocity, streamflow and water depth measurements were provided by Alachua County for data collected from 2010-2016. Hydraulic data sets collected before 2010 to support the Gainesville Creeks project (Alachua County, 2003, 2007) and other studies are archived in pdf format with other historical data. As the archived records are available only as handwritten field notes, the data sets were not transcribed and compiled with the data from the electronic data files. Velocity data were also collected by Frydenborg Ecologic, LLC at stations upstream and downstream of the J.R. Kelly Generating Station in 2015 to support this modeling study.

Streamflow data are available from two St. Johns River Water Management District (SJRWMD) gages on Sweetwater Branch. One gage is located upstream of the J.R. Kelly Generating Station (SJRWMD 12522349) and the other gage (SJRWMD 01980199) is located downstream of the MSWRF outfall at State Road 331 (SR331). Effluent discharge data are available from GRU's MSWRF and KGS monthly Discharge Monitoring Report (DMR) effluent files which include effluent quality data from daily operating records.

Water quality data are available from Florida Department of Environmental Protection (FDEP) Impaired Waters Rule (IWR) IWR-Run50, Alachua County data sets that were not included in IWR-Run50, water quality files compiled by Frydenborg Ecologic, LLC for the Plan of Study, and MSWRF monthly DMR files and MSWRF Quarterly files that included ambient water quality data collected at stations upstream and downstream of the MSWRF effluent discharge. In support of this WQBEL study, Frydenborg Ecologic, LLC and GRU's KGS personnel both collected water quality and biological data at stations upstream and downstream of the KGS discharge.

5.4 Model Setup for Sweetwater Branch

5.4.1 Channel Geometry for Reach Segmentation and Hydraulics

The 3.7 mile (6.0 km) upper and lower reaches of Sweetwater Branch downstream of the Duck Pond weir were divided into eleven reaches for the QUAL2K model domain. The model domain for Lower Sweetwater Branch includes JEA Reach 2 (downstream) to JEA Reach 8 (upstream). The model domain for Upper Sweetwater Branch includes reaches of the stream from JEA Reach 9 (Rosewood Branch) through the upstream end of JEA Reach 11. The downstream end of JEA Reach 12 downstream of the Duck Pond weir was used to define the upstream boundary of the model domain as shown in Figure 2. The locations shown in the map mark the downstream end of each of the JEA reaches. The channel profile survey data for the upper and lower reaches are presented in Table 2 and Figure 3. In the upper reaches of the stream, JEA Reach 10 was sub-divided into two sub-reaches (10A and 10B) to represent the location of the inflow of the discharge from the KGS. In the lower reaches of the stream, JEA Reach 6 was sub-divided into two sub-reaches (6B and 6A) to represent the location of the inflow of the wastewater discharge from the MSWRF.

Hydraulic properties in a stream can be represented in QUAL2K with three options: (1) flow over a weir, (2) hydraulic geometry relationships, and (3) Manning's equation. Manning's equation was used with cross-section data from JEA (2010) for Reach 2 through Reach 8 in Lower Sweetwater Branch because stream velocity data were not readily available to develop hydraulic geometry relationships. Reach-dependent coefficients for bottom friction are based on stream bed properties and the literature (Arcement & Schneider, 1989). In the second part of the project, stream depth and velocity data were collected by Frydenborg Ecologic in 2015-2016 at stations upstream and downstream of the KGS discharge location. Streamflow and the new velocity and depth data were used to develop coefficients for hydraulic geometry relationships (Leopold and Maddox, 1953) that were applied to Reaches 9,10, and 11 for Upper Sweetwater Branch. Table 3 and Table 4 present the data used for input to the QUAL2K model to represent reach length, elevation, cross-sections, channel slope, and hydraulic properties.

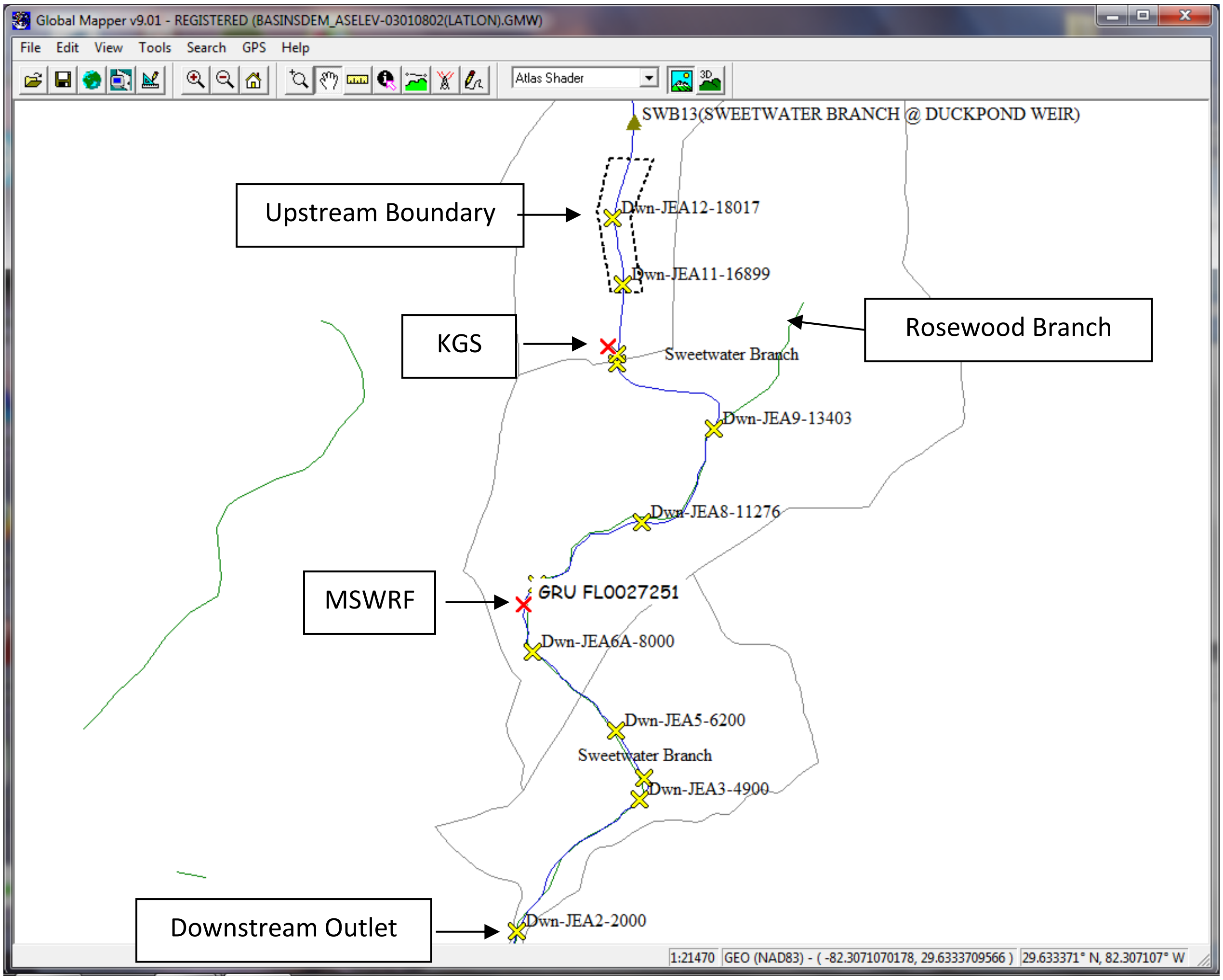
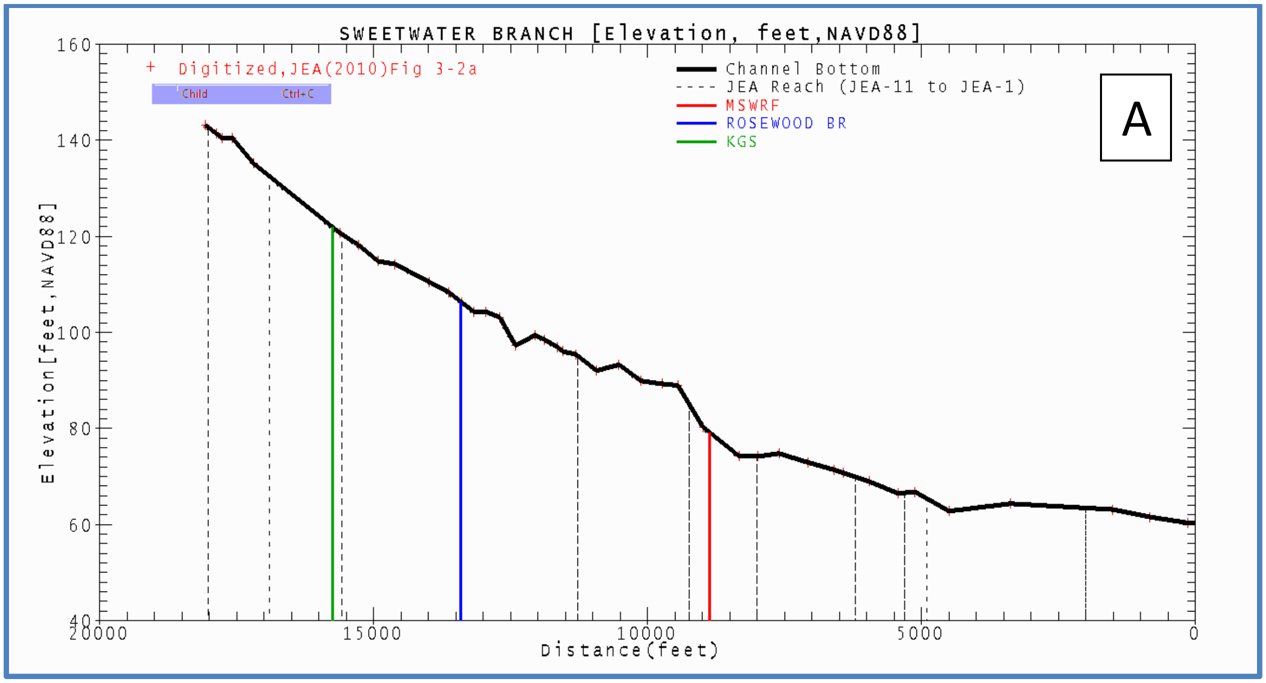


Figure 2- JEA Reaches on Upper and Lower Sweetwater Branch.

Downstream locations of each reach are indicated by yellow X markers. Red X markers show locations of KGS and MSWRF effluent discharges. Black dashed line polygon represents area used to compile station data to assign upstream boundary and NPS inflow water quality conditions.



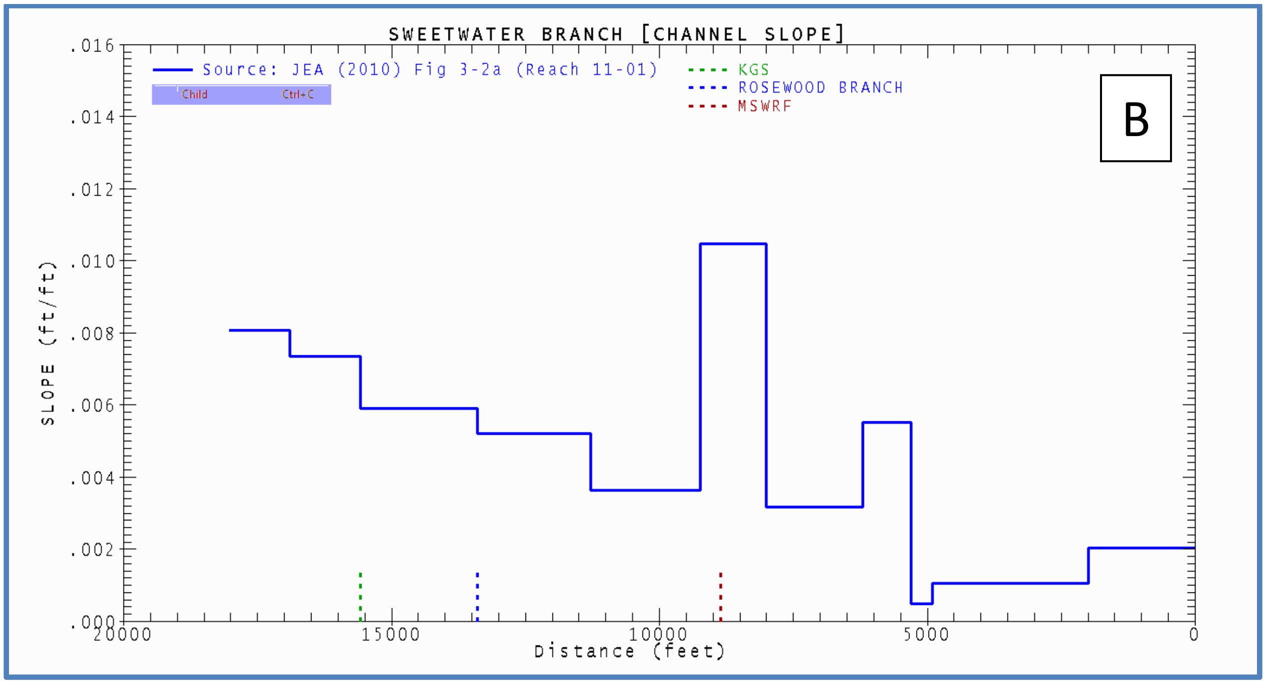


Figure 3- Longitudinal Profile of Sweetwater Branch (A) Channel Bottom Elevation and (B) Channel Slope.

Elevation data digitized from Figure 3-2a in JEA (2010). Location of MSWRF discharge is shown as red line, Rosewood Branch is shown as blue line, and KGS discharge is shown as green line. JEA reach boundaries from JEA Reach 11 (upstream) through JEA Reach 1 (downstream) are shown as black dotted lines.

Table 2- Sweetwater Branch Reach Geometry. Source: JEA (2010).

Source: JEA (2010)			NAVD88	NAVD88		
JEA Reach	DwnStrm X (ft)	Upstrm X (ft)	DwnStrm Elev(ft)	Upstrm Elev(ft)	Length ft	Slope ft/ft
11	16899	18017	132.08	141.12	1118	0.00808
10B	15752	16899	123.64	132.08	1147	0.00736
10A (KGS)	15584	15752	122.40	123.64	168	0.00736
9	13403	15584	109.54	122.40	2181	0.00590
8(Rosewood)	11276	13403	98.45	109.54	2127	0.00521
7	9240	11276	91.06	98.45	2036	0.00363
6B	8857	9240	87.05	91.06	383	0.01048
6A(MSWRF)	8000	8857	78.07	87.05	857	0.01048
5	6200	8000	72.36	78.07	1800	0.00317
4	5300	6200	67.40	72.36	900	0.00551
3	4900	5300	67.20	67.40	400	0.00050
2	2000	4900	64.10	67.20	2900	0.00107
1	0	2000	60.00	64.10	2000	0.00205

Table 3- Sweetwater Branch Channel Geometry Characteristics for QUAL2K Stream Reaches.

	JEA Reach	QUAL2K Reach	DwnSt X (km)	UpStr X (km)	Reach Length (km)	NAVD88 Upstrm Elev (m)	NAVD88 Downstrm Elev (m)	Downstream Lat (N)	Lon (W)
Upper	11	1	5.151	5.492	0.341	43.012	40.259	29.64865	-82.3201
	10B	2	4.801	5.151	0.350	40.259	37.685	29.6455	-82.3204
	10A (KGS)	3	4.750	4.801	0.051	37.685	37.309	29.64508	-82.3204
	9	4	4.085	4.750	0.665	37.309	33.386	29.64212	-82.316
Lower	8(Rosewood)	5	3.437	4.085	0.648	33.386	30.009	29.63788	-82.3193
	7	6	2.816	3.437	0.621	30.009	27.756	29.63507	-82.324
	6B	7	2.700	2.816	0.117	27.756	26.533	29.63413	-82.3247
	6A(MSWRF)	8	2.438	2.700	0.261	26.533	23.795	29.63198	-82.3242
	5	9	1.890	2.438	0.549	23.795	22.056	29.62843	-82.3205
	4	10	1.615	1.890	0.274	22.056	20.544	29.62625	-82.3192
	3	11	1.494	1.615	0.122	20.544	20.483	29.62527	-82.3194
	2	12	0.610	1.494	0.884	20.483	19.538	29.6193	-82.325

Table 4- Sweetwater Branch Hydraulic Characteristics for QUAL2K Stream Reaches.

	JEA Reach	QUAL2K Reach	Upstrm X (km)	Dwnstrm X (km)	Upstrm Elev(m)	DwnStrm Elev(m)	Stream Slope (m/m)	Empirical Rating Curve Velocity Coefficier	Velocity Exponent	Depth Coefficier	Depth Exponent
Upper	11	1	5.492	5.151	43.012	40.259	0.00808	0.134	0.45	1.34	0.4
	10B	2	5.151	4.801	40.259	37.685	0.00736	0.134	0.45	1.34	0.4
	10A(JRK)	3	4.801	4.750	37.685	37.309	0.00736	0.134	0.45	1.34	0.4
	9	4	4.750	4.085	37.309	33.386	0.0059	0.305	0.45	1.34	0.4
	JEA Reach	QUAL2K Reach	Upstrm X (km)	Dwnstrm X (km)	Upstrm Elev(m)	DwnStrm Elev(m)	Stream Slope (m/m)	Manning Coeff "n"	Bottom Width (m)	Left-Side Slope (m/m)	Right-Side Slope (m/m)
Lower	8	5	4.085	3.437	33.386	30.009	0.00521	0.040	3.472	1.900	1.330
	7	6	3.437	2.816	30.009	27.756	0.00363	0.025	4.017	1.750	1.480
	6B	7	2.816	2.700	27.756	26.533	0.01048	0.035	3.500	2.600	1.640
	6A(MSWR	8	2.700	2.438	26.533	23.795	0.01048	0.035	3.500	2.600	1.640
	5	9	2.438	1.890	23.795	22.056	0.00317	0.025	5.095	0.730	0.970
	4	10	1.890	1.615	22.056	20.544	0.00551	0.025	2.664	0.689	0.794
	3	11	1.615	1.494	20.544	20.483	0.0005	0.035	4.237	0.494	0.988
	2	12	1.494	0.610	20.483	19.538	0.00107	0.025	3.804	0.619	1.129

5.4.2 Streamflow Conditions

Using stream flow and effluent flow data compiled from 2004-2016, the urban runoff component of measured stream flow data was derived as the difference between stream flow recorded at SR331 at the SJRWMD Gage 01980199 (Figure 4) and KGS and MSWRF effluent flow (Figure 5). Three flow bin conditions were assigned based on the breakpoints for the 25th and 75th percentiles of the log-transformed stream flow data (Figure 6) as follows:

- BIN1: Low flow conditions, flow less than the 25th percentile flow;
- BIN2: Medium flow conditions, flow between the 25th to 75th percentile;
- BIN3: High flow conditions, flow greater than the 75th percentile

The flow analysis was used to assign the upstream boundary for stream flow downstream of the Duck Pond. Upstream boundary flow for the three flow bin conditions was derived from SR331 stream flow observations and effluent flow records available from both KGS and MSWRF for 2004-2016. Flow records were compiled beginning in 2004 because electronic flow records for KGS effluent discharge were not available earlier than 2004. Summary statistics used to derive the flow bin 25th and 75th percentile breakpoints were compiled from the urban runoff component of stream flow data pooled for the period of record from 2004-2016.

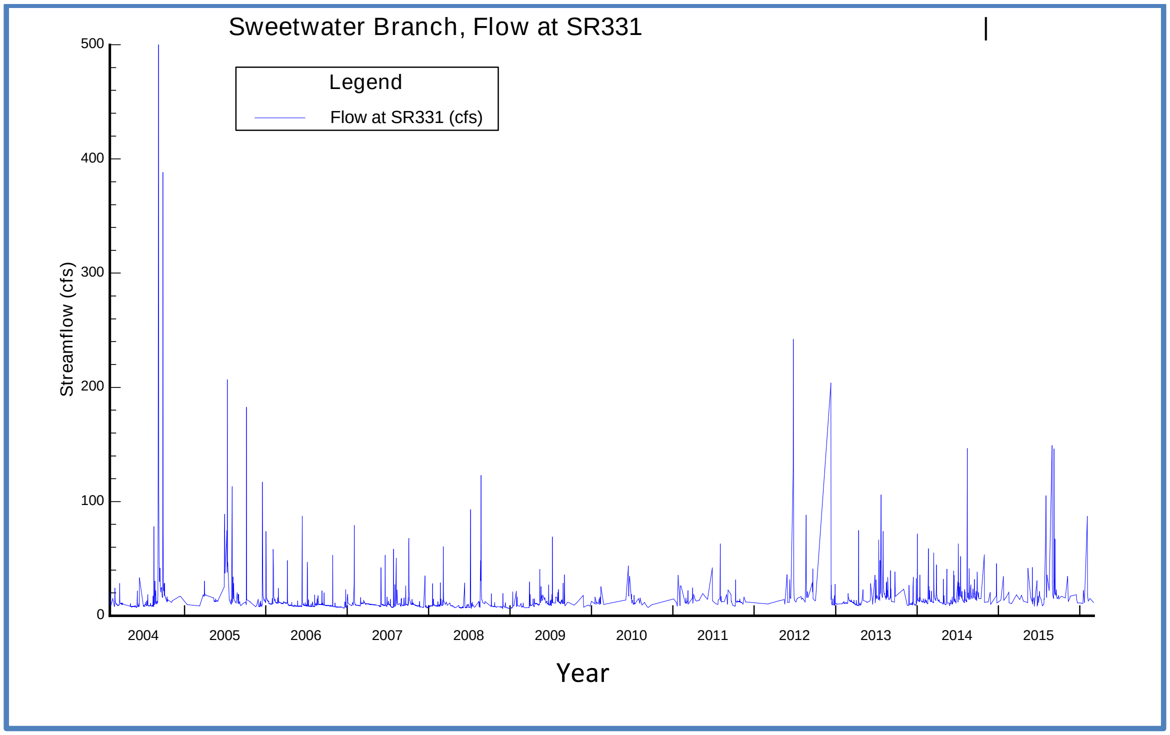


Figure 4- Sweetwater Branch stream flow (as cfs) at SJRWMD Gage 01980199 at SR 331.

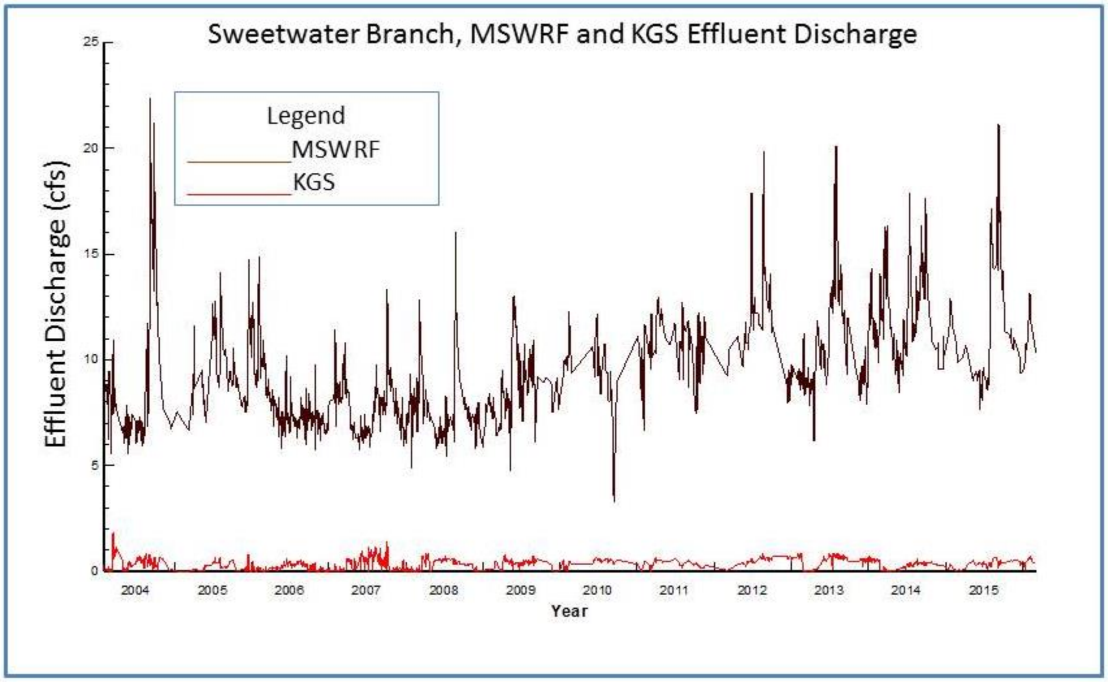


Figure 5- Effluent flow from Main Street Wastewater Reclamation Facility (MSWRF) and John R. Kelly Generating (KGS) station discharges to Sweetwater Branch.

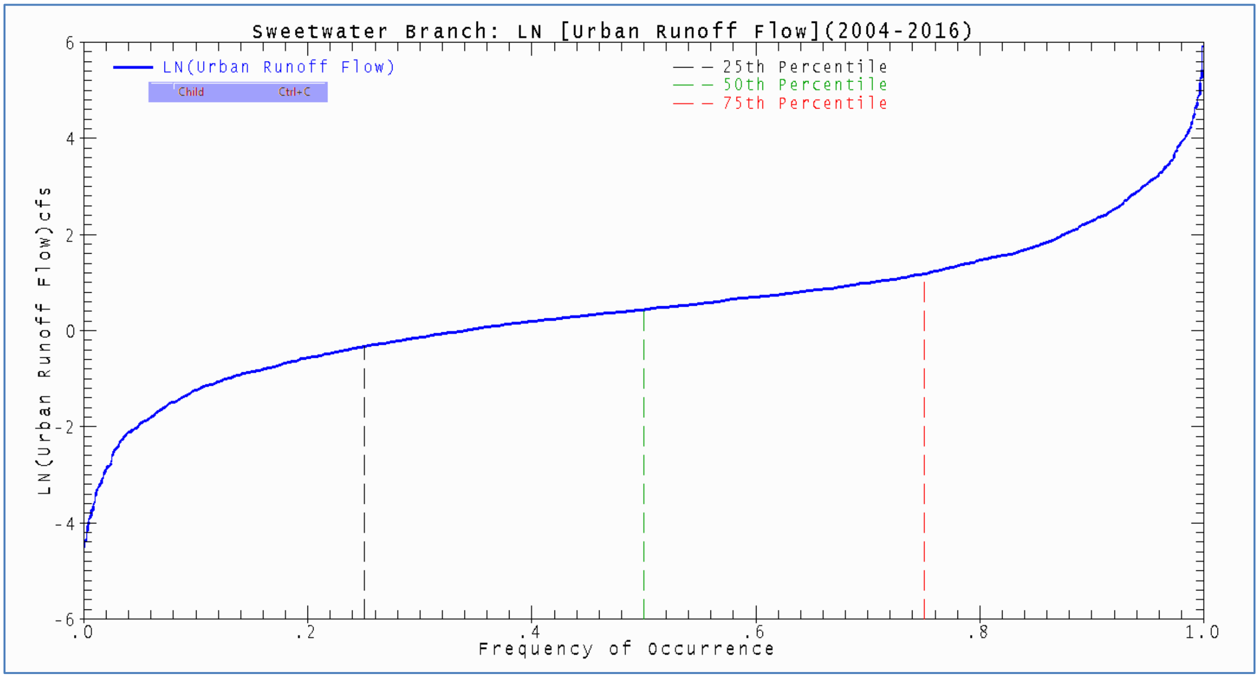


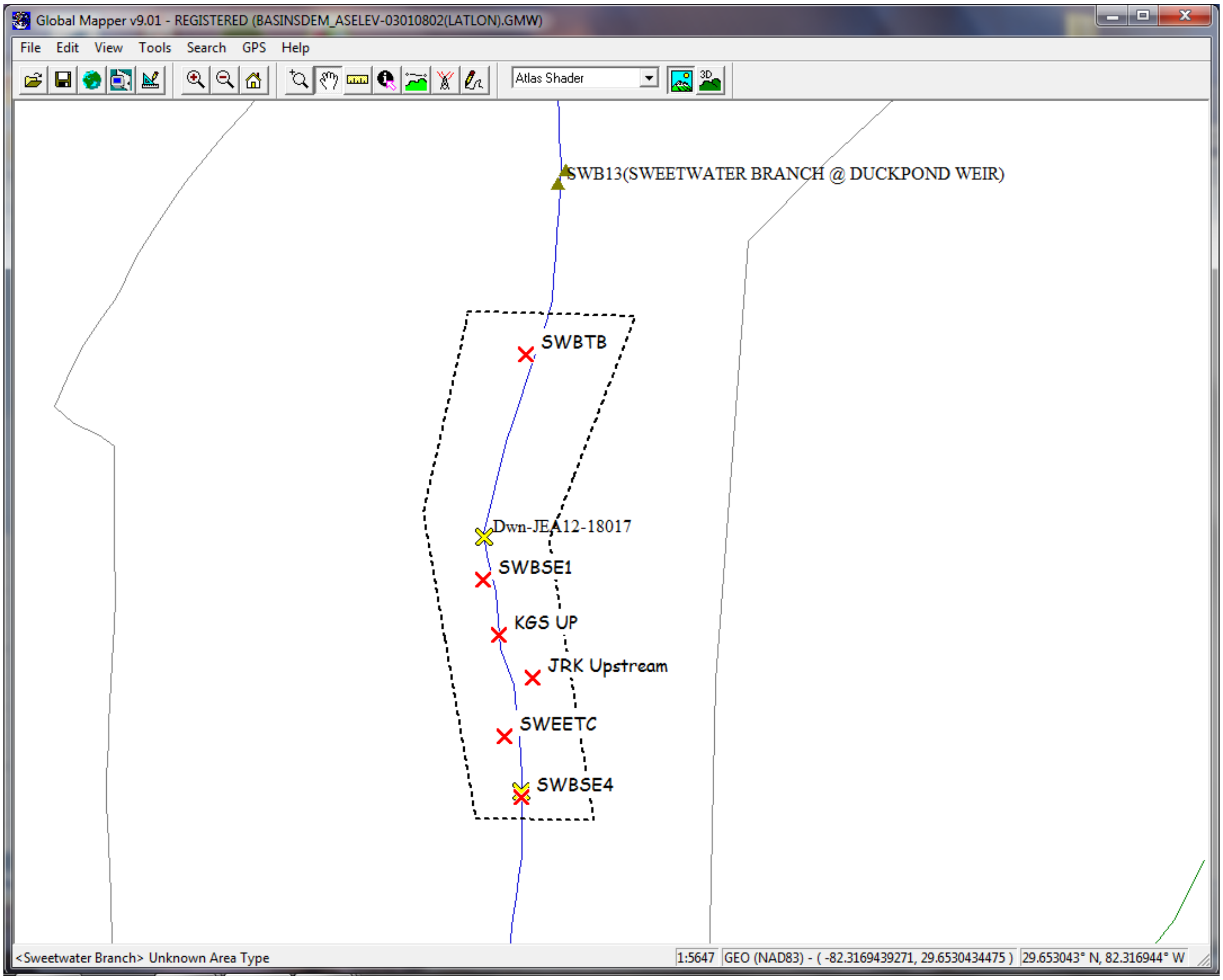
Figure 6- Frequency Distribution of Log Transformed Urban Runoff Flow Data.

Summary statistics have been processed and compiled for the three flow bin conditions to provide observed flow and water quality data for model setup for (a) upstream boundary conditions; (b) nonpoint source (NPS) inflow; and (c) MSWRF and KGS point source discharge data; and model confirmation based on (d) observed flow and water quality data at each monitoring station located along the one-dimensional (1d) path of the QUAL2K stream model reaches. As QUAL2K represents steady-state time-averaged conditions, daily flow bin assignments for extraction of water quality records were used to check antecedent flow conditions to ensure that stream flow was consistent for 3 days prior to sampling dates for water quality observations.

5.4.3 Upstream Boundary Headwater

The QUAL2K model requires specification of an upstream boundary input for stream flow and water quality conditions. The upstream boundary was defined as the location just downstream of the Duck Pond weir. Station locations used to assign the headwater upstream boundary conditions are listed and shown in Figure 7. Summary statistics have been processed and compiled for the three flow bin conditions (BIN1, BIN2, and BIN3) to provide observed flow and water quality data to assign upstream boundary conditions (Table 5).

Flow and water quality data used to establish the upstream boundary represent the combined urban runoff flow and loads entering Sweetwater Branch upstream of the KGS's outfall and consist of base flow and storm water runoff coming from the urbanized area of the City of Gainesville. Upstream boundary flow conditions are based on pooled data from 2004-2016, while upstream boundary water quality data were compiled for the period from 1998-2016 to derive water quality boundary conditions considered to be representative of urban runoff in this area of Gainesville.



LON	LAT	Station-ID	Source
-82.32033	29.64931	SWEETC	FDEP IWR50
-82.32013	29.64858	SWBSE4	FDEP IWR50
-82.32059	29.65118	SWBSE1	FDEP IWR50
-82.32007	29.65387	SWBTB	FDEP IWR50
-82.32013	29.64858	SWBSE4AVE	FDEP IWR50
-82.32040	29.65052	KGS UP	Frydenborg
-82.32000	29.65000	JRK Upstream	GRU JRK

Figure 7- Station Locations Used for Upstream Boundary Conditions and NPS Inflow.

Table 5- Upstream Boundary and Nonpoint Source Inflow: for Model Confirmation Run 529. Median Flow and Water Quality for Urban Runoff Conditions (BIN1, BIN2, and BIN3)

	Statistic-->	Median	Median	Median			
QUAL2K State Variables	Units				Data Source		
HDW		BIN1	BIN2	BIN3	Obs	Deriv	Const
Streamflow	MGD	0.0804018	0.2509646	0.469872	X		
Streamflow	cfs	0.1244	0.3883	0.727	X		
Streamflow	cms	0.003523	0.0109967	0.0205886	X		
Water temperature	Deg C	18.85	20.6	24.35	X		
Conductivity	µmhos/cm	318.3	321.15	308.45	X		
Inorganic SS (PIM, dw)	mg/L	0.75	1.25	1.25		X	
Dissolved Oxygen	mg/L	6.94	7.66	7.17	X		
Slow CBOD (ultimate)	mg/L	16.047266	15.014221	23.561867		X	
Fast CBOD (ultimate)	mg/L	1.5747345	1.4329793	1.3892829		X	
Organic-N, Total	µg/L	554.43	346.64	468.25		X	
Ammonia-N	µg/L	24.72	32.96	35.5	X		
Nitrate/Nitrite-N	µg/L	311.85	204.4	271.25		X	
Organic-P, Total	µg/L	66	51	34.05		X	
Inorganic-P (SRP, Diss_PO4)	µg/L	154	119	79.45		X	
Phytoplankton-Chl	µg/L	1.202	2.1	0.988	X		
Phytoplankton-N	µg/L	12.9816	22.68	10.6704		X	
Phytoplankton-P	µg/L	1.803	3.15	1.482		X	
Organic Detritus (POM, dw)	mg/L	0.5897333	0.97	1.1182667		X	
Pathogens	cfu/100mL	0	0	0			X
Alkalinity	mg CaCO3/L	103.891	120.193	110.566	X		
Constituent 1	mg/L	0	0	0			X
Constituent 2	mg/L	0	0	0			X
Constituent 3	mg/L	0	0	0			X
PH	SU	7.32	7.4	7.43	X		
Total Nitrogen	µg/L	891	584	775	X		
Total Kjeldahl Nitrogen	µg/L	579.15	379.6	503.75		X	
Total Phosphorus	µg/L	220	170	113.5	X		
Total Organic Carbon	mg/L	6.6	6.16	9.345	X		
BOD-5-Day	mg/L	0.5	0.5	0.5	X		
TSS [PIM+POM(D)+POM(A)]	mg/L	1.5	2.5	2.5	X		

5.4.3.1 Methodology for Derivation of Upstream Boundary Conditions

Observed records for upstream flow, alkalinity, water temperature, pH, specific conductance, BOD5, phytoplankton chlorophyll-a, dissolved oxygen (DO), total organic carbon (TOC), dissolved organic carbon (DOC), ammonia-N (NH4), nitrate/nitrite-N (NO3NO2), total Kjeldahl nitrogen (TKN), total nitrogen (TN), dissolved orthophosphate (PO4), total phosphorus (TP), and Total Suspended Solids (TSS) were compiled to derive median values for each of the three flow bin conditions. Table 5 presents the upstream boundary data developed for flow and water quality for input to QUAL2K for the three flow bin conditions for model setup, model confirmation, and application of the confirmed stream water quality model. Table 6 presents the stoichiometric values used to derive water quality constituents that were not available from station data records.

Where a QUAL2K state variable (see Table 1) could not be assigned directly from observed data, observed water quality records were used with appropriate stoichiometric coefficients and ratios of observed constituent measurements to derive state variables for upstream boundary input to the QUAL2K model. The methodology used to derive upstream boundary input data based on stoichiometric relationships and available water quality observations is described below from DSLLC (2016).

Stream flow. Flow data were not directly available to define an upstream boundary for the time period being modeled. The upstream boundary flow was, therefore, derived as the difference between daily stream flow downstream of the MSWRF discharge at SR331 (SJRWMD 01980199), the combined daily effluent flow discharged from the KGS facility and the MSWRF facility (see Figure 4 and Figure 5).

Inorganic and Detrital Solids. QUAL2K represents TSS as Particulate Inorganic Matter (PIM) and Particulate Organic Matter (POM) forms of suspended solids. Inorganic suspended solids are derived for input to QUAL2K using observed TSS and an estimate of the organic fraction of TSS. The organic component of suspended solids (POM) was derived from observed TOC and ratios to define DOC: TOC and carbon: dry weight (C: DW) as follows:

POM = TOC * (1-DOC: TOC)/C: DW.

Analysis of paired observations (n=29) of TOC and DOC measured at SWB331 and SWBSE4 in 1999-2000 gave a DOC: TOC ratio of 0.92 and a corresponding POC/TOC ratio of 0.08. A typical Carbon: Dry Weight (C: DW) ratio for organic matter is 0.45 mg C/mg DW (Stoddard, Harcum, Pagenkopf, Simpson, & Bastian, 2002). The particulate inorganic form of suspended solids (PIM) was derived by difference from the observed TSS and the estimate of POM:

PIM = TSS – POM.

Detrital (non-living) POM is derived for input to QUAL2K by filtering out the phytoplankton biomass component from POM using stoichiometric ratios for Carbon: Chlorophyll (C: CHL) and C: DW as follows:

Detrital POM = POM – Phytoplankton Chl * C: CHL/C: DW

Table 6 - Stoichiometric Parameters Used for Upstream Boundary Data

Stoichimetric Parameters			Value	Source
POM:TSS	Particulate Organic Matter:TSS	mg/mg	0.50	Src_1
CBODU:CBOD5	Ultimate-5-Day ratio for BOD	mg/mg	4.00	Src_2
C:DW	Carbon to Dry Weight	mg C/mg DW	0.45	Src_1
POC:TOC	Particulate : Total Organic Carbon	mg/mg	0.05	Src_3
O2:C	Oxygen:Carbon	mg O2/mg C	2.67	Src_2
N:CHL	Nitrogen: Chlorophyll	µg N/µg Chl	10.80	Src_2
P:CHL	Phosphorus: Chlorophyll	µg P/µg Chl	1.50	Src_2
C:CHL	Carbon:Chlorophyll	µg C/µg Chl	60.00	Src_2
C:N	Carbon:Nitrogen	mg C/mg N	5.56	Src_2
N:P	Nitrogen:Phosphorus	mg N/mg P	7.20	Src_2
C:P	Carbon:Phosphorus	mg C/mg P	40.00	Src_2
DOC:TOC	Dissolved : Total Organic Carbon	mg C/mg C	0.950	Src_3
DISSOP:TOTP	Dissolved Orthophosphate:TP	mg P/mg P	0.700	Src_3
TKN:TN	TKN: Total Nitrogen	mg N/mg N	0.650	Src_3
NO3NO2:TN	Nitrate:Total Nitrogen	mg N/mg N	0.350	Src_3
KN	Nitrification rate	1/day	1.000	Src_2
Src_1	Stoddard et al. (2002)			
Src_2	Chapra (1997); Bowie et al. (1985)			
Src_3	Sweetwater Branch data			

Carbonaceous BOD (CBOD). QUAL2K represents ultimate Carbonaceous BOD (CBOD) as a slow reacting (refractory) component and a fast reacting (labile) component. The slow and fast forms of CBOD were derived for input to QUAL2K using observed data for TOC and BOD5 and a ratio of ultimate BOD to 5-day BOD. The fast (labile) form of CBOD was derived from observed BOD5 and ammonia and a ratio of CBODU: CBOD5 = 4 which is appropriate for natural streams such as the upstream boundary of Sweetwater Branch.

Stream water quality data for BOD was reported by FDEP IWR Run 50 and Alachua County as BOD5. BOD5 is the uninhibited measure of BOD that includes both the carbonaceous and nitrogenous components of the oxygen demand in the stream. In contrast, the effluent data from both MSWRF and KGS reported CBOD5 as the nitrogen-inhibited form of CBOD where nitrification is suppressed and the measurement reflects only the carbonaceous component of the oxygen demand. As QUAL2K models the carbonaceous form of BOD, the stream BOD5 was used with stream ammonia records to derive estimates of in-stream CBOD5 as the nitrogen-inhibited component of the BOD5 measurement. Ji (2008) presents an equation showing the components of BOD5 based on TOC and ammonia. The equation was used to develop the following relationship between BOD5, NH4-N and CBOD5.

$CBOD5 = BOD5 – 4.33 \times NH4 \times [1\text{-}\exp(-5 \times K_N)]$

In the equation, the coefficient 4.33 is the stoichiometric ratio for Oxygen: Nitrogen, 5 represents the 5 days for the BOD5 measurement and K_N is the nitrification rate. A compilation of data reported by

Bowie et al., (1985) was used to assign the nitrification rate as K_N=1.0/day. Fast CBOD is derived from the estimate of CBOD5 and the ratio of ultimate CBOD: CBOD5 as follows:

CBOD (fast) = CBOD5 * CBODU: CBOD5

The slow (refractory) form of CBOD is derived by difference from observed TOC, the component of organic carbon that is included in fast CBOD and the ratio for Oxygen:Carbon (O2:C=2.67 mg O2/mg C) as follows:

CBOD (slow) = TOC * O2: C – CBOD (fast)

Observed levels of TOC, ranging from 6.1 to 9.3 mg/L, are based on stream water quality data compiled for the upstream boundary stations (Figure 7) for the three flow bin conditions presented in Table 5.

Inorganic Phosphorus. Dissolved orthophosphate (PO4) or Soluble Reactive Phosphate (SRP) is the state variable defined for inorganic phosphorus for QUAL2K. Alachua County reports inorganic phosphorus as "phosphorus, orthophosphate" and "phosphorus, soluble reactive" while FDEP IWR reports inorganic phosphorus as "dissolved orthophosphate" and "orthophosphate". The water quality database compiled for this study merged FDEP IWR and Alachua County phosphorus records defined by these parameter names into a single parameter. All of these forms are equivalent to inorganic phosphorus (or dissolved orthophosphate) represented as the state variable in QUAL2K (see Aulenbach, et al., 2007). Analysis of paired stream records for total phosphorus and dissolved orthophosphate collected from 1998-2003 were used to derive an in-stream ratio for PO4: TP with a mean of 0.75 (n=171 observations).

Organic Phosphorus and Organic Nitrogen. Organic phosphorus (Org-P) is derived from observed Total Phosphorus (TP) and observed dissolved orthophosphate (PO4) as:

Org-P = TP – PO4

In cases where the median value of TP was less than the median value for dissolved orthophosphate, Organic-P was derived from TP and the ratio for PO4: TP as:

Org-P = TP * (1-PO4: TP)

Organic nitrogen (Org-N) is derived from observed Total Nitrogen (TN), observed nitrate/nitrite (NO3NO2) and observed ammonia (NH4) as:

Org-N =TN – NO3NO2 – NH4

5.4.4 Point Source Effluent Input

The QUAL2K model requires specification of point source inputs for effluent flow and effluent quality. Two point source National Pollutant Discharge Elimination System (NPDES) dischargers are represented in the model of Sweetwater Branch. GRU's MSWRF and KGS facilities are the two point source NPDES discharges represented in the model. Daily effluent records, available from the KGS and MSWRF monthly DMR files, were compiled and used to develop model input data for these two point source NPDES dischargers. Summary statistics have been compiled using effluent data available for the period from 2013-2016 to provide median effluent flow and effluent concentration values as point source flow and loading data input to the model. Effluent records from MSWRF and KGS were pooled with data records extracted for all flow bin conditions (i.e., BIN9 has data from BIN1, BIN2, and BIN3) since effluent quality is not dependent on stream flow conditions.

Data were available from MSWRF DMR records to develop summary statistics for effluent flow, water temperature, pH, CBOD5, dissolved oxygen, ammonia, nitrate/nitrite, total Kjeldahl nitrogen, total nitrogen, dissolved orthophosphate, total phosphorus, and total suspended solids.

Data were available from KGS DMR records for Unit 8 Cooling Tower Blowdown (CTBD8) and Low Volume Waste (LVW) to develop summary statistics for effluent flow, water temperature, specific conductance, pH, ammonia, nitrate/nitrite, total Kjeldahl nitrogen, total nitrogen, dissolved orthophosphate, and total phosphorus.

5.4.4.1 Methodology for Derivation of Wastewater Effluent Conditions

Effluent flow, nutrient concentrations and loads for the MSWRF and KGS discharges are summarized for Scenario #1 in Table 7. KGS effluent records for flow and nutrient concentrations are used to compute effluent loads for the CTBD8 and LVW outfalls. The combined sums of effluent flow and nutrient loads from the cooling water and low volume wastewater outfalls (see Table 7) are shown to facilitate comparison of the relative contributions of effluent flow and nutrient loading from the MSWRF and KGS discharges. Effluent data used to characterize the effluent discharges from MSWRF, KGS Unit 8 Cooling Tower Blowdown (CTBD8) and KGS Low Volume Waste (LVW) are presented in Table 8 (MSWRF), Table 9 (KGS CTB08), and Table 10 (KGS LVW). Stoichiometric parameter values used to characterize the effluent discharges from MSWRF, KGS Unit 8 Cooling Tower Blowdown (CTBD8) and KGS Low Volume Waste (LVW) are presented in Table 11, Table 12 and Table 13.

Table 7- Summary of MSWRF and KGS Effluent Flow and Nutrient Loading Rates for Model Confirmation

Model Confirmation Run 529	MSWRF Median	KGS CTBD8 Median	KGS LVW Median	KGS CTBD8+LVW Median
Annual Flow (MGD)	6.68	0.221	0.0182	0.2392
Total Nitrogen (mg N/L)	5.27	1.29	0.57	1.235
Total Phosphorus (mg P/L)	0.51	0.435	0.11	0.410
Total Nitrogen (lbs N/yr)	107,227.5	868.4	31.6	900.0
Total Phosphorus (lbs P/yr)	10,376.9	292.8	6.1	298.9

Load (lbs/yr) = MGD x mg/L x 8.345 x 365. MSWRF and KGS effluent flow and effluent levels of Total Nitrogen and Total Phosphorus based on median statistics compiled for all hydrologic flow conditions (BIN9) during period of record from 2013-2016. Combined TN and TP concentrations for CTBD8 + LVW outfalls are flow weighted.

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Table 8- MSWRF Point Source Discharge: for Model Confirmation Run 529. Median Effluent Flow and Quality for All Stream Flow Conditions (BIN9)

Calibration_Run529	Statistic-->	Median				
QUAL2K State Variables	Units	BIN9	N_Obs	Data Source		
MSWRF(BIN9)			2013-2016	Obs	Derive	Const
Effluent Flow	MGD	6.680002	1182	X		
Effluent Flow	cfs	10.3355	1182	X		
Effluent Flow	cms	0.292701	1182	X		
Water temperature	Deg C	23.9	847	X		
Conductivity	µmhos/cm	862	0			X
Inorganic SS (PIM, dw)	mg/L	0.5	0		X	
Dissolved Oxygen	mg/L	8.7	1134	X		
Slow CBOD (ultimate)	mg/L	10.515	0		X	
Fast CBOD (ultimate)	mg/L	1.5	0		X	
Organic-N, Total	µg/L	710	0		X	
Ammonia-N	µg/L	90	848	X		
Nitrate/Nitrite-N	µg/L	4470	848	X		
Organic-P, Total	µg/L	110	0		X	
Inorganic-P (SRP, Diss_PO4)	µg/L	400	167	X		
Phytoplankton-Chl	µg/L	0.65	0			X
Phytoplankton-N	µg/L	7.02	0		X	
Phytoplankton-P	µg/L	0.975	0		X	
Organic SS Detritus (POM, dw)	mg/L	0.5	0		X	
Pathogens	cfu/100mL	0	0			
Alkalinity	mg CaCO3/L	70	0			X
Constituent 1	mg/L	0	0			
Constituent 2	mg/L	0	0			
Constituent 3	mg/L	0	0			
PH	SU	7.2	847	X		
Total Nitrogen	µg/L	5270	846	X		
Total Kjeldahl Nitrogen	µg/L	800	846	X		
Total Phosphorus	µg/L	510	169	X		
Total Organic Carbon	mg/L	4.5	0		X	
Carbonaceous BOD-5-Day	mg/L	0.5	846	X		
TSS [PIM+POM(D)+POM(A)]	mg/L	1	848	X		

Table 9- KGS Unit 8 Cooling Tower Blowdown Point Source Discharge: for Model Confirmation Run 529. Median Effluent Flow and Quality for All Stream Flow Conditions (BIN9)

Table 7 Run 529 Calib						
CALIBRATION (RUN 529)	**Statistic-->**	**Median**				
QUAL2K State Variables	**Units**	**BIN9**	**N_Obs**	**Data Source**		
KGS_CTBD8(BIN9)			**2013-2016**	**Obs**	**Derive**	**Const**
Effluent Flow	MGD	0.221205	1307	X		
Effluent Flow	cfs	0.342255	1307	X		
Effluent Flow	cms	0.009693	1307	X		
Water temperature	Deg C	23.1	138	X		
Conductivity	µmhos/cm	820.1	138	X		
Inorganic SS (PIM, dw)	mg/L	0.5	0		X	
Dissolved Oxygen	mg/L	8	0			X
Slow CBOD (ultimate)	mg/L	10.015	0		X	
Fast CBOD (ultimate)	mg/L	2	0		X	
Organic-N, Total	µg/L	815	0		X	
Ammonia-N	µg/L	85	22	X		
Nitrate/Nitrite-N	µg/L	390	0		X	
Organic-P, Total	µg/L	160.95	0		X	
Inorganic-P (SRP, Diss_PO4)	µg/L	274.05	0		X	
Phytoplankton-Chl	µg/L	0	0			X
Phytoplankton-N	µg/L	0	0		X	
Phytoplankton-P	µg/L	0	0		X	
Organic SS Detritus (POM, dw)	mg/L	0.5	0		X	
Pathogens	cfu/100mL	0	0			
Alkalinity	mg CaCO3/L	100	0			X
Constituent 1	mg/L	0	0			
Constituent 2	mg/L	0	0			
Constituent 3	mg/L	0	0			
PH	SU	8.2	138	X		
Total Nitrogen	µg/L	1290	25	X		
Total Kjedhal Nitrogen	µg/L	900	26	X		
Total Phosphorus	µg/L	435	26	X		
Total Organic Carbon	mg/L	4.5	0		X	
Carbonaceous BOD-5-Day	mg/L	0.5	0	X		
TSS [PIM+POM(D)+POM(A)]	mg/L	1	0	X		

Table 10- KGS Low Volume Waste (LVW) Point Source Discharge for Model Confirmation Run 529. Median Effluent Flow and Quality for All Stream Flow Conditions (BIN9)

CALIBRATION (Run 529)	Statistic-->	Median				
QUAL2K State Variables	Units	BIN9	N_Obs	Data Source		
KGS_LVW(BIN9)			2013-2016	Obs	Derive	Const
Effluent Flow	MGD	0.018174	1295	X		
Effluent Flow	cfs	0.028119	1295	X		
Effluent Flow	cms	0.000796	1295	X		
Water temperature	Deg C	23	172	X		
Conductivity	µmhos/cm	375.95	2	X		
Inorganic SS (PIM, dw)	mg/L	0.5	0		X	
Dissolved Oxygen	mg/L	8	0			X
Slow CBOD (ultimate)	mg/L	10.015	0		X	
Fast CBOD (ultimate)	mg/L	2	0		X	
Organic-N, Total	µg/L	185	0		X	
Ammonia-N	µg/L	50	26	X		
Nitrate/Nitrite-N	µg/L	335	0		X	
Organic-P, Total	µg/L	40.7	0		X	
Inorganic-P (SRP, Diss_PO4)	µg/L	69.3	0		X	
Phytoplankton-Chl	µg/L	0	0			X
Phytoplankton-N	µg/L	0	0		X	
Phytoplankton-P	µg/L	0	0		X	
Organic SS Detritus (POM, dw)	mg/L	0.5	0		X	
Pathogens	cfu/100mL	0	0			
Alkalinity	mg CaCO3/L	100	0			X
Constituent 1	mg/L	0	0			
Constituent 2	mg/L	0	0			
Constituent 3	mg/L	0	0			
PH	SU	7.7	172	X		
Total Nitrogen	µg/L	570	27	X		
Total Kjedhal Nitrogen	µg/L	235	30	X		
Total Phosphorus	µg/L	110	31	X		
Total Organic Carbon	mg/L	4.5	0		X	
Carbonaceous BOD-5-Day	mg/L	0.5	0	X		
TSS [PIM+POM(D)+POM(A)]	mg/L	1	0	X		

Table 11 - Stoichiometric Parameters Used for MSWRF Effluent Data

MSWRF Effluent	Stoichimetric Parameters	Units	Value	Source
POM:TSS	Particulate Organic Matter:TSS	mg/mg	0.5	Src_1
CBODU:CBOD5	Ultimate-5-Day ratio for BOD	mg/mg	3	Src_1
C:DW	Carbon to Dry Weight	mg C/mg DW	0.45	Src_1
POC:TOC	Particulate : Total Organic Carbon	mg/mg	0.05	Src_1
O2:C	Oxygen:Carbon	mg O2/mg C	2.67	Src_2
N:CHL	Nitrogen: Chlorophyll	µg N/µg Chl	10.8	Src_2
P:CHL	Phosphorus: Chlorophyll	µg P/µg Chl	1.5	Src_2
C:CHL	Carbon:Chlorophyll	µg C/µg Chl	60	Src_2
C:N	Carbon:Nitrogen	mg C/mg N	5.56	Src_2
N:P	Nitrogen:Phosphorus	mg N/mg P	7.2	Src_2
C:P	Carbon:Phosphorus	mg C/mg P	40	Src_2
NH4:TKN	Ammonia:TKN	mg N/mg N	0.1	Src_3
NO3NO2:TOTN	NitrateNitrite:TN	mg N/mg N	0.85	Src_3
TKN:TOTN	(Organic N+Ammonia):TN	mg N/mg N	0.15	Src_3
DISSOP:TOTP	Dissolved Orthophosphate:TP	mg P/mg P	0.63	Src_3
Src_1	Stoddard et al. (2002)			
Src_2	Chapra (1997)			
Src_3	MSWRF effluent data (2013-2016)			

Table 12 - Stoichiometric Parameters Used for KGS Unit 8 Cooling Tower Blowdown (CTBD8) Effluent

KGS_CTBD8(BIN9)	Stoichimetric Parameters	Units	Value	Source
POM:TSS	Particulate Organic Matter:TSS	mg/mg	0.5	Src_1
CBODU:CBOD5	Ultimate-5-Day ratio for BOD	mg/mg	4	Src_1
C:DW	Carbon to Dry Weight	mg C/mg DW	0.45	Src_1
POC:TOC	Particulate : Total Organic Carbon	mg/mg	0.05	Src_1
O2:C	Oxygen:Carbon	mg O2/mg C	2.67	Src_2
N:CHL	Nitrogen: Chlorophyll	µg N/µg Chl	10.8	Src_2
P:CHL	Phosphorus: Chlorophyll	µg P/µg Chl	1.5	Src_2
C:CHL	Carbon:Chlorophyll	µg C/µg Chl	60	Src_2
C:N	Carbon:Nitrogen	mg C/mg N	5.56	Src_2
N:P	Nitrogen:Phosphorus	mg N/mg P	7.2	Src_2
C:P	Carbon:Phosphorus	mg C/mg P	40	Src_2
NH4:TKN	Ammonia:TKN	mg N/mg N	0.066	Src_4
NO3NO2:TOTN	NitrateNitrite:TN	mg N/mg N	0.302	Src_4
TKN:TOTN	(Organic N+Ammonia):TN	mg N/mg N	0.698	Src_4
DISSOP:TOTP	Dissolved Orthophosphate:TP	mg P/mg P	0.63	Src_3
Src_1	Stoddard et al. (2002)			
Src_2	Chapra (1997)			
Src_3	MSWRF effluent data (2013-2016)			
Src_4	KGS CTBD8 effluent data (2013-2016)			

Table 13 - Stoichiometric Parameters Used for KGS Low Volume Waste (LVW) Effluent

KGS_LVW(BIN9)	Stoichimetric Parameters	Units	Value	Source
POM:TSS	Particulate Organic Matter:TSS	mg/mg	0.5	Src_1
CBODU:CBOD5	Ultimate-5-Day ratio for BOD	mg/mg	4	Src_1
C:DW	Carbon to Dry Weight	mg C/mg DW	0.45	Src_1
POC:TOC	Particulate : Total Organic Carbon	mg/mg	0.05	Src_1
O2:C	Oxygen:Carbon	mg O2/mg C	2.67	Src_2
N:CHL	Nitrogen: Chlorophyll	µg N/µg Chl	10.8	Src_2
P:CHL	Phosphorus: Chlorophyll	µg P/µg Chl	1.5	Src_2
C:CHL	Carbon:Chlorophyll	µg C/µg Chl	60	Src_2
C:N	Carbon:Nitrogen	mg C/mg N	5.56	Src_2
N:P	Nitrogen:Phosphorus	mg N/mg P	7.2	Src_2
C:P	Carbon:Phosphorus	mg C/mg P	40	Src_2
NH4:TKN	Ammonia:TKN	mg N/mg N	0.088	Src_4
NO3NO2:TOTN	NitrateNitrite:TN	mg N/mg N	0.588	Src_4
TKN:TOTN	(Organic N+Ammonia):TN	mg N/mg N	0.412	Src_4
DISSOP:TOTP	Dissolved Orthophosphate:TP	mg P/mg P	0.63	Src_3
Src_1	Stoddard et al. (2002)			
Src_2	Chapra (1997)			
Src_3	MSWRF effluent data (2013-2016)			
Src_4	KGS LVW effluent data (2013-2016)			

Median values of water quality constituents were assigned to represent effluent loading from the MSWRF and KGS permitted discharges for all stream flow conditions. Where a QUAL2K state variable (see Table 1) could not be assigned directly from MSWRF or KGS effluent records, observed effluent data were used with appropriate stoichiometric coefficients and ratios of observed effluent constituent measurements to derive concentrations of effluent constituents for point source input to the QUAL2K model. The methodology used to derive wastewater effluent data based on stoichiometric relationships and available effluent observations is described below from DSLLC (2016).

Alkalinity. Beginning in 2011, alkalinity has been recorded daily in DMR files from the MSWRF facility to track concentrations in the raw influent and the filter. It was assumed that measurements at the filter are representative of the final effluent discharge to the stream. Alkalinity records were "sampled" on the 15th day of March and September from 2013 through 2016 to develop an estimate of alkalinity levels in the effluent. For n=7 samples, alkalinity ranged from a low of 50 to a high of 112 mg/L with a mean value of 70.9 mg/L. The average for the period from 2013-2016 was assigned as a constant value (70 mg/L) to represent effluent alkalinity levels after the MSWRF facility was upgraded to reduce effluent phosphorus levels in early 2013.

Alkalinity records are not available to characterize loading of this constituent from the KGS discharges for Unit 8 Cooling Tower Blowdown and Low Volume Waste. KGS obtains water used for cooling and other purposes from wells at the facility. It is appropriate therefore to assign effluent alkalinity for the KGS discharges based on typical levels measured in groundwater. A groundwater status and trends report from SJRWMD (2020) reported a median of 137 mg/L with a range from 75 mg/L (10^{th} percentile) to 208 mg/L (90^{th} percentile) for Total Alkalinity (n=50 observations) at stations located within the Ocklawaha Basin in the Upper Floridan Aquifer. In a South Florida Water Management District (SFWMD) study of groundwater chemistry (n=199 observations) in the Lower Floridan Aquifer (Geddes, Coonts and Carroll, 2020), Total Alkalinity was reported with an average of 110 mg/L with a range from a low of 77 mg/L for the 25^{th} percentile to a high of 190 mg/L for the 75^{th} percentile. Based on the SJRWMD and SFWMD groundwater chemistry studies, alkalinity was assigned a concentration of 100 mg/L to represent alkalinity discharged from the Unit 8 Cooling Tower Blowdown and the Low Volume Waste outfalls to Sweetwater Branch.

Specific Conductance. Specific conductance was not available in the MSWRF DMR records. A constant value (862 µmhos/cm) was assigned based on typical wastewater effluent characteristics for chloride and specific conductance reported in (Metcalf & Eddy, 1991). Measured records of specific conductance, available from KGS, were used to assign this state variable for the KGS Unit 8 discharges.

Inorganic and Detrital Solids. QUAL2K represents TSS as particulate inorganic matter (PIM) and particulate organic matter (POM) forms of suspended solids. Inorganic suspended solids are derived for input to QUAL2K using observed TSS and an estimate of the organic fraction of TSS. With effluent TSS concentrations of ~1 mg/L observed in the MSWRF DMR records, TSS was split into the inorganic (PIM) and organic (POM) forms for model input using a POM:TSS ratio (0.5) that is appropriate for very low TSS concentrations associated with advanced secondary and better levels of waste treatment (Stoddard, Harcum, Pagenkopf, Simpson, & Bastian, 2002). Limited effluent TSS data were available for the KGS discharges from data sets collected for renewal of NPDES discharge permits. A TSS concentration of 1 mg/L was representative of the data collected for renewal of the NPDES permits for cooling water blowdown and low volume waste discharged by KGS. It was assumed that the POM: TSS ratio (0.5) assigned for the MSWRF discharge was representative of the KGS discharges.

PIM = TSS*(1-POM: TSS)

POM = TSS*POM: TSS

Carbonaceous BOD (CBOD). QUAL2K represents ultimate Carbonaceous BOD (CBOD) as a slow reacting (refractory) component and a fast reacting (labile) component. The slow and fast forms of CBOD were derived for input to QUAL2K using an estimate of effluent TOC, observed effluent CBOD5 and a ratio of ultimate CBOD to 5-day CBOD. CBOD5 measurements were available for the MSWRF discharge and a limited amount of effluent CBOD5 data were available for the KGS discharges from data sets collected for renewal of NPDES discharge permits. The very low MSWRF effluent concentration of 0.5 mg/L is consistent with the concentration of CBOD5 measured for the permit renewals for the KGS cooling water and low volume waste discharges. An effluent CBOD5 concentration of 0.5 mg/L was assigned for MSWRF and the KGS cooling water and low volume waste discharges.

The fast (labile) form of CBOD was derived from observed CBOD5 and a ratio of CBODU: CBOD5. A ratio of 3 is appropriate for advanced secondary and better levels of waste treatment with low effluent levels of CBOD5 such as attained by the MSWRF plant (Stoddard, Harcum, Pagenkopf, Simpson, & Bastian, 2002). As groundwater is the source of the cooling water, the KGS discharge is assigned a CBODU: CBOD5 ratio of 4 which is consistent with the characteristics of a natural stream rather than a wastewater treatment facility like MSWRF.

CBOD (fast) = Effluent CBOD5 * CBODU: CBOD5

The slow (refractory) form of CBOD is derived by difference from estimated effluent levels of TOC (which is the component of organic carbon included in fast CBOD) and the ratio for Oxygen: Carbon (O2: C=2.67 mg O2/mg C) as follows:

CBOD (slow) = TOC * O2: C – CBOD (fast)

As effluent TOC data were not available for MSWRF and only a limited amount of TOC data were available from permit renewal data sets for the KGS discharges, effluent TOC levels for both MSWRF and KGS were estimated from TSS and ratios for POM:TSS; C:DW and POC:TOC as follows:

TOC= [TSS x POM: TSS x C: DW] / POC: TOC

As most of the organic carbon in effluent from advanced secondary and better levels of wastewater treatment is in the dissolved form, a DOC:TOC ratio of 0.95 and a corresponding POC:TOC ratio of 0.05 is assigned to estimate TOC for both the MSWRF and KGS discharges. The same values for TSS (1 mg/L), POM: TSS ratio (0.5) and C: DW ratio (0.45 mg C/mg DW) were assigned for both MSWRF and the KGS discharges (cooling water blowdown and low volume waste) to derive TOC effluent levels.

Phosphorus. QUAL2K represents Total Phosphorus (TP) as the sum of inorganic phosphorus (PO4), non-living detrital organic phosphorus (Org-P) and living organic phosphorus (phytoplankton biomass as P). Total Phosphorus (TP) and dissolved orthophosphate (PO4) data are available from the MSWRF DMR records. Paired DMR records from MSWRF were compiled and analyzed to estimate an effluent ratio for total phosphate (PO4: TP = 0.63). Total Phosphorus and dissolved orthophosphate data were available for the KGS cooling water and low volume waste discharges. Organic phosphorus was derived by difference from Total Phosphorus and dissolved orthophosphate as:

Org-P = TP – PO4

Nitrogen. QUAL2K represents Total Nitrogen (TN) as the sum of inorganic nitrogen (ammonia-N and nitrite/nitrate-N), non-living detrital organic nitrogen (Org-N) and living organic nitrogen (phytoplankton biomass as N). Observations of ammonia, nitrate/nitrite, TKN and Total Nitrogen are available from both MSWRF and KGS records. Although nitrate/nitrite measurements are available, the median values of the different measured forms of nitrogen may not add up to the median value for total nitrogen.

Observations of TN, TKN and NH4-N are used, therefore, to derive Nitrate/Nitrite and Organic Nitrogen by difference for input to the model as follows:

Org-N = TKN-NH4-N

NO3/NO2 = TN – TKN

Phytoplankton Chl. Phytoplankton biomass in wastewater effluent is typically assigned a concentration of zero. In the modeling study of the MSWRF discharge (DSLLC, 2015), however, a mass balance analysis of the upstream boundary data, wastewater discharge and data downstream of the MSWRF discharge were used to estimate a range of effluent phytoplankton chlorophyll concentration (0.5-0.75 µg/L) that resulted in reasonable agreement between model results and observed phytoplankton chlorophyll downstream of the MSWRF discharge. The analysis showed that upstream phytoplankton was simply diluted by the much larger effluent flow from the wastewater discharge. The presence of a large scour hole in the stream resulting from the effluent discharge suggests that, with a sufficient residence time, the scour hole near the outfall pipe could serve as a 'batch reactor' to support phytoplankton growth (Frydenborg, 2015). The scour hole could, thus, export a non-zero concentration of phytoplankton biomass for mixing with the main channel of Sweetwater Branch. For the 2013-2016 modeling analysis of the KGS and MSWRF discharges, a mass-balance derived concentration of chlorophyll-a (0.65 µg/L) was assigned as input for the MSWRF discharge. Phytoplankton chlorophyll was assigned as zero for the KGS Cooling Water and Low Volume Waste discharges.

5.4.5 Nonpoint Source Diffuse Input

The QUAL2K model supports specification of nonpoint source (NPS) diffuse inputs for flow and water quality loading to a stream system. In contrast to the methodology used in the initial modeling analysis of Sweetwater Branch (DSLLC, 2015), the QUAL2K model of the Upper and Lower reaches of Sweetwater Branch explicitly represents nonpoint source inflow and loading of nutrients and other water quality constituents. Nonpoint source flow was estimated from the areas of three sub-watersheds that define the drainage area of Sweetwater Branch. As shown in Figure 8, sub-basins for Sweetwater Branch were delineated by SJRWMD (2016) as Quad Basin maps.

As part of the urbanized area of Gainesville, the Sweetwater Branch watershed has undergone extensive urbanization over the past few decades. Residential and urban commercial areas in Gainesville now account for the majority of land use in the Sweetwater Branch watershed with 64% classified as built-up urban residential and commercial (Gao et al., 2006) (see Table 14). In the upper and lower reaches of Sweetwater Branch, urban built up land use is 82-83%. Figure 9 from Gao et al. (2006) shows that land use characteristics of commercial and residential areas in the vicinity of Rosewood Branch are similar to land uses contributing to the upstream boundary stations in Upper Sweetwater Branch. Water quality data sets compiled for the upstream boundary (see Table 5) were used to assign point source (PS) loading from Rosewood Branch as a tributary discharge to Lower Sweetwater Branch. The same upstream boundary water quality data sets were also used to assign nonpoint source loading for the nonpoint source zones defined for Upper and Lower Sweetwater Branch (see Table 15 and Table 17).

Table 15 presents the drainage areas for the three sub-basins and the allocation of the sub-basin area to the area for the five zones defined for the reaches of the QUAL2K model. The urban runoff component of stream flow observations at the SR331 gage for the period of record from 2004-2016 was used to compute summary statistics for nonpoint source flow (see Table 16) that were normalized to the drainage area at the SR331 gage (2.5367 mi^2) to derive flow per unit area (cfs/mi^2) for each of the flow bin conditions (Table 17). Median flow statistics were used to derive nonpoint source inflow for model confirmation while 90th percentile flow statistics for BIN3 were used to derive "worst-case" stormwater flow conditions for model scenario evaluations.

Zone-dependent estimates of nonpoint source inflow and tributary flow for Rosewood Branch were then derived from the contributing drainage area estimated for each zone and the normalized flow rates estimated for each flow bin condition. Nonpoint source inflow was estimated for the contributing drainage areas for each zone for input to Upper Sweetwater Branch, Rosewood Branch, Lower Sweetwater Branch from Rosewood Branch to the SR331 gage, and Lower Sweetwater Branch from the SR331 gage to the downstream outlet of the model domain at the Enhancement Wetland Area (see Table 17).

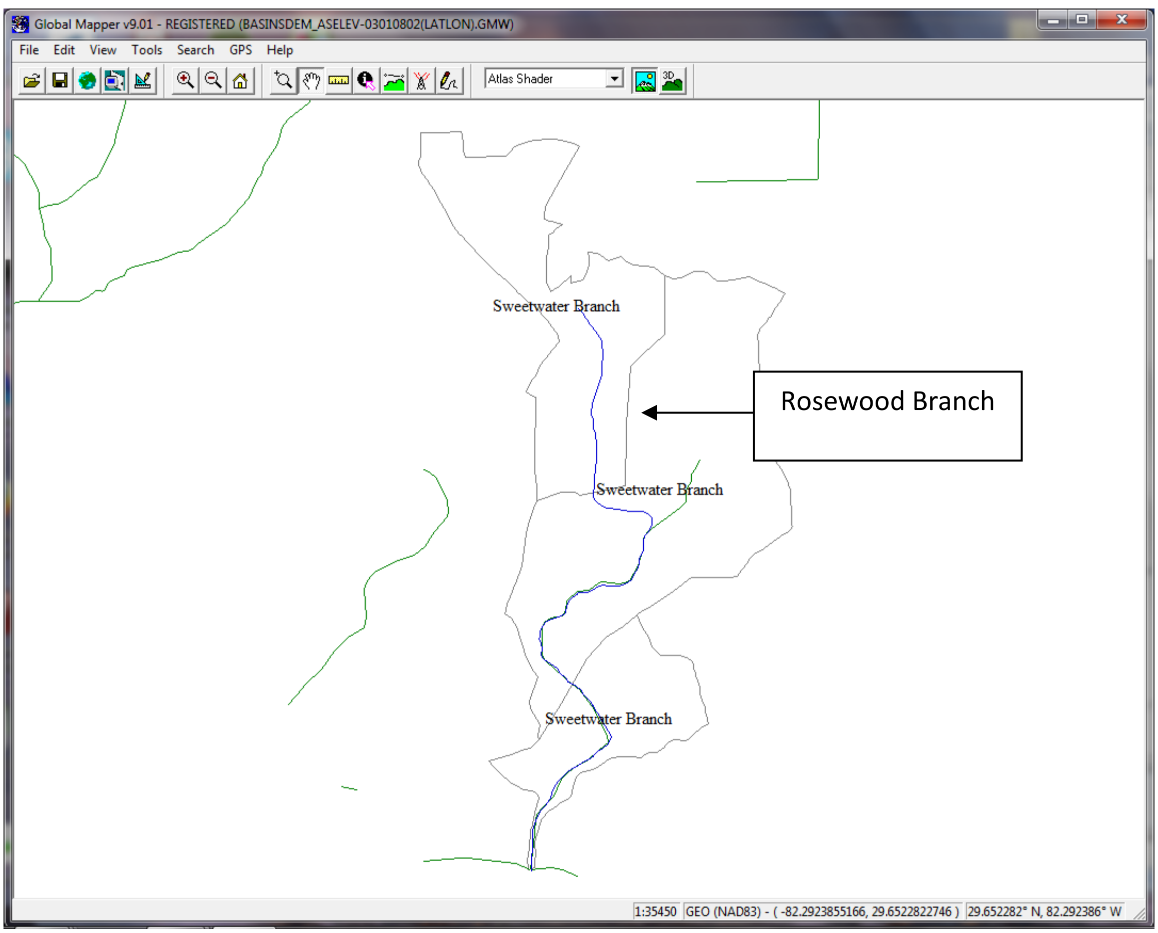

Figure 8- Sweetwater Branch Quad Basin Sub-Watersheds. Source: (SJRWMD, 2016).

Table 14- Land Use Categories for Upper, Lower Sweetwater Branch and the Upper Extension Ditch. Source: (Gao et al., 2006, Table 6)

Land Use Category	**Upper Sweetwater Branch (acres)**	**Lower Sweetwater Branch (acres)**	**Upper Extension Ditch (acres)**	**Sweetwater Branch, Total (acres)**
Forest and rural open	136	94	292	522
Urban open	608	60	18	686
Agriculture	8	9	144	161
Low-density residential	25	106	2	133
Medium-density residential	808	833	100	1,741
High-density residential	54	0	0	54
Transportation, communication, utilities	90	5	0	95
Rangeland	5	39	11	55
Water and wetlands	87	56	498	641
Total	**1,821**	**1,202**	**1,065**	**4,088**
Urban open & Residential	1,495	999	120	2,614
Urban open & Residential	82%	83%	11%	64%

Water quality observations were compiled for the upstream boundary polygon and for a polygon defined for Rosewood Branch. The initial plan was to develop separate sets of summary statistics to specify the upstream boundary and the input from Rosewood Branch as a point source discharge to Sweetwater Branch. Although water quality observations were available at monitoring stations on Rosewood Branch, an adequate pool of data records for the years from 2004-2016 was not available to define robust summary statistics to characterize point source loading from Rosewood Branch for the three flow bin conditions.

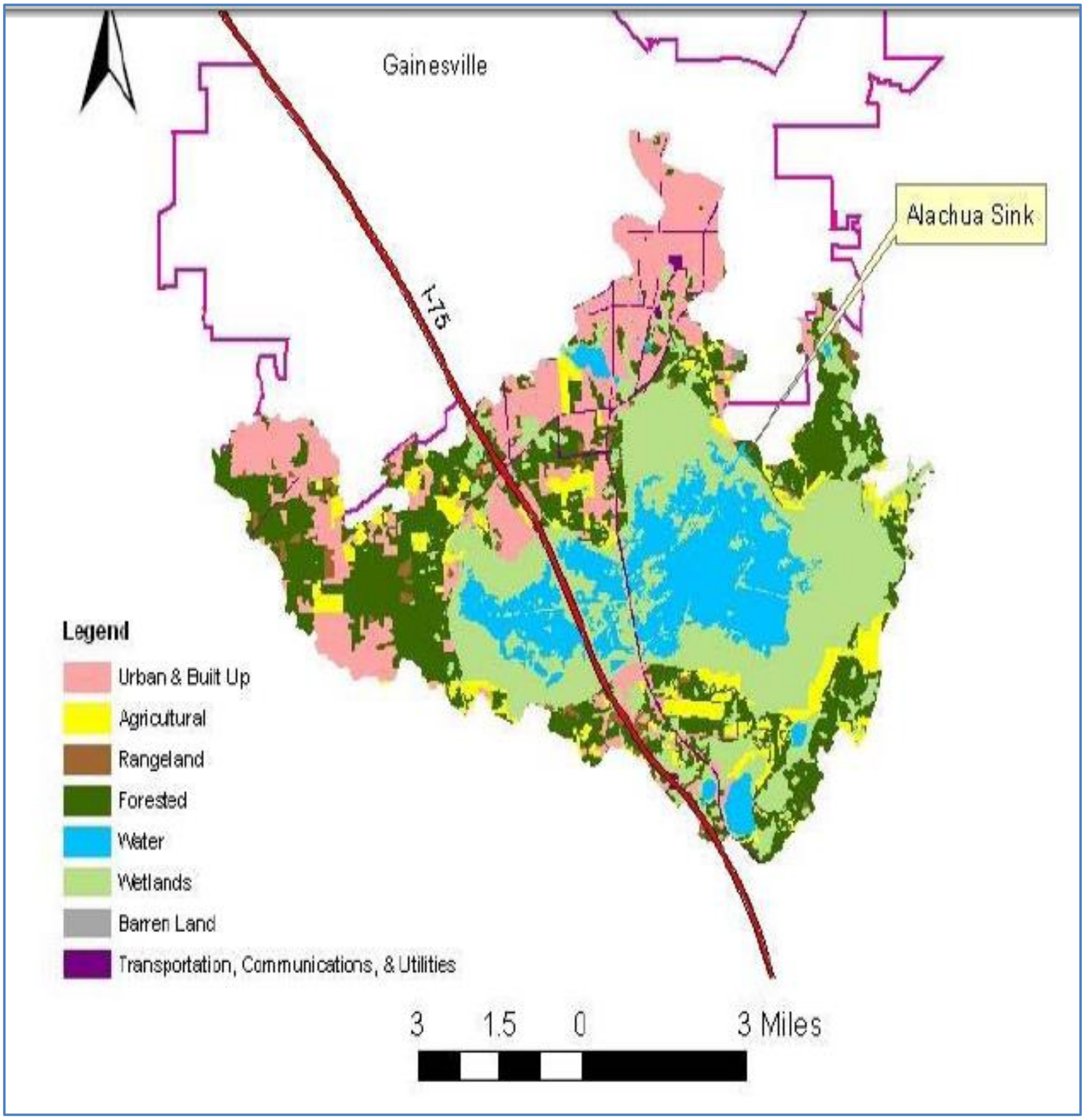

Figure 9- Land Uses for Alachua Sink and Sweetwater Branch Watersheds (Gao et al., 2006, Figure 1)

Table 15- Drainage Area for SJRWMD Sub-Basins and Nonpoint Source Flow Zones.

SJRWMD Sub-Basin	Area (mi^2)		
Sub_Basin_1	0.9735		
Sub_Basin_2	1.5632		
Sub_Basin_3	0.4902		
Total Drainage Area	3.0268		
Zone_Number	Area (mi^2)	Allocation of Area	Description
Zone_1	0.7301	75% of sub_basin 1	Headwater to Reach 11
Zone_2	0.2434	25% of sub_basin 1	Reach 11 and 10
Zone_3	0.7816	50% of sub_basin 2	Rosewood as tributary
Zone_4	0.7816	50% of sub_basin 2	Reach 9,8,7,6
Zone_5	0.4902	100% of sub_basin 3	Reach 5,4,3,and 2
Total	3.0268	100% of whole basin	Whole basin
Drainage area at SRS331	2.5367		

Table 16- Summary Statistics for Nonpoint Source Flow at SR331 Gage

SJRWMD Flow @ SR331	BIN9 (cfs)	BIN3 (cfs)	BIN2 (cfs)	BIN1 (cfs)
N_Obs	2,003	314	644	171
Mean	5.54825	7.3307	2.73478	0.572515
Min	0.00187522	0.017131	0.0131	0.01786
10%ile	0.29071	0.510466	0.29537	0.122452
25%ile	0.716594	1.09599	0.731944	0.252169
50%ile (Median)	1.54502	2.52561	1.34916	0.432197
75%ile	3.24394	5.5013	2.14869	0.821703
90%ile	9.77589	13.3407	3.21393	1.22125
Max	478.042	372.561	134.007	2.05968

Table 17- Median Nonpoint Source Flow Conditions for Model Confirmation

Streamflow	BIN9	BIN3	BIN2	BIN1	
(2004-2016)	(cfs)	(cfs)	(cfs)	(cfs)	
N_Observations	2,003	314	644	171	
Median	1.54502	2.52561	1.34916	0.432197	
Area @ SR331 (mi^2)	2.5367	2.5367	2.5367	2.5367	
Flow/Area	**(cfs/mi^2)**	**(cfs/mi^2)**	**(cfs/mi^2)**	**(cfs/mi^2)**	
Median	0.6091	0.9956	0.5319	0.1704	
Zone	**BIN9**	**BIN3**	**BIN2**	**BIN1**	**Area**
Median Flow (cfs)	**(cfs)**	**(cfs)**	**(cfs)**	**(cfs)**	**(mi^2)**
Zone_1 Upstrm Hdw	0.4447	0.7270	0.3883	0.1244	0.7301
Zone_2 Reach 11,10	0.1482	0.2423	0.1294	0.0415	0.2434
Zone_3 Rosewood(PS)	0.4760	0.7782	0.4157	0.1332	0.7816
Zone_4 Reach 9,8,7, 6	0.4760	0.7782	0.4157	0.1332	0.7816
Zone_5 Reach 5,4,3,2	0.2985	0.4880	0.2607	0.0835	0.4902
Total	1.8436	3.0136	1.6099	0.5157	3.0268

5.4.6 Meteorological, Light and Heat Data

The QUAL2K water temperature model is based on a first-principles heat balance formulation that requires data to characterize meteorology, stream shading, and properties of light and heat. As a steady-state model, QUAL2K requires specification of a single date that is representative of conditions being modeled. As described in previous sections, data that have been compiled to assign upstream boundary conditions, wastewater effluent and observed spatial distribution of water quality are based on summary statistics of pooled data available from 2013-2016 for all months that meet the criteria for each of the three flow bin conditions. The meteorology data, however, are intended to represent conditions in September 2015 when Frydenborg Ecologic, LLC collected data to characterize periphyton upstream and downstream of the KGS discharge in Sweetwater Branch. Historical meteorology data, compiled by NOAA's National Climatic Data Center (NCDC) to characterize "Normal" conditions based on data from 1981-2010, are available from the Florida Climate Center (FCC) of Florida State University (https://climatecenter.fsu.edu/products-services/data).

NOAA NCDC "normal" data for the month of September are summarized in Table 18. September was selected for the model simulation to provide meteorological data that would be representative of the periphyton survey conducted by Frydenborg Ecologic, LLC in September 2015. As QUAL2K requires a specific date, the mid-point date of September 15, 2015 was arbitrarily assigned for the QUAL2K model runs. Diurnal solar radiation and photoperiod was computed from latitude, date-dependent theoretical clear sky radiation and cloud cover. Table 19 presents reach data used to define coverage for benthic algae, bottom SOD coverage, stream shade coverage, and bottom type characteristics of the stream bed **(Frydenborg, 2015)**. QUAL2K allows the modeler to empirically classify the stream bed of a QUAL2K reach as (1) completely covered by soft substrate/organic matter that will contribute to sediment-water consumption of dissolved oxygen or (2) partially covered by hard substrate that will not contribute to sediment oxygen demand. Field observations of stream bed material by Frydenborg Ecologic, LLC and the JEA (2010) geomorphic study of Sweetwater Branch were used to assign complete coverage (100%) of the stream bed reaches for sediment oxygen demand (SOD).

Table 18- Meteorology Data Assigned for September 2015.

Gainesville, FL	September	
Source: Florida Climate Center		
Air Temperature	Deg-C	25.67
Dew Point Temperature	Deg-C	21.58
Wind Speed	m/sec	2.50
Cloud Cover	Percent	42

Table 19- Sweetwater Branch Reach-Dependent Coverage for Algae, Benthic Algae, SOD and Shade.

	JEA Reach	QUAL2K Reach	Bottom Algae Coverage	Bottom SOD Coverage	Stream Shade Coverage	Bottom Type
Upper	11	1	2%	100%	82%	Clean straight Sand, some rubble
	10B	2	2%	100%	82%	Clean straight Sand, some rubble
	10A(JRK)	3	2%	100%	92%	Clean straight Sand, some rubble
	9	4	2%	100%	92%	Clean straight Sand, some rubble
Lower	8	5	2%	100%	65%	Clean straight Sand, some rubble
	7	6	2%	100%	75%	Clean straight Sand
	6B	7	2%	100%	75%	Clean straight Clay, Sand
	6A(MSWRF)	8	2%	100%	75%	Clean straight Clay, Sand
	5	9	2%	100%	80%	Clean straight Sand
	4	10	2%	100%	80%	Clean straight Sand
	3	11	2%	100%	80%	Clean straight Clay, Sand
	2	12	2%	100%	80%	Clean straight Sand
Stream shade: Percent of solar radiation blocked by shade from topography & vegetation						

5.4.7 Kinetic Coefficients, Rates, Stoichiometric Constants and Model Parameters

The QUAL2K model requires numerous kinetic coefficients, rate reactions, stoichiometric constants and model parameters to describe reactions and transformations of organic and inorganic matter represented in the water quality model. The initial set of model coefficients, listed in the 'RATES' input data worksheet of the Excel spreadsheet for the QUAL2K model, were taken from the documentation manual for QUAL2K (Chapra et al., 2012) and the literature (Bowie & Others, 1985). Adjustments were made, as needed, within the accepted range of parameter values to achieve acceptable confirmation of the model results with stream observations. Flynn et al. (2015) present a summary of default values and the literature range of QUAL2K kinetic rates and coefficients that was used to guide confirmation of the model for Sweetwater Branch. Appendix A presents a listing of the QUAL2K kinetic rates, parameters, and stoichiometric coefficients for the water quality model and the parameters used to model light and heat transfer in Sweetwater Branch.

5.4.7.1 Benthic Algae Kinetics

QUAL2K models benthic algae growth as a temperature-dependent maximum zero-order rate that is attenuated by nutrient and light limitation. The maximum growth rate (as mg Chl m^{-2} day^{-1}) can be assigned in QUAL2K as either a uniform rate for all reaches or as spatially variable rates for each reach. Flynn et al (2015) present maximum growth rates from ~15 to 500 mg Chl $m^{-2}day^{-1}$ as the literature range for benthic algae. Preliminary model results performed by DSLLC (2015) for the MSWRF modeling study quickly showed that spatially variable reach-dependent rates were needed to reproduce the observed spatial distribution of benthic algae biomass measured by Water and Air Research WAR (2011) in Lower Sweetwater Branch. In the second modeling study (DSLLC, 2016) the model domain was extended to include Upper Sweetwater Branch and the KGS effluent discharge. Maximum benthic algae growth rates were empirically assigned by model confirmation for three zones of the stream to obtain good agreement with biomass observations collected by Frydenborg Ecologic, LLC in 2015-2016 in Upper Sweetwater Branch and by WAR (2011) in Lower Sweetwater Branch. The maximum rates assigned for the three zones, developed by confirmation of the model to benthic algal biomass measurements, are within the range of maximum rates from ~15 to 500 mg Chl $m^{-2}day^{-1}$ reported by Flynn et al. (2015).

- Zone 1, upstream of KGS discharge, Reach 11 and Reach 10B (160 mg Chl m^{-2} day^{-1})
- Zone 2, downstream of KGS discharge, Reach 10A and Reach 9 (60 mg Chl m^{-2} day^{-1})
- Zone 3, downstream of Rosewood Branch, Reach 8 to Reach 2 (3 mg Chl m^{-2} day^{-1})

Numerous studies over the past 30 years have demonstrated that stream velocity is a major factor that can control the observed distribution and abundance of benthic algae. Steep gradient reaches of streams and rivers with high current velocity (~50 cm/sec) and sufficient light, substrate conditions and nutrient supply are typically characterized by maximum rates of benthic primary productivity from periphyton (Horner & Welch, 1981); (Welch, Horner, & Patmont, 1989); (Biggs, Goring, & Nikora, 1998). Stream velocity increases up to ~50 cm/sec have been observed to result in enhanced biomass accumulation and productivity of periphyton (Horner & Welch, 1981); (Horner, Welch, Seeley, & Jacoby, 1990). Velocities greater than ~50 cm/sec, however, have been shown to result in reduced biomass accumulation because of physical transport processes that scour, and slough off biomass attached to stream bed substrate (Biggs & Close, 1989); (Biggs, Goring, & Nikora, 1998); (Horner, Welch, Seeley, & Jacoby, 1990).

As Sweetwater Branch is characterized by steep elevation gradients (see Figure 3) and high velocity conditions, such as JEA Reach 6 in the lower reaches of the stream, it is appropriate to include the effect of stream velocity as a controlling factor for modeling periphyton in Sweetwater Branch. Photosynthetic production of benthic algae is parameterized in the Sweetwater Branch QUAL2K model using reach-dependent growth rates and a normalized velocity distribution function. The velocity function is derived from a Gaussian distribution with a mean of 50 cm/sec and a standard deviation of 17 cm/sec.

Figure 10 shows the normalized velocity function with observed data sets taken from (Horner & Welch, 1981) consistent with the velocity function at the low velocity range. The validity of the Gaussian velocity function over a wider range of stream velocity is, however, demonstrated by a numerical model of periphyton (Saravia, Momo, & Boffi Lissin, 1998). Figure 11, taken from Saravia et al., clearly shows the functional dependence of velocity as a controlling factor for growth and accumulation of periphyton biomass. Peak biomass is simulated for a velocity range of ~30-50 cm/sec which is comparable to the findings of Horner and Welch (1981). The range of velocity in Sweetwater Branch (~2-90 cm/sec) is consistent with the normalized velocity function (see Figure 9) and the periphyton biomass response to velocity shown by Saravia et al. (see Figure 11).

Spatially variable benthic algae growth rates were estimated for each reach using the maximum growth rate determined for each zone and the velocity-dependent multiplier computed from the reach velocity and the normalized Gaussian velocity function. Using velocity data extracted from the QUAL2K model results and the Gaussian velocity function, reach-dependent benthic algae growth rates were computed and assigned as model input data for the low, middle, and high flow conditions for model confirmation. Growth rates assigned for each reach of Sweetwater Branch are presented in Table 20 for the low, middle, and high flow conditions assigned for model confirmation to 2013-2016 observations.

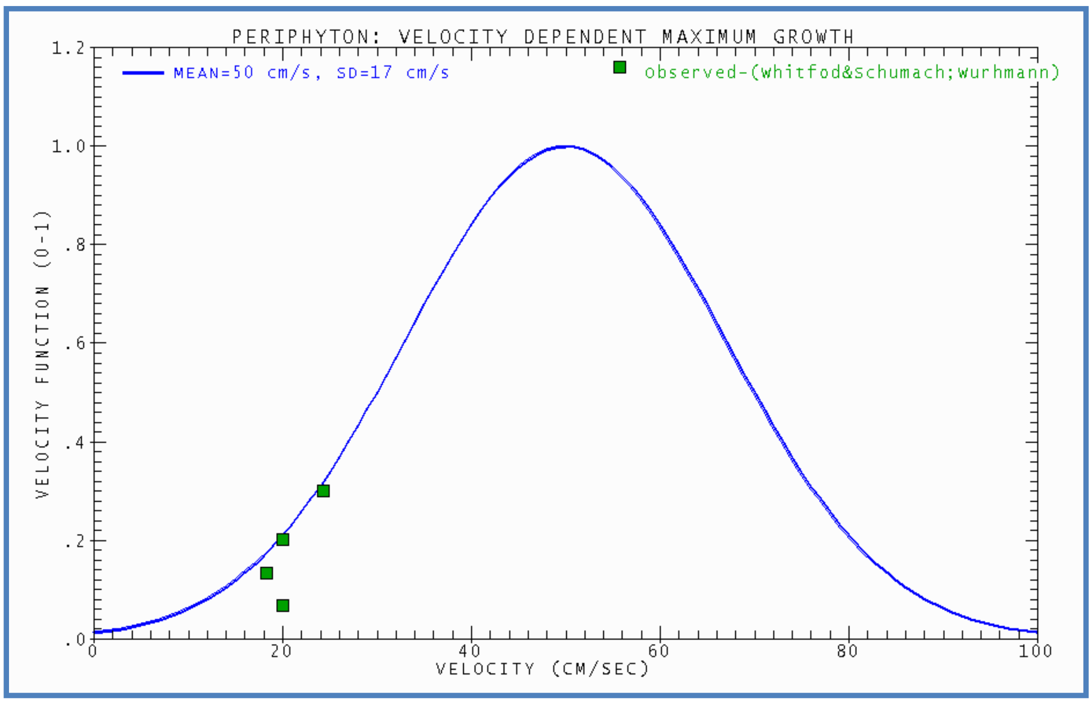

Figure 10- Normalized Periphyton Production as Function of Stream Velocity.
Data points shown are taken from (Horner & Welch, 1981).

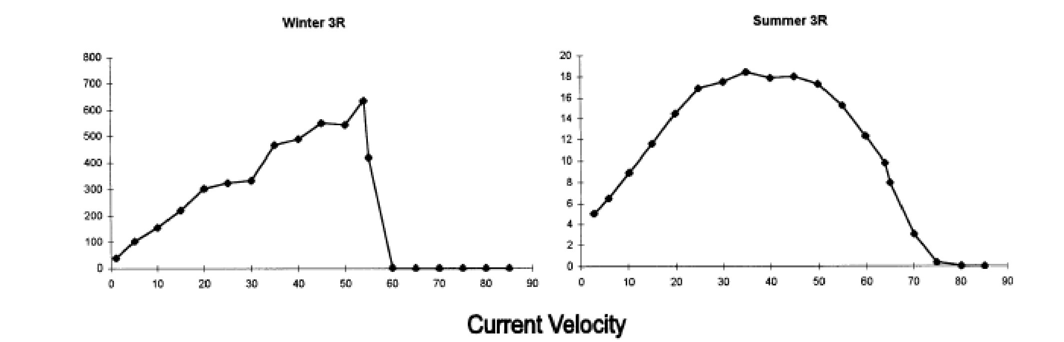

Fig. 2. Biomass response to current velocity (cm s^{-1}). Each point is the result of averaging biomass values (mg chl-a m^{-2}) of 200 stochastic simulations.

Figure 11- Biomass response to current velocity (cm/sec). Vertical axis is simulated periphyton biomass (mg Chl-a m^{-2}) Source: Figure 2 from (Saravia, Momo, & Boffi Lissin, 1998).

Table 20 - Velocity-Dependent Benthic Algae Growth Rates for Low, Middle and High Flow-Dependent Conditions in Sweetwater Branch assigned for model confirmation to 2013-2016 observations

Zone 1: Max Rate	ABOVE KGS (11,10B)		160	
Zone 2: Max Rate	BELOW KGS (10A,9)		60	
Zone 3: Max Rate	LOWER (8-2)		3	
BIN1 (LOW FLOW) RUN 529 (CONFIRM)	**Velocity (m/s)**	**Velocity Multiplier**	**Growth Rate mg Chl $m^{-2}day^{-1}$**	**Zone**
JEA Reach 11 Upstream	0.0109	0.0159	2.551	1
JEA Reach 10B	0.0116	0.0161	2.581	1
JEA Reach 10A(KGS)	0.0204	0.0187	1.121	2
JEA Reach 9	0.0467	0.0286	1.715	2
JEA Reach 8 (Rosewood Br)	0.1772	0.1648	0.495	3
JEA Reach 7	0.2125	0.2393	0.718	3
JEA Reach 6B	0.6736	0.5936	1.781	3
JEA Reach 6A(MSWRF)	0.6738	0.5930	1.779	3
JEA Reach 5	0.5139	0.9967	2.990	3
JEA Reach 4	0.7994	0.2122	0.637	3
JEA Reach 3	0.3170	0.5601	1.680	3
JEA Reach 2 Last Segment	0.4044	0.8538	2.561	3

Zone 1: Max Rate	ABOVE KGS (11,10B)		160	
Zone 2: Max Rate	BELOW KGS (10A,9)		60	
Zone 3: Max Rate	LOWER (8-2)		3	
BIN2 (MIDDLE FLOW)	**Velocity**	**Velocity**	**Growth Rate**	**Zone**
RUN 529 (CONFIRM)	**(m/s)**	**Multiplier**	**mg Chl $m^{-2}day^{-1}$**	
JEA Reach 11 Upstream	0.0182	0.0180	2.884	1
JEA Reach 10B	0.0193	0.0184	2.939	1
JEA Reach 10A(KGS)	0.0256	0.0204	1.221	2
JEA Reach 9	0.0590	0.0346	2.075	2
JEA Reach 8 (Rosewood Br)	0.2331	0.2916	0.875	3
JEA Reach 7	0.2832	0.4433	1.330	3
JEA Reach 6B	0.6927	0.5259	1.578	3
JEA Reach 6A(MSWRF)	0.6932	0.5241	1.572	3
JEA Reach 5	0.5300	0.9846	2.954	3
JEA Reach 4	0.8248	0.1613	0.484	3
JEA Reach 3	0.3273	0.5967	1.790	3
JEA Reach 2 Last Segment	0.4177	0.8894	2.668	3

Zone 1: Max Rate	ABOVE KGS (11,10B)		160	
Zone 2: Max Rate	BELOW KGS (10A,9)		60	
Zone 3: Max Rate	LOWER (8-2)		3	
BIN3 (HIGH FLOW)	**Velocity**	**Velocity**	**Growth Rate**	**Zone**
RUN 529 (CONFIRM)	**(m/s)**	**Multiplier**	**mg Chl $m^{-2}day^{-1}$**	
JEA Reach 11 Upstream	0.0241	0.0199	3.180	1
JEA Reach 10B	0.0256	0.0204	3.259	1
JEA Reach 10A(KGS)	0.0307	0.0221	1.328	2
JEA Reach 9	0.0713	0.0416	2.495	2
JEA Reach 8 (Rosewood Br)	0.2827	0.4417	1.325	3
JEA Reach 7	0.3455	0.6616	1.985	3
JEA Reach 6B	0.7159	0.4465	1.339	3
JEA Reach 6A(MSWRF)	0.7168	0.4436	1.331	3
JEA Reach 5	0.5495	0.9585	2.875	3
JEA Reach 4	0.8554	0.1124	0.337	3
JEA Reach 3	0.3397	0.6410	1.923	3
JEA Reach 2 Last Segment	0.4336	0.9266	2.780	3

5.4.7.2 Benthic Algae Field Surveys

In QUAL2K, the units for periphyton biomass are mg Chlorophyll-a (Chl-a) m^{-2}. Benthic algae biomass data collected by Frydenborg Ecologic, LLC in stream surveys conducted in September 2015, December 2015 and March 2016 were reported with biomass units as mg Chl-a m^{-2} and mg Ash Free Dry Weight (AFDW) m^{-2}. Periphyton biomass data collected by Water and Air Research (WAR, 2011) and Frydenborg Ecologic, LLC are presented in Table 21.

Biomass data collected for the summer 2011 survey were reported with units of periphyton density reported as units cm^{-2} and the assumption was made that units cm^{-2} are equivalent to cells cm^{-2}. Using a log-log regression relationship based on paired data sets (n=98) for cell density and periphyton biomass as chlorophyll (Figure 12) and as Ash Free Dry Weight (Figure 13), cell density observations were transformed to periphyton biomass as mg Chl-a m^{-2} and mg AFDW m^{-2} (Table 21). Data used to transform the (WAR, 2011) periphyton density measurements to periphyton biomass as chlorophyll-a were collected by Feeney (1998) and are presented in Appendix K.

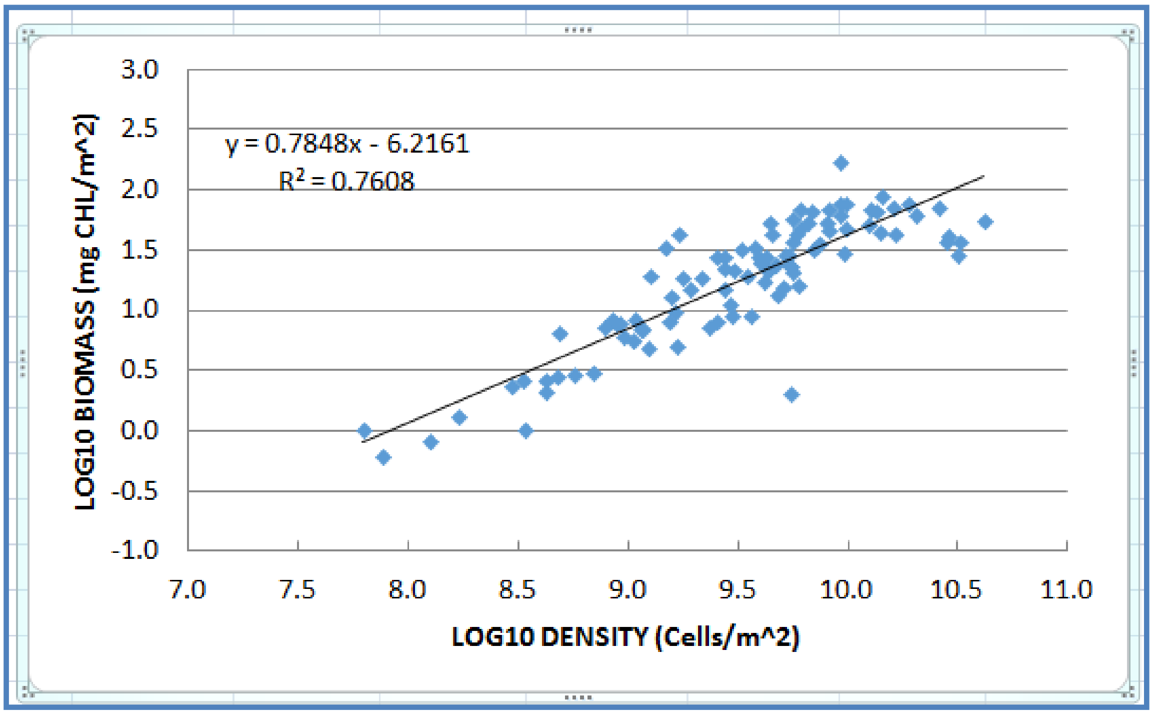

Figure 12- Log-log relationship of periphyton cell density and biomass as Chlorophyll-a.
Data source: (Feeney, 1998)

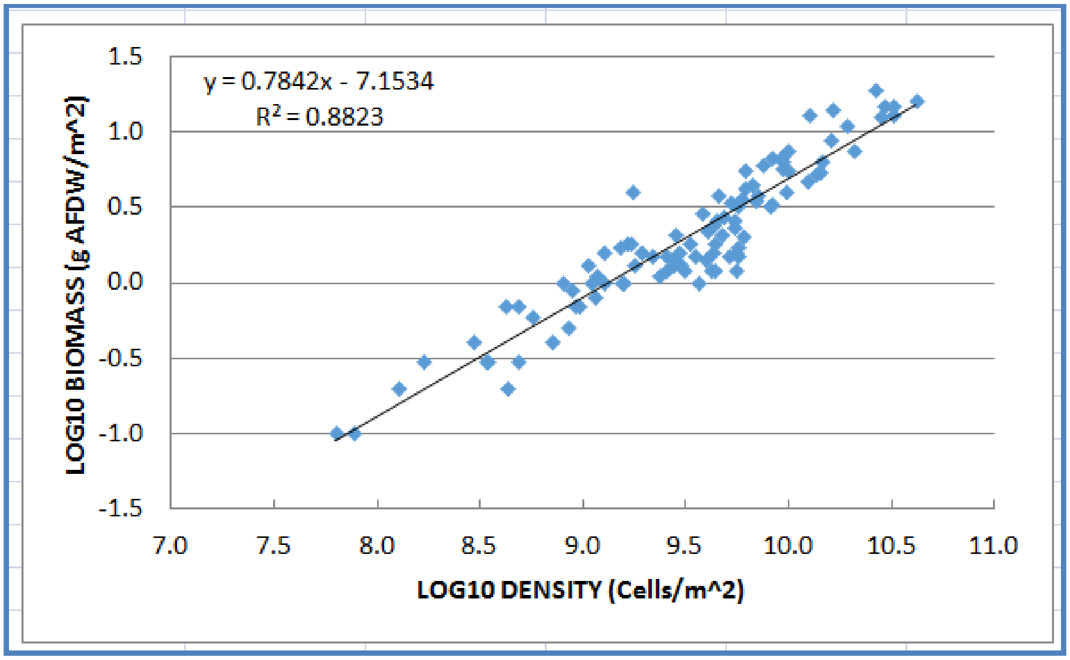

Figure 13 - Log-log relationship of periphyton cell density and biomass as Ash Free Dry Weight. Data source: (Feeney, 1998)

Table 21 - Sweetwater Branch Periphyton Surveys in 2015-2016 and 2011

Frydenborg Ecologic, LLC			CHL-A	AFDW
Sample Location	Sample Date	Velocity (m/sec)	Periphyton mg Chl m^{-2}	Periphyton mg AFDW m^{-2}
KGS UP	2015-09-04	0.040	0.675	1,173
KGS UP	2015-12-21	0.050	0.748	167
KGS DOWN	2015-09-04	0.120	0.249	933
KGS DOWN	2015-12-21	0.070	0.320	153
KGS DOWN	2016-03-21	0.100	0.783	130
KGS UP		29.650522	-82.320367	
KGS DOWN		29.643738	-82.317587	

Sweetwater Branch Periphyton Survey WAR (2011)		Begin End	8/24/2011 9/21/2011		
Station	Stream 1D(x) km	Density units cm^{-2}	Density units m^{-2}	Biomass mg Chl m^{-2}	Biomass mg AFDW m^{-2}
Old Landfill	2.739	3,399	33,990,000	0.495	57
SE 16th Ave	1.972	7,561	75,610,000	0.927	106
Songbird Sign	1.58	1,252	12,520,000	0.226	26

5.5 Model Confirmation to Observed Data

The steady-state QUAL2K model was setup to represent low flow (BIN1), middle flow (BIN2) and high flow (BIN3) conditions. Observed station data were used to assign the upstream boundary flow and water quality conditions and observed effluent data from the KGS and MSWRF DMR records were used to specify effluent flow and loads to Sweetwater Branch. Observations of water quality monitoring data in Upper and Lower Sweetwater Branch were pooled for the period from 2013-2016 to develop data sets for comparison to model results for the three sets of hydrologic flow conditions (BIN1, BIN2 and BIN3). Observed station data were used to compile steady-state time averaged, one-dimensional (1D[x]) spatial distributions of flow, water depth, velocity, water temperature and water quality constituents for comparison to model results. In evaluating the agreement between model results and observed data, it is important to understand that, as a steady-state model, QUAL2K simulates hydraulic and water quality state variables based on long-term average meteorological conditions. As described under data sources, meteorological conditions for the Sweetwater Branch model were assigned for mid-September (see Table 18). The range of observed data, however, is based on data compiled from 2013-2016 from January to December and the observed data range is shown by the 10th and 90th percentile values of hydraulic and water quality state variables for the middle flow condition (BIN2).

In this section, selected model confirmation results are presented for hydraulic properties, water temperature and key water quality state variables for the middle flow bin condition (BIN2). Model-data plots are presented as 1D(x) distributions where the vertical y-axis is the state variable concentration and the horizontal x-axis is distance as kilometers measured from the downstream end of the model domain in JEA Reach 2. The upper and lower reaches of the stream model domain extend from the upstream end of Reach 11 (x=5.49 km) to the downstream end of Reach 2 (x=0.61 km). Table 3 presents a summary of the downstream and upstream distance coordinates (as km) for the upper and lower reaches of Sweetwater Branch.

5.5.1 Hydraulics

Hydraulic properties of stream reaches were represented using empirical hydraulic geometry rating curves for the upper reaches (Reach 11, 10, and 9) and Manning's hydraulic equation for the lower reaches of the stream (Reach 8 through Reach 2). Stream depth and velocity were modeled using flow balance data and these two methodologies to derive steady-state flow balance hydraulic properties. Rating curve coefficients, cross-section data, channel slope, and bottom friction coefficients assigned for the hydraulic calculations are given in Table 4.

5.5.1.1 Stream Flow

Streamflow measurements are available from surveys conducted by Alachua County in Upper Sweetwater Branch from 2010-2016 and streamflow data are available for SJRWMD stations upstream of the KGS discharge and downstream of the MSWRF discharge at the SJRWMD gage at SR331. The comparison between observed and modeled stream flow for the middle flow condition (BIN2) is shown in Figure 14. As can be seen in the model-data plot, the flow balance of the model shows reasonable agreement with the observed streamflow data. The model flow balance shows the small increase in streamflow from the KGS discharge, the small inflow from Rosewood Branch, and the much larger inflow from the MSWRF effluent discharge. The gradual increase of flow along the length of the stream results from the nonpoint source inflow assigned for reaches in Upper and Lower Sweetwater Branch.

The flow balance is based on the urban runoff component of streamflow estimated for the SR331 gage by subtracting out effluent flow from KGS and MSWRF. Urban runoff flow was filtered to compute summary statistics for streamflow (normalized to drainage area) for the low, middle and high flow bin conditions. KGS and MSWRF effluent flows were processed to compute summary statistics and median flow rates were assigned as input for the flow balance without filtering for sample dates defined by low, middle and high streamflow conditions. Under the middle (BIN2) flow condition, the model results show good agreement with the average and median flow. Model results for the comparison of the flow balance for the low-flow (BIN1) and high-flow (BIN3) hydrologic conditions are presented in Appendix B. Flow measured at the SR331 gage is dominated by the effluent flow from the MSWRF discharge particularly under the low and middle flow conditions. The variability of observed streamflow at the SR331 gage and downstream of the SR331 gage is greatest under the high flow condition (BIN3) with less variability observed for the middle flow (BIN2) and the smallest variability seen for the low-flow (BIN1) hydrologic conditions.

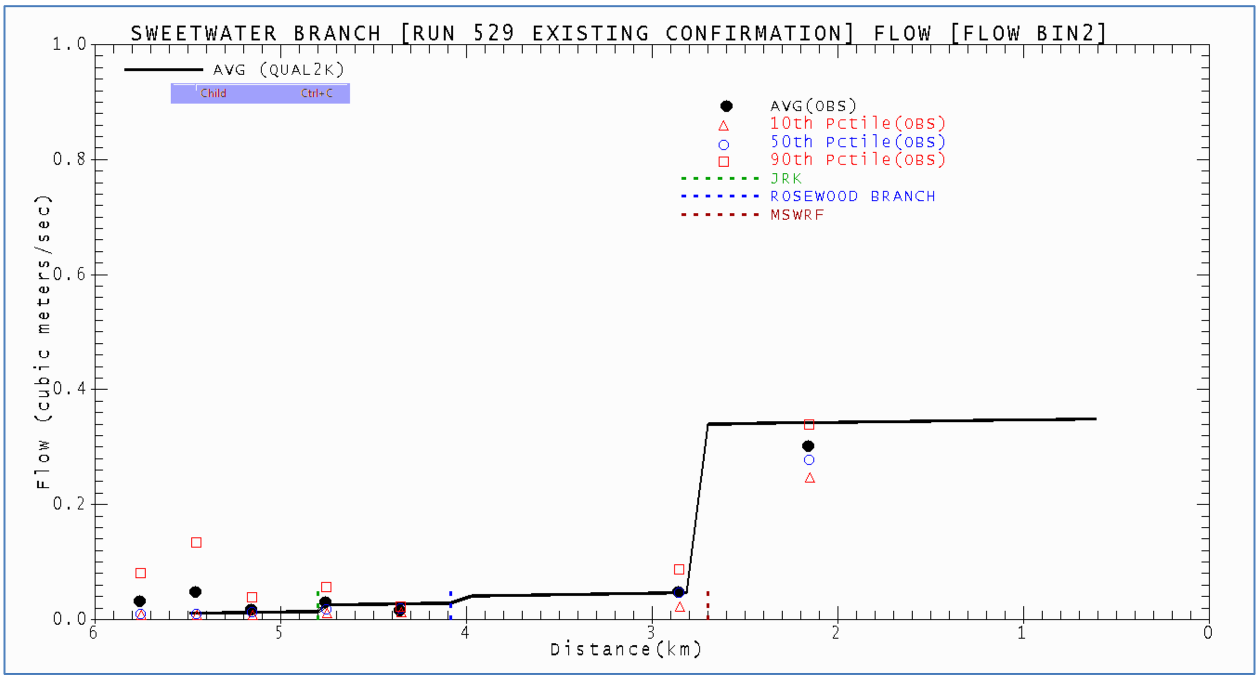

Figure 14- Model confirmation results for Flow BIN2: Stream flow (m^3/sec).

5.5.1.2 Water Depth

Water depth data are available from Alachua County, the FDEP IWR Run 50 database for the parameter BOTTOM, and surveys conducted by Frydenborg Ecologic, LLC at stations upstream and downstream of the KGS discharge. Figure 15 shows a comparison of the agreement between the average and median values of observed depth and modeled water depth in the upper reaches of the stream. In the lower reach of the stream in Reach 5 at SR331, the reason for the discrepancy between model depth (~0.1 m) and observed water depth (~0.4 m) at the downstream SR331 station is unknown. In the modeling study by DSLLC(2015), stream flow was ~0.28 cms compared to the present flow of ~0.34 cms at the SR331 station. As the agreement between observed and modeled depth of ~0.12 m for comparable stream flow rates at this station was very good in the previous study, it is unclear how the observed water depth at SR331 can be so much deeper than a model depth that is similar to the previous study for a similar flow rate. Alachua County reports bottom depth in different data columns in their station files with units of either feet or meters. Although the data provided by the Alachua County files matches the data records used to process the summary statistics, it is possible that the original data for bottom depth may have been entered in error.

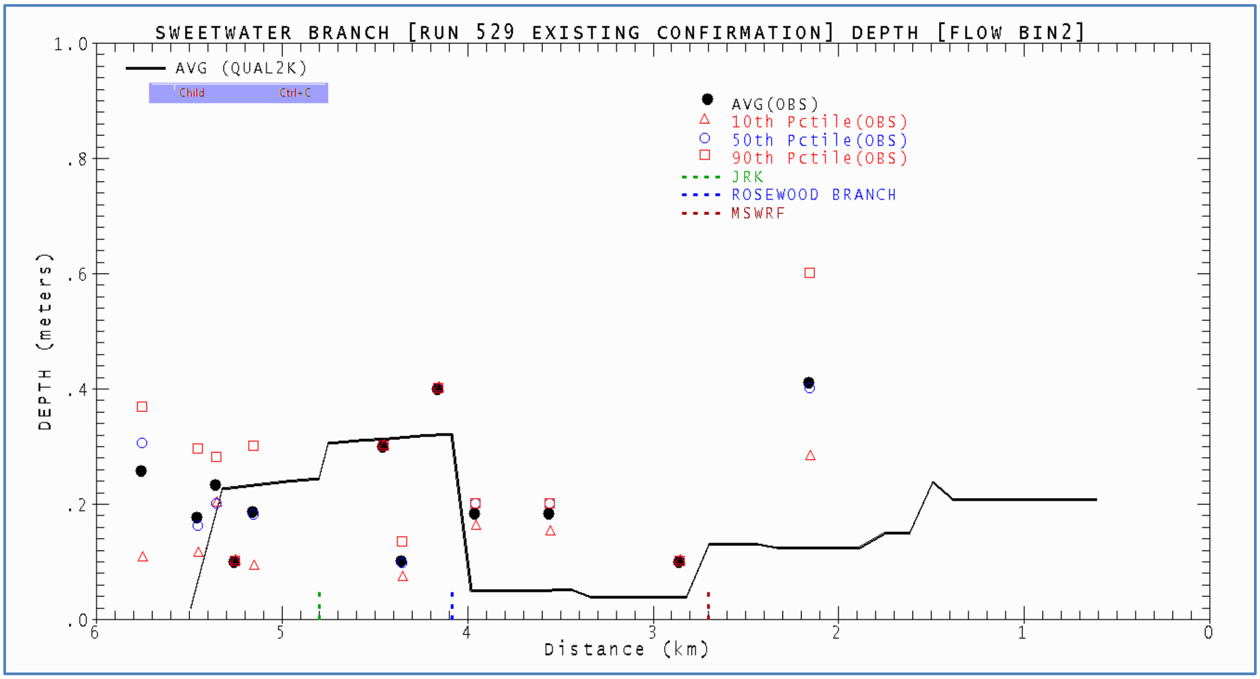

Figure 15- Model confirmation results for Flow BIN2: Depth (meters)

5.5.1.3 Stream Velocity

Velocity measurements are available from surveys conducted by Alachua County from 2010-2016 and surveys conducted by Frydenborg Ecologic, LLC at stations upstream (Reach 11) and downstream (Reach 9) of the KGS discharge. Although Alachua County (2003, 2007) velocity measurements collected before 2010 are available as archived handwritten field notes in pdf format, these non-electronic data records were not compiled for comparison to hydraulic model results. As can be seen in Figure 16, the model results are in reasonable agreement with the averages of the velocity measurements upstream and downstream of the KGS discharge in Reach 11 and Reach 9. The spatial pattern of stream velocity downstream of Rosewood Branch in Lower Sweetwater Branch is dependent on channel slope, bottom friction, and cross-sectional area of the stream. As shown in Figure 3, channel slope gradually decreases from the upstream end of Reach 11 in Upper Sweetwater Branch to the area upstream of the MSWRF discharge. Downstream of the MSWRF facility, however, channel slope is quite variable and the hydraulic representation of stream velocity reflects the increases and decreases in channel slope defined for the model geometry (see Figure 3).

In the lower reaches of the stream downstream of the confluence with Rosewood Branch (x=4.1 km), the magnitude of modeled velocity (~0.2-0.8 m/sec) was consistent with assessments of the velocity pattern in the stream based on personal observations (Frydenborg, 2015). As shown in Appendix B, velocity data available downstream of the MSWRF discharge from Alachua County stormwater studies are in reasonable agreement with the model results at ~x=1.5 km for the high-flow hydrologic conditions (BIN3).

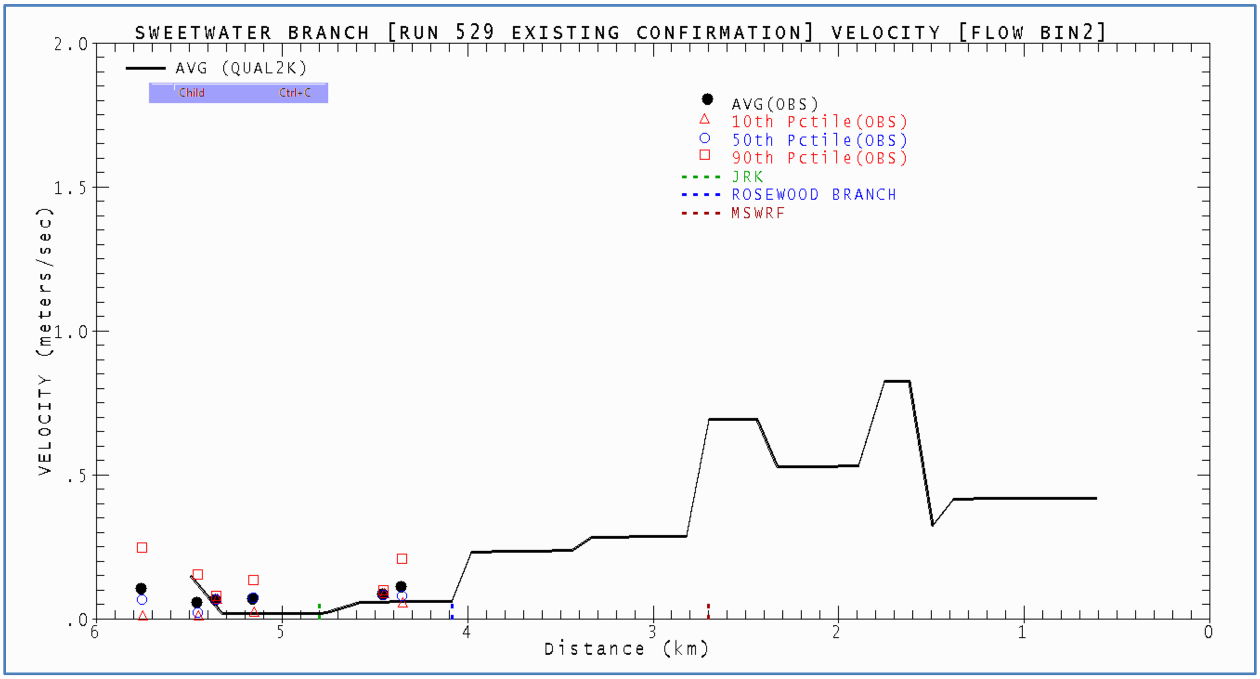

Figure 16- Model results for Flow BIN2: Velocity (m/sec).

5.5.2 Water Temperature and Water Quality

State variables of the QUAL2K model include water temperature, CBOD, dissolved oxygen, nitrogen, phosphorus, phytoplankton, benthic algae, conductivity, alkalinity and pH. Kinetic rates, coefficients, stoichiometric constants, and model parameters developed for confirmation of the Sweetwater Branch QUAL2K model are based on either default values (Chapra, Pelletier, & Tao, 2012), the literature (Bowie & Others, 1985), Flynn et al. (2015), the model confirmation process in the first modeling study of lower Sweetwater Branch (DSLLC, 2015), and the model confirmation process for the second modeling study of the upper and lower reaches of Sweetwater Branch (DSLLC, 2016).

Selected comparisons of model confirmation results for key water quality variables are presented in this section to demonstrate the credibility of the QUAL2K model developed for the upper and lower reaches of Sweetwater Branch. Model data results for the middle flow condition (BIN2) are presented in this section for water temperature, total nitrogen, total phosphorus, phytoplankton and benthic algae biomass. Model-data results for the low-flow (BIN1) and high-flow (BIN3) hydrologic conditions are presented in Appendix B. Observed data are presented as the average value (filled black circle), median value (open blue circle) of the data compiled from 2013-2016 for the middle flow condition (BIN2). The range of observations (10^{th} and 90^{th} percentile values) is shown by the open red triangle and square symbols. Markers are shown to identify the KGS discharge, Rosewood Branch, and MSWRF discharge locations. Where a state variable is characterized by diel variability modeled by QUAL2K, the upper and lower diel range is shown as a dashed red line. The x-axis of each plot is stream distance (as kilometers) measured from the downstream end of JEA Reach 2 (at x=0.61 km) to the upstream end of the model domain at the upstream end of JEA Reach 11 (x=5.49 km).

5.5.2.1 Water Temperature

As can be seen in Figure 17, the model results are in agreement with the spatial pattern of the average and median values and the lower/upper range of observed water temperature. In interpreting the match between model results and observed data, it is important to understand that as a steady-state model, QUAL2K simulates water temperature based on long-term average heat flux assigned for mid-September. The range of observed data, however, is based on data compiled from 2013-2016 for all months. The January-December data range is shown by the 10^{th} and 90^{th} percentile values of water temperature for the middle flow condition (BIN2). Consistent with the expected spatial pattern, the model indicates a small increase in water temperature as a result of the KGS cooling water discharge (x= 4.8 km) and an increase in water temperature from the MSWRF discharge (x=2.7 km). The diel pattern for simulated water temperature shows a larger low/high range modeled upstream of the MSWRF discharge than downstream of the MSWRF facility.

Although the model results are somewhat warmer than the average and median observations downstream of MSWRF, the data does clearly show a pattern of an increase in water temperature from the wastewater inflow for both the middle (BIN2) and high flow (BIN3, see Appendix B) conditions. Station data are not available immediately upstream and downstream of the KGS discharge to show the spatial gradient from the effluent discharge at this location. Under the low-flow (BIN1, see Appendix B) and middle-flow (BIN2) conditions, the model does show a small increase in water temperature from the KGS cooling water discharge. Under the high-flow (BIN3, see Appendix B) condition, the impact of the KGS inflow on water temperature is masked by high-flow from the upstream boundary inflow. The model results for the middle flow condition (BIN2) tend to be consistently warmer than the observed average and median water temperature in Upper and Lower Sweetwater Branch. At the locations just upstream and downstream of the MSWRF discharge the model results are in agreement with the upper range (90^{th} percentile) of the observed water temperature. Observed water temperature data are shown in Appendix B for comparison to the low flow (BIN1) and high flow (BIN3) model results. In contrast to the middle flow condition (BIN2) where the model results are warmer than the observed average and median data, the model results for the high-flow conditions (BIN3) tend to be cooler than observed water temperature particularly in Upper Sweetwater Branch upstream of Rosewood Branch.

In evaluating how well the QUAL2K model represents water temperature for the low, middle and high-flow conditions it must be understood that the QUAL2K model is steady-state. Model input includes specification of a discrete date (15 September) that is used to assign input data for solar radiation as a function of latitude and calendar date. In the first report prepared for the Lower Sweetwater Branch (DSLLC, 2015), the date assigned for model input (15 September 2011) corresponded to the midpoint of the time period for collection of periphyton biomass measurements by WAR (2011) in Lower Sweetwater Branch. The same mid-September date was assigned for the follow-on modeling studies (DSLLC, 2016; 2017; 2020) to ensure comparability between the different model confirmation periods and model scenarios. QUAL2K simulates the heat balance for the water temperature model based on heat input from air temperature (Gainesville average for September) and incident solar radiation derived as a function of latitude and average cloud cover for Gainesville in September (see Table 18). The model is driven by the median water temperature inflows compiled from composite data sets for the upstream boundary (2004-2016, January-December) for the low, middle and high flow conditions and the overall median water temperature data reported for the KGS and MSWRF effluent. The model is compared against summary statistics of composite data sets compiled for stations in the upper and lower reaches of the stream from 2013-2016 (January to December) for the low, middle, and high flow conditions.

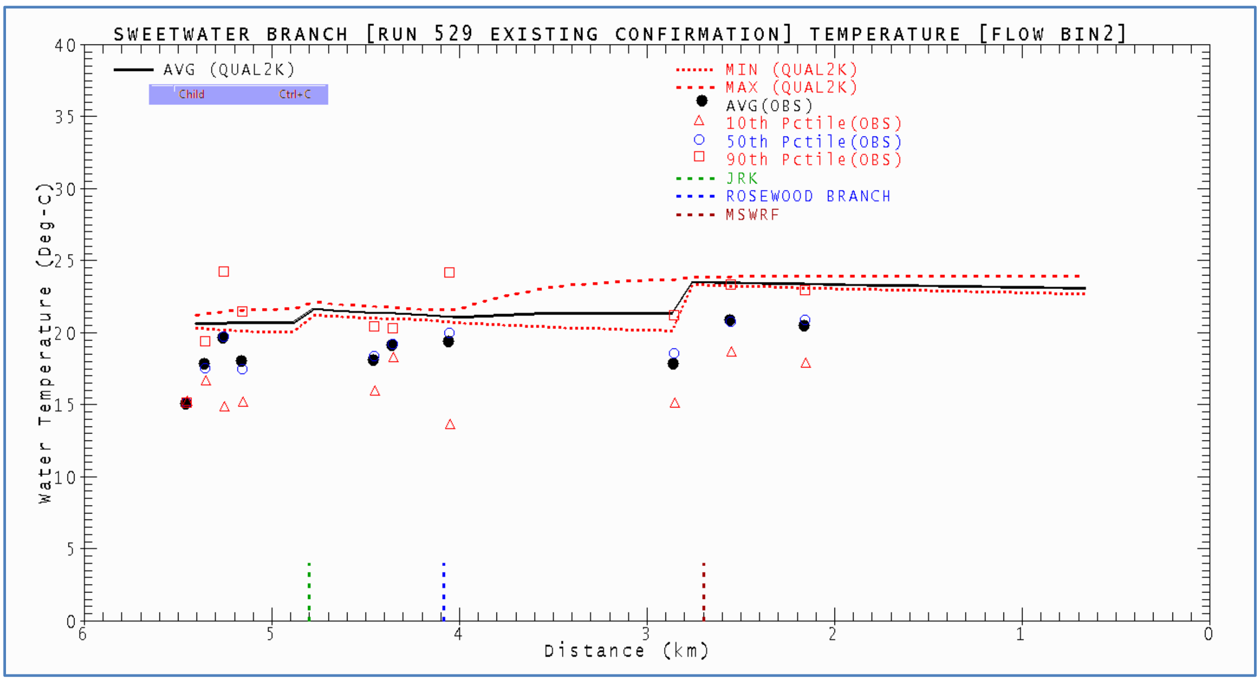

Figure 17- Model confirmation results for Flow BIN2: Water Temperature (^{o}C).

With input data based on mid-September heat flux and water temperature input data based on a statistical composite of stream observations collected from 2004-2016 and median effluent temperature for the KGS and MSWRF discharges, the model is not expected to agree perfectly with the observations of water temperature. Visual inspection of the model results for water temperature presented for the low, middle and high flow hydrologic conditions in Appendix B demonstrates fair agreement with the range of observations in the Upper and Lower reaches of Sweetwater Branch and that the model results captures the impact of the KGS and MSWRF effluent discharges with a small downstream increase in water temperature. The impact of the MSWRF discharge is captured by observations of water temperature upstream and downstream of the MSWRF discharge for the middle-flow (BIN2) and high-flow (Bin3) hydrologic conditions.

What are the implications for the over-prediction and under-prediction of model results compared to observed water temperature? A slightly warmer (or cooler) temperature pattern will result in slightly higher (or lower) reaction rates for temperature-dependent water quality kinetics and temperature-dependent growth, respiration, and excretion terms for phytoplankton and benthic algae. Water quality model results for nutrients, CBOD, and phytoplankton, although influenced by temperature dependent kinetic reactions, are also controlled by hydraulic residence time in the upper and lower reaches of the stream as demonstrated with the model scenarios for high stormwater flow (Scenario#2) and removal of effluent discharges to the stream (Scenario#4).

5.5.2.2 Total Nitrogen

The spatial distribution of Total Nitrogen is seen to be in very good agreement with the observed average and median values and the lower/upper range of Total Nitrogen (Figure 18). As can be seen in the plot, the model indicates a small increase in Total Nitrogen as a result of the KGS discharge at km 4.8. The model also clearly shows the large increase in Total Nitrogen as a result of the upstream load mixed with the effluent load of Total Nitrogen from the MSWRF. The variability of Total Nitrogen is shown to be much greater at stations downstream of the MSWRF effluent discharge than at stations above and below KGS in the upper reaches of the stream. The inorganic nitrogen levels in the stream are not limiting productivity because the modeled stream concentrations for inorganic nitrogen are much greater than the half-saturation nitrogen constants assigned for phytoplankton (K_n = 15 µg N/L) and periphyton (K_n = 300 µg P/L) growth in the model.

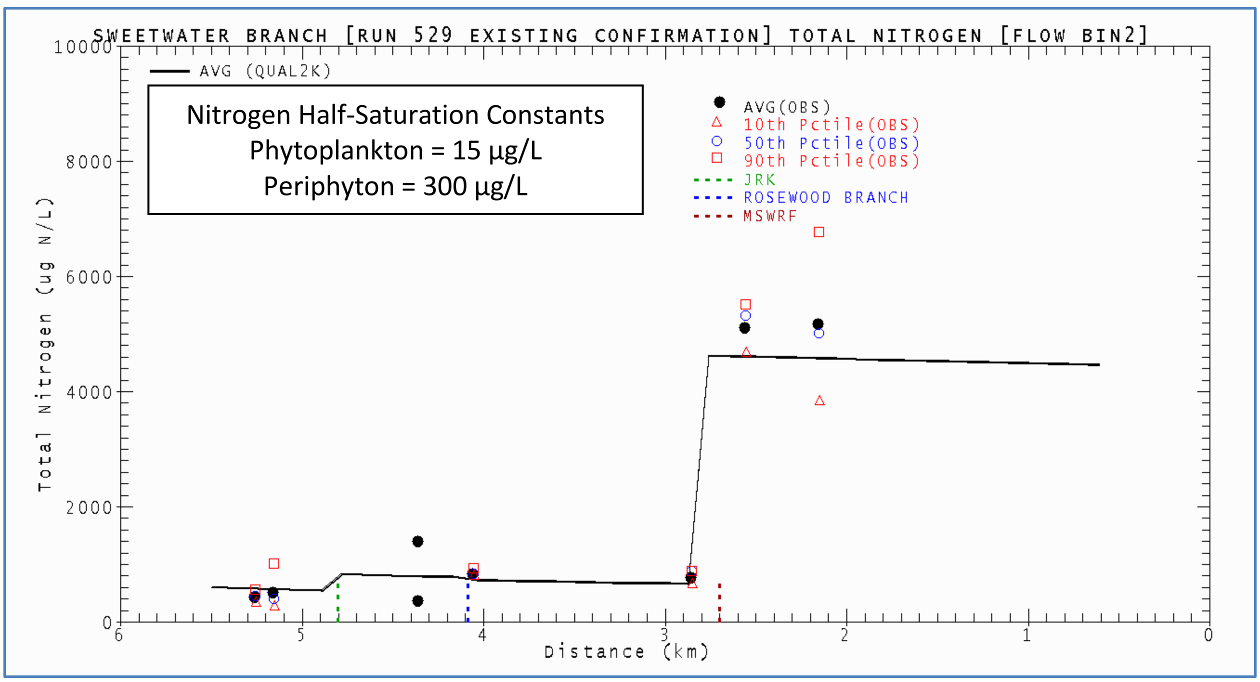

Figure 18- Model confirmation results for Flow BIN2: Total Nitrogen (µg N/L).

5.5.2.3 Total Phosphorus

As can be seen in Figure 19, the spatial distribution of simulated Total Phosphorus falls within the lower (10^{th} percentile) and upper (90^{th} percentile) of the observed range of monitoring data. In Upper Sweetwater Branch, however, the two sampling observations located at Station SWBSE8 (x=4.36 km) are very different. The lower TP concentration (210 µg/L) is in good agreement with the model results but the much higher TP concentration of 1,606 µg/L appears to be an outlier at this station (SWBSE8).

Table 22 shows the limited number of only two (2) observations available for Station SWBSE8 for the middle flow (BIN2) hydrologic conditions for the period of record from 2013-2016. As shown in the legends for TP (Figure 19) and TN (Figure 18), the plots are formatted to show the average and the 10^{th} and 90^{th} percentile range of observations that satisfy the filtering criteria for extraction of data records. Nutrient concentrations measured on 2/18/2013 are higher than the 95^{th} percentile and the TN and TP observations collected on 5/8/2013 are lower than the 5^{th} percentile. The number of records for each station, such as SWBSE8 at x=4.36 km, are not reported as a statistic on each of the model-data plots. As the data set for SWBSE8 was limited to only N=2 observations, it would not be accurate to plot average, 10^{th} and 90^{th} percentile observations for this particular station location. A skewed range of nutrient records would give an erroneous impression of large variability based on only N=2 nutrient records.

The two solid circle symbols plotted at x=4.36 km for both TN (Figure 18) and TP (Figure 19) show the individual observations recorded for 2/18/2013 and 5/8/2013 (see Table 22). As a “special case” for model-data plots, the plot symbol and label were not modified to indicate that the data points at x=4.36 km represented only single observations for two different sampling dates.

Table 22- Nutrient Observations at Station SWBSE8 for Middle Flow BIN2 Hydrologic Conditions

Sample Date	TN µg N/L	TP µg P/L
2/18/2013	1,400	1,680
5/8/2013	370	210
N_Observations	2	2
Average	885	945
5%ile	421.5	283.5
10% ile	473	357
90% ile	1,297	1,533
95% ile	1,348.5	1,606.5

The model shows the small impact of the KGS discharge and the much larger impact of the effluent load from the MSWRF. Downstream of the MSWRF discharge, the model results are somewhat lower than the observed median but are within range of the lower 10^{th} percentile end of the observed data. The discrepancy between modeled and observed TP in Lower Sweetwater Branch may be explained, in part, by the assignment of the median effluent concentration of 510 µg P/L which is two-thirds of the mean concentration of 750 µg P/L (n=169). If the mean TP of 750 µg P/L was assigned for MSWRF, then the mass balance with the increased MSWRF load would result in an increase in modeled TP from 461 to 658 µg P/L downstream of the MSWRF discharge and the model results would be in much better agreement with the observations downstream of MSWRF. Although the model under-estimates the distribution of TP, water column and bottom algae biomass are controlled by hydraulic characteristics of the stream rather than ambient nutrient levels. The inorganic phosphorus levels in the stream are not limiting productivity because the modeled stream concentrations for inorganic phosphorus are much greater than the half-saturation phosphorus constants assigned for phytoplankton (K_p = 2 µg P/L) and periphyton (K_p = 100 µg P/L) growth in the model.

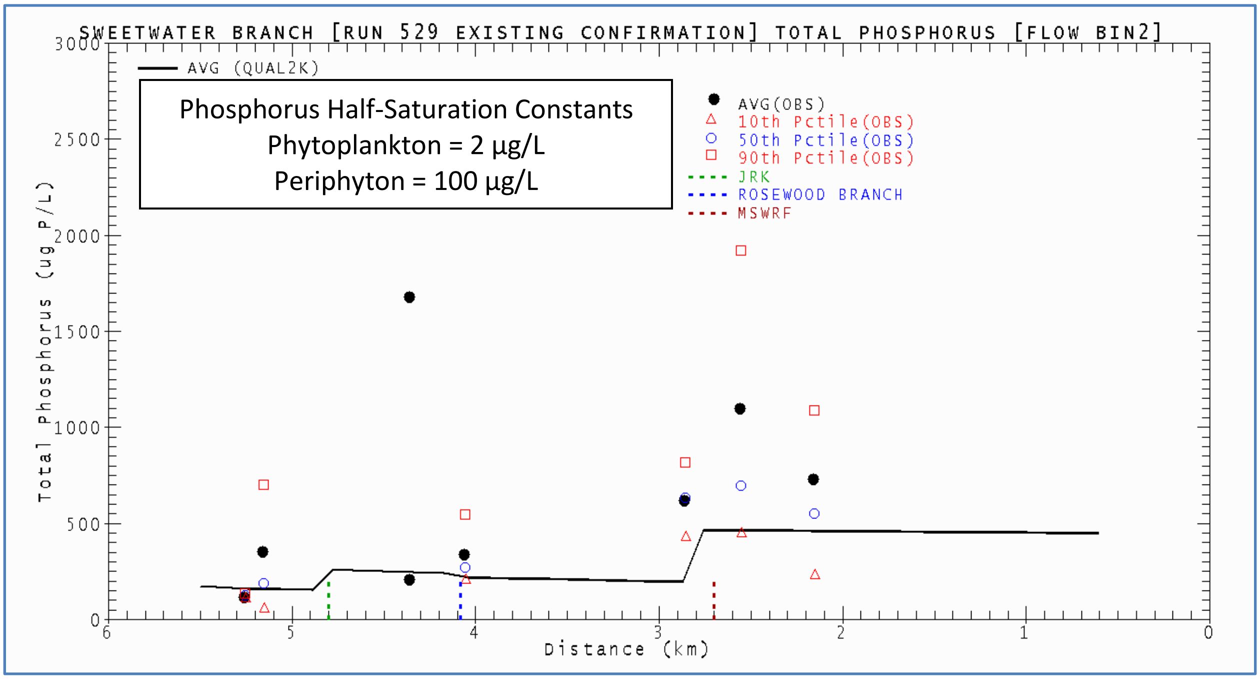

Figure 19- Model confirmation results for Flow BIN2: Total Phosphorus (µg P/L).

5.5.2.4 Phytoplankton

In contrast to the data shown above for Total Nitrogen and Total Phosphorus, variability of phytoplankton, ranging from <1 to 6 µg/L, is greater in the upper reaches of the stream and just upstream of the MSWRF effluent discharge than in the lower reaches downstream of the MSWRF discharge (Figure 20). This pattern probably results from the much smaller flow upstream of the MSWRF effluent discharge and the greater impact of stream flow-related fluctuations in residence time. Although the observed median value of ~3 µg/L just upstream of the wastewater discharge (at x=2.8 km) is higher than the model result of ~1.5 µg/L, the model results are in agreement with the 10^{th} percentile value (~1.5 µg/L) of chlorophyll at this location. Downstream of the MSWRF effluent discharge, chlorophyll is relatively constant at <1 µg/L because of the short residence time that does not allow sufficient time for growth and accumulation to occur in these reaches of lower Sweetwater Branch. In the upper reaches of the stream, the model shows that the discharge from KGS serves to reduce the upstream level of chlorophyll from ~2 µg/L to ~1.2 µg/L. Overall, visual inspection of the model results for phytoplankton Chlorophyll for the middle flow condition demonstrates that the model results (average, min and max) are in approximate agreement with the lower end of the observations as indicated by the 10th percentile distribution of Chl records.

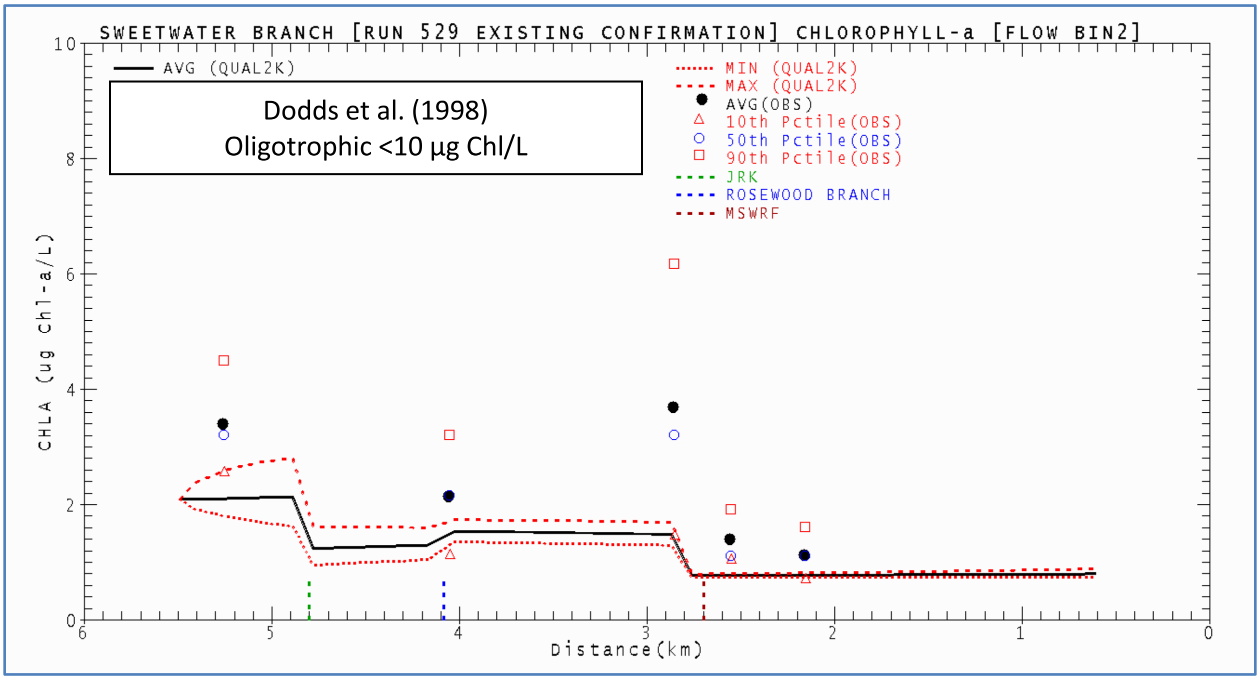

Figure 20- Model confirmation results for Flow BIN2: Phytoplankton Chlorophyll (µg Chl/L).

In evaluating how well the QUAL2K model represents phytoplankton chlorophyll, it must be understood that the QUAL2K model is steady-state. Model input includes assignment of a discrete date (mid-September) that is used to assign input data for solar radiation as a function of latitude and calendar date. Upstream boundary data used to specify inflows to the model domain and station observations in the upper and lower reaches of the stream used for comparison to model results represent a composite data set for each flow condition based on samples collected from January to December during 2013-2016. Observed chlorophyll records for the low, middle, and high flow conditions, therefore, are representative of a potentially wide range of available sunlight conditions that would control variability of phytoplankton growth and primary productivity in the stream.

The discussion provided above is intended to show that the output from the model is within range of the measured phytoplankton biomass values. A primary objective of the project is to assess potential outcomes downstream of the MSWRF to evaluate if the wastewater discharge significantly impacted sestonic and benthic plant growth in Sweetwater Branch. As demonstrated by both the measured data and the model results, chlorophyll a levels are consistently low for all flow conditions. All concentrations are <6 µg/L and many station records show levels <3 µg/L. Despite nutrient levels indicative of eutrophic conditions in a stream (Dodds et al., 1998), low phytoplankton biomass conditions in the stream are due to hydraulic conditions of a short residence time and heavy shade coverage that is characteristic of Sweetwater Branch. Based on criteria developed by Dodds et al. (1998) to characterize trophic status of streams, an oligotrophic stream is classified by mean sestonic chlorophyll levels <10 µg/L. Based on the observed low levels of sestonic plant biomass, Sweetwater Branch would be considered to be an oligotrophic stream and the levels of chlorophyll shown for model confirmation are also consistent with Florida's evidentiary threshold (3.2 µg/L) for phytoplankton chlorophyll in free-flowing streams and rivers.

5.5.2.5 Benthic Algae

Figure 21 shows the good agreement of the model results for periphyton with benthic algae biomass data collected by Frydenborg Ecologic, LLC in September 2015, December 2015 and March 2016. Having achieved a good match of model results to the observed periphyton biomass data with the velocity-dependent growth function (see Figure 9) and the empirically assigned maximum growth rates for the reaches upstream and downstream of the KGS outfalls, it is apparent that the observed spatial pattern of periphyton biomass in Sweetwater Branch is strongly influenced by the hydraulic and velocity characteristics of the stream (see Figure 16).

In the previous study that covered the period from 1998-2012, data collected by Water and Air Research (WAR, 2011) in August-September 2011 in the lower sections of Sweetwater Branch were used to calibrate the model for periphyton biomass. The WAR (2011) data set from 2011 is plotted for the lower reaches of the stream to supplement the upper reach data collected by Frydenborg Ecologic, LLC in 2015-2016. As shown in Figure 21, the model shows very good agreement to the observed periphyton biomass collected by Frydenborg Ecologic in 2015-2016 and by WAR (2011) in 2011.

Benthic biomass values, both measured and predicted, are all very low compared to periphyton biomass reported for other streams in the literature. Table 23 shows a comparison of Sweetwater Branch periphyton biomass (Ash Free Dry Weight basis) with data from a reference site for Armstrong Slough in the Kissimmee Basin, Florida. Periphyton biomass data have also been compiled from a variety of literature sources to show typical ranges of periphyton biomass. For sites other than Sweetwater Branch, median biomass is seen to vary widely from a low of ~1,600 to a high of ~8,135 mg AFDW m^{-2}. The median value of the biomass data for Sweetwater Branch (57 and 167 mg AFDW m^{-2}) is about an order of magnitude lower than the literature data presented in the table. Benthic algae biomass in Sweetwater Branch is, therefore, at the very low end of periphyton biomass observed at the Armstrong Slough reference site in Florida and the other sites reported in the literature.

Benthic biomass levels in Sweetwater Branch do not indicate impaired conditions (See section 6.1.5.4 of EPA's Periphyton Protocols https://archive.epa.gov/water/archive/web/html/ch06main.html). Based on criteria developed by Dodds et al. (1998) to characterize trophic status of streams, an oligotrophic stream is classified by mean benthic chlorophyll levels <20 mg Chl m^{-2}. Based on the observed low levels of benthic plant biomass (<2 mg Chl m^{-2}), Sweetwater Branch would be categorized as an oligotrophic stream.

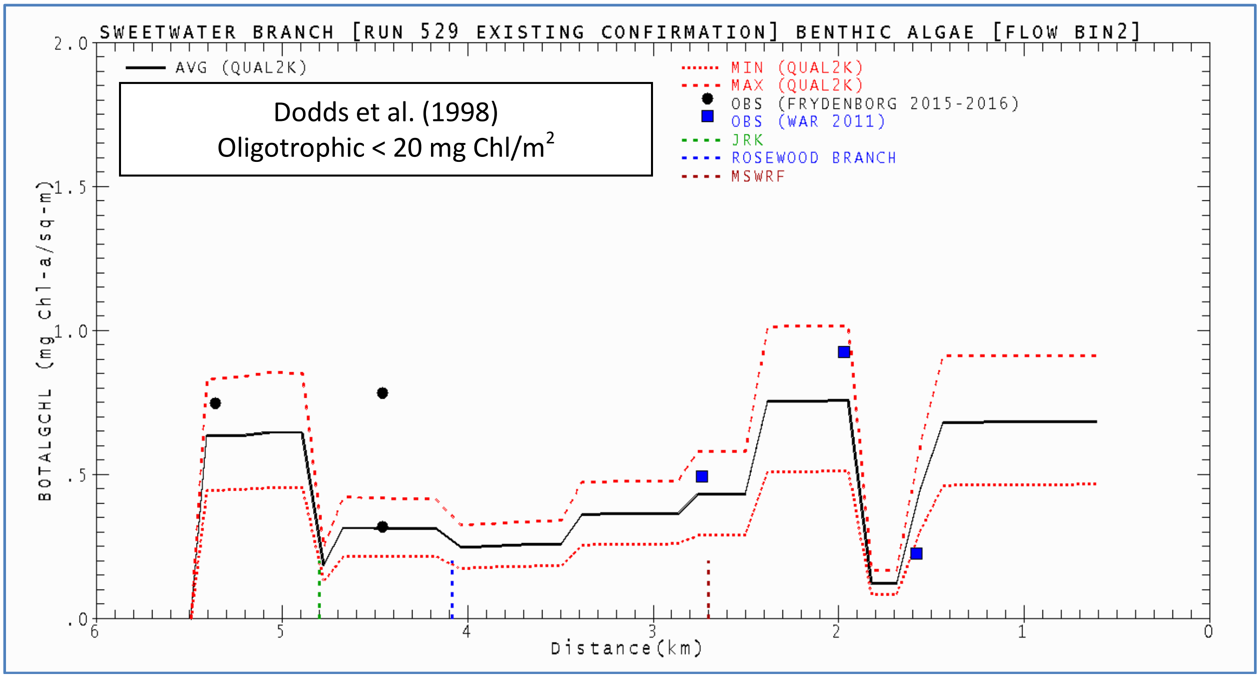

Figure 21- Model confirmation results for Flow BIN2: Periphyton Biomass (mg Chl m^{-2}).

Table 23- Periphyton Biomass (as mg Ash Free Dry Weight m^{-2}): Comparison of Sweetwater Branch, Reference Site in Florida and the Literature

	Periphyton Biomass			mg AFDW m^{-2}				
Site	**N_Obs**	**MIN**	**10%ile**	**25%ile**	**50%ile**	**75%ile**	**90%ile**	**Max**
Sweetwater Br, FL (Upper)	5	130	139	153	167	933	1,077	1,173
Sweetwater Br, FL (Lower)	3	26	32	42	57	82	96	106
Armstrong Slough, FL	17	700	920	1,300	1,600	2,100	2,720	3,500
New Zealand	n/d	n/d	200	700	2,000	5,000	8,000	n/d
Angelo Coastal Range, CA	18	930	1,137	2,305	8,135	23,603	43,830	52,170
Indian Head, MD	18	181	238	413	2,101	4,023	7,589	11,798
Lough Gill, Ireland	98	100	470	1,100	1,750	4,150	7,860	18,800
NW Ozark Plateau, AR	n/d	1,000	n/d	n/d	n/d	n/d	n/d	47,000
	Data Source							
Sweetwater Br, FL (Upper)	Frydenborg Ecologic (2016)							
Sweetwater Br, FL (Lower)	WAR (2011)							
Armstrong Slough, FL	Thompson et al. (1982)							
New Zealand	Biggs (1996)							
Angelo Coastal Range, CA	Warnaars et al (2007)							
Indian Head, MD	Halliburton (1994)							
Lough Gill, Ireland	Feeney (1998)							
NW Ozark Plateau, AR	Drake et al (2012)							

5.6 Model Application: Point Source and Nonpoint Source Scenarios

As described under Section 5.1, the purpose of this study is to prepare technical materials to support development of WQBELs for GRU's Main Street Wastewater Reclamation Facility (MSWRF) and the John R. Kelly Generating Station (KGS). Assessments of existing and future stormwater loads are also included in the modeling analyses to evaluate the potential water quality and biological impact of urban growth and development on conditions in Sweetwater Branch. Based on input from GRU and the City of Gainesville staff, and using the existing QUAL2K model of Sweetwater Branch set up for hydrologic and water quality conditions covering the period from 2013-2016 (see Section 5.5 and DSLLC, 2016), QUAL2K model runs were performed to assess the potential water quality and biological impacts from management scenario changes in effluent flow and loading from MSWRF and KGS in combination with stormwater flow and loading scenarios. As described under Section 5.1, stream and effluent data from 2013-2016 were selected to provide a representative water quality assessment of current operating conditions for effluent discharges from the KGS and MSWRF outfalls. The QUAL2K runs applied the confirmed model setup for three flow bin conditions (BIN1, BIN2 and BIN3) for 2013-2016 data sets to represent a range of hydrologic conditions in Sweetwater Branch.

This section of the WQBEL report summarizes MSWRF and KGS point and urban nonpoint source flow and nutrient loads applied as input to the QUAL2K model and the outflow of nutrient loads predicted by the stream model going into the enhancement treatment wetland system. Predicted water column chlorophyll concentrations and periphyton biomass in Sweetwater Branch are identified near monitoring station locations downstream of the KGS outfalls and the MSWRF outfall. QUAL2K model results are extracted at the KGS and MSWRF locations for each scenario and compared to model confirmation "baseline" results for 2013-2016 hydrology and water quality conditions. Baseline model results are presented in Section 5.5 and DSLLC (2016). Changes in water column travel time, chlorophyll a and periphyton biomass are identified at the KGS and MSWRF locations for model scenarios related to point source loading from KGS and MSWRF and nonpoint source loading from stormwater loading.

During the course of this study, various assumptions were used to represent point and nonpoint source flow and loads from the MSWRF municipal wastewater facility, the KGS steam-generating station and urban runoff. Table 24 presents a summary of the seven (7) point and nonpoint source loading scenarios (Scenario#0 to Scenario#6) developed for comparison to the results simulated for the model confirmation run (Run 529). Explanatory notes are provided in the table to describe assumptions for MSWRF, KGS and nonpoint source flow and loads used for model input. A description of data sources and data tables used to represent urban nonpoint source and NPDES permitted point source discharges for the MSWRF municipal wastewater facility and KGS steam-electric generating station are presented in Section 5.4 for documentation of model confirmation to observed data from 2013-2016. As new data sources are described for the first time to represent the model application scenarios developed for Point Source and Nonpoint Source Scenarios (Section 5.6), Sensitivity Analyses (Section 5.7) and Future Buildout Point Source and Nonpoint Source Scenarios (Section 5.8), data tables will be presented to document flow, nutrients and other water quality constituent concentrations used for model input.

Table 24- Summary of QUAL2K Stream Model Point and Nonpoint Source Load Scenario Runs

Section 5 WQBEL- Summary of QUAL2K Model Runs					
Scenario (Run ID)	**Description**	**MSWRF**	**KGS**	**NPS**	**Note**
Confirmation (529)	Baseline (2013-2016)	Baseline 2013-2016 data	Baseline 2013-2016 data	Baseline 2013-2016 Data	1
Scenario#0 (600)	Existing NPDES Permits	Q=7.5 MGD, TN=8 mg/L, TP = 0.45 mg/L	Q=2.402 MGD, 95th percentile TN & TP	Same as Confirmation Run	2
Scenario#1 (601)	9 MGD MSWRF Buildout & Upgrade	Q=9 MGD, TN=8 mg/L, TP = 0.375 mg/L	EPA MDL 95% Confidence Interval for Q,TN,TP	Same as Confirmation Run	3
Scenario#2 (602)	"Worst-Case" Stormflow & 9 MGD MSWRF Buildout & Upgrade	Same as Scenario #1	Same as Scenario #1	"Worst Case" NPS Stormflow (BIN3)	4
Scenario#3 (603)	Shade Sensitivity	Same as Scenario #1	Same as Scenario #1	Same as Confirmation Run	5
Scenario#4 (604)	NPDES Point Source Removal	No discharge (Q=0)	No discharge (Q=0)	Same as Confirmation Run	6
Scenario#5 (605)	12 MGD MSWRF Full Buildout & Upgrade	Q=12 MGD, TN=8 mg/L, TP = 0.375 mg/L	Same as Scenario #1	Same as Confirmation Run	7
Scenario#6 (606)	"Worst-Case" Stormflow & 12 MGD MSWRF Full Buildout & Upgrade	Q=12 MGD, TN=8 mg/L, TP = 0.3 mg/L	Same as Scenario #1	Same as Scenario #2	8

Notes for Table
1- Confirmation Run 529 using observed data collected from Jan-2013 through Dec-2016. MSWRF (6.68 MGD, TN=5.27 mg/L, TP=0.51 mg/L); KGS CTBD8 (0.22 MGD, TN= 1.3 mg/L, TP=0.9 mg/L for Cooling Tower Blowdown) and KGS LVW (0.0182 MGD, TN= 0.57 mg/L, TP=0.235 mg/L for Low Volume Waste). NPS flow based on median discharge for BIN1, BIn2 and BIN3 conditions.
2- Scenario#0: MSWRF set at existing NPDES permitted annual average flow (7.5 MGD, TN=8 mg/L, TP=0.45 mg/L). Use of KGS NPDES permitted flow and 95th percentile of TN and TP observations yields inflated KGS TN and TP load estimates that are not realistic. Results of this scenario are conservative.
3- Scenario#1: Upgrade of MSWRF (9 MGD, TN=8 mg/L, TP=0.375 mg/L). KGS flow, TN and TP loads derived from observed effluent records and EPA Maximum Daily Load (MDL) methodology with 95% Confidence Interval. EPA MDL method gives much more realistic estimates of flow, TN and TP loads from KGS.

4- Scenario#2: "Worst-Case" NPS Stormflow loads calculated using 90th percentile flow and 90th percentile TN & TP from 2013-2016 data for BIN3 high-flow conditions. Method yields TN and TP loads similar to loads calculated in FDEP (2006) TMDL for Alachua Sink.
5- Scenario#3: Model sensitivity run with stream shade coverage reduced by 50% to test sensitivity to increase of available light.
6- Scenario#4: Model sensitivity run with MSWRF and KGS discharges removed to test sensitivity response to only urban NPS flow and loads.
7- Scenario#5: Full Future Buildout of MSWRF (12 MGD, TN = 8 mg/L, TP = 0.375 mg/L) and Median NPS flow conditions for BIN1, BIN2 and BIN3.
8- Scenario#6: Full Future Buildout of MSWRF (12 MGD, TN = 8 mg/L, TP = 0.300 mg/L) and "Worst-Case" NPS Stormflow conditions for BIN3 only. Method yields TN and TP loads similar to loads calculated in FDEP (2006) TMDL for Alachua Sink.

5.6.1 Scenario#0: Existing NPDES Permitted Point Source Effluent Flow and Loads

Model input data and results obtained for the confirmation run for the three flow conditions (BIN1, BIN2, and BIN3) were used as the baseline for comparison to results obtained for the existing permitted point source management run. The focus of the evaluation for Scenario #0 was to test a hypothetical effluent loading scenario typically required by Florida DEP to examine "what if" NPDES permitted facilities discharged flow and nutrient loads at their full permitted capacity.

5.6.1.1 Scenario #0: Input Data for Nonpoint Source and Point Source Flow and Loads

Nonpoint source flow and loading data are based on the 2013-2016 baseline data sets for water quality and streamflow conditions compiled for model confirmation to existing hydrology and water quality conditions. Stream discharge records at the SR331 gage include point and nonpoint source components of flow. NPDES permitted point source discharges in Sweetwater Branch include effluent flow from the KGS and MSWRF outfalls. Nonpoint source discharge to the stream is characterized by runoff over the 3.0 mi^2 urban drainage area of the City of Gainesville. The nonpoint source component of urban runoff in Sweetwater Branch is derived from streamflow records at the SR331 gage and effluent discharge records from the KGS and MSWRF outfalls. Summary statistics for nonpoint source water quality (see Table 5) and the urban runoff component of stream flow records at the SR331 gage (see Table 16) are presented for water quality and flow data compiled for the three flow bins (BIN1, BIN2, and BIN3).

Under Scenario#0, model input data for nonpoint source flow and water quality conditions were defined by median (50^{th} percentile) statistics compiled for the baseline model confirmation under BIN1, BIN2, and BIN3 hydrologic conditions (see Table 24). Estimates of the annual nonpoint source flow and loads are based on a weighting of the median flow and median nutrient concentrations derived for the three flow bin conditions as shown in Table 25. A description of the data sources and methodology used to develop nonpoint source water quality and flow data sets is presented in Section 5.4.3 and Section 5.4.5.

Table 25- Scenario #0 Annual Median Streamflow and Nutrient Loads for Stormwater Runoff

Weight Factor	0.25	0.5	0.25	Annual	Data
Median	**BIN1**	**BIN2**	**BIN3**	**BIN(1+2+3)**	**Source**
NPS Flow (cfs)	0.5157	1.6098	3.0136	1.6872	Table 17
NPS Total N (lbs/yr)	904.6	1,850.9	4,598.0	2,301.1	Table 5
NPS Total-N (mg/L)	0.891	0.584	0.775	0.693	
NPS Total P (lbs/yr)	223.4	538.8	673.4	493.6	Table 5
NPS Total-P (mg/L)	0.220	0.170	0.114	0.149	

Load (lbs/yr) = cfs x mg/L x 5.39377 x 365; Annual Median = 0.25xBIN1 + 0.5xBIN2 + 0.25xBIN3

Effluent flow, nutrient concentrations and loads for the MSWRF and KGS discharges are summarized for Scenario #0 in Table 26. The KGS facility reports effluent discharge records for two outfalls: (1) Unit 8 Cooling Water Discharge (CTBD8) and (2) Low Volume Waste (LVW). KGS permitted discharge rates and effluent records for nutrient concentrations are used to compute effluent loads for each outfall. The combined sum of effluent flow and nutrient loads from the cooling water and low volume wastewater outfalls are presented in Table 26. The combined flow and loads from the CTBD8 and LVW outfalls were used to derive flow-weighted nutrient concentrations. The combined KGS flow and nutrient loading data are shown to facilitate comparison of the relative contributions of flow and nutrient loading from the MSWRF and KGS discharges.

The KGS NPDES discharge permit allows for an effluent flow rate of 1.958 MGD for the Unit 8 Cooling Tower Blowdown (CTBD8) and 0.444 MGD for Low Volume Waste (LVW). Under the model confirmation conditions described in Section 5.4.4, the median effluent flow rates for the KGS Unit 8 Cooling Tower Blowdown (0.222 MGD) and Low Volume Waste (0.018 MGD) outfalls (see Table 9 and Table 10) are, however, seen to be an order of magnitude lower than the permitted effluent flow rates for the two outfalls. The effluent flow and corresponding nutrient loading rates assigned for KGS for Scenario#0 are, therefore, extremely high and do not provide realistic expectations of potential nutrient loading from the KGS discharge. As the methodology used to assign effluent flow and loading from KGS for Scenario#0 is considered to be flawed, a more robust methodology has been developed to properly characterize KGS effluent flow and nutrient loading for all other scenarios (Scenario#1 through Scenario #6) presented in this report.

Table 26- Scenario #0 Summary of MSWRF and KGS Effluent Flow and Nutrient Loading Rates

Permitted PS Discharge **Scenario#0 (Run 600)**	**MSWRF** **NPDES Permit**	**KGS CTBD8** **Permit & 95%ile**	**KGS LVW** **Permit & 95%ile**	**KGS CTBD8+LVW** **Permit & 95%ile**
Annual Flow (MGD)	7.5	1.958	0.444	2.402
Total Nitrogen (mg N/L)	8	2.712	2.641	2.699
Total Phosphorus (mg P/L)	0.45	0.983	0.22	0.842
Total Nitrogen (lbs N/yr)	182,755.5	16,174.2	3,571.7	19,745.8
Total Phosphorus (lbs P/yr)	10,280.0	5,862.5	297.5	6,160.1

Load (lbs/yr) = MGD x mg/L x 8.345 x 365. MSWRF based on NPDES permitted flow and expected effluent levels of nitrogen and phosphorus. KGS based on NPDES permitted flow rates combined with upper range (95th percentile statistics) of effluent concentration for nitrogen and phosphorus derived from observed KGS effluent records. KGS TN and TP concentrations for combined CTBD8+LVW outfalls are flow-weighted. Use of KGS NPDES permitted flow and 95th percentile of TN and TP observations yield inflated KGS TN and TP load estimates that are not realistic.

The MSWRF NPDES permit allows a discharge of 7.5 MGD with total nutrient concentrations for TN (8 mg/L) and TP (0.45 mg/L). Model input for MSWRF effluent flow and nutrient levels were assigned to reflect NPDES permitted levels for flow, TN and TP loading conditions. Effluent levels of non-nutrient water quality constituents (water temperature, total suspended sediment, dissolved oxygen, TOC, CBOD, pH and alkalinity) for Scenario#0 were based on characterization of MSWRF effluent developed for the existing model confirmation conditions (see Table 8) as described in Section 5.4.4. Effluent flow, nutrient concentrations and other non-nutrient water quality constituent concentrations used to assign model input data for the MSWRF discharge for Scenario#0 are given in Table 27.

The combined KGS effluent flow rate of 2.4 MGD for the Cooling Tower Blowdown (1.958 MGD) and the Low Volume Waste (0.444 MGD) is based on the NPDES permitted flow rates for these two outfalls. KGS effluent loading rates are based on the permitted effluent discharge rates combined with the existing (2013-2016) water quality observations for the Unit 8 Cooling Tower Blowdown (CTBD8) and Low Volume Wastewater (LVW) outfalls. As cooling-water discharges from coal-fired electric power plants are not usually assigned nutrient limits for NPDES permits, an upper bound analysis for characterizing expected nutrient loading was developed from summary statistics for nitrogen and phosphorus derived from KGS effluent discharge operating records. KGS nutrient loads were estimated from the NPDES permitted flow rate and 95th percentile statistics based on observed effluent nutrient concentrations. KGS effluent data for non-nutrient water quality constituents were based on 50th percentile (median) concentrations developed for model confirmation for water temperature, conductivity, dissolved oxygen, inorganic sediment, TOC, CBOD, pH and alkalinity (see Table 9 and Table 10). Effluent flow rates, nutrient concentrations and non-nutrient water quality constituent concentrations used to assign model input data for the two KGS outfalls for Scenario #0 are given in Table 28 and Table 29.

Table 27- Scenario #0 MSWRF Point Source Discharge: NPDES Permitted Effluent Flow and Nutrients. Effluent Non-Nutrient Constituents based on Median or Constant values.

SCEN0 (RUN 600)	Statistic >>	Median		Data Source			Statistic &
QUAL2K State Variables	Units	BIN9	N_Obs				DESIGN
MSWRF(BIN9)			2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	7.5	0				NPDES Permit
Effluent Flow	cfs	11.604225	0		X		NPDES Permit
Effluent Flow	cms	0.3286317	0		X		NPDES Permit
Water temperature	Deg C	23.9	847	X			Median
Conductivity	µmhos/cm	862	0			X	Constant
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8.7	1134	X			Median
Slow CBOD (ultimate)	mg/L	10.515	0		X		Median
Fast CBOD (ultimate)	mg/L	1.5	0		X		Median
Organic-N, Total	µg/L	1080	0		X		Median
Ammonia-N	µg/L	120	0		X		Median
Nitrate/Nitrite-N	µg/L	6800	0		X		Median
Organic-P, Total	µg/L	166.5	0		X		Median
Inorganic-P (SRP, Diss_PO4)	µg/L	283.5	0		X		Median
Phytoplankton-Chl	µg/L	0.65	0			X	Constant
Phytoplankton-N	µg/L	7.02	0		X		Constant
Phytoplankton-P	µg/L	0.975	0		X		Constant
Organic SS Detritus (POM, dw)	mg/L	0.5	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	70	0			X	Median
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	7.2	847	X			Median
Total Nitrogen	µg/L	8000	0				NPDES Permit
Total Kjedhal Nitrogen	µg/L	1200	0		X		NPDES Permit
Total Phosphorus	µg/L	450	0				NPDES Permit
Total Organic Carbon	mg/L	4.5	0		X		Median
Carbonaceous BOD-5-Day	mg/L	0.5	846	X			Median
TSS [PIM+POM(D)+POM(A)]	mg/L	1	848	X			Median

Table 28- Scenario #0 KGS Cooling Tower Blowdown Units 8 (CTBD) Point Source Discharge: NPDES Permitted Effluent Flow. Effluent Nutrients Based on 95th Percentile of Observed Data. Effluent Non-Nutrient Constituents based on Median or Constant values.

SCEN0 (Run 600)	Statistic >>	95%ile or					Statistic &
QUAL2K State Variables	Units	Median	N_Obs	Data Source			DESIGN
JRK_CTBD8(BIN9)		BIN9	2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	1.958	1307				NPDES Permit
Effluent Flow	cfs	3.0294763	1307				NPDES Permit
Effluent Flow	cms	0.0857948	1307				NPDES Permit
Water temperature	Deg C	23.1	138	X			Median
Conductivity	µmhos/cm	820.1	138	X			Median
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8	0			X	Constant
Slow CBOD (ultimate)	mg/L	10.015	0		X		Median
Fast CBOD (ultimate)	mg/L	2	0		X		Median
Organic-N, Total	µg/L	1692	0		X		95th Percentile
Ammonia-N	µg/L	178	22	X			95th Percentile
Nitrate/Nitrite-N	µg/L	842	0		X		95th Percentile
Organic-P, Total	µg/L	363.525	0		X		95th Percentile
Inorganic-P (SRP, Diss_PO4)	µg/L	618.975	0		X		95th Percentile
Phytoplankton-Chl	µg/L	0	0			X	Constant
Phytoplankton-N	µg/L	0	0			X	Constant
Phytoplankton-P	µg/L	0	0			X	Constant
Organic SS Detritus (POM, dw)	mg/L	0.5	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	100	0			X	Median
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	8.2	138	X			Median
Total Nitrogen	µg/L	2712	25	X			95th Percentile
Total Kjedhal Nitrogen	µg/L	1870	26	X			95th Percentile
Total Phosphorus	µg/L	982.5	26	X			95th Percentile
Total Organic Carbon	mg/L	4.5	0		X		Constant
Carbonaceous BOD-5-Day	mg/L	0.5	0			X	Constant
TSS [PIM+POM(D)+POM(A)]	mg/L	1	0			X	Constant

Table 29- Scenario #0 KGS Low Volume Waste (LVW) Point Source Discharge: NPDES Permitted Effluent Flow. Effluent Nutrients Based on 95th Percentile of Observed Data. Effluent Non-Nutrient Constituents based on Median or Constant values.

SCEN0 (Run 600)	Statistic >>	95%ile or					Statistic &
QUAL2K State Variables	Units	Median	N_Obs	Data Source			DESIGN
JRK_LVW(BIN9)		BIN9	2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	0.444	1295	X			NPDES Permit
Effluent Flow	cfs	0.6869701	1295	X			NPDES Permit
Effluent Flow	cms	0.019455	1295	X			NPDES Permit
Water temperature	Deg C	23	172	X			Median
Conductivity	µmhos/cm	375.95	2	X			Median
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8	0			X	Constant
Slow CBOD (ultimate)	mg/L	10.015	0		X		Median
Fast CBOD (ultimate)	mg/L	2	0		X		Median
Organic-N, Total	µg/L	1652.5	0		X		95th Percentile
Ammonia-N	µg/L	102.5	26	X			95th Percentile
Nitrate/Nitrite-N	µg/L	886	0		X		95th Percentile
Organic-P, Total	µg/L	81.4	0		X		95th Percentile
Inorganic-P (SRP, Diss_PO4)	µg/L	138.6	0		X		95th Percentile
Phytoplankton-Chl	µg/L	0	0			X	Constant
Phytoplankton-N	µg/L	0	0		X		Constant
Phytoplankton-P	µg/L	0	0		X		Constant
Organic SS Detritus (POM, dw)	mg/L	0.5	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	100	0			X	Median
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	7.7	172	X			Median
Total Nitrogen	µg/L	2641	27	X			95th Percentile
Total Kjedhal Nitrogen	µg/L	1755	30	X			95th Percentile
Total Phosphorus	µg/L	220	31	X			95th Percentile
Total Organic Carbon	mg/L	4.5	0		X		Constant
Carbonaceous BOD-5-Day	mg/L	0.5	0			X	Constant
TSS [PIM+POM(D)+POM(A)]	mg/L	1	0			X	Constant

5.6.1.2 Scenario #0: Model Results and Findings

Model results are extracted for locations downstream of the KGS outfalls (x=4.17 km), the MSWRF outfall (x=2.05 km), and the downstream outlet from Sweetwater Branch to the enhancement wetland (x=0.61 km). Model results for each scenario are shown for comparison to the model confirmation results simulated for existing 2013-2016 conditions (Run529). Changes in travel time, velocity, phytoplankton, and periphyton biomass are identified at the KGS and MSWRF locations and at the downstream outlet of the model to the Enhancement Wetland (see Table 30).

As described in Section 5.6.1.1, Scenario #0 provides an assessment of the predicted changes in Sweetwater Branch from KGS and MSWRF point source effluent flow and loading based on current NPDES permit limits for MSWRF and KGS. Model results for comparison of model confirmation and Scenario #0 are presented in Figure 22, Figure 23, Figure 24, Figure 25 and Table 30. Appendix C presents the full set of model plots for BIN1, BIN2 and BIN3. The discussion of model results for Scenario#0 emphasizes the results obtained under BIN2 hydrologic conditions.

Effluent flow from both MSWRF (7.5 MGD) and KGS (2.4 MGD for CTBD8+LVW) for Scenario #0 was higher than the effluent flow assigned for MSWRF (6.68 MGD) and KGS (0.239 MGD for CTBD8+LVW) assigned for model confirmation (see Table 8, Table 9 and Table 10). The increased total point source effluent flow from 6.9 MGD (10.7 cfs) to 9.9 MGD (15.3 cfs) resulted in an increase in velocity and a decrease in travel time in the stream (see Figure 24 and Table 30). Downstream of the KGS outfall, the 93% increase in BIN2 velocity from 6.1 to 11.9 cm/s caused an increase in the velocity-dependent maximum growth rate (Figure 25) and an increase of 140% for BIN2 periphyton biomass from 0.3 to 0.7 mg Chl/m^2 (see Figure 23 and Table 30). The decrease in travel time results in a shorter residence time and a 76% decrease in BIN2 water column chlorophyll from 1.3 to 0.3 µg/L (see Figure 22 and Table 30). Downstream of the MSWRF outfall, the 13% increase in BIN2 stream velocity from 53 to 60 cm/s caused a decrease in the velocity-dependent maximum growth rate (see Figure 25) and a 15% decrease for periphyton biomass (see Figure 23 and Table 30). The decreased travel time results in a shorter residence time and a 19.5% decrease in BIN2 water column chlorophyll from 0.78 to 0.625 µg/L.

The loading from Scenario #0 for nonpoint sources and KGS and MSWRF point sources resulted in the downstream BIN2 outflow of Total Nitrogen (201,444 lbs/yr) and Total Phosphorus (16,449 lbs/yr) to the Enhancement Wetland Area (Table 30). This represented an increase of 86% for Total Nitrogen and 51% for Total Phosphorus compared to the existing nutrient export conditions for model confirmation. Although nitrogen and phosphorus increased significantly in Sweetwater Branch downstream of the MSWRF outfall, water column chlorophyll and periphyton are not controlled by either the increase in KGS or MSWRF effluent loading of nutrients. Water column and bottom algae biomass are controlled by hydraulic characteristics of the stream rather than ambient nutrient levels. The inorganic nutrient levels in the stream are not limiting productivity or biomass because the modeled stream concentrations for nitrogen and phosphorus are much larger than the half-saturation constants assigned for phytoplankton and periphyton in the model (see Figure 18 and Figure 19).

Nonpoint and point source nitrogen loading for Scenario #0 resulted in a 85% increase of the downstream outflow of Total Nitrogen to the enhanced wetland from the existing conditions for RUN(529) model confirmation (108,479 lbs/yr) to the outlet load for Scenario #0 (201,444 lbs/yr). The phosphorus loading for Scenario #0 resulted in a 50% increase of the downstream outflow of Total Phosphorus to the enhanced wetland from the existing conditions for RUN(529) model confirmation (10,918 lbs/yr) to the outlet load for Scenario #0 (16,449 lbs/yr) (see Table 30).

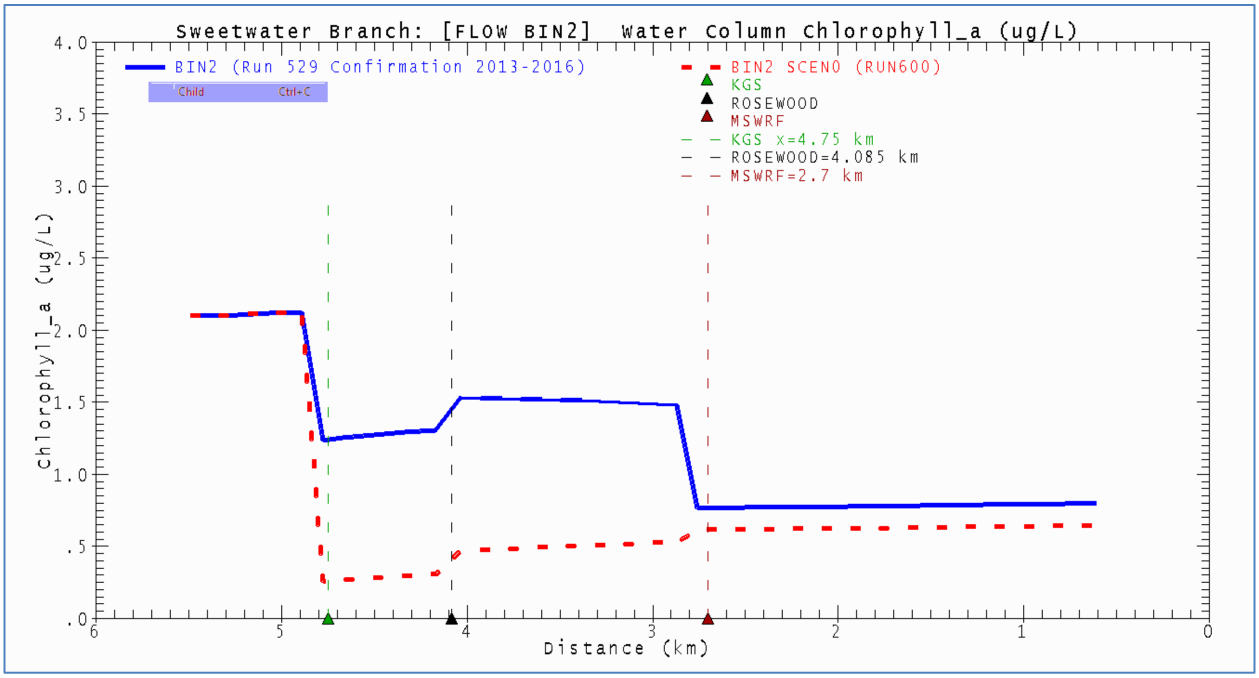

Figure 22- Water Column Chlorophyll, BIN2, Scenario #0 (Run 600)

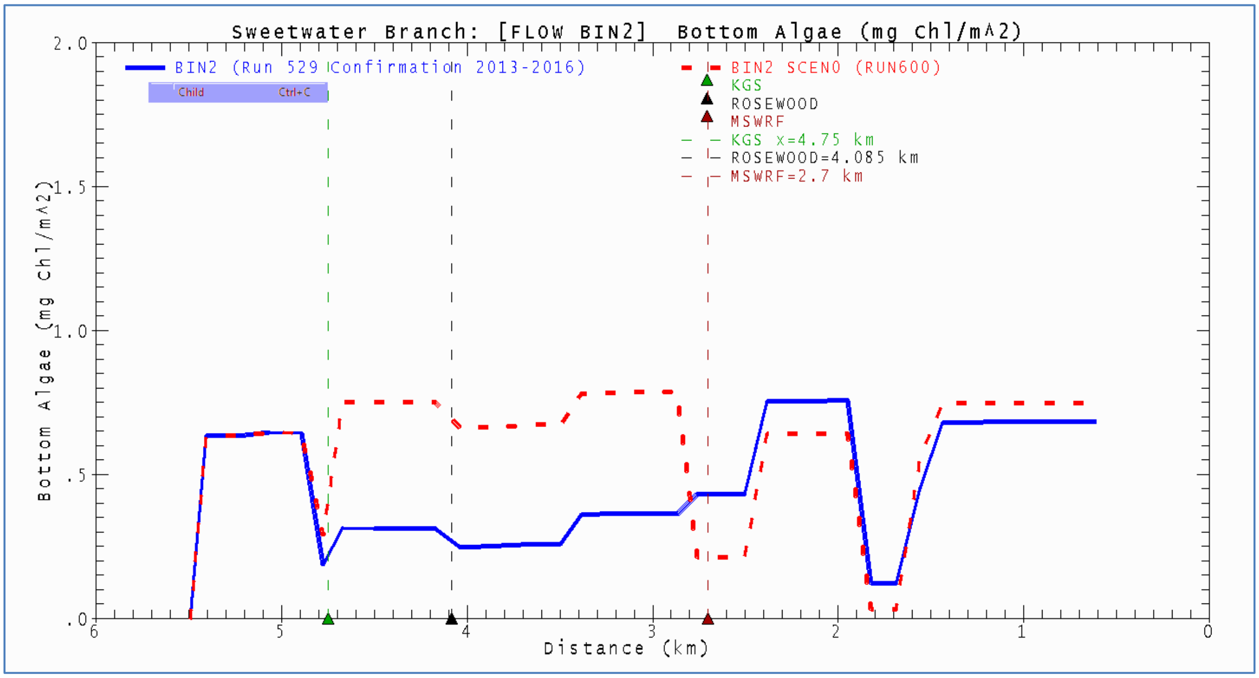

Figure 23- Bottom Algae, BIN2, Scenario #0 (Run 600)

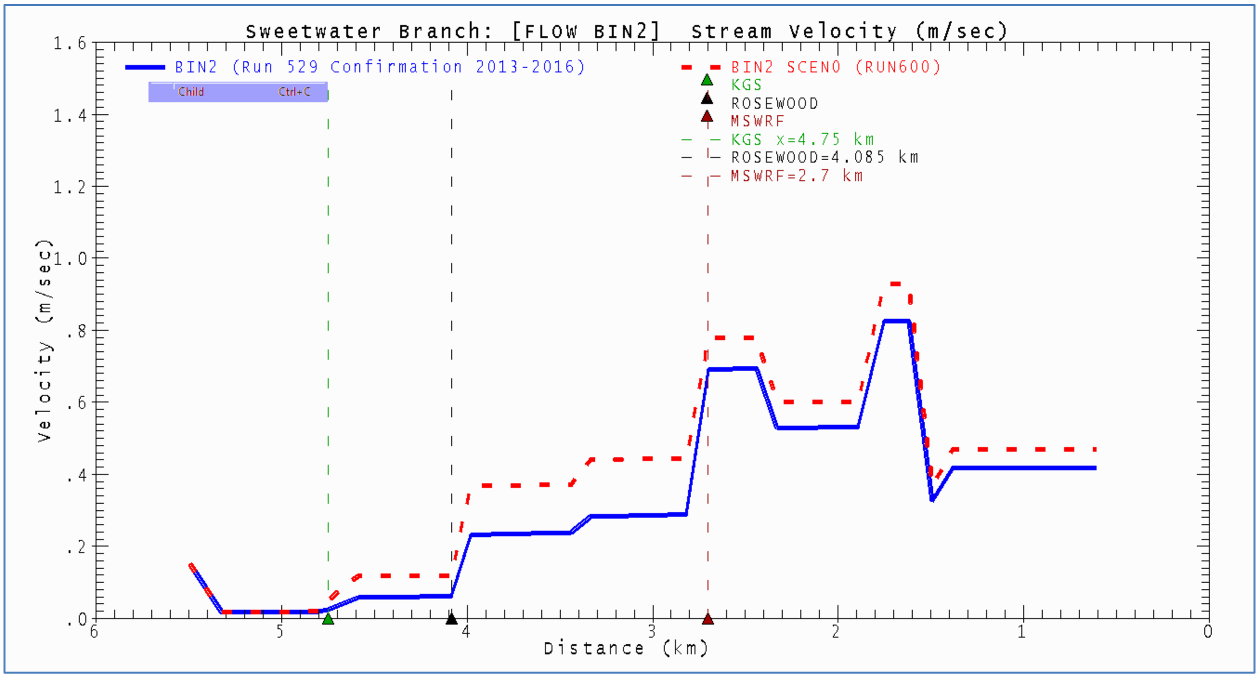

Figure 24- Stream Velocity, BIN2, Scenario #0 (Run 600)

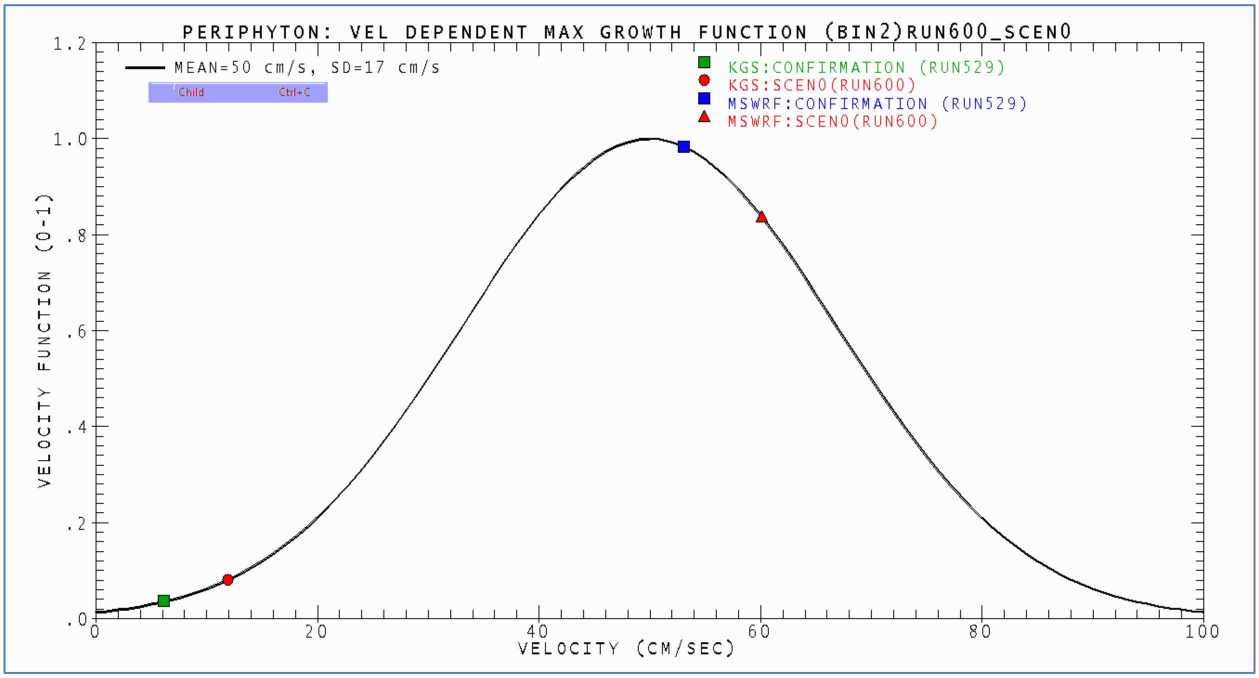

Figure 25- Velocity-Dependent Maximum Growth Function for Bottom Algae, BIN2, Scenario #0 (Run 600)

Table 30-Scenario #0 Model Results for Existing NPDES Permitted Point Source Loads

SCEN(0)	KGS Downstream JEA 9	x=4.17 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.89257	0.57062	0.44159
RUN(529)	Cross-Section Area	m^2	0.34038	0.46362	0.5903
RUN(529)	Velocity	m/sec	0.0478	0.06155	0.075
RUN(529)	Chlorophyll-a	ug/L	0.362362	1.309709	0.798005
RUN(529)	Periphyton (Chl a)	mg /m2	0.269018	0.312372	0.37506
SCEN(0)	Travel time	days	0.78051	0.49627	0.38982
SCEN(0)	Cross-Section Area	m^2	0.9788	1.03687	1.10768
SCEN(0)	Velocity	m/sec	0.11344	0.11891	0.12552
SCEN(0)	Chlorophyll-a	ug/L	0.055362	0.310424	0.257031
SCEN(0)	Periphyton (Chl a)	mg/m2	0.715815	0.750374	0.803688
SCEN(0)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(0)	Travel time	days	-0.11206	-0.07435	-0.05177
SCEN(0)	Cross-Section Area	m^2	0.63842	0.57325	0.51738
SCEN(0)	Velocity	m/sec	0.06564	0.05736	0.05052
SCEN(0)	Chlorophyll-a	ug/L	-0.307	-0.999285	-0.540974
SCEN(0)	Periphyton (Chl a)	mg /m2	0.446797	0.438002	0.428628
SCEN(0)	Travel time	Pct Change	-12.6%	-13.0%	-11.7%
SCEN(0)	Cross-Section Area	Pct Change	187.6%	123.6%	87.6%
SCEN(0)	Velocity	Pct Change	137.3%	93.2%	67.4%
SCEN(0)	Chlorophyll-a	Pct Change	-84.7%	-76.3%	-67.8%
SCEN(0)	Periphyton	Pct Change	166.1%	140.2%	114.3%
SCEN(0)	MSWRF Downstream JEA 5	x=2.05 km			
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.98201	0.64097	0.50132
RUN(529)	Cross-Section Area	m^2	0.61444	0.64603	0.68525
RUN(529)	Velocity	m/sec	0.51406	0.53051	0.55045
RUN(529)	Chlorophyll-a	ug/L	0.637788	0.777035	0.695213
RUN(529)	Periphyton (Chl a)	mg /m2	0.766559	0.756985	0.736065
SCEN(0)	Travel time	days	0.83174	0.54469	0.43542
SCEN(0)	Cross-Section Area	m^2	0.76034	0.78826	0.82324
SCEN(0)	Velocity	m/sec	0.5873	0.60058	0.61694
SCEN(0)	Chlorophyll-a	ug/L	0.509508	0.625428	0.568262
SCEN(0)	Periphyton (Chl a)	mg /m2	0.671523	0.642005	0.603364
SCEN(0)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(0)	Travel time	days	-0.15027	-0.09628	-0.0659
SCEN(0)	Cross-Section Area	m^2	0.1459	0.14223	0.13799
SCEN(0)	Velocity	m/sec	0.07324	0.07007	0.06649
SCEN(0)	Chlorophyll-a	ug/L	-0.12828	-0.151607	-0.126951

SCEN(0)	Periphyton (Chl a)	mg /m2	-0.095036	-0.11498	-0.132701
SCEN(0)	Travel time	Pct Change	-15.3%	-15.0%	-13.1%
SCEN(0)	Cross-Section Area	Pct Change	23.7%	22.0%	20.1%
SCEN(0)	Velocity	Pct Change	14.2%	13.2%	12.1%
SCEN(0)	Chlorophyll-a	Pct Change	-20.1%	-19.5%	-18.3%
SCEN(0)	Periphyton	Pct Change	-12.4%	-15.2%	-18.0%
RUN(529)	Downstream (Outflow from Model)		BIN1	BIN2	BIN3
RUN(529)	Total-N	lbs/yr	107,257	108,479	111,232
RUN(529)	Total-P	lbs/yr	10,581	10,918	11,103
SCEN(0)	Total-N	lbs/yr	200,214	201,444	204,292
SCEN(0)	Total-P	lbs/yr	16,092	16,449	16,637
SCEN(0)	Downstream Change from Model Confirm		BIN1	BIN2	BIN3
SCEN(0)	Total-N	lbs/yr	92,957	92,965	93,060
SCEN(0)	Total-P	lbs/yr	5,512	5,532	5,534
SCEN(0)	Total-N	Pct Change	86.7%	85.7%	83.7%
SCEN(0)	Total-P	Pct Change	52.1%	50.7%	49.8%

5.6.2 Scenario #1: Future Build-Out and Upgrade of Point Source Loads

Model input data and results obtained for the confirmation run for the three flow conditions (BIN1, BIN2, and BIN3) were used as the baseline for comparison to results obtained for the point source management run. The focus of the evaluation for Scenario#1 was to test the impact of proposed changes in KGS and MSWRF effluent flow rates and nutrient levels to represent future flow and loading conditions from KGS and the build-out and upgrade of the MSWRF.

5.6.2.1 Scenario #1: Input Data for Nonpoint Source and Point Source Flow and Loads

Nonpoint source (NPS) flow and loading data for Scenario #1 are based on median statistics derived from the 2013-2016 baseline data sets for water quality and streamflow conditions compiled for model confirmation to existing conditions (Table 24). A brief description of the methodology used to assign median values for nonpoint source flow and loads is given in Section 5.6.1 for Scenario#0. A full description of the data sources and methodology used to develop nonpoint source water quality and stream flow data sets is presented in Section 5.4.3 and Section 5.4.5.

Effluent flow, nutrient concentrations and loads for the MSWRF and KGS discharges are summarized for Scenario #1 in Table 31. The KGS facility reports effluent discharge records for two outfalls: (1) Unit 8 Cooling Water Discharge (CTBD8) and (2) Low Volume Waste (LVW). KGS permitted discharge rates and effluent records for nutrient concentrations are used to compute effluent loads for each outfall. The combined sums of effluent flow and nutrient loads from the cooling water and low volume wastewater KGS outfalls are shown to facilitate comparison of the relative contributions of flow and nutrient loading from the MSWRF and KGS effluent discharges.

Table 31- Scenario #1 Summary of MSWRF and KGS Effluent Flow and Nutrient Loading Rates

Future Conditions **Scenario#1 (Run 601)**	**MSWRF** **Build-Out-Upgrade**	**KGS CTBD8** **EPA MDL**	**KGS LVW** **EPA MDL**	**KGS CTBD8+LVW** **EPA MDL**
Annual Flow (MGD)	9	0.418	0.087	0.505
Total Nitrogen (mg N/L)	8.0	2.2	0.984	1.991
Total Phosphorus (mg P/L)	0.375	0.636	0.125	0.548
Total Nitrogen (lbs N/yr)	219,306.6	2,801.0	260.8	3,061.8
Total Phosphorus (lbs P/yr)	10,280.0	809.8	33.1	842.9

Load (lbs/yr) = MGD x mg/L x 8.345 x 365. MSWRF based on build-out effluent flow and expected upgrade of nutrient removal. KGS effluent flow and nutrient loads based on EPA MDL calculations for 95% Confidence Interval. KGS effluent nutrient concentrations are derived from flow-weighted calculation of MDL estimates for CTBD8 and LVW flow and nutrient loading rates.

Effluent flow and loading for the MSWRF was based on a proposed build-out expansion of the facility to 9 MGD and upgrade of the existing facility processes to achieve effluent nutrient concentrations for TN of 8 mg/L and TP of 0.375 mg/L. Model input for MSWRF effluent flow and nutrient levels were assigned to reflect the proposed expansion and upgrade for flow, TN and TP loading conditions. Effluent levels of non-nutrient water quality constituents (water temperature, total suspended sediment, dissolved oxygen, TOC, CBOD, pH and alkalinity) for Scenario#1 were based on either constant or median concentrations of MSWRF effluent developed for model confirmation conditions. Effluent flow, nutrient concentrations and other non-nutrient water quality constituent concentrations used to assign model input data for the MSWRF discharge for Scenario#1 are given in Table 32.

As described in the previous Section 5.6.1, the methodology used to estimate nutrient loading from the KGS outfalls results in inflated loading rates that are not realistic. An improved technically defensible methodology has been developed to characterize KGS effluent flow and nutrient loading for Scenario#1 and all the other scenarios (Scenario#2 through Scenario #6) presented in this report. The methodology is briefly described below with detailed documentation of the methodology given in Appendix J.

KGS effluent records for flow, TN and TP were used to calculate flow and loading rates considered to be representative of an upper bound for effluent flow and TN and TP loading. The methodology, recommended by EPA to calculate load allocations and waste load allocations for Maximum Daily Load (MDL) determinations (EPA, 1991; 2007), was used to develop statistically-based upper bounds for KGS effluent flow and effluent loading of TN and TP based on actual effluent operating records. The upper bounds for effluent flow and TN and TP loads were calculated with the MDL methodology based on the 95% Confidence Interval. Flow weighted effluent concentrations of TN and TP were then computed from the 95% Confidence Interval upper bound values determined for effluent flow, and TN and TP loads. The KGS flow and loads were based on MDL statistics derived from the existing (2013-2016) operating conditions for the Unit 8 Cooling Tower Blowdown (CTBD8) and Low Volume Waste (LVW) outfalls. Effluent flow, nutrient concentrations derived from EPA's MDL methodology, and other non-nutrient water quality constituents for Scenario#1 (water temperature, total suspended sediment, dissolved oxygen, TOC, CBOD, pH and alkalinity) were based on either constant or median concentrations of KGS effluent characteristics developed for model confirmation conditions. Effluent flow, nutrient concentrations and other non-nutrient water quality constituent concentrations used to assign model input data for the KGS outfalls for Scenario#1 are given in Table 33 and Table 34.

Table 32- Scenario #1 MSWRF Point Source Discharge Effluent Flow for Proposed Build-Out Expansion of MSWRF. Effluent Nutrients based on Upgrade of MSWRF and Non-Nutrient effluent constituents based on median or constant values.

SCEN1 (RUN 601)	Statistic >>	Median					Statistic &
QUAL2K State Variables	Units	BIN9	N_Obs	Data Source			DESIGN
MSWRF(BIN9)			2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	9	0				Build-out
Effluent Flow	cfs	13.92507	0				Build-out
Effluent Flow	cms	0.394358	0				Build-out
Water temperature	Deg C	23.9	847	X			Median
Conductivity	µmhos/cm	862	0			X	Constant
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8.7	1134	X			Median
Slow CBOD (ultimate)	mg/L	0.403	0		X		Median
Fast CBOD (ultimate)	mg/L	2	0		X		Median
Organic-N, Total	µg/L	1032	0		X		Upgrade
Ammonia-N	µg/L	168	0		X		Upgrade
Nitrate/Nitrite-N	µg/L	6800	0		X		Upgrade
Organic-P, Total	µg/L	67.5	0		X		Upgrade
Inorganic-P (SRP, Diss_PO4)	µg/L	307.5	0		X		Upgrade
Phytoplankton-Chl	µg/L	0.65	0			X	Constant
Phytoplankton-N	µg/L	7.02	0		X		Constant
Phytoplankton-P	µg/L	0.975	0		X		Constant
Organic Detritus (POM, dw)	mg/L	0.413333	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	70	0			X	Constant
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	7.2	847	X			Median
Total Nitrogen	µg/L	8000	0				Upgrade
Total Kjedhal Nitrogen	µg/L	1200	0		X		Upgrade
Total Phosphorus	µg/L	375	0				Upgrade
Total Organic Carbon	mg/L	4.5	0		X		Median
CBOD-5-Day	mg/L	0.5	846	X			Median
TSS [PIM+POM(D)+POM(A)]	mg/L	1	848	X			Median

Table 33- Scenario #1 KGS Cooling Tower Blowdown Unit 8 (CTBD8) Point Source Discharge Effluent Flow and Nutrients Based on Maximum Daily Load (MDL) 95% Confidence Interval. Non-Nutrient effluent constituents based on median or constant values.

SCEN1 (RUN 601)	Statistic >>	MDL or					Statistic &
QUAL2K State Variables	Units	Median	N_Obs	Data Source			DESIGN
JRKCTBD8(BIN9)		BIN9	2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	0.4182	943	X			Max Daily Load
Effluent Flow	cfs	0.647052	943	X			Max Daily Load
Effluent Flow	cms	0.018325	943	X			Max Daily Load
Water temperature	Deg C	23.1	138	X			Median
Conductivity	µmhos/cm	820.1	138	X			Median
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8	0			X	Constant
Slow CBOD (ultimate)	mg/L	0.403	0		X		Median
Fast CBOD (ultimate)	mg/L	2	0		X		Median
Organic-N, Total	µg/L	1433.65	0		X		Max Daily Load
Ammonia-N	µg/L	150.4937	0		X		Max Daily Load
Nitrate/Nitrite-N	µg/L	616.056	0		X		Max Daily Load
Organic-P, Total	µg/L	139.92	0		X		Max Daily Load
Inorganic-P (SRP, Diss_PO4)	µg/L	496.08	0		X		Max Daily Load
Phytoplankton-Chl	µg/L	0	0			X	Constant
Phytoplankton-N	µg/L	0	0		X		Constant
Phytoplankton-P	µg/L	0	0		X		Constant
Organic Detritus (POM, dw)	mg/L	0.5	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	70	0			X	Median
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	8.2	138	X			Median
Total Nitrogen	µg/L	2200.2	37				Max Daily Load
Total Kjedhal Nitrogen	µg/L	1584.144	0		X		Max Daily Load
Total Phosphorus	µg/L	636	18				Max Daily Load
Total Organic Carbon	mg/L	4.5	0		X		Constant
CBOD-5-Day	mg/L	0.5	0		X		Constant
TSS [PIM+POM(D)+POM(A)]	mg/L	1	0			X	Constant

Table 34- Scenario #1 KGS Low Volume Waste (LVW) Point Source Discharge Effluent Flow and Nutrients Based on Maximum Daily Load (MDL) 95% Confidence Interval. Non-Nutrient effluent constituents based on median or constant values.

SCEN1 (Run 601)	Statistic >>	MDL or					Statistic &
QUAL2K State Variables	Units	Median	N_Obs	Data Source			DESIGN
LVW(BIN9)MDL95%CI		BIN9	2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	0.0865	953	X			Max Daily Load
Effluent Flow	cfs	0.133835	953	X			Max Daily Load
Effluent Flow	cms	0.00379	953	X			Max Daily Load
Water temperature	Deg C	23	172	X			Median
Conductivity	µmhos/cm	375.95	2	X			Median
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8	0			X	Constant
Slow CBOD (ultimate)	mg/L	0.403	0		X		Median
Fast CBOD (ultimate)	mg/L	2	0		X		Median
Organic-N, Total	µg/L	459.0309	0		X		Max Daily Load
Ammonia-N	µg/L	62.59512	0		X		Max Daily Load
Nitrate/Nitrite-N	µg/L	462.574	0		X		Max Daily Load
Organic-P, Total	µg/L	26.789	0		X		Max Daily Load
Inorganic-P (SRP, Diss_PO4)	µg/L	97.811	0		X		Max Daily Load
Phytoplankton-Chl	µg/L	0	0			X	Constant
Phytoplankton-N	µg/L	0	0		X		Constant
Phytoplankton-P	µg/L	0	0		X		Constant
Organic Detritus (POM, dw)	mg/L	0.5	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	70	0			X	Median
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	7.7	172	X			Median
Total Nitrogen	µg/L	984.2	37	X			Max Daily Load
Total Kjedhal Nitrogen	µg/L	521.626	0		X		Max Daily Load
Total Phosphorus	µg/L	124.6	45	X			Max Daily Load
Total Organic Carbon	mg/L	4.5	0		X		Constant
CBOD-5-Day	mg/L	0.5	0		X		Constant
TSS [PIM+POM(D)+POM(A)]	mg/L	1	0			X	Constant

5.6.2.2 Scenario #1: Model Results and Findings

Model results are extracted for locations downstream of the KGS outfalls (4.09 km), the MSWRF outfall (2.00 km), and the downstream outlet from Sweetwater Branch to the enhancement wetland (0.61 km). Model results for each scenario are shown for comparison to the model confirmation results simulated for existing 2013-2016 conditions (Run529). Changes in travel time, velocity, phytoplankton, and periphyton biomass are identified at the KGS and MSWRF locations and at the downstream outlet of the model to the Enhancement Wetland (see Table 35).

Scenario #1 provides an assessment of the predicted changes in Sweetwater Branch from KGS and MSWRF point source effluent flow and loading based on proposed build out and expansion of the MSWRF for the City of Gainesville. Model results for comparison of model confirmation and Scenario #1 are presented in Figure 26, Figure 27, Figure 28, and Table 35. The full set of model plots (BIN1, BIN2, and BIN3) for Scenario #1 are presented in Appendix D. The discussion of model results for Scenario#1 emphasizes the results obtained under BIN2 hydrologic conditions.

Effluent flow from both MSWRF (9 MGD) and KGS (0.505 MGD for CTBD8+LVW) for Scenario #1 was higher than the effluent flow assigned for MSWRF (6.68 MGD) and KGS (0.239 MGD for CTBD8+LVW) assigned for model confirmation conditions (see Table 8, Table 9 and Table 10). The increase in NPDES point source effluent flow from 6.9 MGD (10.7 cfs) to 9.5 MGD (14.7 cfs) resulted in an increase in velocity and a decrease in travel time in the stream (see Figure 28 and Table 35). Downstream of the KGS outfall, the 17% increase in BIN2 velocity from 6.1 to 7.1 cm/s caused a small increase in the velocity-dependent maximum growth rate (Figure 29) and an increase of only 21% for BIN2 periphyton biomass from 0.31 to 0.37 mg Chl/m^2 (see Figure 27 and Table 35). The decrease in travel time results in a shorter residence time and a 28% decrease in BIN2 water column chlorophyll from 1.3 to 0.94 µg/L (see Figure 26 and Table 35). Downstream of the MSWRF outfall, the 12% increase in BIN2 stream velocity from 53 to 59 cm/s caused a decrease in the velocity-dependent maximum growth rate (Figure 29) and a 13% decrease for periphyton biomass (see Figure 27 and Table 35). Downstream of MSWRF, the decreased travel time results in a shorter residence time and only a 5.5% decrease in BIN2 water column chlorophyll from 0.78 to 0.73 µg/L.

The loading from Scenario#1 for nonpoint sources and KGS and MSWRF point sources resulted in the downstream BIN2 outflow of Total Nitrogen (221,391 lbs/yr) and Total Phosphorus (11,393 lbs/yr) to the Enhancement Wetland Area (see Table 35). This represented an increase of 104% for Total Nitrogen but only 4% for Total Phosphorus compared to the existing downstream export conditions for model confirmation. The explanation for the small 4% change in TP loading exported to the wetland is presented below.

TP concentrations for the model confirmation run were derived from stream and KGS and effluent data pooled for the period of record from 2013-2016. Prior to the upgrade of MSWRF treatment processes to reduce phosphorus, effluent TP was 510 µg/L and effluent flow was 6.68 MGD (see Table 8). MSWRF effluent characteristics for Scenario #1 were based on a decrease of effluent TP to 375 µg/L and an increase of effluent flow to 9 MGD (see Table 32). At the downstream outlet of the stream, stream flow increased by 32% from 12.3 cfs to 16.3 cfs, primarily because of the increase in MSWRF effluent flow, while the TP level in the stream decreased by 21% from 450 to 355 µg/L. Overall, the small 4% increase in the TP load at the outflow of the stream reflected the 35% increase in MSWRF effluent flow that was offset by the 26% decrease in effluent TP levels from 510 to 375 µg/L because of the upgrade for phosphorus removal.

Although the export of nitrogen from the stream doubled, water column chlorophyll and periphyton are not controlled by either the increase in KGS or MSWRF effluent loading of nutrients. Water column and bottom algae biomass are controlled by hydraulic characteristics of the stream rather than ambient nutrient levels. The inorganic nutrient levels in the stream are not limiting productivity or biomass because the modeled concentrations for nitrogen and phosphorus are much larger than the half-saturation constants assigned for phytoplankton and periphyton (see Figure 18 and Figure 19).

Nonpoint and point source nitrogen loading for Scenario #1 resulted in a 104% increase of the downstream outflow of Total Nitrogen to the enhanced wetland from the existing conditions for RUN(529) model confirmation (108,479 lbs/yr) to the outlet load for Scenario #1 (221,391 lbs/yr). The phosphorus loading for Scenario #1 resulted in only a 4% increase of the downstream outflow of Total Phosphorus to the enhanced wetland from the existing conditions for RUN(529) model confirmation (10,918 lbs/yr) to the outlet load for Scenario #1 (11,393 lbs/yr) (see Table 35).

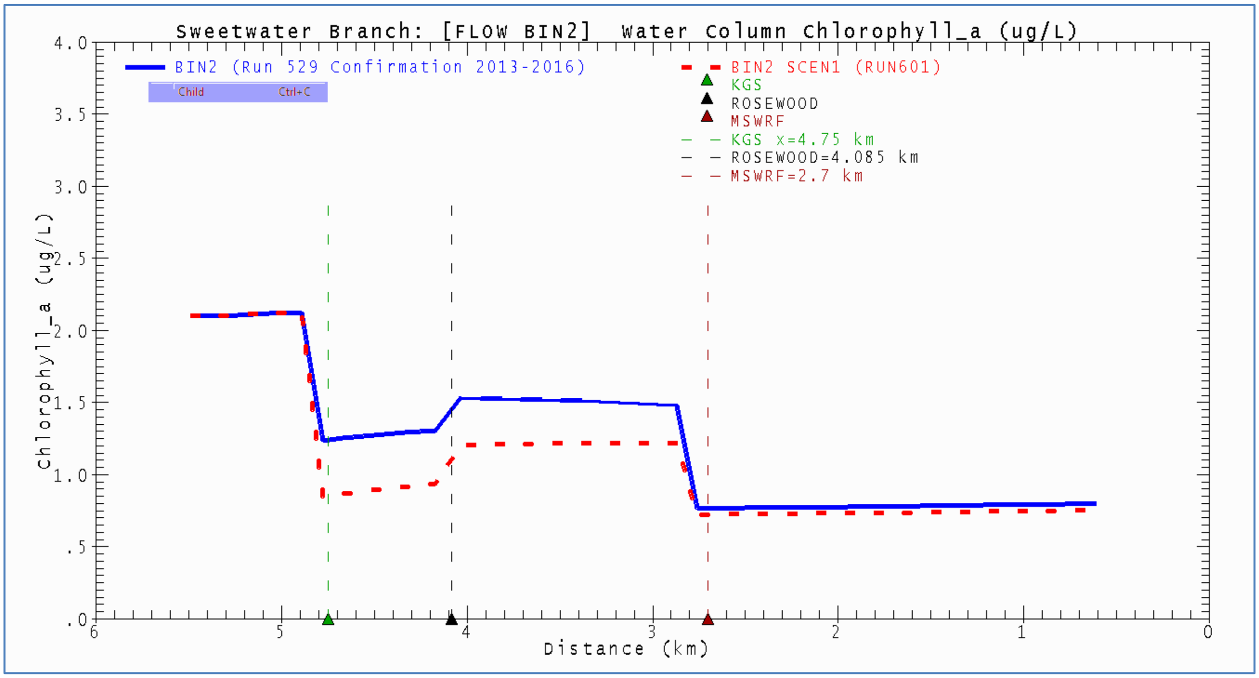

Figure 26- Water Column Chlorophyll, BIN2, Scenario #1 (Run 601)

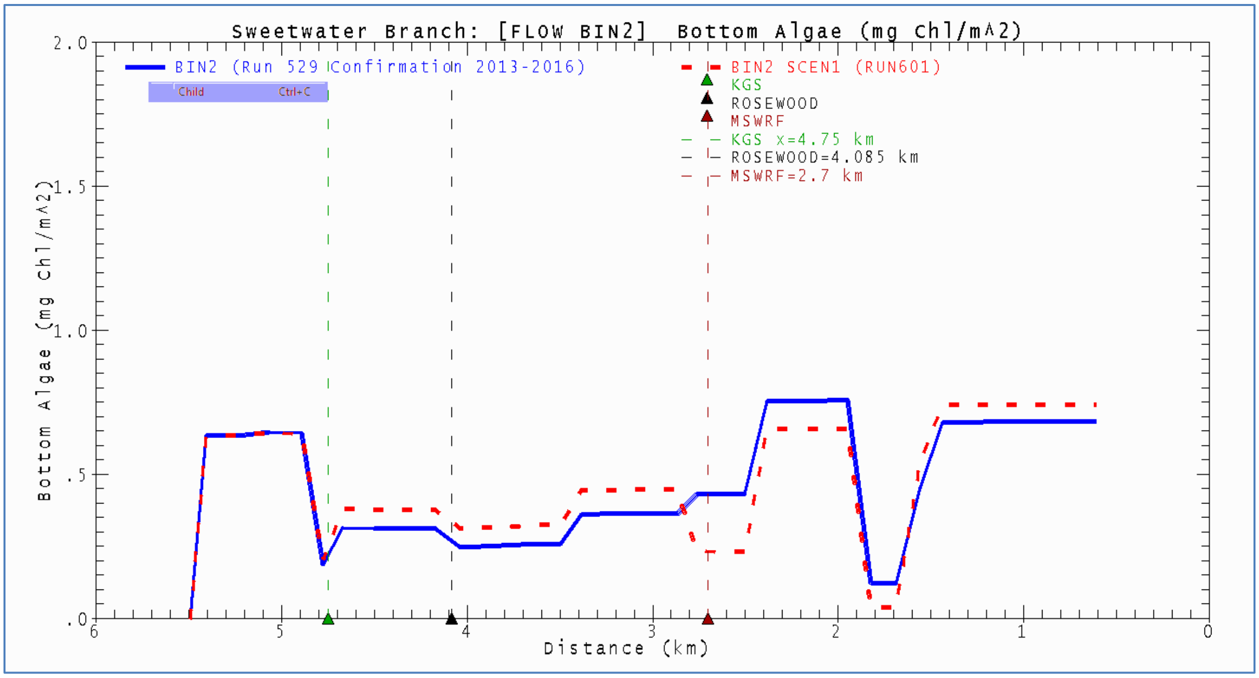

Figure 27- Bottom Algae, BIN2, Scenario #1 (Run 601)

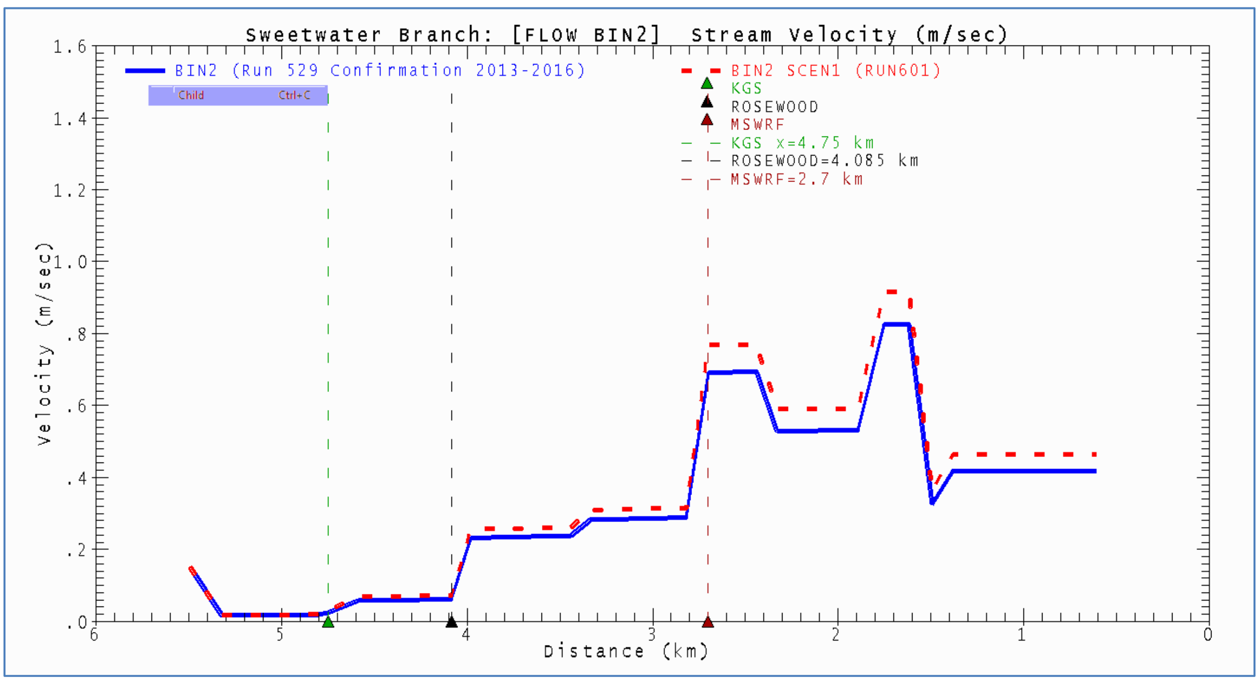

Figure 28- Stream Velocity, BIN2, Scenario #1 (Run 601)

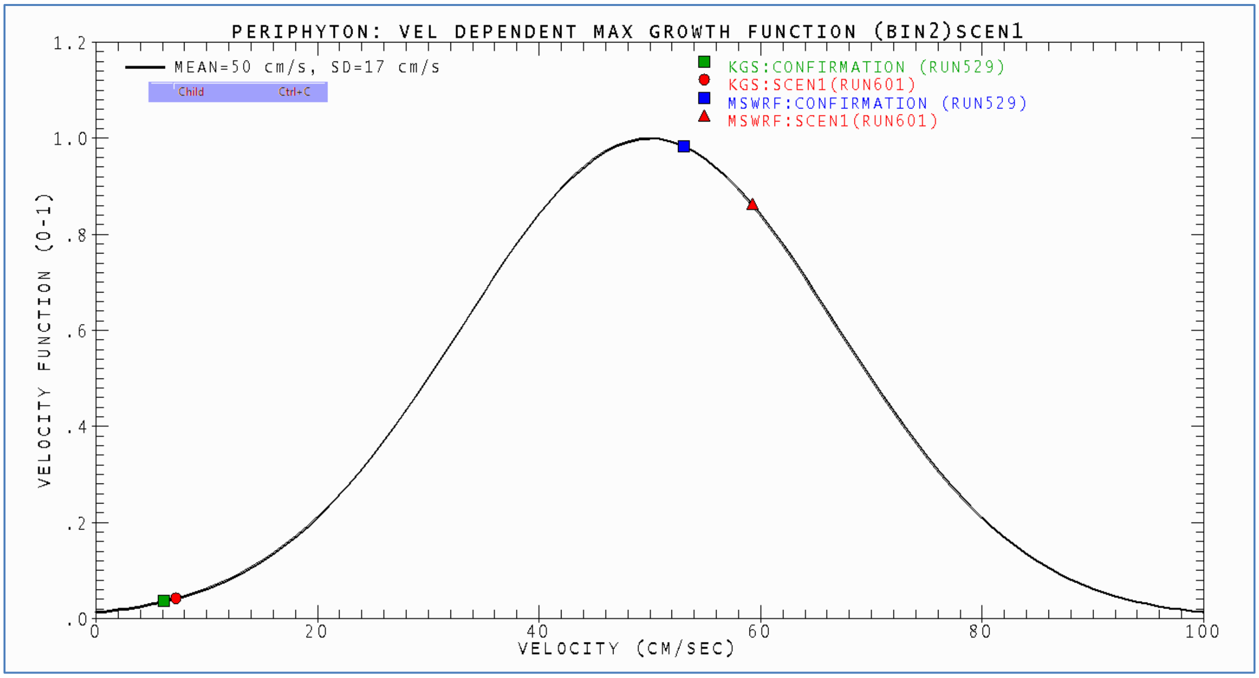

Figure 29- Velocity-Dependent Maximum Growth Function for Bottom Algae, BIN2, Scenario #1 (Run 601)

Green and blue symbols show model confirmation baseline (Run 529) for KGS and MSWRF and red symbols show change in velocity under model Scenario#1 (Run 601).

Table 35- Scenario #1 Model Results for Future Build-Out and Upgrade of Point Source Loads

SCEN(1)	KGS Downstream JEA 9	x=4.17 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.89257	0.57062	0.44159
RUN(529)	Cross-Section Area	m^2	0.34038	0.46362	0.5903
RUN(529)	Velocity	m/sec	0.0478	0.06155	0.075
RUN(529)	Chlorophyll-a	ug/L	0.362362	1.309709	0.798005
RUN(529)	Periphyton (Chl a)	mg /m2	0.269018	0.312372	0.37506
SCEN(1)	Travel time	days	0.8503	0.5481	0.4284
SCEN(1)	Cross-Section Area	m^2	0.45788	0.5595	0.67107
SCEN(1)	Velocity	m/sec	0.06092	0.07178	0.0833
SCEN(1)	Chlorophyll-a	ug/L	0.215719	0.93931	0.633988
SCEN(1)	Periphyton (Chl a)	mg/m2	0.336744	0.376788	0.432739
SCEN(1)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(1)	Travel time	days	-0.04227	-0.02252	-0.01319
SCEN(1)	Cross-Section Area	m^2	0.1175	0.09588	0.08077
SCEN(1)	Velocity	m/sec	0.01312	0.01023	0.0083
SCEN(1)	Chlorophyll-a	ug/L	-0.146643	-0.370399	-0.164017

SCEN(1)	Periphyton (Chl a)	mg /m2	0.067726	0.064416	0.057679
SCEN(1)	Travel time	Pct Change	-4.7%	-3.9%	-3.0%
SCEN(1)	Cross-Section Area	Pct Change	34.5%	20.7%	13.7%
SCEN(1)	Velocity	Pct Change	27.4%	16.6%	11.1%
SCEN(1)	Chlorophyll-a	Pct Change	-40.5%	-28.3%	-20.6%
SCEN(1)	Periphyton	Pct Change	25.2%	20.6%	15.4%
SCEN(1)	MSWRF Downstream JEA 5	x=2.05 km			
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.98201	0.64097	0.50132
RUN(529)	Cross-Section Area	m^2	0.61444	0.64603	0.68525
RUN(529)	Velocity	m/sec	0.51406	0.53051	0.55045
RUN(529)	Chlorophyll-a	ug/L	0.637788	0.777035	0.695213
RUN(529)	Periphyton (Chl a)	mg /m2	0.766559	0.756985	0.736065
SCEN(1)	Travel time	days	0.92629	0.61209	0.4843
SCEN(1)	Cross-Section Area	m^2	0.74192	0.77024	0.80569
SCEN(1)	Velocity	m/sec	0.57841	0.59203	0.60877
SCEN(1)	Chlorophyll-a	ug/L	0.626458	0.733977	0.671441
SCEN(1)	Periphyton (Chl a)	mg /m2	0.684822	0.658295	0.621193
SCEN(1)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(1)	Travel time	days	-0.05572	-0.02888	-0.01702
SCEN(1)	Cross-Section Area	m^2	0.12748	0.12421	0.12044
SCEN(1)	Velocity	m/sec	0.06435	0.06152	0.05832
SCEN(1)	Chlorophyll-a	ug/L	-0.01133	-0.043058	-0.023772
SCEN(1)	Periphyton (Chl a)	mg /m2	-0.081737	-0.09869	-0.114872
SCEN(1)	Travel time	Pct Change	-5.7%	-4.5%	-3.4%
SCEN(1)	Cross-Section Area	Pct Change	20.7%	19.2%	17.6%
SCEN(1)	Velocity	Pct Change	12.5%	11.6%	10.6%
SCEN(1)	Chlorophyll-a	Pct Change	-1.8%	-5.5%	-3.4%
SCEN(1)	Periphyton	Pct Change	-10.7%	-13.0%	-15.6%
RUN(529)	Downstream (Outflow from Model)		BIN1	BIN2	BIN3
RUN(529)	Total-N	lbs/yr	107,257	108,479	111,232
RUN(529)	Total-P	lbs/yr	10,581	10,918	11,103
SCEN(1)	Total-N	lbs/yr	220,082	221,391	224,252
SCEN(1)	Total-P	lbs/yr	11,052	11,393	11,573
SCEN(1)	Downstream Change from Model Confirm		BIN1	BIN2	BIN3
SCEN(1)	Total-N	lbs/yr	112,826	112,912	113,020
SCEN(1)	Total-P	lbs/yr	472	475	470
SCEN(1)	Total-N	Pct Change	105.2%	104.1%	101.6%
SCEN(1)	Total-P	Pct Change	4.5%	4.4%	4.2%

5.6.3 Scenario #2: "Worst-Case" Nonpoint Source Stormwater Scenario

Model input data and results obtained for the confirmation run for the high-flow condition (BIN3) were used as the baseline for comparison to results obtained for "worst-case" stormwater conditions defined for Scenario#2. The focus of the evaluation for Scenario#2 was to test the impact of "worst-case" stormwater flow and loading of nutrients in combination with the proposed representation of flow and loading conditions from KGS and the future build-out and upgrade of the MSWRF as described under Scenario#1 in Section 5.6.2. Scenario#2 was modeled in order to demonstrate reasonable assurance that the natural systems will be protected even with extreme assumptions for nonpoint source loads. This scenario will also demonstrate a margin of safety for Sweetwater Branch.

5.6.3.1 Scenario #2: Input Data for Nonpoint Source and Point Source Flow and Loads

Summary statistics for the urban runoff component of stream flow records at the SR331 gage (see Table 16) are based on data compiled for the three flow bins (BIN1, BIN2, and BIN3). Under Scenario#2, "worst-case" nonpoint source (NPS) stormwater conditions are defined by 90th percentile statistics derived from urban runoff flow data and water quality records characterized by high-flow (BIN3) hydrologic conditions. Estimates of nonpoint source "worst-case" stormwater flow and nutrient loads for Scenario#2 (see Table 36) are derived from 90th percentile urban runoff flow (see Table 37) and 90th percentile statistics for nutrient and non-nutrient water quality data sets pooled for high-flow (BIN3) hydrologic conditions (see Table 38). A description of data sources and methodology used to develop nonpoint source water quality and flow data sets is presented in Section 5.4.3 and Section 5.4.5.

Table 36- Scenario #2 Summary of "Worst-Case" Stormwater Flow and Nutrient Loading Under High-Flow Hydrologic Conditions (BIN3)

"Worst-Case" Stormwater Loading	90th Percentile BIN3	Data Source
NPS Urban Runoff (cfs)	15.920	Table 37
Total Nitrogen (mg N/L)	0.996	Table 38
Total Phosphorus (mg P/L)	0.2145	Table 38
Total Nitrogen (lbs N/yr)	31,216	
Total Phosphorus (lbs P/yr)	6,723	
Load (lbs/yr) = cfs x mg/L x 5.39377 x 365		

MSWRF and KGS point source effluent flow and loads assigned for Scenario#2 are based on effluent flow and loading data as described for Scenario#1 in Section 5.6.2. MSWRF effluent flow and loads are based on a proposed future 9 MGD buildout, upgrade of treatment processes, and median values of non-nutrient water quality constituents compiled for model confirmation (see Table 32). KGS effluent flow and nutrient loads are based on EPA's MDL methodology and existing (2013-2016) operating conditions for the KGS discharge outfalls. Effluent flow, nutrient concentrations and median or constant values of non-nutrient water quality constituents assigned for Scenario#5 are summarized for Scenario#1 in Table 33 and Table 34.

Table 37- Scenario #2 "Worst-Case" Stormwater Flow (BIN3) by Nonpoint Source Zones

Streamflow	**BIN9**	**BIN3**	**BIN2**	**BIN1**	
(2004-2016)	**(cfs)**	**(cfs)**	**(cfs)**	**(cfs)**	
N_Observations	2,003	314	644	171	
90th Percentile	9.77589	13.3407	3.21393	1.22125	
Area @ SR331 (mi^2)	2.5367	2.5367	2.5367	2.5367	
Flow/Area	**(cfs/mi^2)**	**(cfs/mi^2)**	**(cfs/mi^2)**	**(cfs/mi^2)**	
90th Percentile	3.8538	5.2591	1.2670	0.4814	
Zone	**BIN9**	**BIN3**	**BIN2**	**BIN1**	**Area**
90th Percentile (cfs)	**(cfs)**	**(cfs)**	**(cfs)**	**(cfs)**	**(mi^2)**
Zone_1 Upstrm Hdw	2.8138	3.8399	0.9251	0.3515	0.7301
Zone_2 Reach 11,10	0.9379	1.2800	0.3084	0.1172	0.2434
Zone_3 Rosewood(PS)	3.0121	4.1104	0.9902	0.3763	0.7816
Zone_4 Reach 9,8,7, 6	3.0121	4.1104	0.9902	0.3763	0.7816
Zone_5 Reach 5,4,3,2	1.8890	2.5778	0.6210	0.2360	0.4902
Total	11.6649	15.9185	3.8349	1.4572	3.0268

90^{th} percentile stormwater flow based on nonpoint source urban runoff component of flow at SR331 gage.

Table 38- Upstream Boundary and Nonpoint Source Inflow: 90th Percentile Flow and Water Quality for "Worst-Case" Stormwater Flow Conditions (BIN3) for Scenario#2 (Run 602)

SCEN2 (Run 602)	Statistic >>	90th				
QUAL2K State Variables	Units	Percentile	N_Obs	Data Source		
HDW(BIN3)90PCTILE		BIN3	2013-2016	Obs	Derive	Const
Streamflow	MGD	2.48179	317	X		
Streamflow	cfs	3.8399	317	X		
Streamflow	cms	0.108746	317	X		
Water temperature	Deg C	26.5	66	X		
Conductivity	µmhos/cm	387.93	64	x		
Inorganic SS (PIM, dw)	mg/L	2.75	0		X	
Dissolved Oxygen	mg/L	9.232	25	X		
Slow CBOD (ultimate)	mg/L	0.1686032	0		X	
Fast CBOD (ultimate)	mg/L	1.5020158	0		X	
Organic-N, Total	µg/L	567.3	0		X	
Ammonia-N	µg/L	80.1	20	X		
Nitrate/Nitrite-N	µg/L	348.6	0		X	
Organic-P, Total	µg/L	64.35	0		X	
Inorganic-P (SRP, Diss_PO4)	µg/L	150.15	0		X	
Phytoplankton-Chl	µg/L	1.5085	8	X		
Phytoplankton-N	µg/L	16.2918	0		X	
Phytoplankton-P	µg/L	2.26275	0		X	
Organic Detritus (POM, dw)	mg/L	2.5488667	0		X	
Pathogens	cfu/100mL	0	0			
Alkalinity	mg CaCO3/L	129.542	17	X		
Constituent 1	mg/L	0	0			
Constituent 2	mg/L	0	0			
Constituent 3	mg/L	0	0			
PH	SU	7.63	63	X		
Total Nitrogen	µg/L	996	19	X		
Total Kjeldahl Nitrogen	µg/L	647.4	0		X	
Total Phosphorus	µg/L	214.5	22	X		
Total Organic Carbon	mg/L	12.514	18	X		
BOD-5-Day	mg/L	0.72	10	X		
TSS [PIM+POM(D)+POM(A)]	mg/L	5.5	16	X		

5.6.3.2 Scenario #2: Model Results and Findings

Model results are extracted for locations downstream of the KGS outfalls (4.09 km), the MSWRF outfall (2.00 km), and the downstream outlet from Sweetwater Branch to the enhancement wetland (0.61 km). Model results for each scenario are shown for comparison to the model confirmation results simulated for existing 2013-2016 conditions (Run529). Changes in travel time, velocity, phytoplankton, and periphyton biomass are identified at the KGS and MSWRF locations and at the downstream outlet of the model to the Enhancement Wetland (see Table 39).

Scenario #2 provides an assessment of the predicted changes in Sweetwater Branch from “worst-case” stormwater flow and load conditions combined with KGS and MSWRF point source effluent flow and loads based on possible MSWRF 9 MGD Buildout and upgrade conditions for the City of Gainesville. The “worst-case” stormwater scenario is based on model input derived from the 90th percentile flow and 90th percentile nutrients and water quality concentration data sets computed for the observed data set compiled to characterize high-flow (BIN3) conditions. Model results for comparison of model confirmation (Run 529) and “worst-case” stormwater conditions (Scenario #2) are presented in Figure 30, Figure 31, Figure 32, Figure 33 and Table 39. The full set of modeling result plots for the 9 MGD Buildout and upgrade of MSWRF under BIN3 “worst-case” stormwater flow conditions are presented in Appendix E.

Total nonpoint source flow increased from the median urban runoff flow of 3.0 cfs for BIN3 for the baseline model confirmation (see Table 17) to 15.92 cfs for the “worst-case” 90th percentile stormwater flow for BIN3 conditions under Scenario#2 (see Table 37). The 5X increase in urban runoff resulted in a significant reduction of travel time with a corresponding increase in velocity and cross-sectional area of the Upper and Lower reaches of Sweetwater Branch.

Downstream of the KGS outfall, travel time was reduced by 52%, cross sectional area of the channel increased by 130%, and velocity increased by 97%. The increase in velocity triggered an increase in the velocity-dependent maximum growth rate for periphyton (see Figure 33) and an increase of 112% for periphyton biomass (Figure 30). Although a doubling of periphyton biomass for the stormwater scenario appears, at first, to represent a significant increase in biomass of bottom algae, it is important understand that both the baseline and the stormwater scenario levels of biomass are very low in comparison to the abundance of periphyton biomass reported for many other streams in the literature. Based on a review of the literature, Dodds et al. (1998) indicate that oligotrophic streams can be characterized by periphyton biomass up to 20 mg Chl-a/m^2 which is considerably higher than periphyton biomass observed in Sweetwater Branch.

Periphyton biomass data have been compiled for Armstrong Slough in the Kissimmee Basin in Florida and from other locations in the literature to show the typical range of periphyton biomass for comparison to the periphyton data collected for Sweetwater Branch. Periphyton biomass is characterized by a wide range from ~0.1 to ~50 g ash-free dry weight (AFDW) m^{-2} for locations other than Sweetwater Branch. Periphyton data collected in Sweetwater Branch, however, varied from only 0.026 to 1.17 g AFDW m^{-2} (see Table 21). The abundance of periphyton in Sweetwater Branch is clearly at the low end of biomass measured for other streams and rivers. Downstream of the MSWRF outfall, travel time was reduced by 50%, cross sectional area of the channel increased by 60%, and velocity increased by 34%. The increase in velocity from 55 cm/s to 73.5 cm/s resulted in a decrease in the velocity-dependent maximum growth rate for periphyton (see Figure 33) and a decrease of 60% for periphyton biomass (see Figure 30).

As shown in Figure 31, water column chlorophyll is consistently higher for the high stormwater flow scenario along the Upper and Lower reaches of Sweetwater Branch than the model confirmation results (Run 529) for high-flow (BIN3) nonpoint source runoff conditions. Under the "worst-case" stormwater scenario, water column chlorophyll increased from the baseline confirmation run by 50% (from 0.988 to 1.5 µg/L) at the headwater upstream boundary (see Table 5 and Table 38), 79% (from 0.8 to 1.4 µg/L) downstream of the KGS outfall and by 55% (from 0.7 to 1.1 µg/L) downstream of the MSWRF outfall (see Table 39).

Although the "worst-case" stormwater scenario results in a consistent increase in phytoplankton biomass throughout the entire stream (Figure 31), the increased level of chlorophyll is driven by the mass loading response to the input of a much larger upstream boundary condition load input of phytoplankton based on the flow (2.58 cfs) and the corresponding chlorophyll level (1.5 µg/L) for the "worst-case" stormwater scenario (see Table 38) compared to a smaller flow (0.73 cfs) and chlorophyll level (1.5 µg/L) for the baseline model confirmation run (Run 529) under high-flow (BIN3) median loading conditions (see Table 5). The "worst-case" stormwater scenario in nutrient loading (see Table 39), however, does not trigger growth of phytoplankton biomass in the stream. The upstream input of much larger flow and corresponding mass loading of phytoplankton biomass controls the "worst-case" stormwater condition model results simulated along the entire length of the stream. It is also important to note that the levels of chlorophyll (<2 µg/L) for both the baseline model confirmation and "worst-case" stormwater scenario are lower than Florida's evidentiary threshold of 3.2 µg Chl-a/L for phytoplankton biomass in free-flowing streams and rivers (FDEP, 2013).

Nonpoint and point source nitrogen loading for Scenario #2 resulted in a 126% increase of the downstream outflow of Total Nitrogen to the enhanced wetland from the existing BIN3 conditions for Run 529 model confirmation (111,231 lbs/yr) to the outlet load for Scenario #2 (252,032 lbs/yr). The phosphorus loading for Scenario #2 resulted in a 58% increase of the downstream outflow of Total Phosphorus to the enhanced wetland from the existing conditions for RUN(529) model confirmation (11,102 lbs/yr) to the outlet load for Scenario #2 (17,606 lbs/yr) (see Table 39).

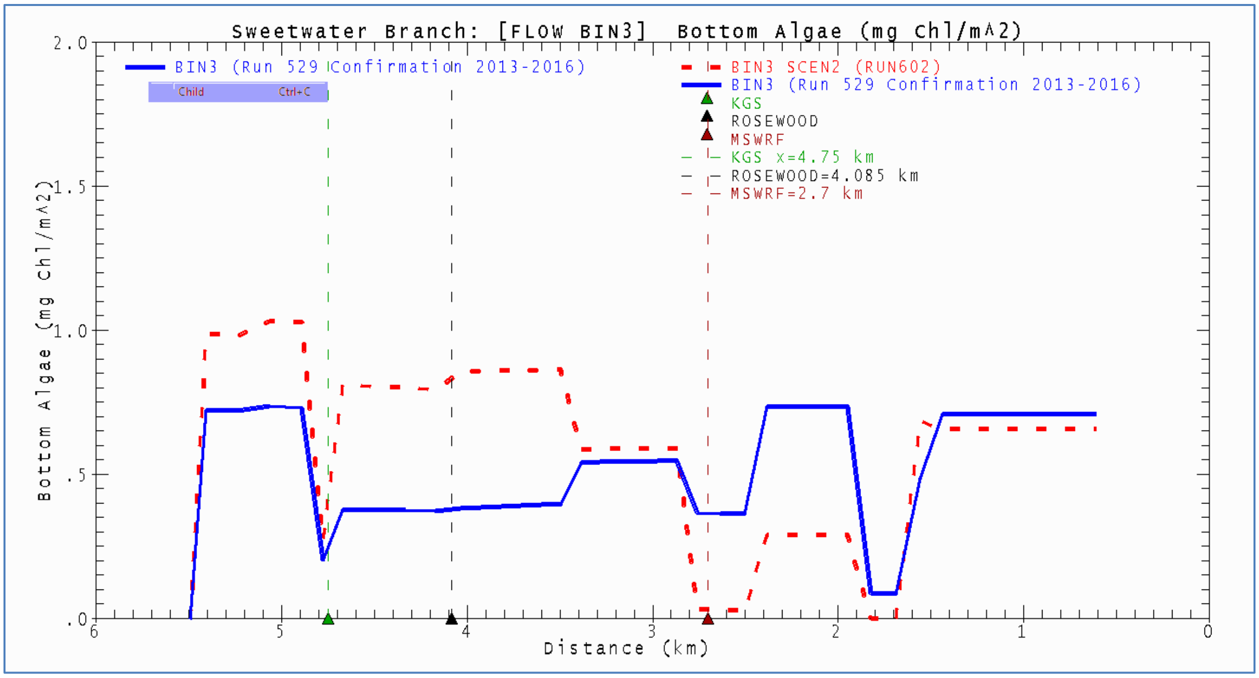

Figure 30- Bottom Algae, BIN3, Scenario #2 (Run 602)

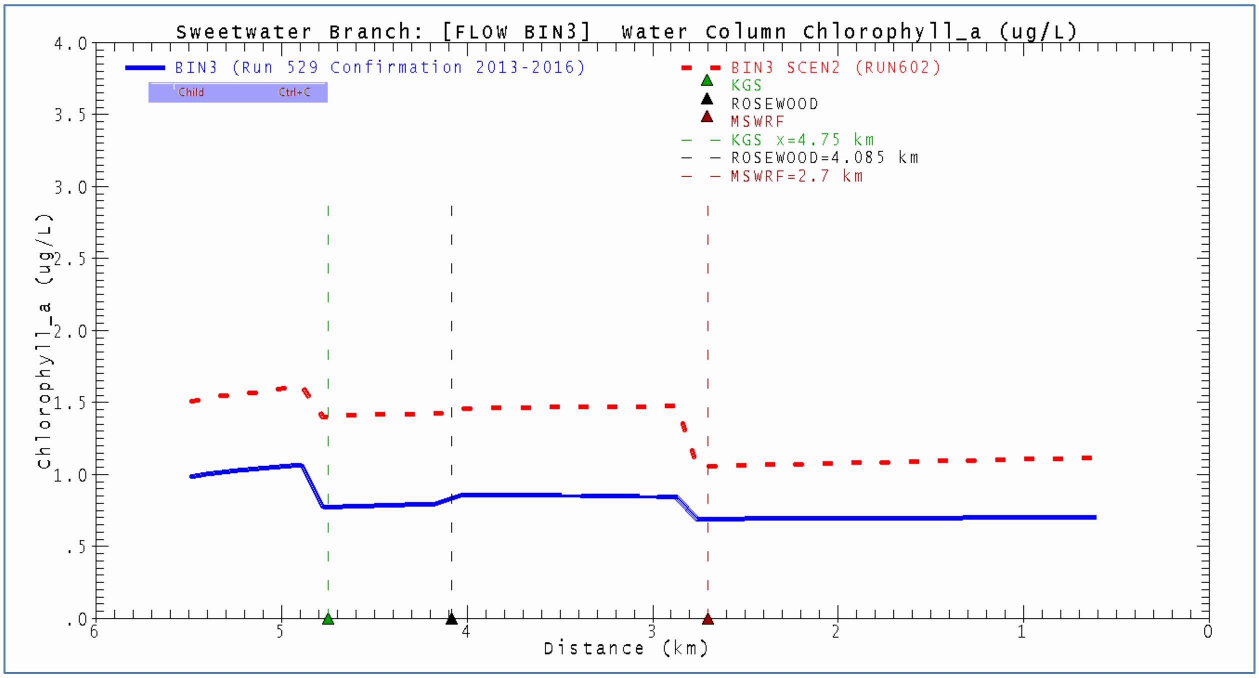

Figure 31- Water Column Chlorophyll, BIN3, Scenario #2 (Run 602)

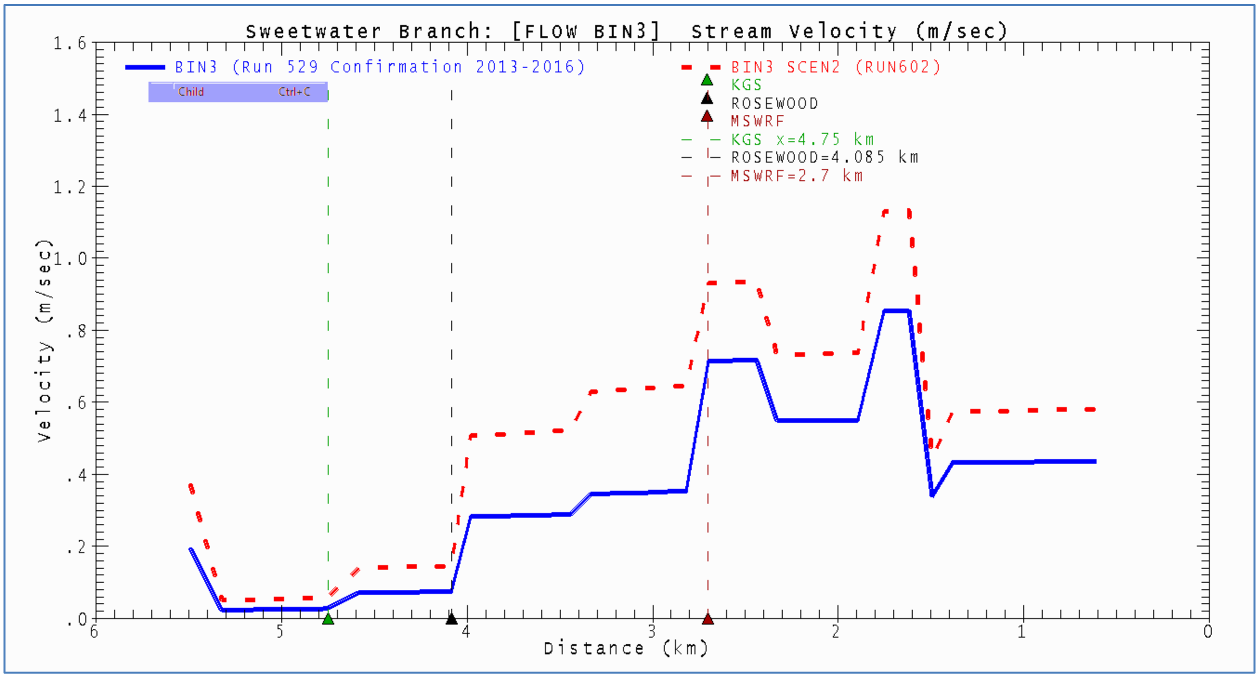

Figure 32- Stream Velocity, BIN3, Scenario #2 (Run 602)

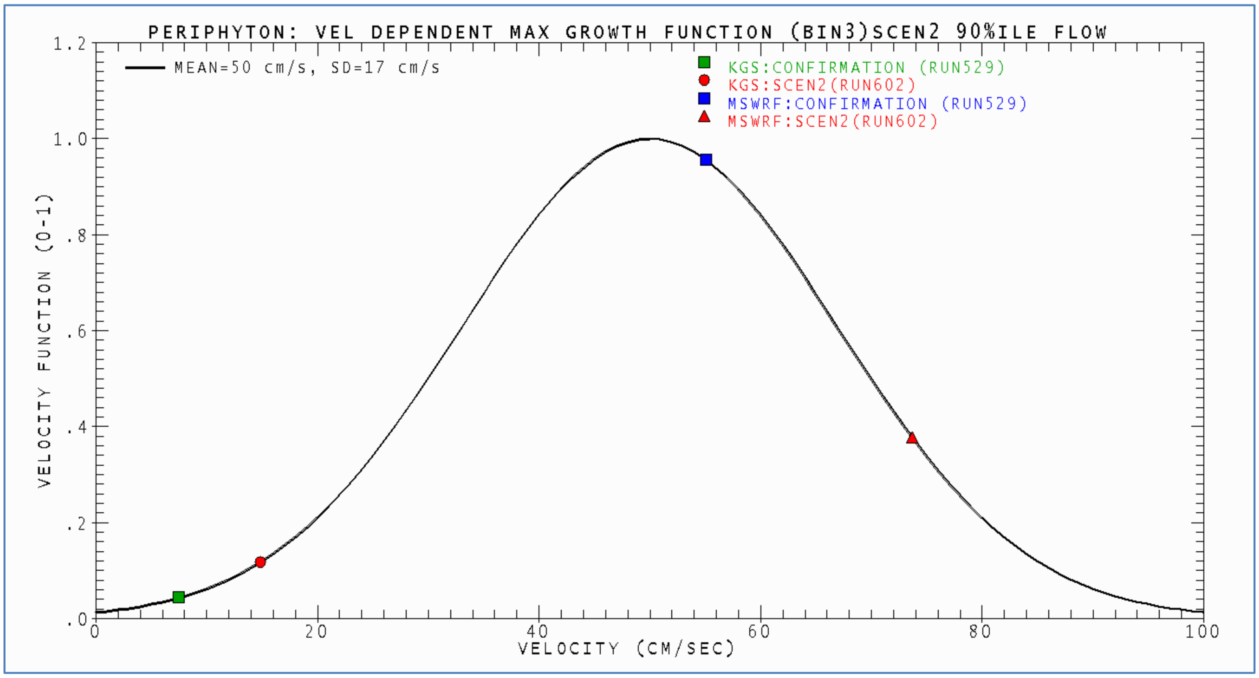

Figure 33- Velocity-Dependent Maximum Growth Function for Bottom Algae, BIN3, Scenario #2 (Run 602)

Green and blue symbols show model confirmation baseline (Run 529) for KGS and MSWRF and red symbols show change in velocity under model Scenario#2 (Run 602).

Table 39- Scenario #2 Model Results for Nonpoint Source Stormwater Scenario for High-Flow (BIN3) Conditions

SCEN(2)	KGS Downstream JEA 9	x=4.17 km	90%ile
RUN(529)	Travel time & Biomass	RUN529	BIN3
RUN(529)	Travel time	days	0.44159
RUN(529)	Cross-Section Area	m^2	0.5903
RUN(529)	Velocity	m/sec	0.075
RUN(529)	Chlorophyll-a	ug/L	0.798005
RUN(529)	Periphyton (Chl a)	mg/m^2	0.37506
SCEN(2)	Travel time	days	0.21339
SCEN(2)	Cross-Section Area	m^2	1.35504
SCEN(2)	Velocity	m/sec	0.14802
SCEN(2)	Chlorophyll-a	ug/L	1.427784
SCEN(2)	Periphyton (Chl a)	mg/m^2	0.797175
SCEN(2)	Travel time & Biomass (Change)		BIN3
SCEN(2)	Travel time	days	-0.2282
SCEN(2)	Cross-Section Area	m^2	0.76474
SCEN(2)	Velocity	m/sec	0.07302
SCEN(2)	Chlorophyll-a	ug/L	0.629779
SCEN(2)	Periphyton (Chl a)	mg/m^2	0.422115
SCEN(2)	Travel time	Pct Change	-51.7%
SCEN(2)	Cross-Section Area	Pct Change	129.6%
SCEN(2)	Velocity	Pct Change	97.4%
SCEN(2)	Chlorophyll-a	Pct Change	78.9%
SCEN(2)	Periphyton (Chl a)	Pct Change	112.5%
SCEN(2)			
SCEN(2)	MSWRF Downstream JEA 5	x=2.05 km	90%ile
RUN(529)	Travel time & Biomass	RUN529	BIN3
RUN(529)	Travel time	days	0.50132
RUN(529)	Cross-Section Area	m^2	0.68525
RUN(529)	Velocity	m/sec	0.55045
RUN(529)	Chlorophyll-a	ug/L	0.695213
RUN(529)	Periphyton (Chl a)	mg/m^2	0.736065
SCEN(2)	Travel time	days	0.24905
SCEN(2)	Cross-Section Area	m^2	1.0977
SCEN(2)	Velocity	m/sec	0.73555
SCEN(2)	Chlorophyll-a	ug/L	1.078384
SCEN(2)	Periphyton (Chl a)	mg/m^2	0.290802
SCEN(2)	Travel time & Biomass (Change)		BIN3
SCEN(2)	Travel time	days	-0.25227
SCEN(2)	Cross-Section Area	m^2	0.41245
SCEN(2)	Velocity	m/sec	0.1851

SCEN(2)	Chlorophyll-a	ug/L	0.383171
SCEN(2)	Periphyton (Chl a)	mg/m^2	-0.445263
SCEN(2)	Travel time	Pct Change	-50.3%
SCEN(2)	Cross-Section Area	Pct Change	60.2%
SCEN(2)	Velocity	Pct Change	33.6%
SCEN(2)	Chlorophyll-a	Pct Change	55.1%
SCEN(2)	Periphyton (Chl a)	Pct Change	-60.5%
SCEN(2)			
RUN(529)	Downstream (Outflow from Model)		BIN3
RUN(529)	Total-N	lbs/yr	111,231.9
RUN(529)	Total-P	lbs/yr	11,102.5
SCEN(2)	Total-N	lbs/yr	252,032.9
SCEN(2)	Total-P	lbs/yr	17,606.6
SCEN(2)	Downstream Change from Model Confirm		BIN3
SCEN(2)	Total-N	lbs/yr	140,801.0
SCEN(2)	Total-P	lbs/yr	6,504.0
SCEN(2)	Total-N	Pct Change	126.6%
SCEN(2)	Total-P	Pct Change	58.6%

5.7 Model Application: Sensitivity Analyses

Sensitivity analysis scenarios were performed to evaluate the impact of flow and nutrient loading on phytoplankton and periphyton biomass in Upper and Lower Sweetwater Branch. Model sensitivity was evaluated for two cases: (1) shade coverage of Sweetwater Branch (Scenario#3) and (2) impact of urban runoff conditions with removal of NPDES discharges from KGS and MSWRF (Scenario#4).

5.7.1 Scenario #3: Model Sensitivity to Shade Coverage

Photo courtesy of Russ Frydenborg, Frydenborg Ecologic, LLC

As shown by the inset photo of the stream taken at a location between the KGS and MSWRF outfalls and model input data summarized in Table 19, Sweetwater Branch is characterized by significant shade canopy cover over the Upper and Lower reaches of the stream. Model sensitivity was evaluated to determine the impact of changes in shade coverage as a likely factor that can suppress the potential for growth and accumulation of phytoplankton and periphyton biomass in Sweetwater Branch. Input data and model results for the model confirmation run for the three flow conditions (BIN1, BIN2, and BIN3) were used as baseline results for comparison to results obtained from application of the confirmed model for the sensitivity analysis of shade coverage.

5.7.1.1 Scenario #3: Input Data for Shade Coverage, Nonpoint and Point Source Flow and Loading

The sensitivity run for Scenario #3 provides an assessment of the water quality and biological impact of changes in shade cover over the stream combined with NPDES point source loading from KGS and the MSWRF. An increase in light availability to Sweetwater Branch was simulated by reducing shade coverage to a uniform 50% over all Upper and Lower reaches of the stream. Existing baseline conditions for shade coverage for model confirmation ranged from 65% to 92%% as shown in Table 19.

Nonpoint source flow and loading data for Scenario #3 are based on median statistics derived from the 2013-2016 baseline data sets for water quality and streamflow conditions compiled for model confirmation to existing conditions (Table 24). A brief description of the methodology used to assign median values for nonpoint source flow and loads is given in Section 5.6.1 for Scenario#0. A full description of the data sources and methodology used to develop nonpoint source water quality and stream flow data sets is presented in Section 5.4.3 and Section 5.4.5.

As described for Scenario#1 in Section 5.6.2, model input data used to represent point source flow and loading from KGS and MSWRF outfalls for Shade Sensitivity (Scenario#3) are based on a proposed 9 MGD buildout and upgrade of the MSWRF (see Table 32). KGS effluent flow and nutrient loads are based on EPA's MDL methodology and existing (2013-2016) operating conditions for the KGS discharge outfalls. Effluent flow, nutrient concentrations and median or constant values of non-nutrient water quality constituents assigned for Scenario#5 are summarized for Scenario#1 in Table 33 and Table 34.

5.7.1.2 Scenario #3: Model Results and Findings

Model results are extracted for locations downstream of the KGS outfalls (4.09 km), the MSWRF outfall (2.00 km), and the downstream outlet from Sweetwater Branch to the enhancement wetland (0.61 km). Model results for each scenario are shown for comparison to the model confirmation results simulated for existing 2013-2016 conditions (Run529). Changes in travel time, velocity, phytoplankton, and periphyton biomass are identified at the KGS and MSWRF locations and at the downstream outlet of the model to the Enhancement Wetland (see Table 40).

Model results for comparison of model confirmation and Scenario #3 are presented for BIN2 hydrologic conditions in Figure 34, Figure 35, Figure 36, Figure 37, and Table 40. A complete set of Scenario#3 model results for BIN1, BIN2, and BIN3 hydrologic conditions are presented in Appendix F. The discussion of model results for Scenario#3 emphasizes the results obtained under BIN2 hydrologic conditions.

Under Scenario#3, the increased effluent flow from the KGS and MSWRF discharges results in an increase in velocity and a decrease in travel time in the upper and lower segments of Sweetwater Branch. The effect of the changes in hydraulics for travel time and velocity are seen in the changes in water column chlorophyll (Figure 34) and periphyton (Figure 35) for Scenario#3 as described in Section 5.6.2.2 for Scenario#1. In comparison to the baseline model confirmation results, the most significant impact of the increased availability of light in the stream for the Shade Sensitivity Scenario#3 run is the more than two-fold (150%) increase of periphyton biomass downstream of the KGS outfall (see Table 40) compared to a more modest 21% increase of periphyton biomass under Scenario #1 (see Table 35). Downstream of the MSWRF outfall the increase in availability of sunlight increased periphyton biomass by 14% (see Table 40) compared to a 13% loss of periphyton biomass under Scenario #1 (see Table 35).

Nonpoint and point source nitrogen loading for Scenario #3 resulted in a 104% increase of the downstream outflow of Total Nitrogen to the enhanced wetland from the existing conditions for RUN(529) model confirmation (108,479 lbs/yr) to the outlet load for Scenario #3 (221,361 lbs/yr). The phosphorus loading for Scenario #3 resulted in only a 4% increase of the downstream outflow of Total Phosphorus to the enhanced wetland from the existing conditions for RUN(529) model confirmation (10,918 lbs/yr) to the outlet load for Scenario #1 (11,393 lbs/yr) (see Table 40).

Although water column chlorophyll declined with increased light availability downstream of both the KGS and MSWRF outfalls, the magnitude of the decrease of phytoplankton biomass at KGS (-8%) and MSWRF (-2%)for Scenario#3 (see Table 40) is less than the decrease of water column chlorophyll at KGS (-28%) and MSWRF (-5.5%) for Scenario #1 (see Table 35). The smaller percentage loss of phytoplankton biomass indicates that the increased availability of sunlight resulted in increased productivity of phytoplankton.

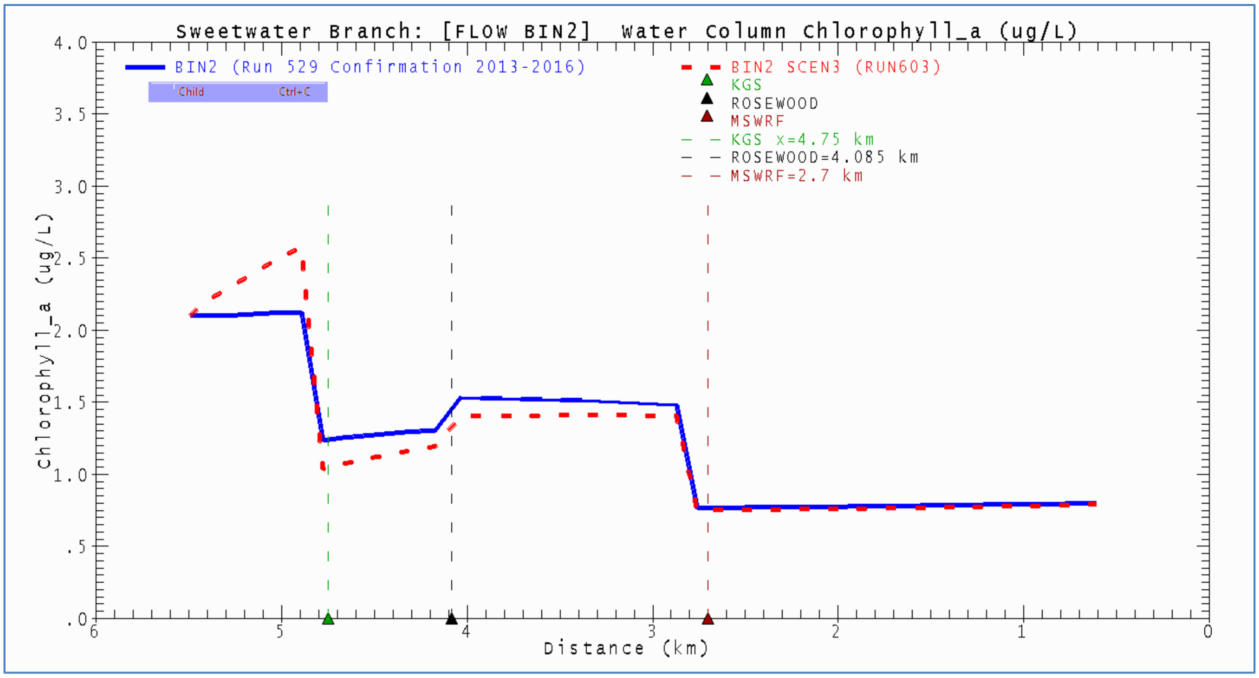

Figure 34- Water Column Chlorophyll, BIN2, Scenario #3 (Run 603)

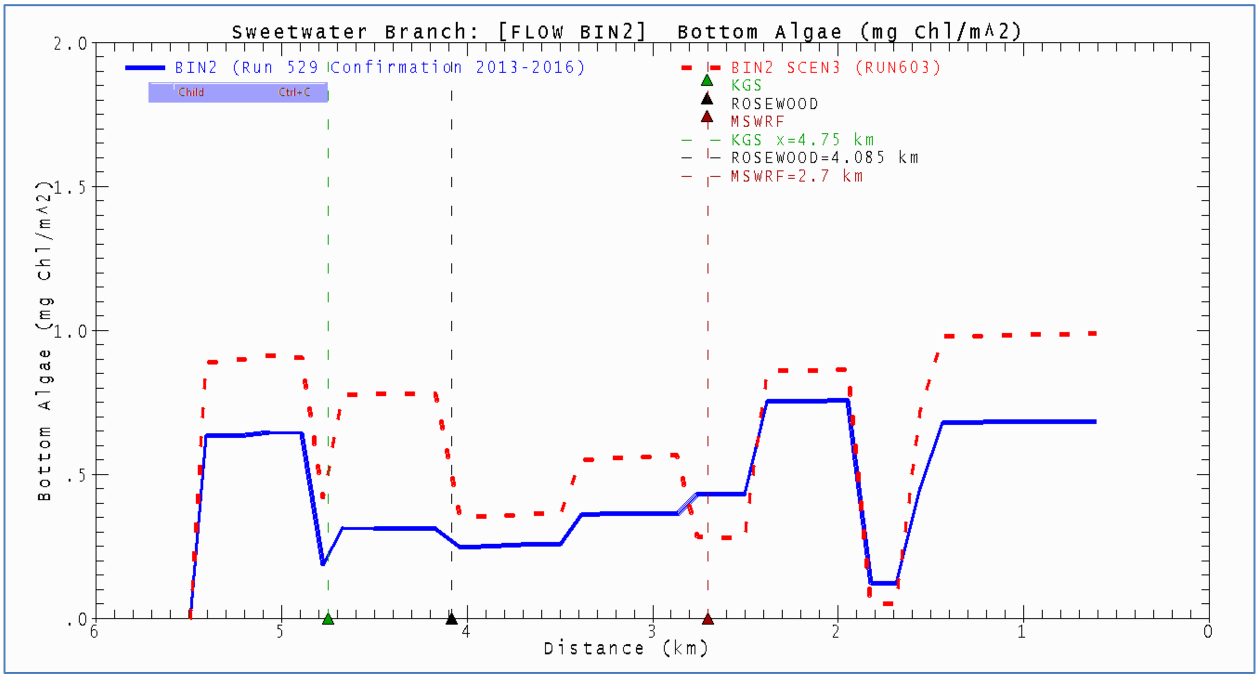

Figure 35- Bottom Algae, BIN2, Scenario #3 (Run 603)

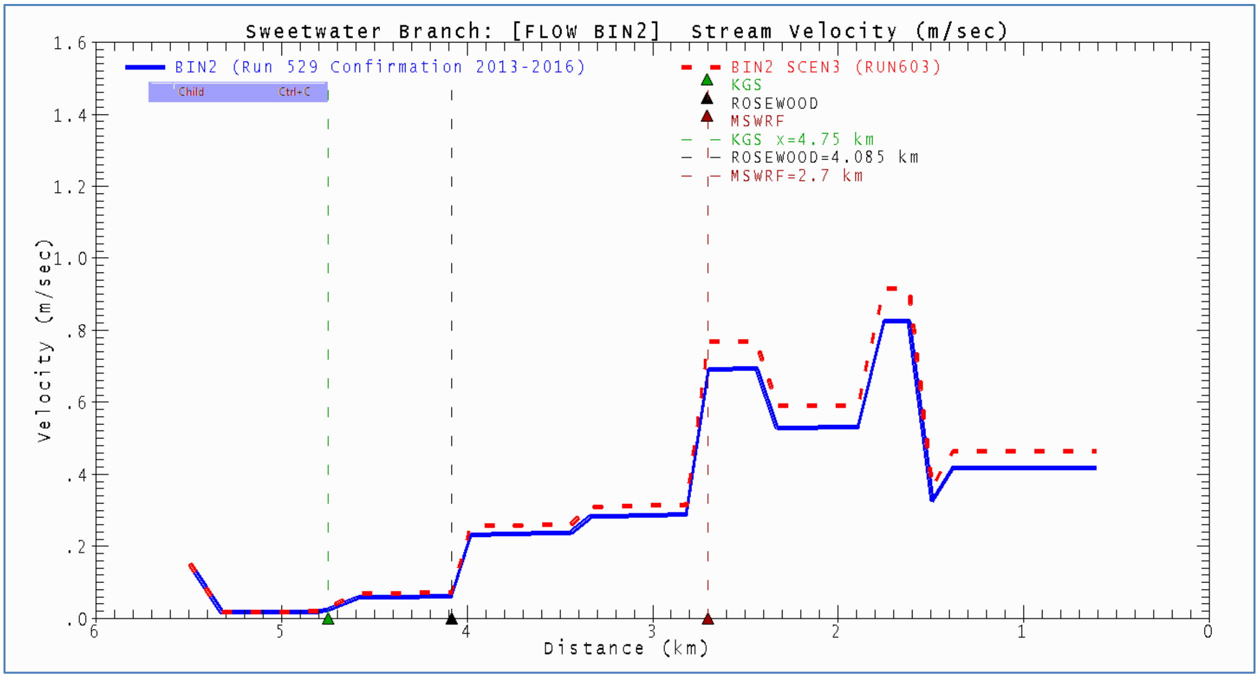

Figure 36- Stream Velocity, BIN2, Scenario #3 (Run 603)

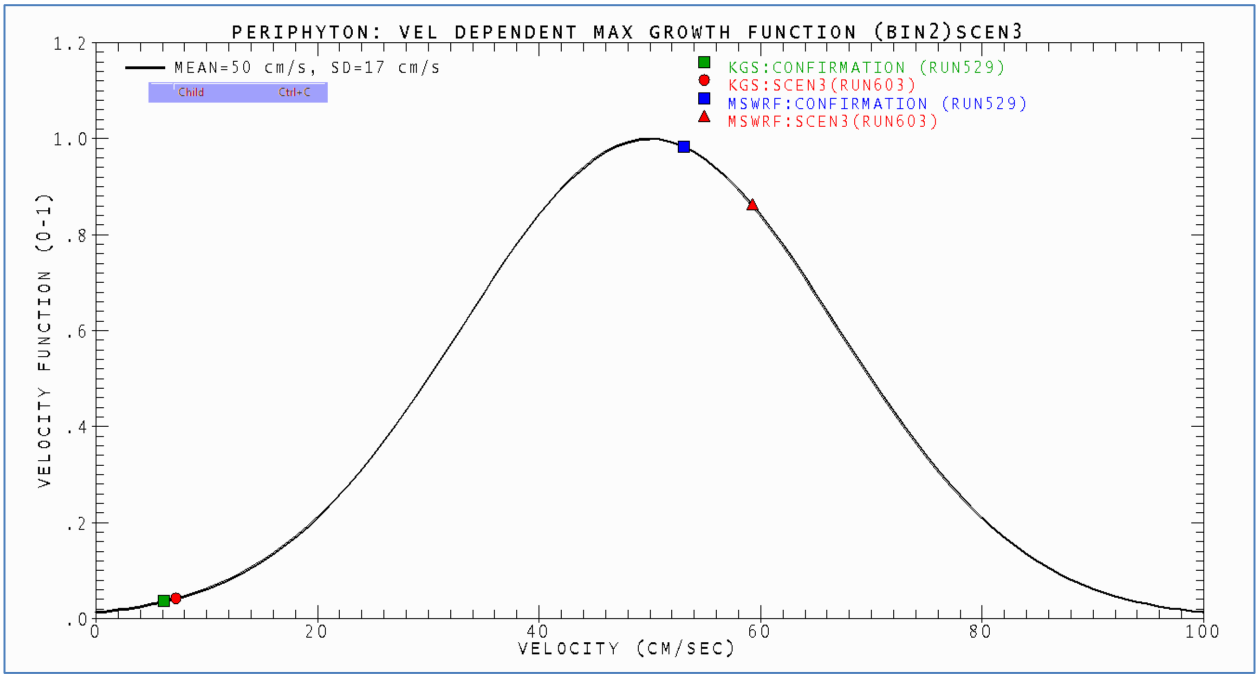

Figure 37-Velocity-Dependent Maximum Growth Function for Bottom Algae, BIN2, Scenario #3 (Run 603)

Green and blue symbols show model confirmation baseline (Run 529) for KGS and MSWRF and red symbols show change in velocity under model Scenario#3 (Run 603).

Table 40- Scenario #3 Model Results for Sensitivity Analysis Based on Shade Coverage

SCEN(3)	KGS Downstream JEA 9	x=4.17 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.89257	0.57062	0.44159
RUN(529)	Cross-Section Area	m^2	0.34038	0.46362	0.5903
RUN(529)	Velocity	m/sec	0.0478	0.06155	0.075
RUN(529)	Chlorophyll-a	ug/L	0.362362	1.309709	0.798005
RUN(529)	Periphyton (Chl a)	mg/m^2	0.269018	0.312372	0.37506
SCEN(3)	Travel time	days	0.8503	0.5481	0.4284
SCEN(3)	Cross-Section Area	m^2	0.45788	0.5595	0.67107
SCEN(3)	Velocity	m/sec	0.06092	0.07178	0.0833
SCEN(3)	Chlorophyll-a	ug/L	0.30986	1.20096	0.798442
SCEN(3)	Periphyton (Chl a)	mg/m^2	0.696518	0.780833	0.902424
SCEN(3)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(3)	Travel time	days	-0.04227	-0.02252	-0.01319
SCEN(3)	Cross-Section Area	m^2	0.1175	0.09588	0.08077
SCEN(3)	Velocity	m/sec	0.01312	0.01023	0.0083
SCEN(3)	Chlorophyll-a	ug/L	-0.052502	-0.108749	0.000437
SCEN(3)	Periphyton (Chl a)	mg/m^2	0.4275	0.468461	0.527364
SCEN(3)	Travel time	Pct Change	-4.7%	-3.9%	-3.0%
SCEN(3)	Cross-Section Area	Pct Change	34.5%	20.7%	13.7%
SCEN(3)	Velocity	Pct Change	27.4%	16.6%	11.1%
SCEN(3)	Chlorophyll-a	Pct Change	-14.5%	-8.3%	0.1%
SCEN(3)	Periphyton (Chl a)	Pct Change	158.9%	150.0%	140.6%
SCEN(3)					
SCEN(3)	MSWRF Downstream JEA 5	x=2.05 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.98201	0.64097	0.50132
RUN(529)	Cross-Section Area	m^2	0.61444	0.64603	0.68525
RUN(529)	Velocity	m/sec	0.51406	0.53051	0.55045
RUN(529)	Chlorophyll-a	ug/L	0.637788	0.777035	0.695213
RUN(529)	Periphyton (Chl a)	mg/m^2	0.766559	0.756985	0.736065
SCEN(3)	Travel time	days	0.92629	0.61209	0.4843
SCEN(3)	Cross-Section Area	m^2	0.74192	0.77024	0.80569
SCEN(3)	Velocity	m/sec	0.57841	0.59203	0.60877
SCEN(3)	Chlorophyll-a	ug/L	0.635458	0.761428	0.694629
SCEN(3)	Periphyton (Chl a)	mg/m^2	0.899345	0.864715	0.816702
SCEN(3)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(3)	Travel time	days	-0.05572	-0.02888	-0.01702
SCEN(3)	Cross-Section Area	m^2	0.12748	0.12421	0.12044
SCEN(3)	Velocity	m/sec	0.06435	0.06152	0.05832
SCEN(3)	Chlorophyll-a	ug/L	-0.00233	-0.015607	-0.000584

SCEN(3)	Periphyton (Chl a)	mg/m^2	0.132786	0.10773	0.080637
SCEN(3)	Travel time	Pct Change	-5.7%	-4.5%	-3.4%
SCEN(3)	Cross-Section Area	Pct Change	20.7%	19.2%	17.6%
SCEN(3)	Velocity	Pct Change	12.5%	11.6%	10.6%
SCEN(3)	Chlorophyll-a	Pct Change	-0.4%	-2.0%	-0.1%
SCEN(3)	Periphyton (Chl a)	Pct Change	17.3%	14.2%	11.0%
SCEN(3)					
RUN(529)	Downstream (Outflow from Model)		BIN1	BIN2	BIN3
RUN(529)	Total-N	lbs/yr	107,256.8	108,478.6	111,231.9
RUN(529)	Total-P	lbs/yr	10,580.6	10,917.8	11,102.5
SCEN(3)	Total-N	lbs/yr	220,047.9	221,361.3	224,225.2
SCEN(3)	Total-P	lbs/yr	11,052.5	11,393.2	11,572.9
SCEN(3)	Downstream Change from Model Confirm		BIN1	BIN2	BIN3
SCEN(3)	Total-N	lbs/yr	112,791.1	112,882.7	112,993.3
SCEN(3)	Total-P	lbs/yr	471.8	475.4	470.3
SCEN(3)	Total-N	Pct Change	105.2%	104.1%	101.6%
SCEN(3)	Total-P	Pct Change	4.5%	4.4%	4.2%

5.7.2 Scenario #4: Model Sensitivity to NPDES Point Source Discharges

Input data and model results for the model confirmation run for the three flow conditions (BIN1, BIN2, and BIN3) were used as baseline results for comparison to results obtained from application of the confirmed model for the sensitivity analysis to NPDES point source dischargers. The focus of the evaluation for Scenario#4 was to isolate the impact of nonpoint source urban runoff on water quality and biological conditions in the stream by the removal of KGS and MSWRF NPDES permitted discharges from Sweetwater Branch.

5.7.2.1 Scenario #4: Input Data for Nonpoint Source and Point Source Flow and Loads

Nonpoint source flow and loading data for Scenario #4 are based on median statistics derived from the 2013-2016 baseline data sets for water quality and streamflow conditions compiled for model confirmation to existing conditions (Table 24). A brief description of the methodology used to assign median values for nonpoint source flow and loads is given in Section 5.6.1 for Scenario#0. A full description of the data sources and methodology used to develop nonpoint source water quality and stream flow data sets is presented in Section 5.4.3 and Section 5.4.5.

Under Scenario#4, point source flow and loading from the KGS and MSWRF outfalls are removed to isolate the impact of urban runoff on water quality and biological conditions in Sweetwater Branch. Effluent flow is set to zero for the KGS and MSWRF outfalls to simulate removal of these point source discharges to the stream.

5.7.2.2 Scenario #4: Model Results and Findings

Model results are extracted for locations downstream of the KGS outfalls (4.09 km), the MSWRF outfall (2.00 km), and the downstream outlet from Sweetwater Branch to the enhancement wetland (0.61 km). Model results for each scenario are shown for comparison to the model confirmation results simulated for existing 2013-2016 conditions (Run529). Changes in travel time, velocity, phytoplankton, and periphyton biomass are identified at the KGS and MSWRF locations and at the downstream outlet of the model to the Enhancement Wetland (see Table 41).

The sensitivity run for Scenario #4 provides an assessment of the predicted changes in Sweetwater Branch from a decrease in stream flow and change in stream velocity based on isolation of nonpoint source urban runoff. Flow and water quality conditions in the stream are changed by removal of the KGS and MSWRF point source effluent flow and loading to the stream. Model results for comparison of model confirmation and Scenario #4 are presented in Figure 38, Figure 39, Figure 40, Figure 41 and Table 41. A complete set of Scenario#4 model results for BIN1, BIN2, and BIN3 hydrologic conditions are presented in Appendix G. The discussion of model results for Scenario#4 emphasizes the results obtained under BIN2 hydrologic conditions.

The substantial decrease of streamflow under Scenario #4 results in an increase of travel time with a corresponding decrease in velocity and cross-sectional area of the stream channel. The increase of residence time results in an increase of 54% in water column chlorophyll downstream of the KGS outfall from 1.3 to 2.0 µg/L and a change of 120% for water column chlorophyll downstream of the MSWRF outfall from 0.77 to 1.7 µg/L (Figure 38). The effect of the decrease in streamflow and velocity for Scenario #4 (Figure 40) results in a significant reduction of the velocity-dependent maximum growth rate for periphyton (Figure 41) with a corresponding decrease in periphyton biomass of 20% downstream of the KGS outfall and a decrease of 73% downstream of the MSWRF outfall (Figure 39).

With removal of point source nutrient loading from KGS and MSWRF discharges, nonpoint and point source nitrogen loading for Scenario #4 resulted in a 98% decrease of the downstream outflow of Total Nitrogen to the enhanced wetland from the existing conditions for RUN(529) model confirmation (108,479 lbs/yr) compared to the outlet load for Scenario #4 (1,518 lbs/yr). Phosphorus loading for Scenario #4 also resulted in a 96% decrease of the downstream outflow of Total Phosphorus to the enhanced wetland from the existing conditions for RUN(529) model confirmation (10,918 lbs/yr) to the outlet load for Scenario #4 (411 lbs/yr) (see Table 41).

Figure 38- Water Column Chlorophyll, BIN2, Scenario #4 (Run 604)

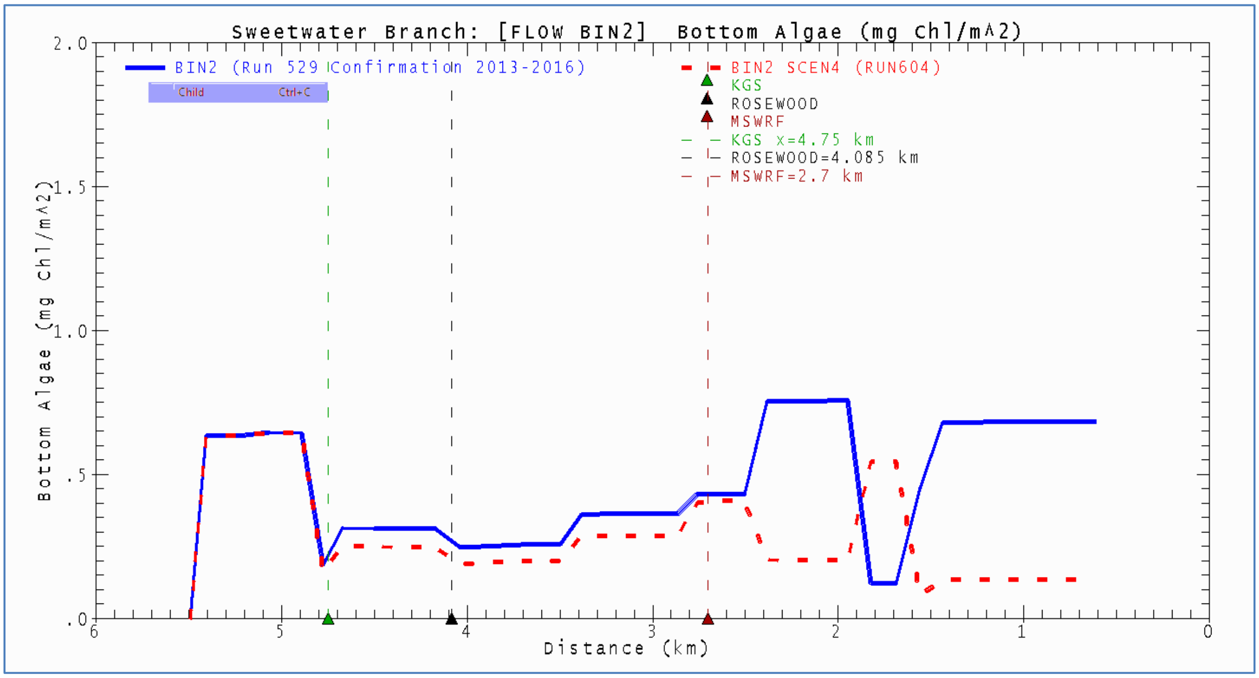

Figure 39- Bottom Algae, BIN2, Scenario #4 (Run 604)

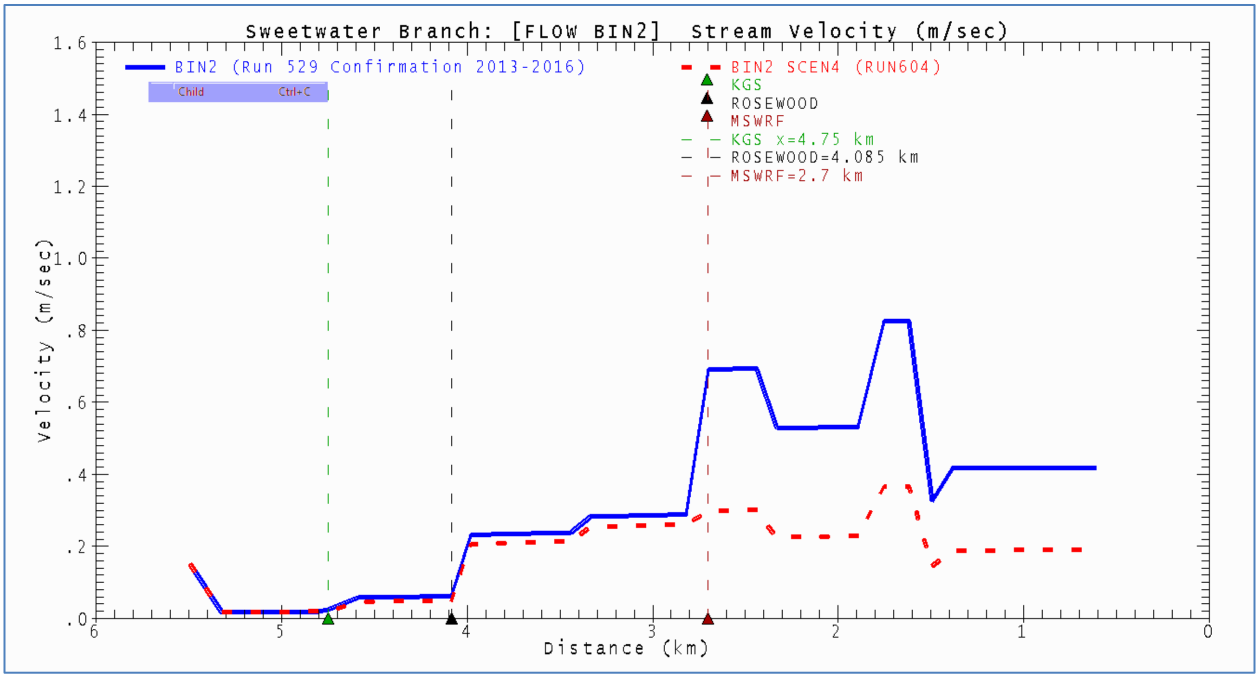

Figure 40 -Stream Velocity, BIN2, Scenario #4 (Run 604)

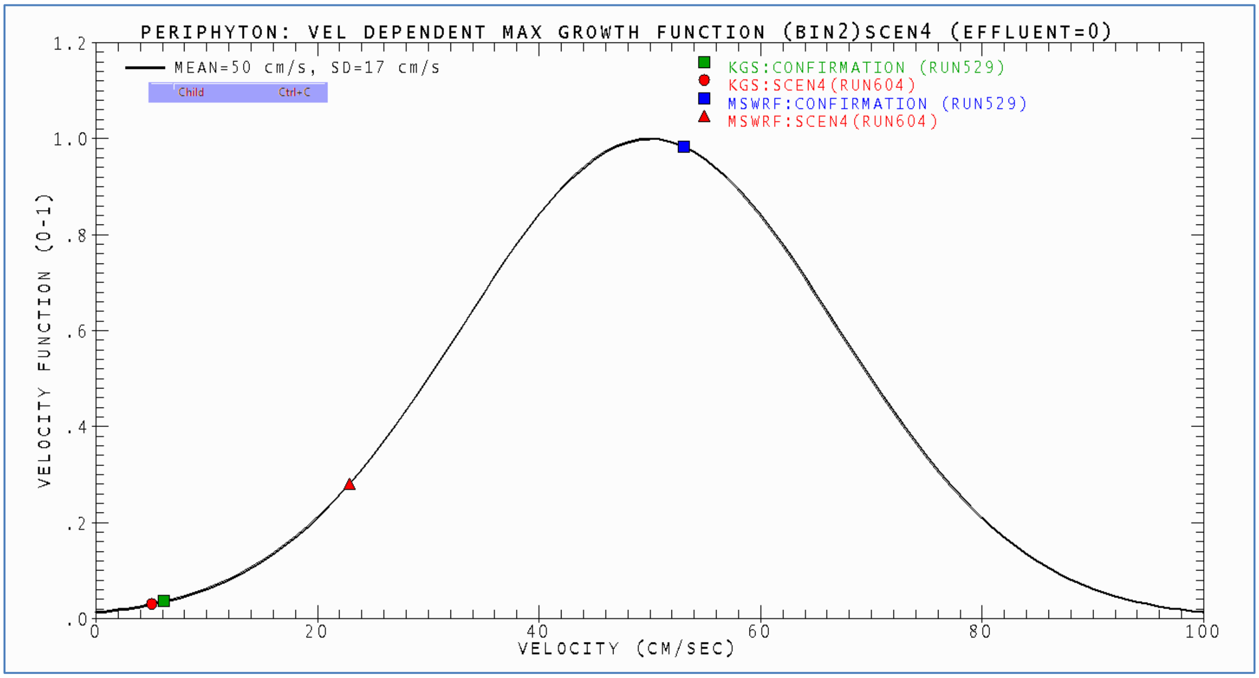

Figure 41-Velocity-Dependent Maximum Growth Function for Bottom Algae, BIN2, Scenario #4 (Run 604)

Green and blue symbols show model confirmation baseline (Run 529) for KGS and MSWRF and red symbols show change in velocity under model Scenario#4 (Run 604).

Table 41-Scenario #4 Model Results for Sensitivity Analysis Based on Removal of NPDES Effluent Flow

SCEN(4)	KGS Downstream JEA 9	x=4.17 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.89257	0.57062	0.44159
RUN(529)	Cross-Section Area	m^2	0.34038	0.46362	0.5903
RUN(529)	Velocity	m/sec	0.0478	0.06155	0.075
RUN(529)	Chlorophyll-a	ug/L	0.362362	1.309709	0.798005
RUN(529)	Periphyton (Chl a)	mg/m^2	0.269018	0.312372	0.37506
SCEN(4)	Travel time	days	1.01524	0.60827	0.45924
SCEN(4)	Cross-Section Area	m^2	0.19267	0.36035	0.50873
SCEN(4)	Velocity	m/sec	0.03001	0.05008	0.06641
SCEN(4)	Chlorophyll-a	ug/L	0.924513	2.024224	1.038575
SCEN(4)	Periphyton (Chl a)	mg/m^2	0.192579	0.248986	0.321052
SCEN(4)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(4)	Travel time	days	0.12267	0.03765	0.01765
SCEN(4)	Cross-Section Area	m^2	-0.14771	-0.10327	-0.08157
SCEN(4)	Velocity	m/sec	-0.01779	-0.01147	-0.00859
SCEN(4)	Chlorophyll-a	ug/L	0.562151	0.714515	0.24057
SCEN(4)	Periphyton (Chl a)	mg/m^2	-0.076439	-0.063386	-0.054008
SCEN(4)	Travel time	Pct Change	13.7%	6.6%	4.0%
SCEN(4)	Cross-Section Area	Pct Change	-43.4%	-22.3%	-13.8%
SCEN(4)	Velocity	Pct Change	-37.2%	-18.6%	-11.5%
SCEN(4)	Chlorophyll-a	Pct Change	155.1%	54.6%	30.1%
SCEN(4)	Periphyton (Chl a)	Pct Change	-28.4%	-20.3%	-14.4%
SCEN(4)					
SCEN(4)	MSWRF Downstream JEA 5	x=2.05 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.98201	0.64097	0.50132
RUN(529)	Cross-Section Area	m^2	0.61444	0.64603	0.68525
RUN(529)	Velocity	m/sec	0.51406	0.53051	0.55045
RUN(529)	Chlorophyll-a	ug/L	0.637788	0.777035	0.695213
RUN(529)	Periphyton (Chl a)	mg/m^2	0.766559	0.756985	0.736065
SCEN(4)	Travel time	days	1.16346	0.70295	0.53339
SCEN(4)	Cross-Section Area	m^2	0.08741	0.17365	0.25376
SCEN(4)	Velocity	m/sec	0.14488	0.22766	0.29164
SCEN(4)	Chlorophyll-a	ug/L	0.577436	1.710263	0.929929
SCEN(4)	Periphyton (Chl a)	mg/m^2	0.084096	0.203296	0.351483
SCEN(4)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(4)	Travel time	days	0.18145	0.06198	0.03207
SCEN(4)	Cross-Section Area	m^2	-0.52703	-0.47238	-0.43149
SCEN(4)	Velocity	m/sec	-0.36918	-0.30285	-0.25881
SCEN(4)	Chlorophyll-a	ug/L	-0.060352	0.933228	0.234716

SCEN(4)	Periphyton (Chl a)	mg/m^2	-0.682463	-0.553689	-0.384582
SCEN(4)	Travel time	Pct Change	18.5%	9.7%	6.4%
SCEN(4)	Cross-Section Area	Pct Change	-85.8%	-73.1%	-63.0%
SCEN(4)	Velocity	Pct Change	-71.8%	-57.1%	-47.0%
SCEN(4)	Chlorophyll-a	Pct Change	-9.5%	120.1%	33.8%
SCEN(4)	Periphyton (Chl a)	Pct Change	-89.0%	-73.1%	-52.2%
SCEN(4)					
RUN(529)	Downstream (Outflow from Model)		BIN1	BIN2	BIN3
RUN(529)	Total-N	lbs/yr	107,256.8	108,478.6	111,231.9
RUN(529)	Total-P	lbs/yr	10,580.6	10,917.8	11,102.5
SCEN(4)	Total-N	lbs/yr	467.1	1,518.8	4,048.2
SCEN(4)	Total-P	lbs/yr	119.5	411.7	588.4
SCEN(4)	Downstream Change from Model Confirm		BIN1	BIN2	BIN3
SCEN(4)	Total-N	lbs/yr	-106,789.7	-106,959.8	-107,183.7
SCEN(4)	Total-P	lbs/yr	-10,461.1	-10,506.0	-10,514.1
SCEN(4)	Total-N	Pct Change	-99.6%	-98.6%	-96.4%
SCEN(4)	Total-P	Pct Change	-98.9%	-96.2%	-94.7%

5.8 Model Application: Point source buildout and nonpoint scenarios

5.8.1 Scenario #5: Updated Full Buildout and Upgrade of Point Source Loads

Model input data and results obtained for the confirmation run for the three flow conditions (BIN1, BIN2, and BIN3) were used as the baseline for comparison to results obtained for this point source management run. The focus of the evaluation for Scenario#5 was to test the impact of proposed changes in KGS and MSWRF effluent flow rates and nutrient levels to represent future flow and loading conditions from KGS and the full build-out and upgrade of the MSWRF.

5.8.1.1 Scenario #5: Input Data for Nonpoint Source and Point Source Flow and Loads

Nonpoint source flow and loading data for Scenario #5 are based on median statistics derived from the 2013-2016 baseline data sets for water quality and streamflow conditions compiled for model confirmation to existing conditions (Table 24). A brief description of the methodology used to assign median values for nonpoint source flow and loads is given in Section 5.6.1 for Scenario#0. A full description of the data sources and methodology used to develop nonpoint source water quality and stream flow data sets is presented in Section 5.4.3 and Section 5.4.5.

Effluent flow, nutrient concentrations and loads for the MSWRF and KGS discharges are summarized for Scenario #5 in Table 42. The KGS facility reports effluent discharge records for two outfalls: (1) Unit 8 Cooling Water Discharge (CTBD8) and (2) Low Volume Waste (LVW). KGS effluent records for discharge and nutrient concentrations are used to compute effluent loads for each outfall. The combined sums of KGS effluent flow and nutrient loads from the cooling water and low volume wastewater outfalls are shown to facilitate comparison of the relative contributions of flow and nutrient loading from the MSWRF and KGS discharges.

Table 42- Scenario #5 Summary of MSWRF and KGS Effluent Flow and Nutrient Loading Rates

Data Source: Table 42 Future Conditions Scenario#5 (Run 605)	MSWRF Full Build-Out - Upgrade	KGS CTBD8 EPA MDL	KGS LVW EPA MDL	KGS CTBD8+LVW EPA MDL
Annual Flow (MGD)	12	0.418	0.087	0.505
Total Nitrogen (mg N/L)	8.0	2.2	0.984	1.991
Total Phosphorus (mg P/L)	0.375	0.636	0.125	0.548
Total Nitrogen (lbs N/yr)	292,408.8	2,801.0	260.8	3,061.8
Total Phosphorus (lbs P/yr)	13,706.7	809.8	33.1	842.9

Load (lbs/yr) = MGD x mg/L x 8.345 x 365. MSWRF based on full build-out effluent flow and expected upgrade of nutrient removal. KGS effluent flow and nutrient loads based on EPA MDL calculations for 95% Confidence Interval. KGS effluent nutrient concentrations are derived from flow-weighted calculation of MDL estimates for CTBD8 and LVW flow and nutrient loading rates.

Effluent flow and loading for the MSWRF was based on a proposed full build-out expansion of the facility to 12 MGD and upgrade of the existing facility treatment processes to achieve effluent nutrient concentrations for TN of 8 mg/L and TP of 0.375 mg/L. Model input for MSWRF effluent flow and nutrient levels were assigned to reflect the proposed expansion and upgrade for flow, TN and TP treatment processes. Effluent levels of non-nutrient water quality constituents (water temperature, total suspended sediment, dissolved oxygen, TOC, CBOD, pH and alkalinity) for Scenario#5 were based on either constant or median concentrations of MSWRF effluent developed for model confirmation (see Table 8). Effluent flow, nutrient concentrations and other non-nutrient water quality constituent concentrations used to assign model input data for the MSWRF discharge for Scenario#5 are summarized in Table 43.

As described for Scenario#1 in Section 5.6.2, KGS effluent flow and nutrient loads are based on EPA's MDL methodology and existing (2013-2016) operating conditions for the KGS discharge outfalls. Effluent flow, nutrient concentrations and median or constant values of non-nutrient water quality constituents assigned for Scenario#5 are summarized in Table 33 and Table 34.

5.8.1.2 Scenario #5: Model Results and Findings

Model results are extracted for locations downstream of the KGS outfall (4.09 km), the MSWRF outfall (2.00 km), and the downstream outlet from Sweetwater Branch to the enhancement wetland (0.61 km). Model results for full Build-out of the MSWRF facility (Scenario #5) are shown for comparison to the model confirmation results simulated for the existing 2013-2016 conditions (Run529). QUAL2K model results extracted at the downstream outlet to the Wetland Enhancement Area are presented in Table 44 for comparison to model input data used for the Wetland Model.

Scenario #5 provides an assessment of the predicted changes in Sweetwater Branch from KGS and MSWRF point source effluent flow and loading based on full build out conditions for the MSWRF discharge from the City of Gainesville. Model results for comparison of model confirmation and Scenario #5 are presented in Figure 42, Figure 43, Figure 44, Figure 45 and Table 45. The full set of stream modeling result plots for Scenario #5 (Run 605) are presented in Appendix H. The discussion of model results for Scenario#5 emphasizes the results obtained under BIN2 hydrologic conditions.

Effluent flow discharged by both MSWRF (12 MGD) and KGS (0.505 MGD) for Scenario #5 was higher than the 6.919 MGD effluent flow assigned for MSWRF (6.68 MGD) and the two combined outfalls for KGS (0.239 MGD) for model confirmation (see Table 8, Table 9, and Table 10). The increased effluent flow of 5.586 MGD (8.6 cfs) resulted in an increase in velocity (Figure 44) and a decrease in travel time in the stream. Downstream of the KGS outfall, the 17% increase in velocity caused an increase in the velocity-dependent maximum growth rate and an increase of 20% for periphyton biomass (see Figure 42). The decrease in travel time results in a shorter residence time and a 28% decrease in water column chlorophyll from 1.3 to 0.9 µg/L (see Figure 43). Downstream of MSWRF outfall, the 23% increase in velocity caused a decrease in the velocity-dependent maximum growth rate (Figure 45) and a decrease of 33% for periphyton biomass (see Figure 42). The decreased travel time results in a shorter residence time and a small 8% decrease in water column chlorophyll from 0.77 to 0.71 µg/L (see Figure 43).

Table 43- Scenario #5 MSWRF Point Source Discharge Effluent Flow for Proposed Full Build-Out Expansion of MSWRF. Effluent Nutrients based on Upgrade of MSWRF and Non-Nutrient effluent constituents based on median or constant values.

SCEN5 (RUN 605)	Statistic >>	Median					Statistic &
QUAL2K State Variables	Units	BIN9	N_Obs	Data Source			DESIGN
MSWRF(BIN9)			2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	12	0				Full Buildout
Effluent Flow	cfs	18.56676	0				Full Buildout
Effluent Flow	cms	0.525811	0				Full Buildout
Water temperature	Deg C	23.9	847	X			Median
Conductivity	µmhos/cm	862	0			X	Constant
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8.7	1134	X			Median
Slow CBOD (ultimate)	mg/L	0.403	0		X		Median
Fast CBOD (ultimate)	mg/L	2	0		X		Median
Organic-N, Total	µg/L	1032	0		X		Upgrade
Ammonia-N	µg/L	168	0		X		Upgrade
Nitrate/Nitrite-N	µg/L	6800	0		X		Upgrade
Organic-P, Total	µg/L	67.5	0		X		Upgrade
Inorganic-P (SRP, Diss_PO4)	µg/L	307.5	0		X		Upgrade
Phytoplankton-Chl	µg/L	0.65	0			X	Constant
Phytoplankton-N	µg/L	7.02	0		X		Constant
Phytoplankton-P	µg/L	0.975	0		X		Constant
Organic Detritus (POM, dw)	mg/L	0.413333	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	70	0			X	Constant
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	7.2	847	X			Median
Total Nitrogen	µg/L	8000	0				Upgrade
Total Kjedhal Nitrogen	µg/L	1200	0		X		Upgrade
Total Phosphorus	µg/L	375	0				Upgrade
Total Organic Carbon	mg/L	4.5	0		X		Median
CBOD-5-Day	mg/L	0.5	846	X			Median
TSS [PIM+POM(D)+POM(A)]	mg/L	1	848	X			Median

Table 44- Scenario#5 QUAL2K Model Results at Downstream Outlet to Wetland Enhancement Area

QUAL2K Model Output at Downstream Outlet to Wetland			
SCEN(5)	**BIN1**	**BIN2**	**BIN3**
Flow rate (cubic m/sec), cms	0.56253	0.59351	0.63327
Flow rate (cubic ft/sec), cfs	19.86557819	20.9596276	22.3637401
Flow rate (million gal/d), MGD	12.83946599	13.546569	14.4540711
Organic-N (µg/L)	993.94	957.40	932.37
Ammonia-N (µg/L)	167.08	159.59	152.10
Nitrate+Nitrite-N (µg/L)	6327.51	6010.10	5659.85
Phytoplankton-N (µg/L)	6.80	7.79	7.13
Total-N (µg/L)	7495.33	7134.89	6751.45
Organic-P (µg/L)	65.70	65.44	60.51
Orthophosphate-P (µg/L)	303.72	292.75	279.26
Phytoplankton-P (µg/L)	0.94	1.08	0.99
Total-P (µg/L)	370.37	359.27	340.76
Total-N (lbs/yr)	293,139	294,409	297,250
Total-P (lbs/yr)	14,485	14,825	15,003

Load (lbs/yr) = Flow (cms) x (µg/L) x 86.4 x 0.001 x 2.2046 x 365

Nitrogen effluent loading from Scenario #5 for KGS and MSWRF resulted in a 171% increase of the downstream outflow of Total Nitrogen to the enhanced wetland from the existing conditions for RUN(529) model confirmation (108,478 lbs/yr) to the outlet load for Scenario #5 (294,409 lbs/yr). The phosphorus effluent loading from Scenario #5 resulted in a 36% increase of the downstream outflow of Total Phosphorus to the enhanced wetland from the existing conditions for RUN(529) model confirmation (10,917 lbs/yr) to the outlet load for Scenario #5 (14,824 lbs/yr) (see Table 45).

Although Total Nitrogen and Total Phosphorus increased in Lower Sweetwater Branch downstream of the MSWRF outfall, water column chlorophyll and periphyton are not controlled by the full build-out and upgrade increase in MSWRF effluent loading of nitrogen and phosphorus. The inorganic nutrient levels in Lower Sweetwater Branch are not limiting primary production because the modeled in-stream concentrations for inorganic-N and inorganic-P are much larger than the half-saturation nutrient constants assigned for growth for the QUAL2K model (see Figure 18 and Figure 19).

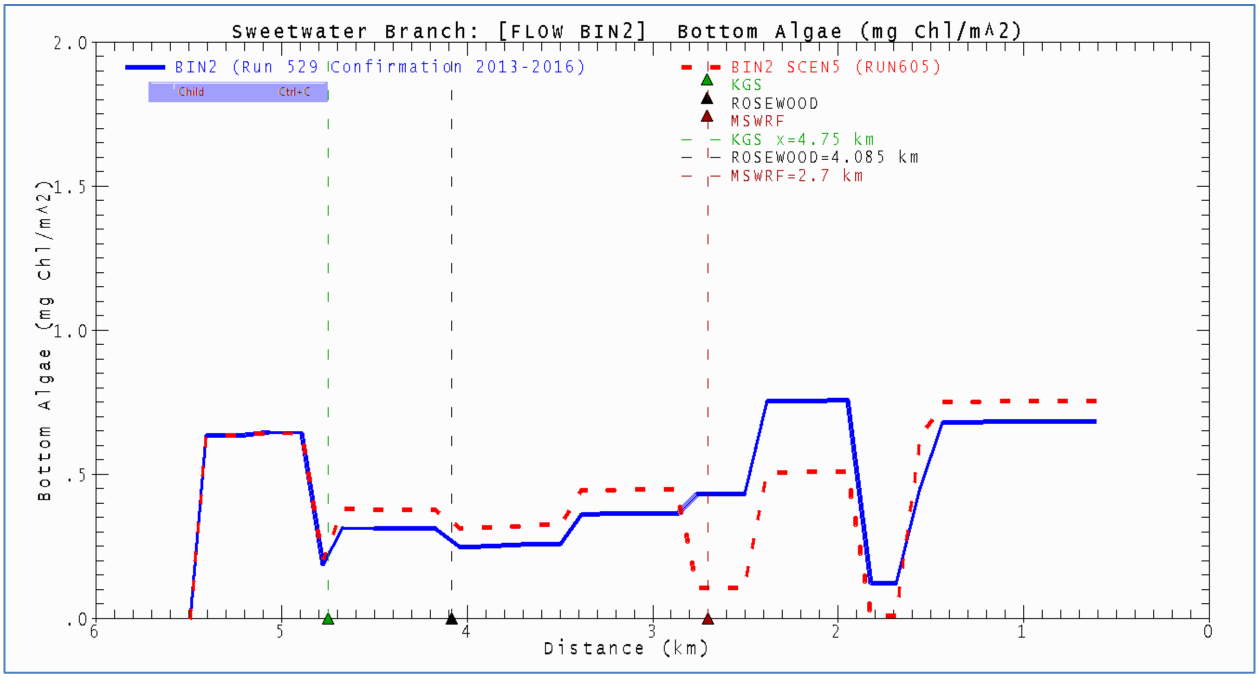

Figure 42- Bottom Algae, BIN2, Scenario #5 (Run 605)

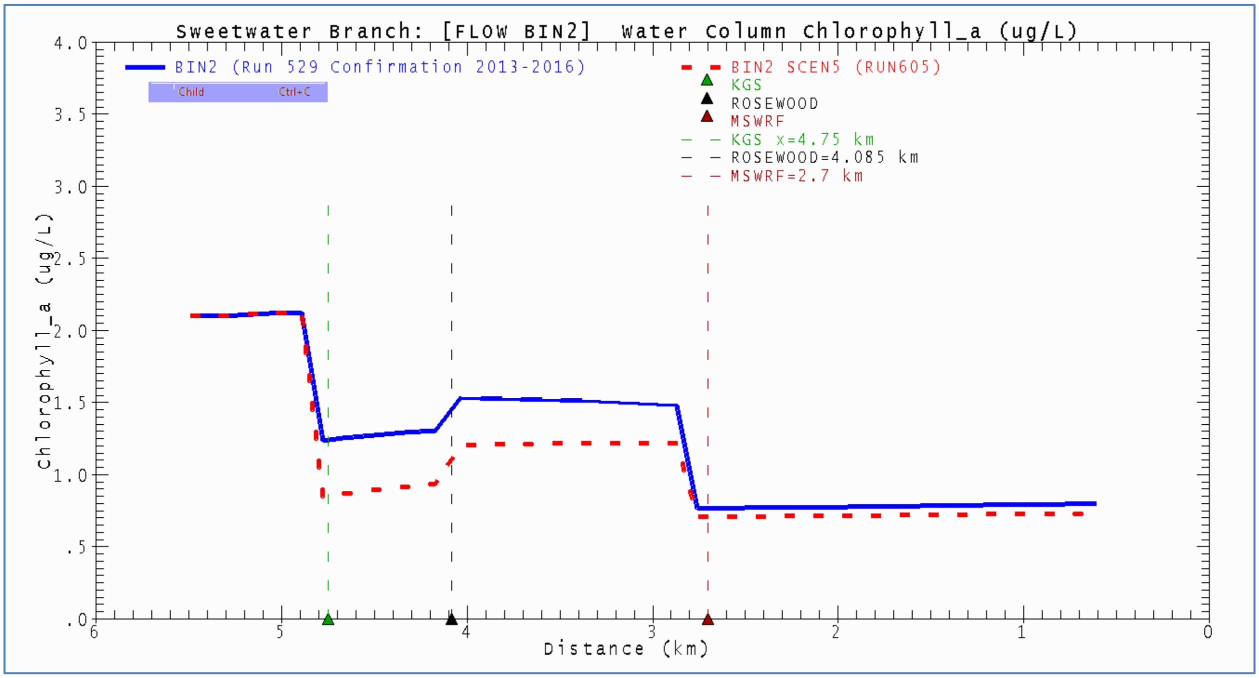

Figure 43- Water Column Chlorophyll, BIN2, Scenario #5 (Run 605)

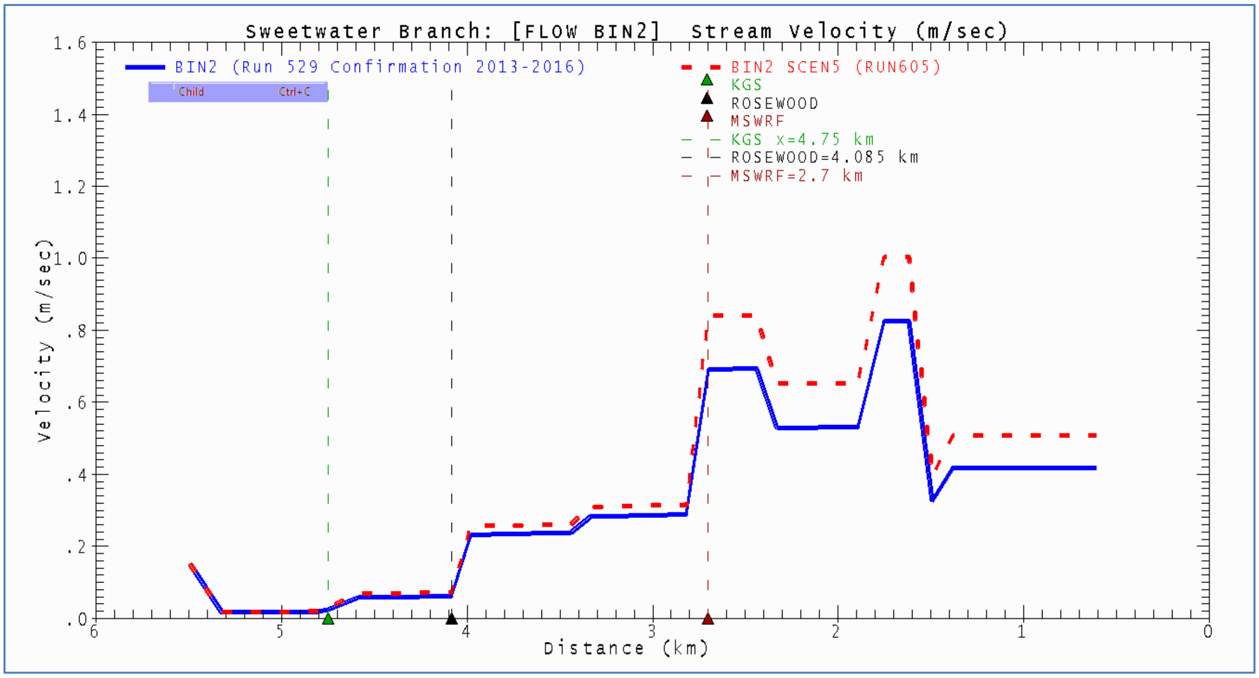

Figure 44- Stream Velocity, BIN2, Scenario #5 (Run 605)

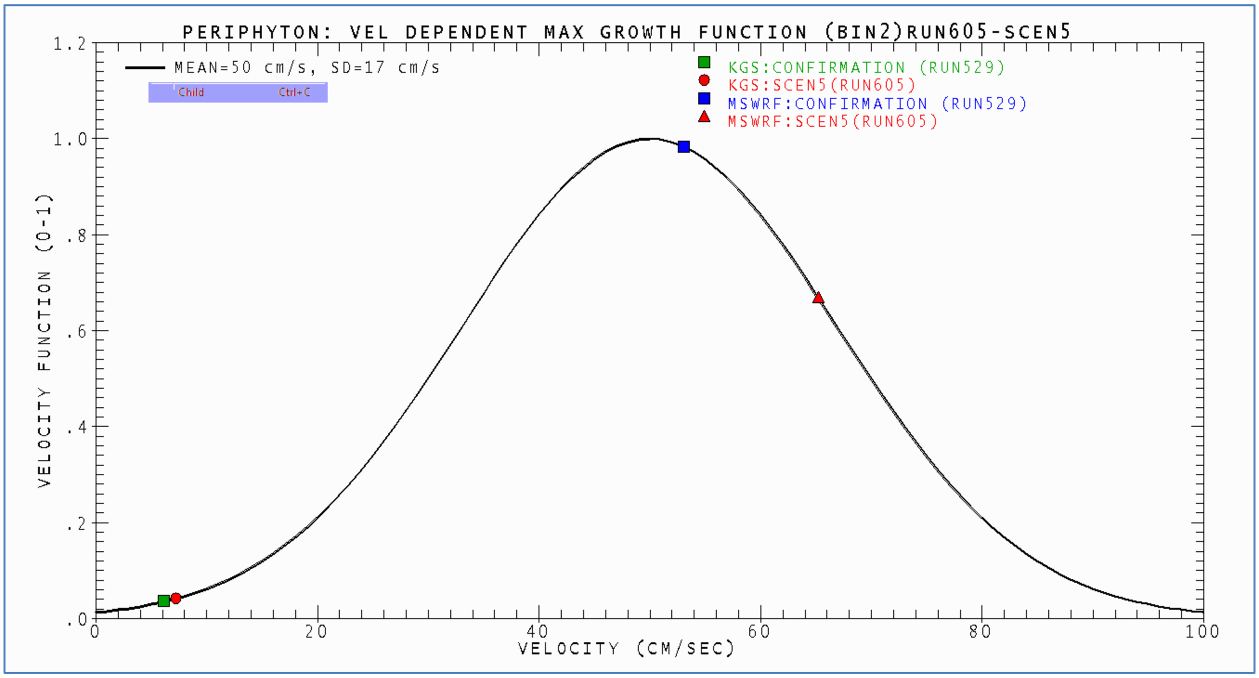

Figure 45- Velocity-Dependent Maximum Growth Function for Bottom Algae, BIN2, Scenario #5 (Run 605).

Green and blue symbols show model confirmation baseline (Run 529) for KGS and MSWRF and red symbols show change in velocity under model Scenario#5 (Run 605).

Table 45- Scenario #5 Model Results for Point Source Loads

SCEN(5)	KGS Downstream JEA 9	x=4.17 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.89257	0.57062	0.44159
RUN(529)	Cross-Section Area	m^2	0.34038	0.46362	0.5903
RUN(529)	Velocity	m/sec	0.0478	0.06155	0.075
RUN(529)	Chlorophyll-a	ug/L	0.362362	1.309709	0.798005
RUN(529)	Periphyton (Chl a)	mg/m^2	0.269018	0.312372	0.37506
SCEN(5)	Travel time	days	0.8503	0.5481	0.4284
SCEN(5)	Cross-Section Area	m^2	0.45788	0.5595	0.67107
SCEN(5)	Velocity	m/sec	0.06092	0.07178	0.0833
SCEN(5)	Chlorophyll-a	ug/L	0.215715	0.939299	0.633979
SCEN(5)	Periphyton (Chl a)	mg/m^2	0.336716	0.376824	0.432703
SCEN(5)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(5)	Travel time	days	-0.04227	-0.02252	-0.01319
SCEN(5)	Cross-Section Area	m^2	0.1175	0.09588	0.08077
SCEN(5)	Velocity	m/sec	0.01312	0.01023	0.0083
SCEN(5)	Chlorophyll-a	ug/L	-0.146647	-0.37041	-0.164026
SCEN(5)	Periphyton (Chl a)	mg/m^2	0.067698	0.064452	0.057643
SCEN(5)	Travel time	Pct Change	-4.7%	-3.9%	-3.0%
SCEN(5)	Cross-Section Area	Pct Change	34.5%	20.7%	13.7%
SCEN(5)	Velocity	Pct Change	27.4%	16.6%	11.1%
SCEN(5)	Chlorophyll-a	Pct Change	-40.5%	-28.3%	-20.6%
SCEN(5)	Periphyton (Chl a)	Pct Change	25.2%	20.6%	15.4%
SCEN(5)	MSWRF Downstream JEA 5	x=2.05 km	50%ile	50%ile	50%ile
RUN(529)	Travel time & Biomass	RUN529	BIN1	BIN2	BIN3
RUN(529)	Travel time	days	0.98201	0.64097	0.50132
RUN(529)	Cross-Section Area	m^2	0.61444	0.64603	0.68525
RUN(529)	Velocity	m/sec	0.51406	0.53051	0.55045
RUN(529)	Chlorophyll-a	ug/L	0.637788	0.777035	0.695213
RUN(529)	Periphyton (Chl a)	mg/m^2	0.766559	0.756985	0.736065
SCEN(5)	Travel time	days	0.92512	0.611	0.48331
SCEN(5)	Cross-Section Area	m^2	0.87509	0.90083	0.93325
SCEN(5)	Velocity	m/sec	0.64061	0.65213	0.66641
SCEN(5)	Chlorophyll-a	ug/L	0.632663	0.715949	0.667542
SCEN(5)	Periphyton (Chl a)	mg/m^2	0.538885	0.508721	0.47068
SCEN(5)	Travel time & Biomass (Change)		BIN1	BIN2	BIN3
SCEN(5)	Travel time	days	-0.05689	-0.02997	-0.01801
SCEN(5)	Cross-Section Area	m^2	0.26065	0.2548	0.248
SCEN(5)	Velocity	m/sec	0.12655	0.12162	0.11596
SCEN(5)	Chlorophyll-a	ug/L	-0.005125	-0.061086	-0.027671
SCEN(5)	Periphyton (Chl a)	mg/m^2	-0.227674	-0.248264	-0.265385

SCEN(5)	Travel time	Pct Change	-5.8%	-4.7%	-3.6%
SCEN(5)	Cross-Section Area	Pct Change	42.4%	39.4%	36.2%
SCEN(5)	Velocity	Pct Change	24.6%	22.9%	21.1%
SCEN(5)	Chlorophyll-a	Pct Change	-0.8%	-7.9%	-4.0%
SCEN(5)	Periphyton (Chl a)	Pct Change	-29.7%	-32.8%	-36.1%
RUN(529)	Downstream (Outflow from Model)		BIN1	BIN2	BIN3
RUN(529)	Total-N	lbs/yr	107,256.8	108,478.6	111,231.9
RUN(529)	Total-P	lbs/yr	10,580.6	10,917.8	11,102.5
SCEN(5)	Total-N	lbs/yr	293,138.5	294,409.4	297,250.3
SCEN(5)	Total-P	lbs/yr	14,484.8	14,824.8	15,002.7
SCEN(5)	Downstream Change from Model Confirm		BIN1	BIN2	BIN3
SCEN(5)	Total-N	lbs/yr	185,881.8	185,930.8	186,018.3
SCEN(5)	Total-P	lbs/yr	3,904.2	3,907.1	3,900.2
SCEN(5)	Total-N	Pct Change	173.3%	171.4%	167.2%
SCEN(5)	Total-P	Pct Change	36.9%	35.8%	35.1%

5.8.2 Scenario #6: Future Build-Out Point Source Loads under "Worst-Case Nonpoint Source Stormwater Flow

Model input data and results obtained for the confirmation run for the three flow conditions (BIN1, BIN2, and BIN3) were used as the baseline for comparison to results obtained for this nonpoint and point source management run. The focus of the evaluation for Scenario#6 was to test the impact of "worst-case" stormwater flow conditions for BIN3 combined with the proposed changes in KGS and MSWRF effluent flow rates and nutrient levels to represent future flow and loading conditions from KGS and full buildout and upgrade of the MSWRF. Scenario#6 was modeled to demonstrate reasonable assurance that the natural systems will be protected even with extreme assumptions for nonpoint source loads. This scenario will also demonstrate a margin of safety for Sweetwater Branch.

5.8.2.1 Scenario #6: Input Data for Nonpoint Source and Point Source Flow and Loads

"Worst-case" nonpoint source stormwater conditions are defined by 90th percentile statistics derived from urban runoff flow data and water quality records characterized by high-flow (BIN3) hydrologic conditions. Estimates of nonpoint source "worst-case" stormwater flow and loads assigned for Scenario#6 are based on stormwater loading data described in Section 5.6.3 for Scenario#2 (see Table 36). Input data for stormwater flow and loading are derived from 90th percentile urban runoff flow (see Table 37) and 90th percentile statistics for nutrient and non-nutrient water quality data sets pooled for high-flow (BIN3) hydrologic conditions (see Table 38). A description of data sources and methodology used to develop nonpoint source water quality and flow data sets is presented in Section 5.4.3 and Section 5.4.5.

Effluent flow, nutrient concentrations and loads for the MSWRF and KGS discharges are summarized for Scenario #6 in Table 46. The KGS facility reports effluent discharge records for two outfalls: (1) Unit 8 Cooling Water Discharge (CTBD8) and (2) Low Volume Waste (LVW). KGS effluent records for discharge and nutrient concentrations are used to compute effluent loads for each outfall. The combined sums of KGS effluent flow and nutrient loads from the cooling water and low volume wastewater outfalls are shown to facilitate comparison of the relative contributions of flow and nutrient loading from the MSWRF and KGS discharges.

As described in Section 5.8.1 for Scenario#5, effluent flow and nitrogen loading for the MSWRF are based on a proposed full build-out expansion of the facility to 12 MGD and upgrade of the existing facility treatment processes to achieve an effluent level for TN of 8 mg/L. Under Scenario#6, however, the proposed upgrade of treatment processes is expected to achieve higher removal efficiency for phosphorus with an effluent level for TP of 0.30 mg/L. Model input for MSWRF effluent flow and nutrient levels were assigned to reflect the proposed expansion and upgrade for flow and nitrogen and phosphorus treatment processes. Effluent levels of non-nutrient water quality constituents for Scenario#6 were based on either constant or median concentrations of MSWRF effluent developed for model confirmation (see Table 8). Effluent flow, nutrient concentrations and other non-nutrient water quality constituent concentrations used to assign model input data for the MSWRF discharge for Scenario#5 are summarized inTable 47.

Table 46- Scenario #6 Summary of MSWRF and KGS Effluent Flow and Nutrient Loading Rates

Future Conditions	**MSWRF**	**KGS CTBD8**	**KGS LVW**	**KGS CTBD8+LVW**
Scenario#6 (Run 606)	**Full Build-Out & Upgrade**	**EPA MDL**	**EPA MDL**	**EPA MDL**
Annual Flow (MGD)	12	0.418	0.087	0.505
Total Nitrogen (mg N/L)	8.0	2.2	0.984	1.991
Total Phosphorus (mg P/L)	0.30	0.636	0.125	0.548
Total Nitrogen (lbs N/yr)	292,408.8	2,801.0	260.8	3,061.8
Total Phosphorus (lbs P/yr)	10,965.3	809.8	33.1	842.9

Load (lbs/yr) = MGD x mg/L x 8.345 x 365. MSWRF based on full build-out effluent flow and expected upgrade of nutrient removal. KGS effluent flow and nutrient loads based on EPA MDL calculations for 95% Confidence Interval. KGS effluent nutrient concentrations are derived from flow-weighted calculation of MDL estimates for CTBD8 and LVW flow and nutrient loading rates.

As described in Section 5.6.2 for Scenario#1, KGS effluent flow and nutrient loads are based on EPA's MDL methodology and existing (2013-2016) operating conditions for the KGS discharge outfalls. Effluent flow, nutrient concentrations and median or constant values of non-nutrient water quality constituents assigned for Scenario#6 are summarized in Table 33 and Table 34.

5.8.2.2 Scenario #6: Model Results and Findings

Model results are extracted for locations downstream of the KGS outfalls (4.09 km), the MSWRF outfall (2.00 km), and the downstream outlet from Sweetwater Branch to the enhancement wetland (0.61 km). Model results for each scenario are shown for comparison to the model confirmation results simulated for existing 2013-2016 conditions (Run529). Changes in travel time, velocity, phytoplankton, and periphyton biomass are identified at the KGS and MSWRF locations and at the downstream outlet of the model to the Enhancement Wetland (see Table 49). QUAL2K model results extracted at the downstream outlet to the Wetland Enhancement Area are presented in Table 48 for comparison to model input data used for the Wetland Model. Note that model results are not presented for BIN1 and BIN2 hydrologic conditions for nonpoint source urban runoff for "worst-case" stormwater flow conditions under Scenario#6.

Table 47- Scenario #6 MSWRF Point Source Discharge Effluent Flow for Proposed Full Build-Out Expansion of MSWRF. Effluent Nutrients based on Upgrade of MSWRF and Non-Nutrient effluent constituents based on median or constant values.

SCEN6 (RUN 606)	Statistic >>	Median					Statistic &
QUAL2K State Variables	Units	BIN9	N_Obs	Data Source			DESIGN
MSWRF(BIN9)			2013-2016	Obs	Derive	Const	SCENARIO
Effluent Flow	MGD	12	0				Full Buildout
Effluent Flow	cfs	18.56676	0				Full Buildout
Effluent Flow	cms	0.5258106	0				Full Buildout
Water temperature	Deg C	23.9	847	X			Median
Conductivity	µmhos/cm	862	0			X	Constant
Inorganic SS (PIM, dw)	mg/L	0.5	0		X		Median
Dissolved Oxygen	mg/L	8.7	1134	X			Median
Slow CBOD (ultimate)	mg/L	0.403	0		X		Median
Fast CBOD (ultimate)	mg/L	2	0		X		Median
Organic-N, Total	µg/L	1032	0		X		Upgrade
Ammonia-N	µg/L	168	0		X		Upgrade
Nitrate/Nitrite-N	µg/L	6800	0		X		Upgrade
Organic-P, Total	µg/L	54	0		X		Upgrade
Inorganic-P (SRP, Diss_PO4)	µg/L	246	0		X		Upgrade
Phytoplankton-Chl	µg/L	0.65	0			X	Constant
Phytoplankton-N	µg/L	7.02	0		X		Constant
Phytoplankton-P	µg/L	0.975	0		X		Constant
Organic Detritus (POM, dw)	mg/L	0.4133333	0		X		Median
Pathogens	cfu/100mL	0	0				Constant
Alkalinity	mg CaCO3/L	70	0			X	Constant
Constituent 1	mg/L	0	0				Constant
Constituent 2	mg/L	0	0				Constant
Constituent 3	mg/L	0	0				Constant
PH	SU	7.2	847	X			Median
Total Nitrogen	µg/L	8000	0				Upgrade
Total Kjedhal Nitrogen	µg/L	1200	0		X		Upgrade
Total Phosphorus	µg/L	300	0				Upgrade
Total Organic Carbon	mg/L	4.5	0		X		Median
CBOD-5-Day	mg/L	0.5	846	X			Median
TSS [PIM+POM(D)+POM(A)]	mg/L	1	848	X			Median

Table 48- Scenario#6 QUAL2K Model Results for BIN3 Flow Conditions at Downstream Outlet to Wetland Enhancement Area

QUAL2K Model Output at Downstream Outlet to Wetland			
SCEN(6)	**BIN1**	**BIN2**	**BIN3**
Flow rate (cubic m/sec), cms	(NA)	(NA)	0.99872
Flow rate (cubic ft/sec), cfs	(NA)	(NA)	35.26949718
Flow rate (million gal/d), MGD	(NA)	(NA)	22.79528464
Organic-N (µg/L)	(NA)	(NA)	807.74
Ammonia-N (µg/L)	(NA)	(NA)	129.67
Nitrate+Nitrite-N (µg/L)	(NA)	(NA)	3732.02
Phytoplankton-N (µg/L)	(NA)	(NA)	10.79
Total-N (µg/L)	(NA)	(NA)	4680.22
Organic-P (µg/L)	(NA)	(NA)	58.42
Orthophosphate-P (µg/L)	(NA)	(NA)	203.93
Phytoplankton-P (µg/L)	(NA)	(NA)	1.50
Total-P (µg/L)	(NA)	(NA)	263.85
Total-N (lbs/yr)	(NA)	(NA)	324,972
Total-P (lbs/yr)	(NA)	(NA)	18,321

Load (lbs/yr) = Flow (cms) x (µg/L) x 86.4 x 0.001 x 2.2046 x 365

Scenario #6 provides an assessment of the simulated changes in Sweetwater Branch from “worst-case” stormwater flow and load conditions combined with KGS and MSWRF point source effluent discharge and loads based on future MSWRF 12 MGD Buildout conditions for the City of Gainesville. The “worst-case” stormwater scenario is based on model input derived from the 90th percentile flow and 90th percentile water quality and nutrient concentrations computed for the pooled observed data set compiled to characterize BIN3 high flow conditions. Model results for comparison of model confirmation (Run 529) and “worst-case” stormwater conditions (Scenario #6) are presented in Figure 46, Figure 47, Figure 48, Figure 49 and Table 49. The full set of Scenario#6 model results for the 12 MGD Buildout for MSWRF under BIN3 “worst-case” stormwater flow conditions are presented in Appendix I.

Total nonpoint source flow increased from the median urban runoff flow of 3.0 cfs for BIN3 for the baseline model confirmation (see Table 17) to 15.92 cfs for the “worst-case” 90th percentile stormwater flow for BIN3 conditions under Scenario#6 (see Table 37). The 5X increase in urban runoff resulted in a significant reduction of travel time with a corresponding increase in velocity and cross-sectional area of the Upper and Lower reaches of Sweetwater Branch.

Downstream of the KGS outfall, travel time was reduced by 52%, cross sectional area of the channel increased by 130%, and velocity increased by 97%. The increase in velocity triggered an increase in the velocity-dependent maximum growth rate for periphyton (see Figure 49) and an increase of 113% for periphyton biomass (Figure 46). Although a doubling of periphyton biomass from 0.37 to 0.8 mg Chl-a/m^2 for the “worst-case” stormwater scenario appears, at first, to represent a significant increase in biomass of attached algae, it is important to understand that both the baseline and the “worst-case” stormwater scenario levels of attached algae biomass are very low in comparison to the abundance of periphyton biomass reported for many other streams in the literature. Based on a review of the literature, Dodds et al. (1998) indicate that oligotrophic streams can be characterized by periphyton biomass up to 20 mg Chl-a/m^2 which is considerably higher than periphyton biomass observed in Sweetwater Branch.

Periphyton biomass data have been compiled for Armstrong Slough in the Kissimmee Basin in Florida and from several other locations identified in the literature to show the typical range of periphyton biomass for comparison to the periphyton data collected for Sweetwater Branch (see Table 23). Periphyton biomass is characterized by a wide range from ~100 to ~52,000 mg Ash-Free Dry Weight (AFDW) m^{-2} for locations other than Sweetwater Branch. Periphyton data collected in Sweetwater Branch, however, varied from only 26 to 1,173 mg AFDW m^{-2} (see Table 21). The abundance of periphyton in Sweetwater Branch is clearly at the low end of periphyton biomass measured for several other streams and rivers.

Downstream of the MSWRF outfall, travel time was reduced by 50%, cross sectional area of the channel increased by 76%, and velocity increased by 41%. The increase in velocity from 55 cm/sec to 77.8 cm/sec resulted in a decrease in the velocity-dependent maximum growth rate for periphyton (see Figure 49) and a corresponding 73% decrease in simulated periphyton biomass (Figure 46).

As shown in Figure 47, water column chlorophyll is consistently higher for the “worst-case” stormwater flow scenario (Scenario #6) along the Upper and Lower reaches of Sweetwater Branch than the model confirmation results (Run 529) for BIN3 high-flow nonpoint source conditions. Under the “worst-case” stormwater scenario, water column chlorophyll concentration increased from the baseline confirmation run by 50% (from 1.0 to 1.5 µg/L) at the headwater upstream boundary, 79% (from 0.8 to 1.4 µg/L) downstream of the KGS outfall, and 47% (from 0.7 to 1.0 µg/L) downstream of the MSWRF outfall. At the downstream outlet of Sweetwater Branch, flow increased by 158% from 13.7 cfs for the baseline case to 35.3 cfs for the “worst-case” stormwater flow condition (Scenario#6), chlorophyll-a biomass increased by 51% from 0.7 to 1.06 µg/L, and the corresponding downstream mass load of chlorophyll-a exiting the stream increased by 284% (see Table 49).

Although phytoplankton biomass loading at the downstream outlet of the stream increased by 284% under the “worst-case” stormwater loading scenario with full buildout of MSWRF, the increase in TN (192%) and TP (69%) nutrient loading at the downstream outflow of the stream for Scenario#6 (see Table 49), however, does not trigger increased production of phytoplankton biomass. The inorganic nutrient levels in Sweetwater Branch are not limiting primary production because the modeled in-stream concentrations for inorganic-N and inorganic-P are much larger than the half-saturation nutrient constants assigned for growth for the QUAL2K model (see Figure 18 and Figure 19).

As can be seen in Figure 47 the “worst-case” stormwater scenario results in a consistent increase in phytoplankton biomass throughout the entire stream. The increased level of chlorophyll is driven, however, by the mass loading response to the input of a much larger upstream boundary load input of phytoplankton based on the flow (2.58 cfs) and the corresponding chlorophyll level (1.5 µg/L) for the "worst-case" stormwater scenario (see Table 38) compared to a much smaller flow (0.73 cfs) and chlorophyll level (1.0 µg/L) for the baseline confirmation model (Run 529) under BIN3 median flow conditions (see Table 5). The upstream input of much larger urban runoff flow and corresponding increase in the mass loading of phytoplankton biomass controls the "worst-case" stormwater model results simulated for Scenario#6 along the entire length of the stream in Figure 47. It is also important to note that the levels of chlorophyll (<2 µg/L) for both the baseline and "worst-case" stormwater scenario are lower than Florida's evidentiary threshold of 3.2 µg/L for phytoplankton chlorophyll in free-flowing streams and rivers. The 3.2 µg/L target threshold is shown by the green dashed line in Figure 47.

Nonpoint and point source nitrogen loading for Scenario #6 resulted in a 192% increase of the downstream outflow of Total Nitrogen to the enhanced wetland from the existing conditions for RUN(529) model confirmation (111,232 lbs/yr) to the outlet load for Scenario #6 (324,972 lbs/yr). The phosphorus loading for Scenario #6 resulted in a 65% increase of the downstream outflow of Total Phosphorus to the enhanced wetland from the existing conditions for RUN(529) model confirmation (11,102 lbs/yr) to the outlet load for Scenario #6 (18,321 lbs/yr) (see Table 49).

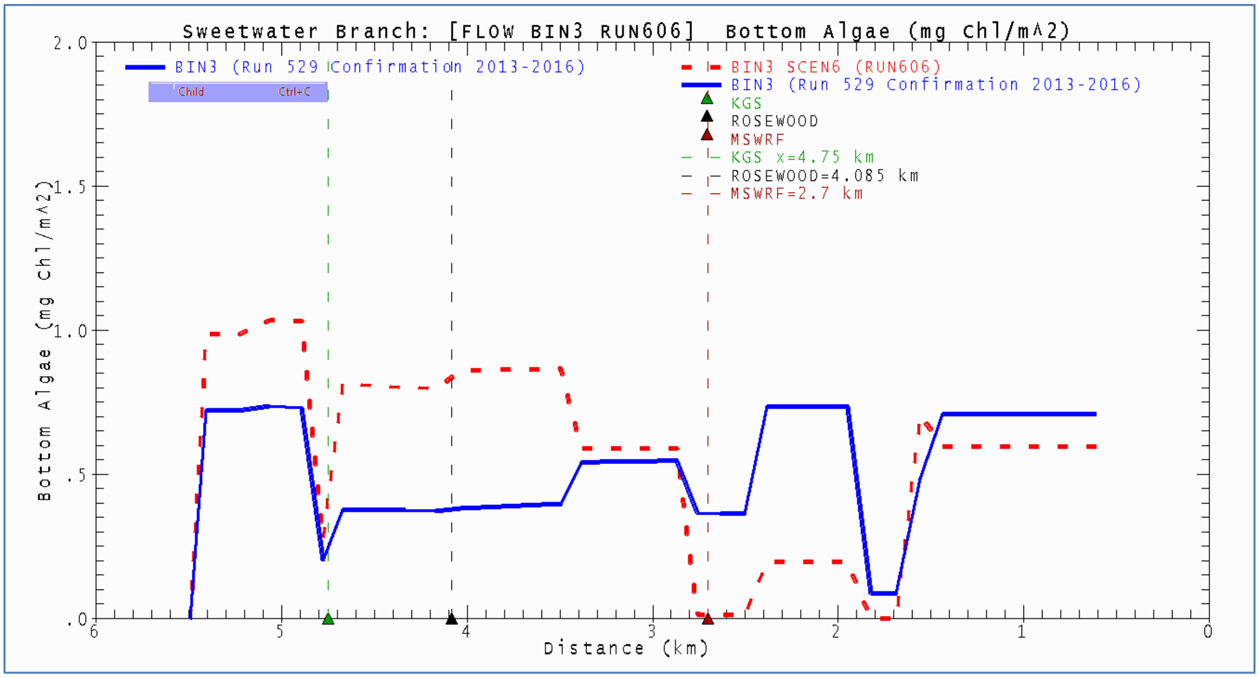

Figure 46- Bottom Algae, BIN3, Scenario #6 (Run 606)

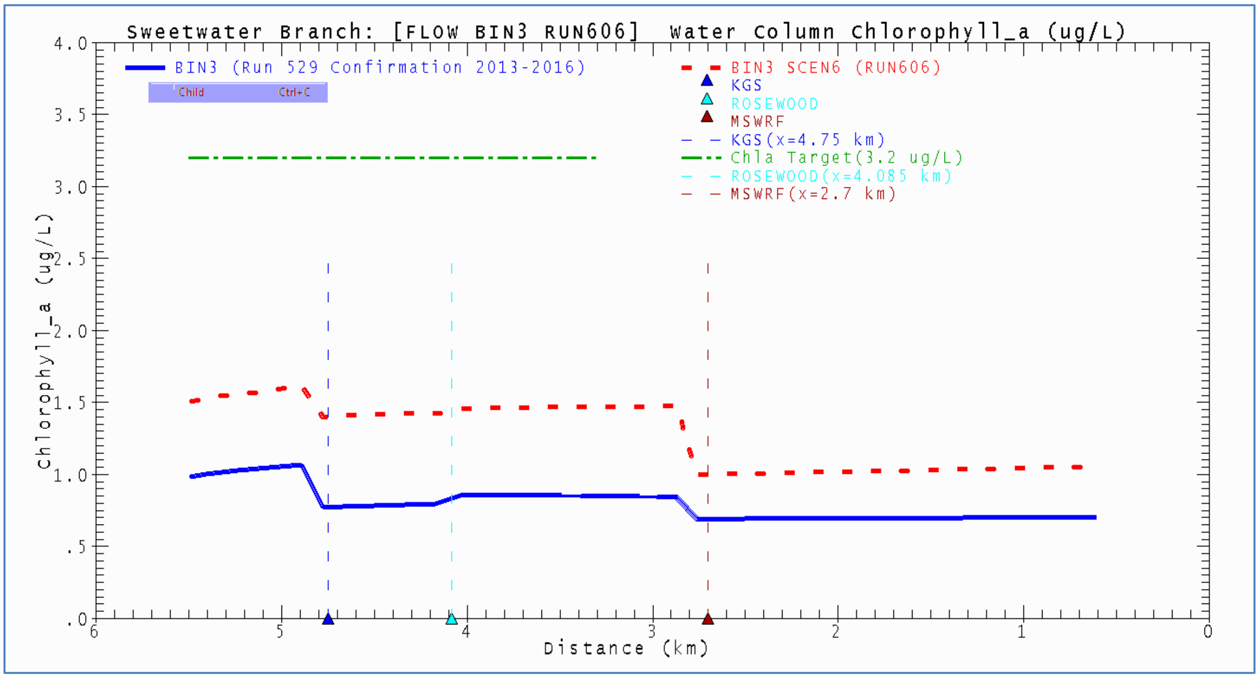

Figure 47- Water Column Chlorophyll, BIN3, Scenario #6 (Run 606)
The evidentiary threshold for chlorophyll-a (3.2 µg/L) in free-flowing streams and rivers is shown by the green dashed line.

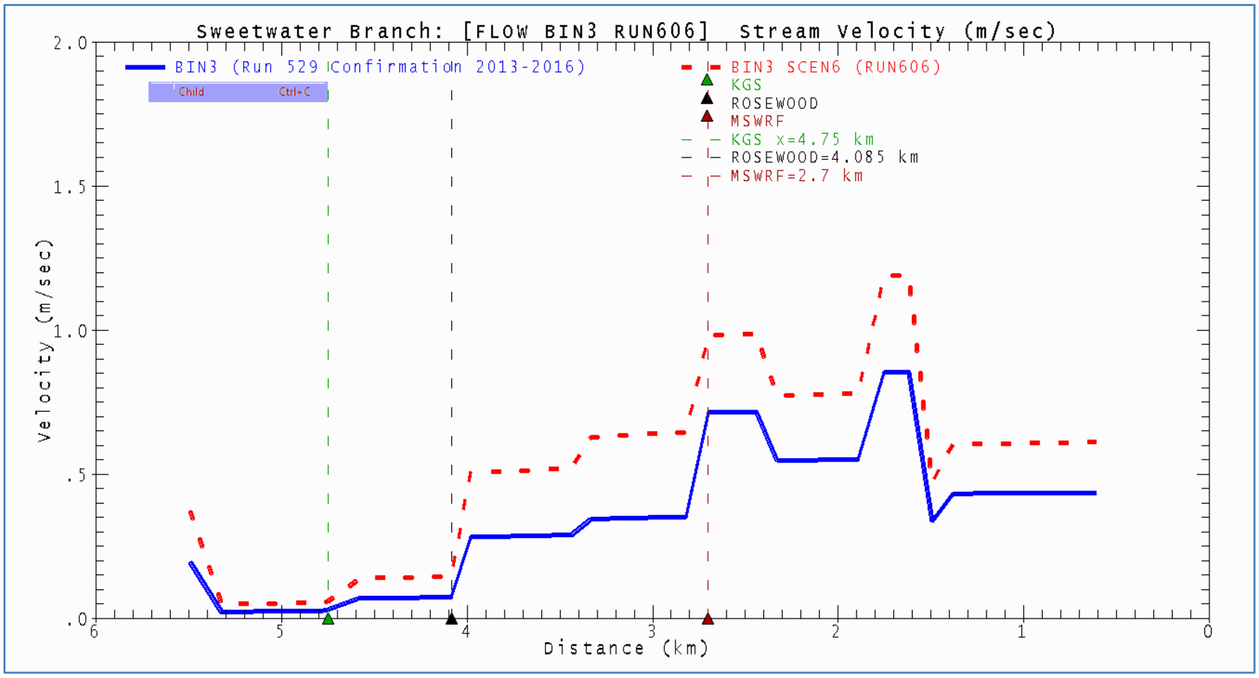

Figure 48- Stream Velocity, BIN3, Scenario #6 (Run 606)

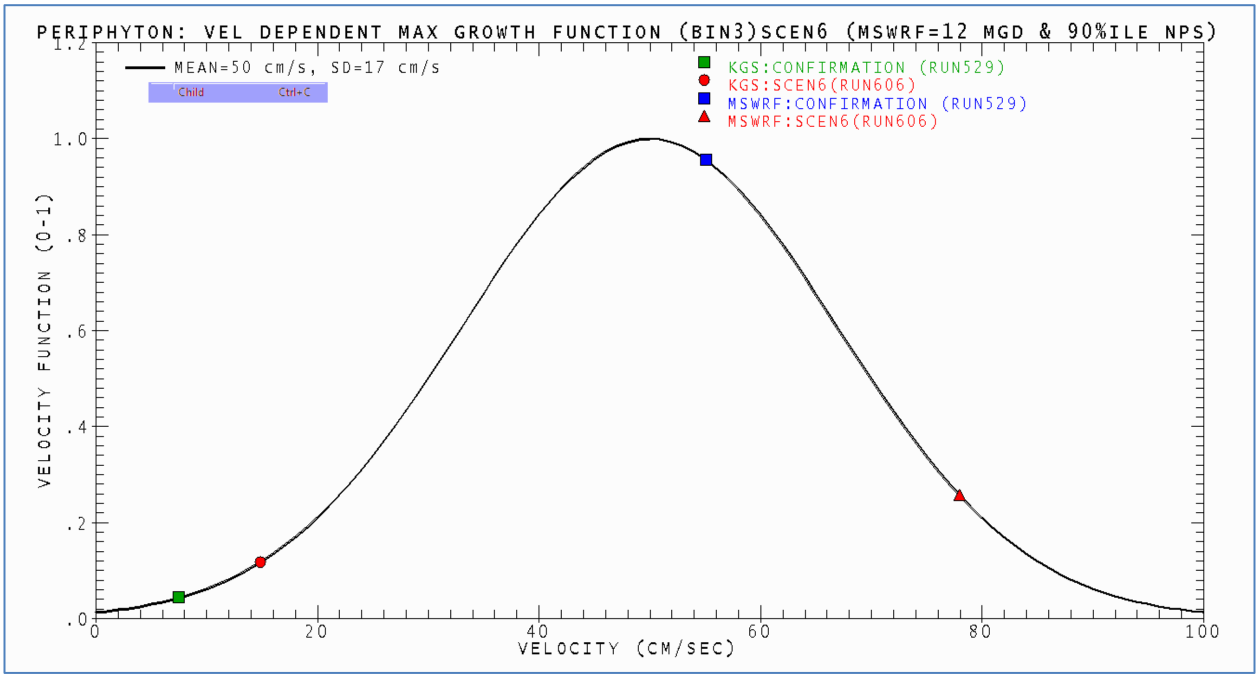

Figure 49- Velocity-Dependent Maximum Growth Function for Bottom Algae, BIN3, Scenario #6 (Run 606).

Green and blue symbols show model confirmation baseline (Run 529) for KGS and MSWRF and red symbols show change in velocity under model Scenario#6 (Run 606) for MSWRF Buildout and “worst-case” NPS stormwater flow for BIN3 flow conditions.

Table 49- Scenario #6 (Run 606) Model Results for 12 MGD MSWRF Buildout and "Worst-Case" NPS Stormwater Scenario for BIN3 High Flow Conditions

SCEN(6)	KGS Downstream JEA 9	x=4.17 km	90%ile
RUN(529)	Travel time & Biomass	RUN529	BIN3
RUN(529)	Travel time	days	0.44159
RUN(529)	Cross-Section Area	m^2	0.5903
RUN(529)	Velocity	m/sec	0.075
RUN(529)	Chlorophyll-a	ug/L	0.798005
RUN(529)	Periphyton (Chl a)	mg/m^2	0.37506
SCEN(6)	Travel time	days	0.21339
SCEN(6)	Cross-Section Area	m^2	1.35504
SCEN(6)	Velocity	m/sec	0.14802
SCEN(6)	Chlorophyll-a	ug/L	1.428309
SCEN(6)	Periphyton (Chl a)	mg/m^2	0.799266
SCEN(6)	Travel time & Biomass (Change)		BIN3
SCEN(6)	Travel time	days	-0.2282
SCEN(6)	Cross-Section Area	m^2	0.76474
SCEN(6)	Velocity	m/sec	0.07302
SCEN(6)	Chlorophyll-a	ug/L	0.630304
SCEN(6)	Periphyton (Chl a)	mg/m^2	0.424206
SCEN(6)	Travel time	Pct Change	-51.7%
SCEN(6)	Cross-Section Area	Pct Change	129.6%
SCEN(6)	Velocity	Pct Change	97.4%
SCEN(6)	Chlorophyll-a	Pct Change	79.0%
SCEN(6)	Periphyton (Chl a)	Pct Change	113.1%
SCEN(6)			
SCEN(6)	MSWRF Downstream JEA 5	x=2.05 km	90%ile
RUN(529)	Travel time & Biomass	RUN529	BIN3
RUN(529)	Travel time	days	0.50132
RUN(529)	Cross-Section Area	m^2	0.68525
RUN(529)	Velocity	m/sec	0.55045
RUN(529)	Chlorophyll-a	ug/L	0.695213
RUN(529)	Periphyton (Chl a)	mg/m^2	0.736065
SCEN(6)	Travel time	days	0.24852
SCEN(6)	Cross-Section Area	m^2	1.20611
SCEN(6)	Velocity	m/sec	0.77842
SCEN(6)	Chlorophyll-a	ug/L	1.019232
SCEN(6)	Periphyton (Chl a)	mg/m^2	0.198085
SCEN(6)	Travel time & Biomass (Change)		BIN3
SCEN(6)	Travel time	days	-0.2528
SCEN(6)	Cross-Section Area	m^2	0.52086
SCEN(6)	Velocity	m/sec	0.22797

SCEN(6)	Chlorophyll-a	ug/L		0.324019
SCEN(6)	Periphyton (Chl a)	mg/m^2		-0.53798
SCEN(6)	Travel time	Pct Change		-50.4%
SCEN(6)	Cross-Section Area	Pct Change		76.0%
SCEN(6)	Velocity	Pct Change		41.4%
SCEN(6)	Chlorophyll-a	Pct Change		46.6%
SCEN(6)	Periphyton (Chl a)	Pct Change		-73.1%
SCEN(6)				
RUN(529)	Downstream (Outflow from Model)			BIN3
RUN(529)	Total-N	lbs/yr		111,231.9
RUN(529)	Total-P	lbs/yr		11,102.5
RUN(529)	Chlorophyll-a	lbs/yr		19.1
SCEN(6)	Total-N	lbs/yr		324,972.3
SCEN(6)	Total-P	lbs/yr		18,320.7
SCEN(6)	Chlorophyll-a	lbs/yr		73.3
SCEN(6)	Downstream Change from Model Confirm			BIN3
SCEN(6)	Total-N	lbs/yr		213,740.4
SCEN(6)	Total-P	lbs/yr		7,218.1
SCEN(6)	Chlorophyll-a	lbs/yr		54.2
SCEN(6)	Total-N	Pct Change		192.2%
SCEN(6)	Total-P	Pct Change		65.0%
SCEN(6)	Chlorophyll-a	Pct Change		284.5%

5.9 Summary

The purpose of the stream modeling study is to provide the Gainesville Regional Utilities (GRU) John R. Kelly Generating Station (KGS) and Main Street Wastewater Reclamation Facility (MSWRF) with the scientific basis needed to establish Level II Water Quality-Based Effluent Limitations (WQBELs) for nutrients. The individual WQBELs will determine effluent nutrient limits for Total Phosphorus and Total Nitrogen for the KGS and MSWRF point source discharges that are expected to attain compliance with Florida's water quality standards.

In Sections 5.1 through 5.5 of this report, Dynamic Solutions, LLC has documented the data sources, model setup and confirmation of the QUAL2K stream model to observed data sets collected in Sweetwater Branch. QUAL2K was applied to develop and confirm a one-dimensional, steady-state water quality model to effluent and stream water quality observations collected to represent existing conditions for the period of record from 2013-2016. As required by Florida DEP, the confirmed stream model was applied to evaluate in-stream water quality impacts, including the ecological impacts on stream phytoplankton and periphyton, resulting from urban runoff and NPDES-permitted flows and nutrient loading from the MSWRF and the KGS coal-fired power plant.

As described in Section 5.6, Section 5.7 and Section 5.8, the confirmed stream model was applied to assess the potential water quality and biological impacts from urban nonpoint source runoff and NPDES-permitted point source discharges within the Sweetwater Branch contributing watershed. Particular emphasis was placed on examining potential growth and accumulation of phytoplankton and periphyton biomass as key biological indicators. The stream model was applied for a number of alternative urban nonpoint source runoff and point source (MSWRF and KGS) flow and pollutant loading conditions. Based on evaluation of changes in phytoplankton and periphyton biomass, model results developed for three hydrologic conditions for urban runoff (low, middle, and high) and the "worst-case" storm flow condition indicate that phytoplankton and periphyton biomass levels (as chlorophyll) are not expected to deviate significantly from existing unimpaired conditions for flora in Sweetwater Branch.

The QUAL2K model of Sweetwater Branch, confirmed to stream data sets compiled from monitoring data collected during 2013-2016, predicted outcome scenarios using the following proposed WQBELs for KGS and MSWRF:

1) The stream model was confirmed using flows and loads for both point sources and nonpoint source urban runoff based on data sets representative of existing conditions during the period of record from 2013 through 2016. The confirmed model was used as the baseline for evaluation of changes in stream water quality and biological conditions from urban nonpoint source runoff and point source effluent management scenarios and analyses of model sensitivity.
2) Urban runoff flow and loads were estimated using representative statistics derived from existing flow, nutrients, and non-nutrient water quality concentrations measured at multiple stations located upstream of KGS. Nonpoint source urban runoff flow estimates were distributed within the model domain on a drainage area-normalized basis to characterize urban runoff within the

entire Upper and Lower Sweetwater Branch contributing watershed that discharges to the Enhancement Wetland Area.

3) Under Scenario#3 and Scenario#4, the confirmed stream model was used as the baseline for evaluation of the sensitivity of the model to (a) available light by changes in shading from canopy coverage and (b) streamflow, velocity, and hydraulic residence time by removal of KGS and MSWRF point source effluent discharges to Sweetwater Branch.
4) Under Scenario#5 and Scenario#6, future point source effluent flow and loads for MSWRF were based on expansion of the plant to 12 MGD Full Build-Out and upgrade of wastewater treatment processes to achieve effluent targets for Total Nitrogen and Total Phosphorus. In the absence of either effluent flow or nutrient target levels for KGS, upper bounds for effluent flow and nutrient loads were based on 95% Confidence Interval statistics derived from KGS effluent records and EPA's Maximum Daily Load methodology.
5) Under Scenario#5, nonpoint source urban runoff flow and loads, derived from median statistics for flow, nutrients, and non-nutrient water quality concentrations, were compiled to provide representative estimates of existing urban runoff conditions for each of the three hydrologic conditions.
6) Under Scenario#6, nonpoint source urban runoff flow and loads were assigned based on representative "worst-case" stormwater flow and pollutant loading conditions for nutrients and non-nutrient water quality constituents. "Worst-case" stormwater conditions were derived from 90^{th} percentile statistics of urban runoff flow, nutrients, and non-nutrient water quality constituent data sets compiled to represent high-flow (BIN3) hydrologic conditions.
7) Under Scenario#6, "worst- case" stormwater flow and loading estimates were comparable to nutrient loading estimates developed by Florida DEP for determination of the 2006 TMDL for Total Nitrogen loading to Alachua Sink (Gao et al., 2006). Scenario#6 demonstrates reasonable assurance that the proposed WQBELs for KGS and MSWRF will be protective of the natural flora of Sweetwater Branch. Since the MSWRF flow of 12 MGD used for Scenario#6 is greater than the 10 MGD flow that was used as the basis of the proposed WQBEL, Scenario#6 also demonstrates a Margin of Safety for Sweetwater Branch for the proposed WQBEL point source discharges to Sweetwater Branch.
8) While the QUAL2K model was not run at the specific nutrient loads established in the WQBEL, a model run with higher nutrient loads (Scenario#6) was conducted and it demonstrated that loads higher than the WQBEL load did not impact Sweetwater Branch (as noted in Section 1.1, the WQBEL load was limited by the Outstanding Florida Waters (OFW) requirements).

5.10 Conclusions

Based on the outcomes of the stream model runs, loads for Total Nitrogen and Total Phosphorus entering the Enhancement Wetland Area as high as those loads assessed under the upper bound loading for KGS and future expansion to 12 MGD Buildout and Upgrade for MSWRF (Scenario#5 and Scenario#6) and the "worst-case" stormwater urban runoff flow and loading conditions described above (see Scenario#6) are expected to be protective of flora in Sweetwater Branch. As demonstrated through application of the confirmed stream model for sensitivity assessments for (a) light availability and (b) flow, velocity, and residence time, the density of tree canopy cover and extremely short residence time in Sweetwater Branch combine to prevent the significant growth and accumulation of both phytoplankton and periphyton biomass in the stream.

Based on criteria developed by Dodds et al. (1998) to characterize trophic status of streams, an oligotrophic stream is classified by mean sestonic chlorophyll levels <10 µg/L. Based on the observed low levels of phytoplankton biomass, Sweetwater Branch is, therefore, characterized as an oligotrophic stream. The levels of phytoplankton chlorophyll shown for model confirmation (see Figure 20) are also consistent with Florida's evidentiary threshold of 3.2 µg/L for phytoplankton chlorophyll in free-flowing streams and rivers (FDEP, 2013).

Periphyton biomass data have been compiled for a reference site in Armstrong Slough in the Kissimmee Basin in Florida and from several other locations reported in the literature to show the typical range of periphyton biomass for comparison to periphyton data collected for Sweetwater Branch. For sites other than Sweetwater Branch, median periphyton biomass varies over a wide range from ~1,600 to ~8,135 mg AFDW m^{-2} (see Table 23). Median values of periphyton biomass for Upper and Lower Sweetwater Branch (167 and 57 mg AFDW m^{-2}), however, are about an order of magnitude lower than the reference site for Armstrong Slough in Florida and the literature data presented in Table 23. Periphyton data collected in Sweetwater Branch, therefore, are clearly at the lower end of the range of periphyton biomass reported in the literature for other stream sites.

Based on criteria developed by Dodds et al. (1998) to characterize trophic status of streams, an oligotrophic stream is classified by mean benthic chlorophyll levels <20 mg Chl m^{-2}. Based on the low levels of periphyton biomass observed in the stream (<2 mg Chl m^{-2}) (see Table 21 and Figure 21), Sweetwater Branch is, therefore, characterized as an oligotrophic stream. In addition, periphyton biomass levels in Sweetwater Branch do not indicate impaired conditions as described by EPA in Section 6.1.5.4 of EPA's Periphyton Protocols https://archive.epa.gov/water/archive/web/html/ch06main.html).

The outcomes of the QUAL2K model developed for Sweetwater Branch provide technically credible support to the request by Gainesville Regional Utilities and the City of Gainesville's for WQBELs for the KGS and MSWRF effluent discharges and the "worst-case" urban stormwater runoff to the stream. The Level II WQBELs for Total Nitrogen and Total Phosphorus, expressed as mass loading rates on an annual basis as lbs/year (see Table 50), are derived from effluent flow rates and nutrient concentrations described in Section 5.6.2 for KGS (Scenario#1: see Table 33 and Table 34), Section 5.8.2 for MSWRF (Scenario #5: see Table 43), and Section 5.6.3 for "worst-case" urban stormwater runoff (Scenario#2: see Table 36). Nonpoint source "worst-case" stormwater loads from urban runoff as high as 31,215 lbs

N per year are shown to be protective of water quality conditions without causing an imbalance of floral conditions for phytoplankton and periphyton in Sweetwater Branch.

Under Scenario#6, the QUAL2K water quality model results demonstrated that the proposed WQBELs and site-specific nutrient criteria will not cause an imbalance in natural floral populations in Sweetwater Branch (Chapter 62-302.530 (48)(b), F. A. C.). Therefore, reasonable assurance is provided that the proposed site-specific nutrient criteria for Sweetwater Branch, as articulated by the WQBELs, will not cause floral or faunal imbalances (complying with the narrative nutrient criterion in Chapter 62-302.48 (b), F.A.C.).

Table 50- Summary of Requested Level II WQBELs for GRU's MSWRF and KGS Point Source Effluent Discharges and Sweetwater Branch Based on "Worst-case" Stormwater Nonpoint Source Runoff

Scenario#6: "Worst-Case" NPS Stormwater Flow + MSWRF Buildout + KGS Upper Bound	NPS	PS: WQBEL	PS: WQBEL	PS: WQBEL	PS: WQBEL	SWB NNC
	Stormflow	MSWRF	KGS (CTBD8)	KGS (LVW)	KGS Total	PS+NPS Total
Annual Flow (cubic m/sec)	0.4508	0.5258	0.0183	0.0038	0.0221	0.9987
Annual Flow (cubic ft/sec)	15.9198	18.5688	0.6471	0.1339	0.7810	35.2697
Annual Flow (MGD)	10.2893	12.0000	0.4182	0.0865	0.5048	22.7954
Total-Nitrogen (µg/L)	996.0	8,000.0	2,200.2	984.2		
Total-Phosphorus (µg/L)	214.5	300.0	636.0	124.6		
Total-Nitrogen (lbs/yr)	31,215	292,409	2,803	259	3,062	326,686
Total-Phosphorus (lbs/yr)	6,723	10,965	810	33	843	18,531

Load (lbs/yr) = MGD x µg/L x 8.345 x 0.001 x 365; Level II WQBELs and Sweetwater Branch (SWB) NNC
"Worst-case" urban runoff stormwater flow is given in Table 37 and "worst-case" nonpoint source nutrient levels are given In Table 38. MSWRF full build-out effluent flow and expected effluent level upgrade of nitrogen and phosphorus is given in Table 47. KGS effluent flow, nitrogen and phosphorus concentration derived from MDL calculations for 95% Confidence Interval are given in Table 33 and Table 34. KGS effluent nitrogen and phosphorus concentrations are derived from flow-weighted calculation of MDL estimates for flow and nutrient loading rates.

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End Section 5 QUAL2K Modeling

Joint WQBEL Report for Sweetwater Branch

Updated March-24-2021 as FINAL REPORT Submitted to GRU, FDEP and EPA Region 4

Appendix A

Water Column Rates

Light Parameters and Surface Heat Transfer Models

QUAL2K

Stream Water Quality Model

Sweetwater Branch (BIN2) (9/15/2015) ***RUN 529***

Water Column Rates

Parameter	*Final Value*	*Units*	*Symbol*	*Default*	*Min*	*Max*	*Ref.*
Stoichiometry:							
Carbon	**40**	**gC**	**gC**	**40**	**n/a**	**n/a**	Chapra et al. (2012)
Nitrogen	**7.2**	**gN**	**gN**	**7.2**	**n/a**	**n/a**	Chapra et al. (2012)
Phosphorus	**1**	**gP**	**gP**	**1**	**n/a**	**n/a**	Chapra et al. (2012)
Dry weight	**89**	**gD**	**gD**	**100**	**n/a**	**n/a**	Chapra et al. (2012)
Chlorophyll	**0.667**	**gA**	**gA**	**1**	**n/a**	**n/a**	Chapra et al. (2012)
Inorganic suspended solids:							
Settling velocity	**0..3**	**m/d**	v_i	**0.1**	**0**	**30**	Flynn et al. (2015)
Oxygen:							
Reaeration model	**Thackston-Dawson**			**Tsivoglou-Neal**			Chapra et al. (2012)
User reaeration coefficient α	**0**		α	**0**			Chapra et al. (2012)
User reaeration coefficient β	**0**		β	**0**			Chapra et al. (2012)
User reaeration coefficient γ	**0**		γ	**0**			Chapra et al. (2012)
Temp correction	**1.024**		θ_a	**1.024**			Chapra et al. (2012)
Reaeration wind effect	**None**			**None**			Chapra et al. (2012)
O2 for carbon oxidation	**2.69**	**gO_2/gC**	r_{oc}	**2.69**			Chapra et al. (2012)
O2 for NH4 nitrification	**4.57**	**gO_2/gN**	r_{on}	**4.57**			Chapra et al. (2012)
Oxygen inhib model CBOD oxidation	**Exponential**			**Exponential**			Chapra et al. (2012)
Oxygen inhib parameter CBOD oxidation	**0.60**	**L/mgO2**	K_{socf}	**0.60**			Chapra et al. (2012)

Oxygen inhib model nitrification	**Exponential**			**Exponential**			Chapra et al. (2012)
Oxygen inhib parameter nitrification	**0.60**	**L/mgO2**	K_{sona}	**0.60**			Chapra et al. (2012)
Oxygen enhance model denitrification	**Exponential**			**Exponential**			Chapra et al. (2012)
Oxygen enhance parameter denitrification	**0.60**	**L/mgO2**	K_{sodn}	**0.60**			Chapra et al. (2012)
Oxygen inhib model phyto resp	**Exponential**			**Exponential**			Chapra et al. (2012)
Oxygen inhib parameter phyto resp	**0.60**	**L/mgO2**	K_{sop}	**0.60**			Chapra et al. (2012)
Oxygen enhance model bot alg resp	**Exponential**			**Exponential**			Chapra et al. (2012)
Oxygen enhance parameter bot alg resp	**0.60**	**L/mgO2**	K_{sob}	**0.60**			Chapra et al. (2012)
Slow CBOD:							
Hydrolysis rate	**0.05**	**/d**	k_{hc}	**4.999**			Chapra et al. (2012)
Temp correction	**1.047**		θ_{hc}	**1.047**			Chapra et al. (2012)
Oxidation rate	**0.01**	**/d**	k_{dcs}	**5**			Chapra et al. (2012)
Temp correction	**1.047**		θ_{dcs}	**1.047**			Chapra et al. (2012)
Fast CBOD:							
Oxidation rate	**0.05**	**/d**	k_{dc}	**0.2**	**0.005**	**5**	Flynn et al. (2015)
Temp correction	**1.047**		θ_{dc}	**1.047**			Chapra et al. (2012)
Organic N:							
Hydrolysis	**0.05**	**/d**	k_{hn}	**0.2**	**0.001**	**1**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{hn}	**1.07**			Chapra et al. (2012)
Settling velocity	**0.1**	**m/d**	v_{on}	**0.1**	**0**	**0.1**	Flynn et al. (2015)
Ammonium:							
Nitrification	**0.15**	**/d**	k_{na}	**1**	**0.01**	**10**	Flynn et al. (2015)
Temp correction	**1.08**		θ_{na}	**1.07**			Chapra et al. (2012)
Nitrate:							

Denitrification	**1**	**/d**	k_{dn}	**0**	**0.002**	**2**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{dn}	**1.07**			Chapra et al. (2012)
Sed denitrification transfer coeff	**0**	**m/d**	v_{di}	**0**			Chapra et al. (2012)
Temp correction	**1.07**		θ_{di}	**1.07**	**1.07**	**1.07**	Chapra et al. (2012)
Organic P:							
Hydrolysis	**0.05**	**/d**	k_{hp}	**0.2**	**0.001**	**1**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{hp}	**1.07**			Chapra et al. (2012)
Settling velocity	**0.1**	**m/d**	v_{op}	**0.1**	**0**	**0.1**	Flynn et al. (2015)
Inorganic P:							
Settling velocity	0.05	**m/d**	v_{ip}	**0**			Chapra et al. (2012)
Inorganic P sorption coefficient	**0.05**	**L/mgD**	K_{dpi}	**0.073**			Chapra et al. (2012)
Sed P oxygen attenuation half sat constant	**0.05**	**mgO_2/L**	k_{spi}	**1.831**			Chapra et al. (2012)
Phytoplankton:							
Max Growth rate	**3**	**/d**	k_{gp}	**2.5**	**0.5**	**3**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{gp}	**1.07**			Chapra et al. (2012)
Respiration rate	**0.2**	**/d**	k_{rp}	**0.3**	**0.02**	**0.8**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{rp}	**1.07**			Chapra et al. (2012)
Excretion rate	**0.05**	**/d**	k_{ep}	**0**			Chapra et al. (2012)
Temp correction	**1.07**		θ_{dp}	**1.07**			Chapra et al. (2012)
Death rate	**0.2**	**/d**	k_{dp}	**0**	**0**	**0.5**	Flynn et al. (2015)
Temp correction	**1**		θ_{dp}	**1**			Chapra et al. (2012)
External Nitrogen half sat constant	**15**	**ugN/L**	k_{sPp}	**70**	**5**	**50**	Flynn et al. (2015)
External Phosphorus half sat constant	**2**	**ugP/L**	k_{sNp}	**10**	**10**	**60**	Flynn et al. (2015)
Inorganic carbon half sat constant	**1.30E-05**	**moles/L**	k_{sCp}	**2.00E-05**			Chapra et al. (2012)
Light model	**Half saturation**			**Half saturation**	**Half saturation**	**Half saturation**	Chapra et al. (2012)
Light constant	**57.6**	**langleys/d**	K_{Lp}	**100**	**30**	**90**	Flynn et al. (2015)

Ammonia preference	**25**	**ugN/L**	k_{hnxp}	**15**	**5**	**30**	Flynn et al. (2015)
Subsistence quota for nitrogen	**0**	**mgN/mgA**	q_{0Np}	**,7**	**0.5**	**5**	Flynn et al. (2015)
Subsistence quota for phosphorus	**0**	**mgP/mgA**	q_{0Pp}	**0.1**	**0.05**	**0.5**	Flynn et al. (2015)
Maximum uptake rate for nitrogen	**0**	**mgN/mgA/d**	ρ_{mNp}	**70**	**5**	**100**	Flynn et al. (2015)
Maximum uptake rate for phosphorus	**0**	**mgP/mgA/d**	ρ_{mPp}	**10**	**1**	**15**	Flynn et al. (2015)
Internal nitrogen half sat constant	**0**	**mgN/mgA**	K_{qNp}	**0.9**	**0.25**	**5**	Flynn et al. (2015)
Internal phosphorus half sat constant	**0**	**mgP/mgA**	K_{qPp}	**0.13**	**0.025**	**0.5**	Flynn et al. (2015)
Settling velocity	**0.1**	**m/d**	v_a	**0.1**	**0**	**1**	Flynn et al. (2015)
Bottom Algae:							
Growth model	**Zero-order**			**Zero-order**	**Zero-order**	**Zero-order**	Chapra et al. (2012)
Max Growth rate	**1.6**	**mgA/m^2/d or /d**	C_{gb}	**400**	**15**	**500**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{gb}	**1.07**			Chapra et al. (2012)
First-order model carrying capacity	**100**	**mgA/m^2**	$a_{b,max}$	**1000**			Chapra et al. (2012)
Respiration rate	**0.7**	**/d**	k_{rb}	**0.3**	**0.02**	**0.8**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{rb}	**1.07**			Chapra et al. (2012)
Excretion rate	**0.5**	**/d**	k_{eb}	**0.5**			Chapra et al. (2012)
Temp correction	**1.05**		θ_{db}	**1.05**			Chapra et al. (2012)
Death rate	**0.25**	**/d**	k_{db}	**0**	**0**	**0.8**	Flynn et al. (2015)
Temp correction	**1.07**		θ_{db}	**1.07**			Chapra et al. (2012)
External nitrogen half sat constant	**300**	**ugN/L**	k_{sPb}	**350**	**10**	**750**	Flynn et al. (2015)
External phosphorus half sat constant	**100**	**ugP/L**	k_{sNb}	**100**	**5**	**175**	Flynn et al. (2015)
Inorganic carbon half sat constant	**1.30E-05**	**moles/L**	k_{sCb}	**1.00E-05**			Chapra et al. (2012)
Light model	**Half saturation**			**Half saturation**	**Half saturation**	**Half saturation**	Chapra et al. (2012)
Light constant	**50**	**langleys/d**	K_{Lb}	**100**	**30**	**90**	Flynn et al. (2015)
Ammonia preference	**25**	**ugN/L**	k_{hnxb}	**15**	**5**	**30**	Flynn et al. (2015)

Subsistence quota for nitrogen	0.72	mgN/mgA	q_{0N}	0.7	0.5	5	Flynn et al. (2015)
Subsistence quota for phosphorus	0.1	mgP/mgA	q_{0P}	0.1	0.05	0.5	Flynn et al. (2015)
Maximum uptake rate for nitrogen	72	mgN/mgA/d	ρ_{mN}	70	5	100	Flynn et al. (2015)
Maximum uptake rate for phosphorus	10	mgP/mgA/d	ρ_{mP}	10	1	15	Flynn et al. (2015)
Internal nitrogen half sat constant	0.9	mgN/mgA	K_{qN}	0.9	0.25	5	Flynn et al. (2015)
Internal phosphorus half sat constant	0.13	mgP/mgA	K_{qP}	0.13	0.025	0.5	Flynn et al. (2015)
Detritus (POM):							
Dissolution rate	0.1	/d	k_{dt}	0.5	0.05	3	Flynn et al. (2015)
Temp correction	1.07		θ_{dt}	1.07			Chapra et al. (2012)
Fraction of dissolution to fast CBOD	0.1		F_f	0.10			Chapra et al. (2012)
Settling velocity	0.1	m/d	v_{dt}	0.1	0	1	Flynn et al. (2015)
Pathogens:							
Decay rate	0.8	/d	k_{dx}	0.8			Chapra et al. (2012)
Temp correction	1.07		θ_{dx}	1.07			Chapra et al. (2012)
Settling velocity	1	m/d	v_x	1			Chapra et al. (2012)
Light efficiency factor	1.00		α_{path}	1.00			Chapra et al. (2012)
pH:							
Partial pressure of carbon dioxide	347	ppm	p_{CO2}	347			Chapra et al. (2012)
Constituent i							
First-order reaction rate	0	/d		0	0	0	Chapra et al. (2012)
Temp correction	1		θ_{dx}	1	1	1	Chapra et al. (2012)
Settling velocity	0	m/d	v_{dt}	0	0	0	Chapra et al. (2012)
Constituent ii							
First-order reaction rate	0	/d		0	0	0	Chapra et al. (2012)
Temp correction	1		θ_{dx}	1	1	1	Chapra et al. (2012)
Settling velocity	0	m/d	v_{dt}	0	0	0	Chapra et al. (2012)
Constituent iii							

First-order reaction rate	**0**	**/d**		**0**	**0**	**0**	Chapra et al. (2012)
Temp correction	**1**		θ_{dx}	**1**	**1**	**1**	Chapra et al. (2012)
Settling velocity	**0**	**m/d**	v_{dt}	**0**	**0**	**0**	Chapra et al. (2012)

References Cited

Chapra, S., Pelletier, G., & Tao, H. (2012). *QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.12: Documentation and User's Manual.* Medford, MA: Civil and Environmental Engineering Dept., Tufts University.

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QUAL2K

Stream Water Quality Model

Sweetwater Branch (BIN2)

(9/15/2015) ***RUN 529***

Light Parameters and Surface Heat Transfer Models:

Parameter	Final Value	Unit		Default	Ref.
Photosynthetically Available Radiation	0.47			0.47	Chapra et al. (2012)
Background light extinction	0.04	/m	k_{eb}	0.2	Chapra et al. (2012)
Linear chlorophyll light extinction	0.0088	1/m-(ugA/L)	α_p	0.0088	Chapra et al. (2012)
Nonlinear chlorophyll light extinction	0.054	1/m-(ugA/L)2/3	α_{pn}	0.054	Chapra et al. (2012)
ISS light extinction	0.052	1/m-(mgD/L)	α_i	0.052	Chapra et al. (2012)
Detritus light extinction	0.174	1/m-(mgD/L)	α_o	0.174	Chapra et al. (2012)
Solar shortwave radiation model					
Atmospheric attenuation model for solar	Bras			Ryan-Stolzenbach	Chapra et al. (2012)
Bras solar parameter (used if Bras solar model is selected)					
atmospheric turbidity coefficient (2=clear, 5=smoggy, default=2)	2		n_{fac}	2	Chapra et al. (2012)
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)					
atmospheric transmission coefficient (0.70-0.91, default 0.8)	0.8		a_{tc}	0.75	Chapra et al. (2012)
Downwelling atmospheric longwave IR radiation					
atmospheric longwave emissivity model	Brunt			Brunt	Chapra et al. (2012)

Evaporation and air convection/conduction					
wind speed function for evaporation and air convection/conduction	**Brady-Graves-Geyer**			**Brady-Graves-Geyer**	Chapra et al. (2012)
Sediment heat parameters					
Sediment thermal thickness	**10**	***cm***	H_s	**10**	Chapra et al. (2012)
Sediment thermal diffusivity	**0.0077**	***cm^2/s***	α_s	**0.005**	Chapra et al. (2012)
Sediment density	**1.6**	***g/cm^3***	ρ_s	**1.6**	Chapra et al. (2012)
Water density	**1**	***g/cm^3***	ρ_w	**1**	Chapra et al. (2012)
Sediment heat capacity	**0.4**	***$cal/(g\ ^oC)$***	C_{ps}	**0.4**	Chapra et al. (2012)
Water heat capacity	**1**	***$cal/(g\ ^oC)$***	C_{pw}	**1**	Chapra et al. (2012)
Sediment diagenesis model					
Compute SOD and nutrient fluxes	**Yes**			**Yes**	Chapra et al. (2012)

References Cited

Chapra, S., Pelletier, G., & Tao, H. (2012). *QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.12: Documentation and User's Manual.* Medford, MA: Civil and Environmental Engineering Dept., Tufts University.

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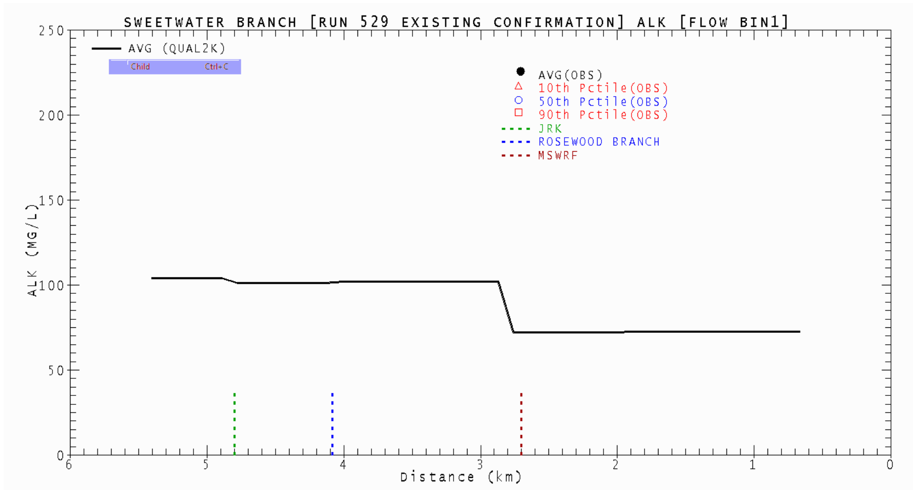
Appendix B

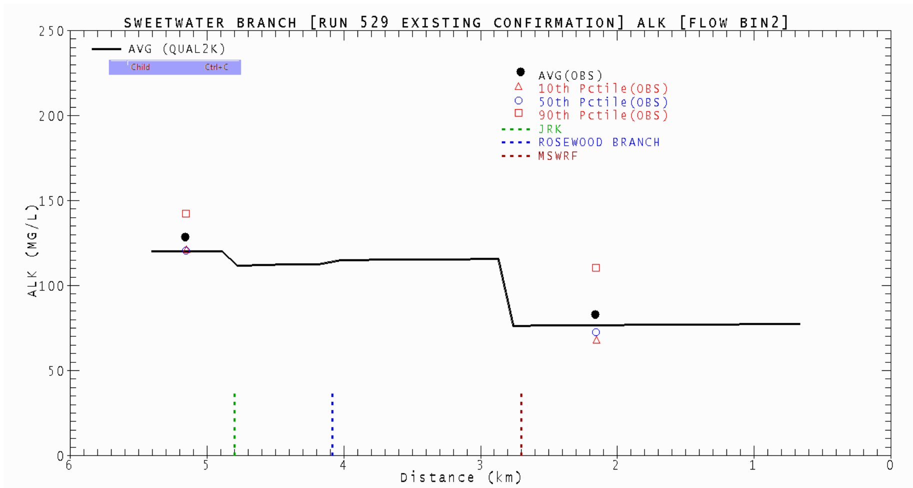
Model Confirmation, Run 529

Run 529: Model Confirmation
Existing Conditions (2013-2016)

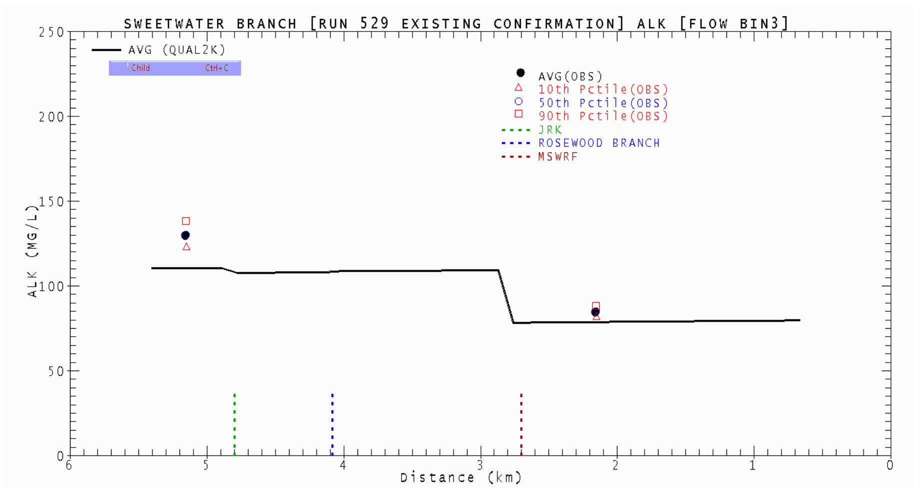
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
ALK	Alkalinity	mg $CaCO_3$/L	2		✓	✓	✓
BOTALGCHL	Bottom Algae Biomass	mg Chl-a/m^2	3		✓	✓	✓
BOTTOM	Water Column Depth	meters	4		✓	✓	✓
CHLA	Sestonic Algae Biomass	µg Chl-a/L	5		✓	✓	✓
COND	Conductivity	µmhos/cm	6		✓	✓	✓
DISSOP	Dissolved Orthophosphate-P	µg P/L	7		✓	✓	✓
FLOW	Streamflow	m^3/sec	8		✓	✓	✓
NH4	Ammonia-N	µg N/L	9		✓	✓	✓
NO3NO2	Nitrite+Nitrate-N	µg N/L	10		✓	✓	✓
OXY	Dissolved Oxygen	mg/L	11		✓	✓	✓
PH	pH	SU	12		✓	✓	✓
TKN	Total Kjeldhal Nitrogen	µg N/L	13		✓	✓	✓
TOC	Total Organic Carbon	mg C/L	14		✓	✓	✓
TOTN	Total Nitrogen	µg N/L	15		✓	✓	✓
TOTP	Total Phosphorus	µg P/L	16		✓	✓	✓
TSS	Total Suspended Solids	mg/L	17		✓	✓	✓
TRAVTIME	Travel Time	days	18		✓	✓	✓
VELOCITY	Stream Velocity	m/sec	19		✓	✓	✓
WTEMP	Water Temperature	Deg-C	20		✓	✓	✓



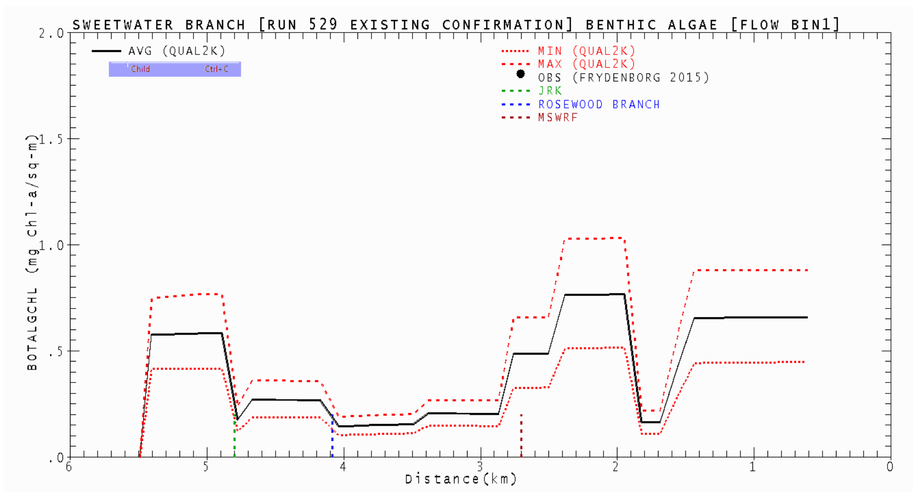
ALK_BIN1_RUN529.BMP



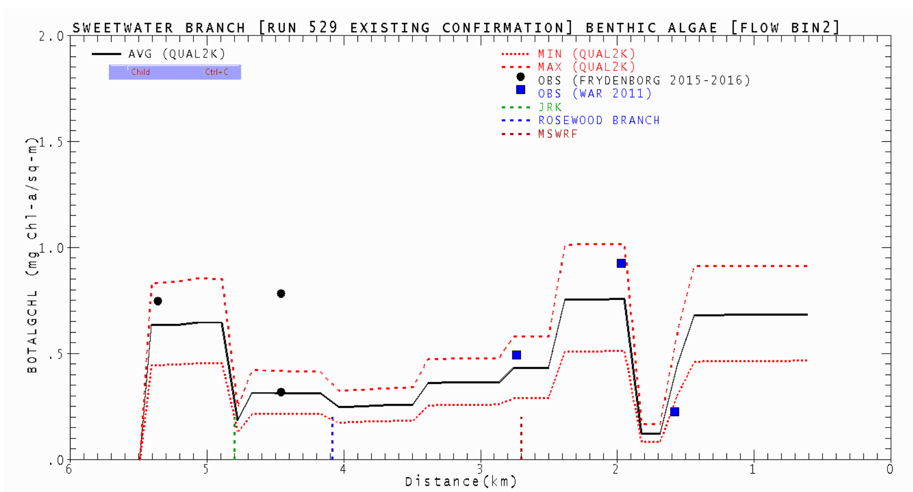
ALK_BIN2_RUN529.BMP



ALK_BIN3_RUN529.BMP



BOTALGCHL_BIN1_RUN529.BMP



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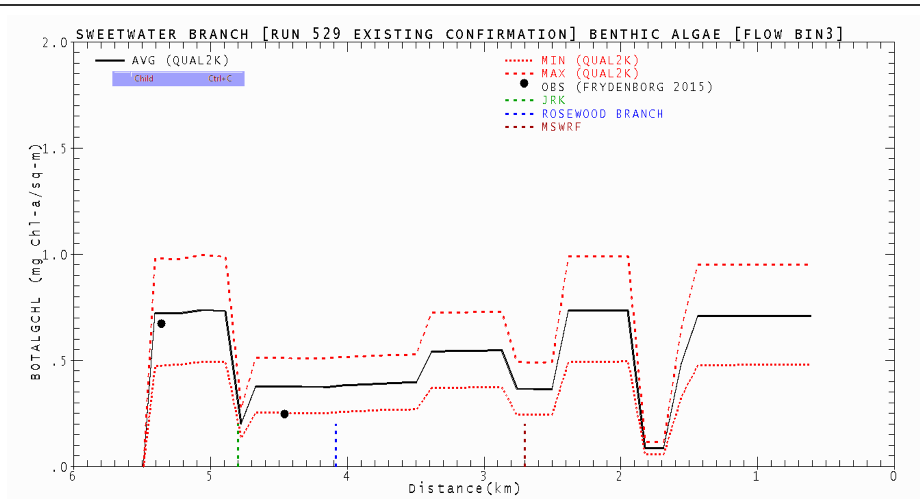

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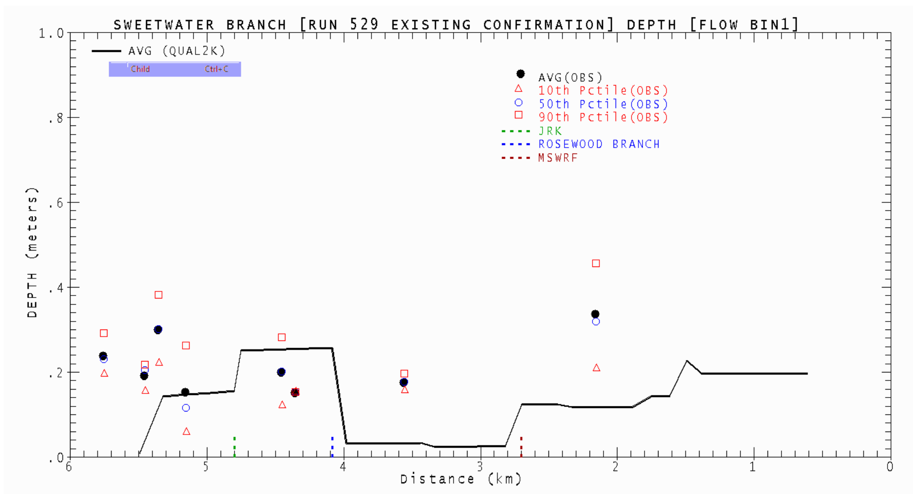

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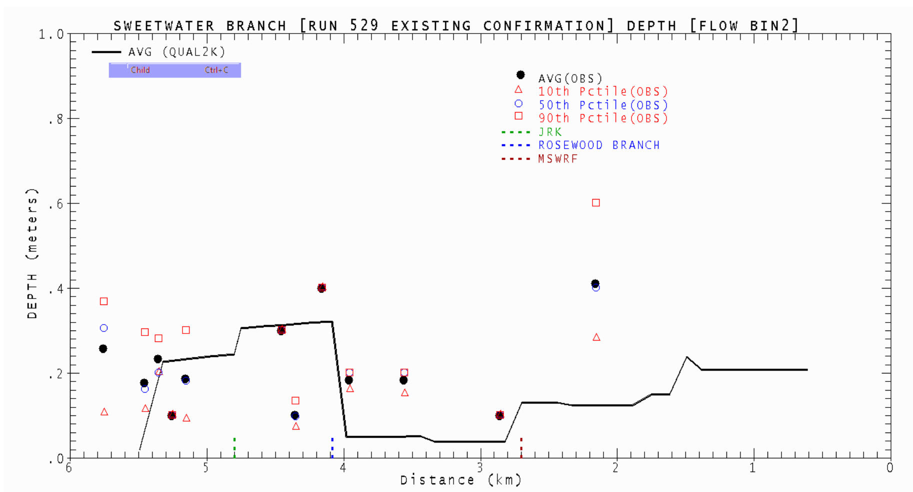
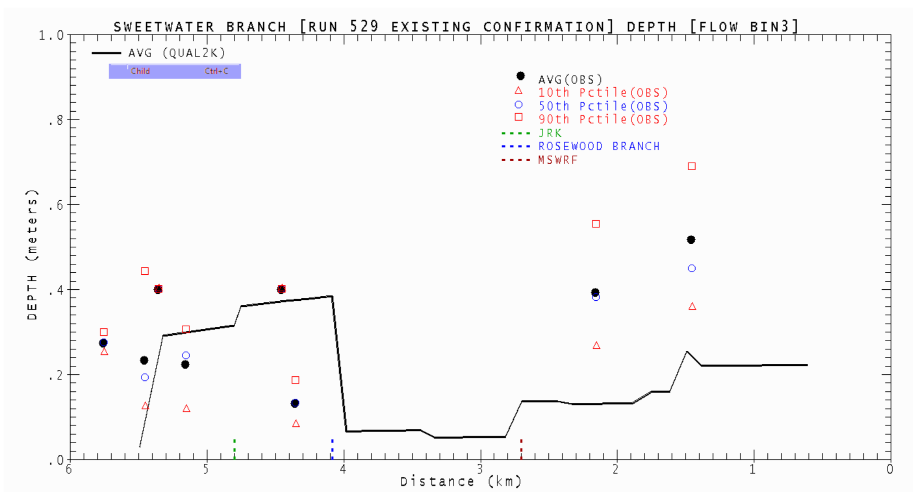
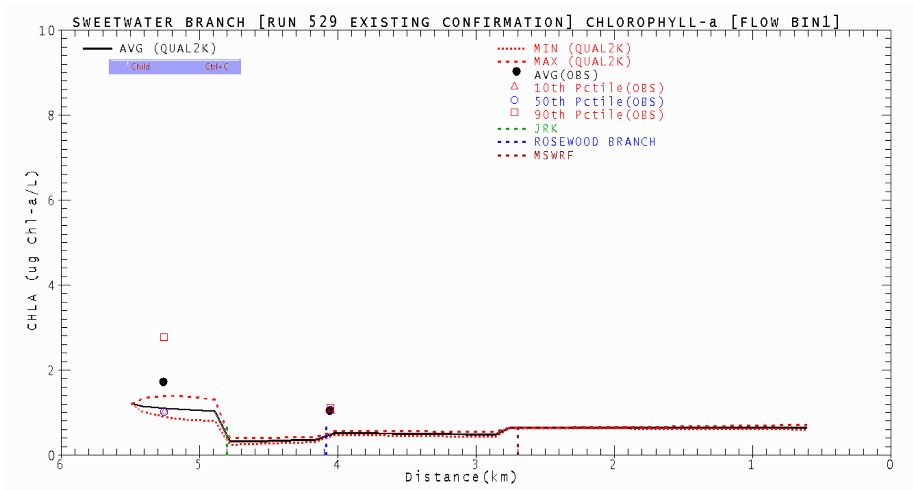


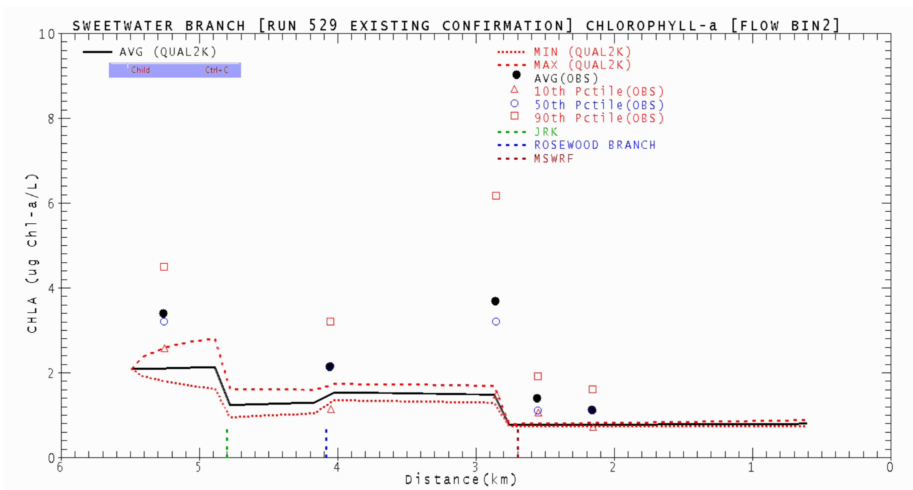
BOTTOM_BIN2_RUN529.BMP



BOTTOM_BIN3_RUN529.BMP



CHLA_BIN1_RUN529.BMP



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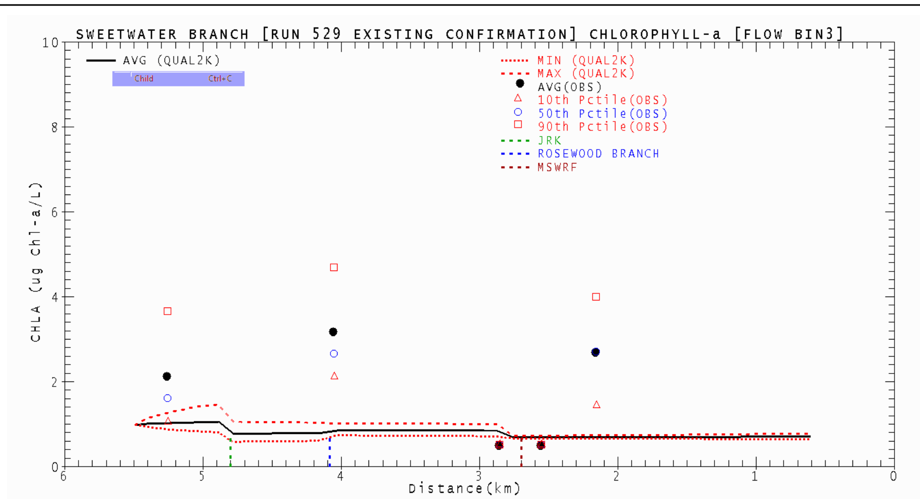
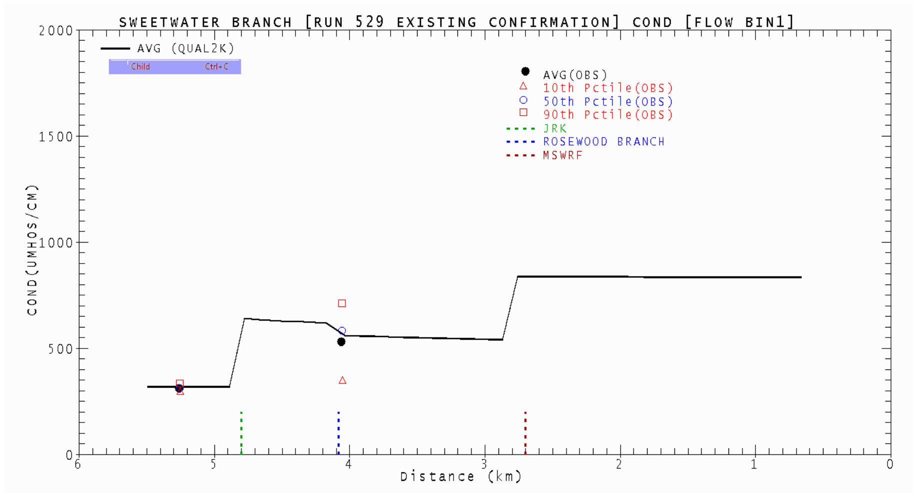


CHLA_BIN3_RUN529.BMP



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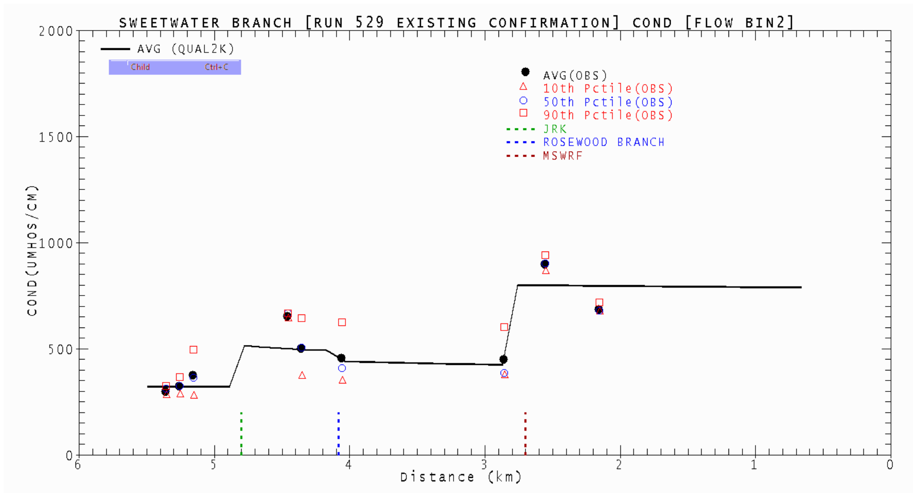
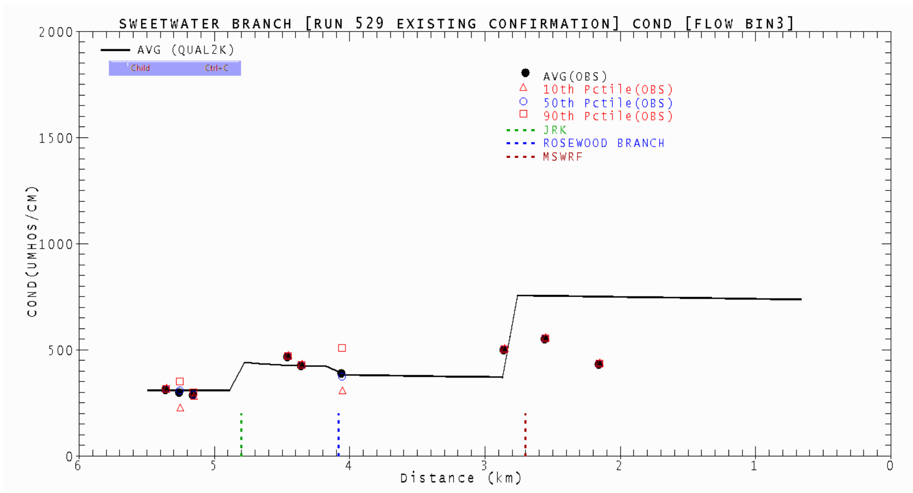


COND_BIN2_RUN529.BMP



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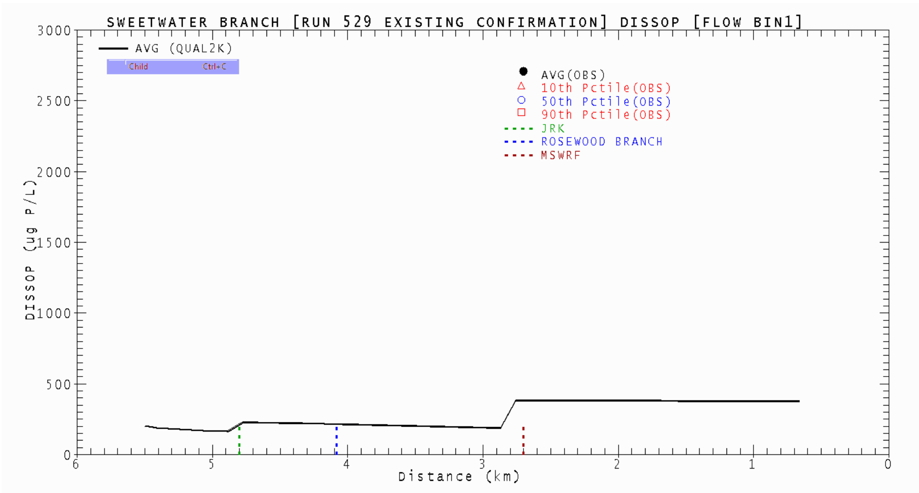

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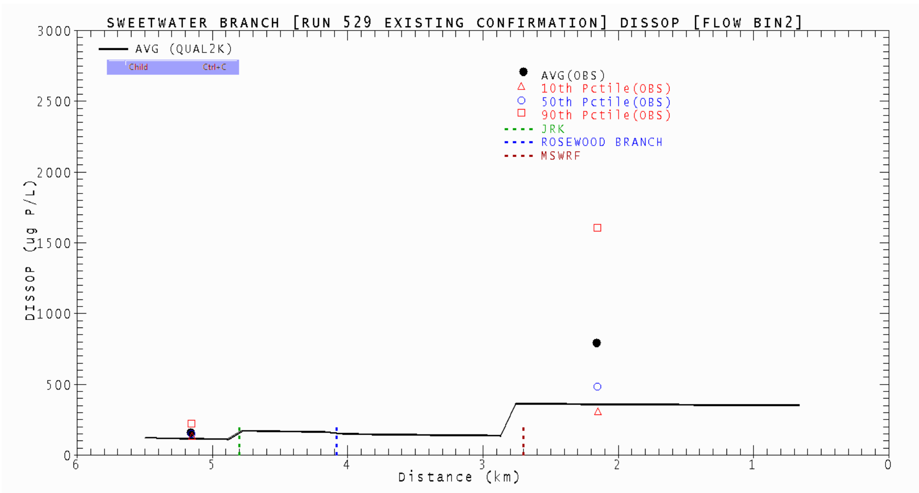

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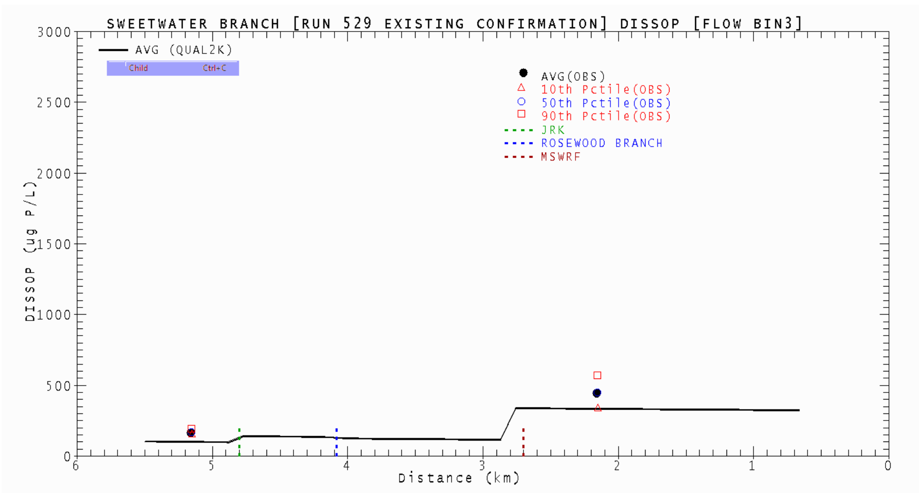

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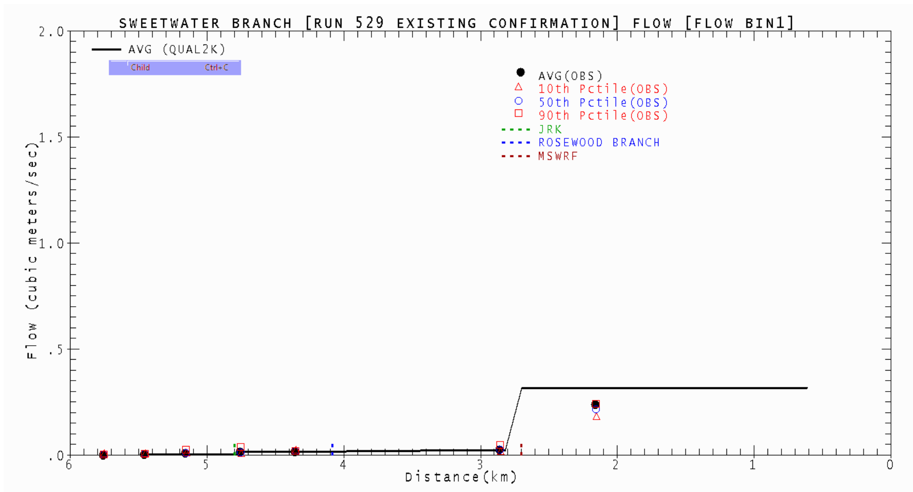

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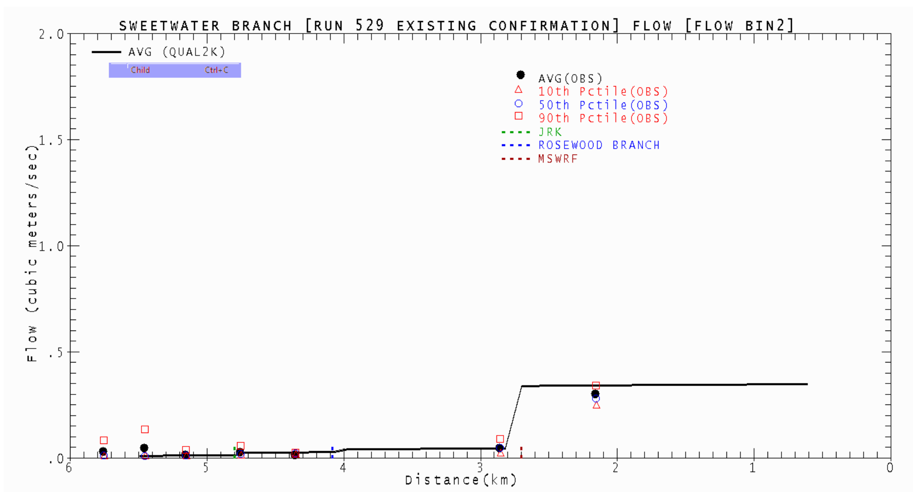

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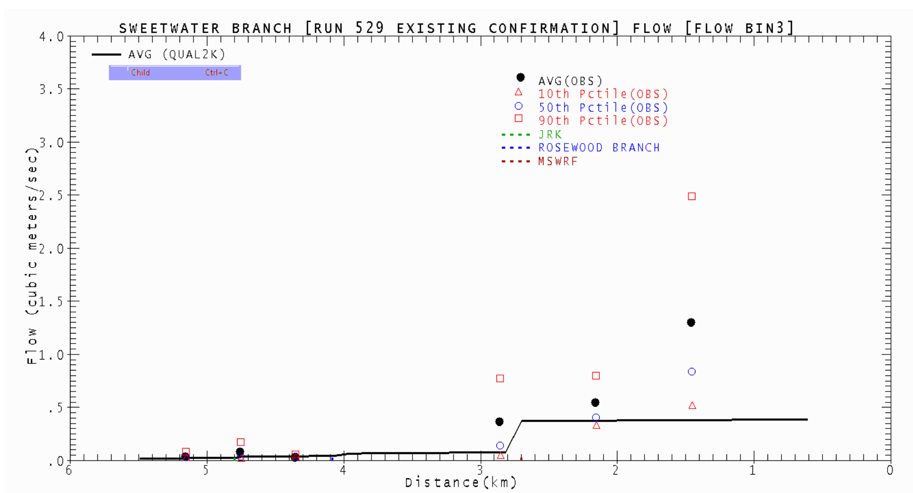

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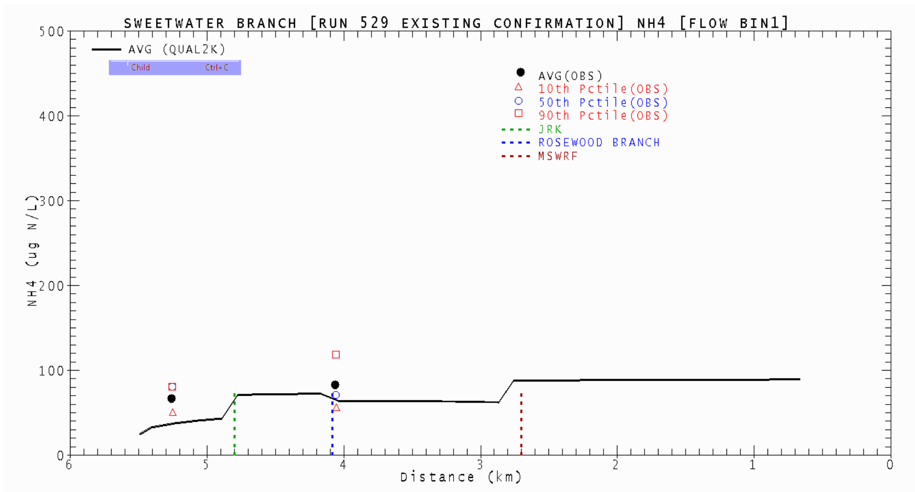
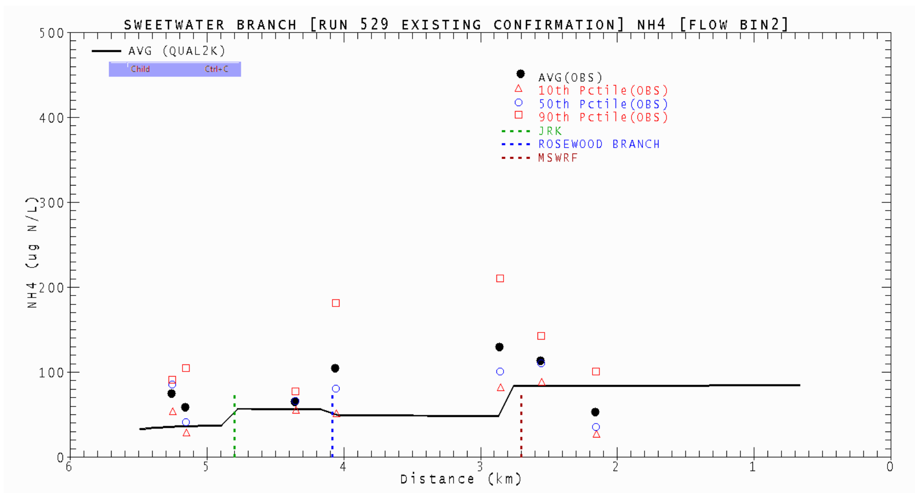


NH4_BIN1_RUN529.BMP



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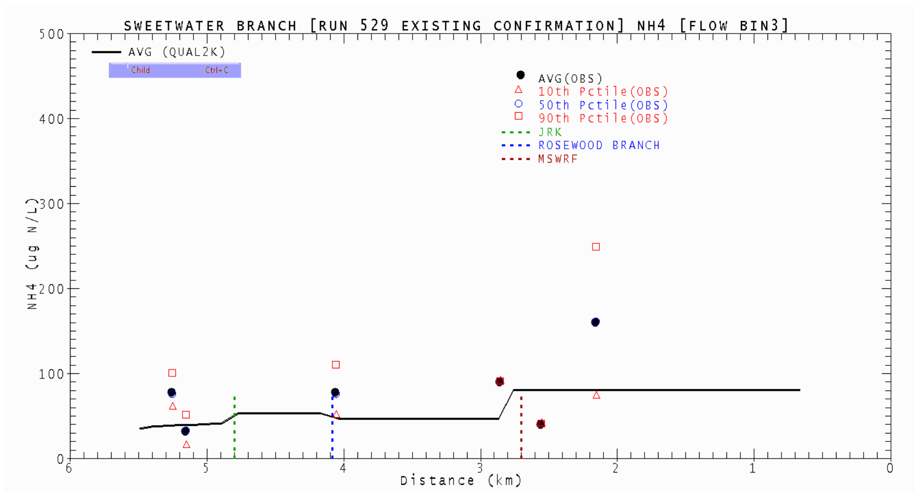

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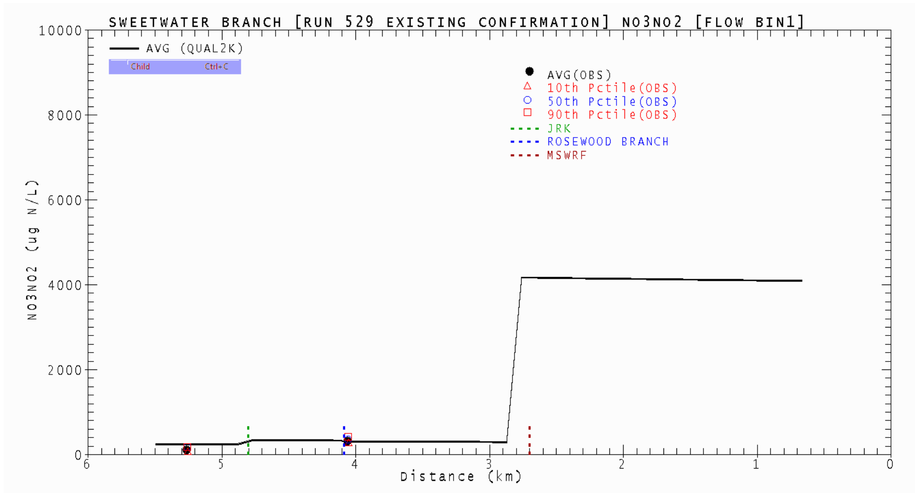
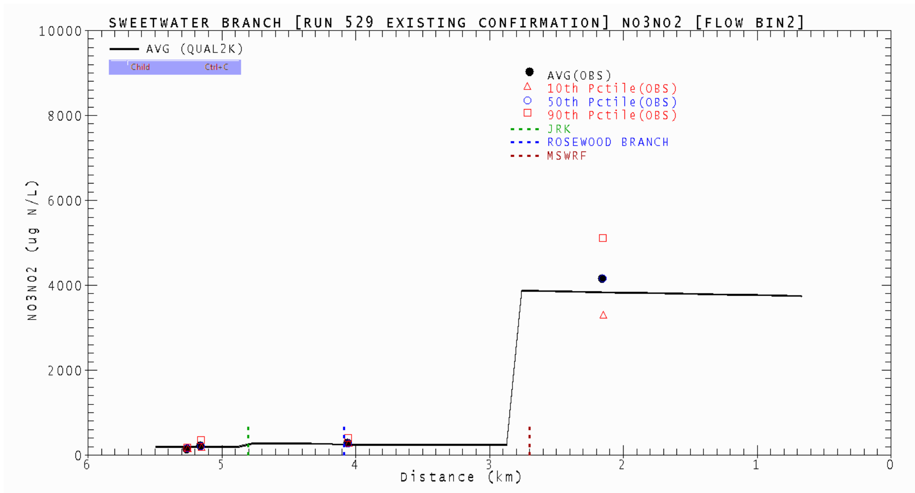


NO3NO2_BIN1_RUN529.BMP



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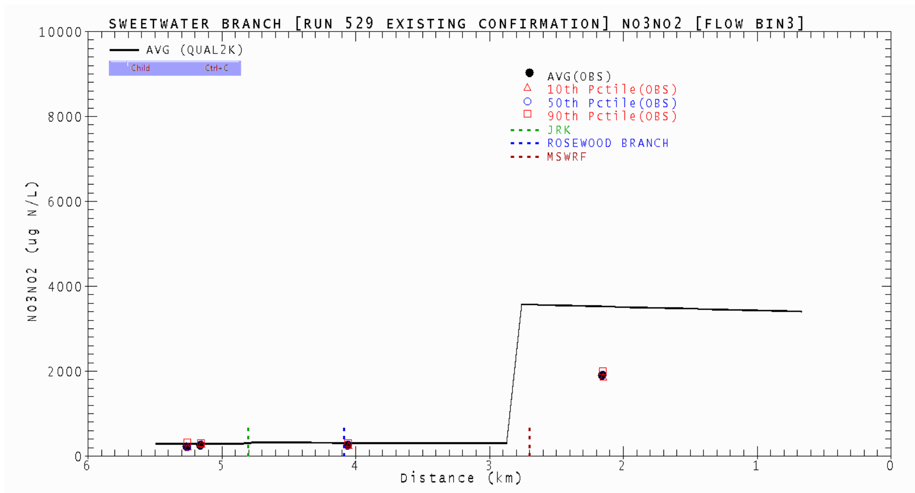

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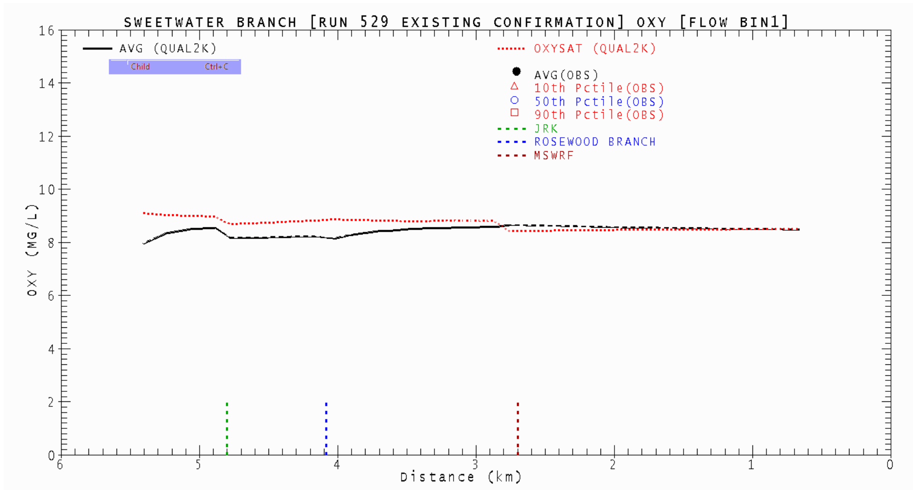
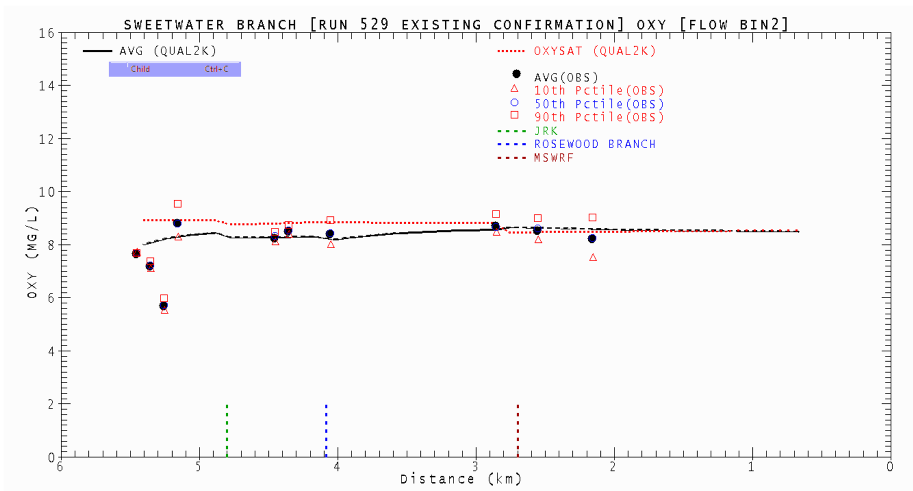
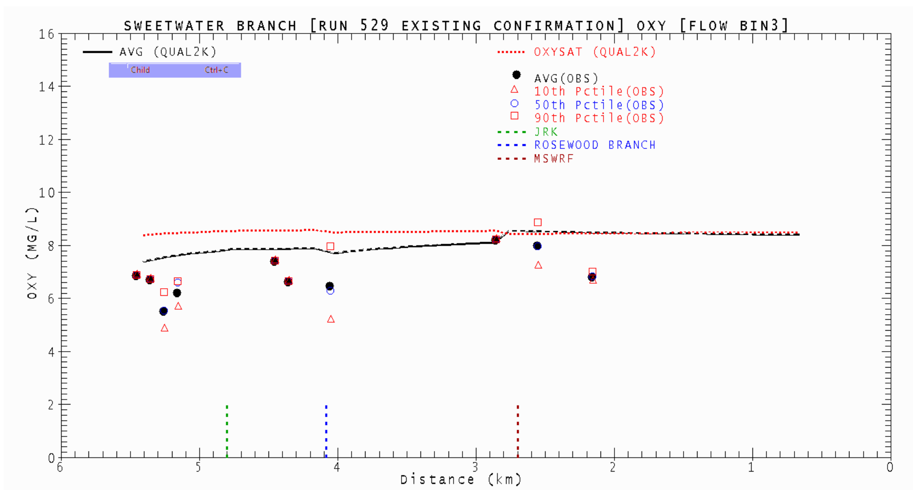


OXY_BIN1_RUN529.BMP



OXY_BIN2_RUN529.BMP



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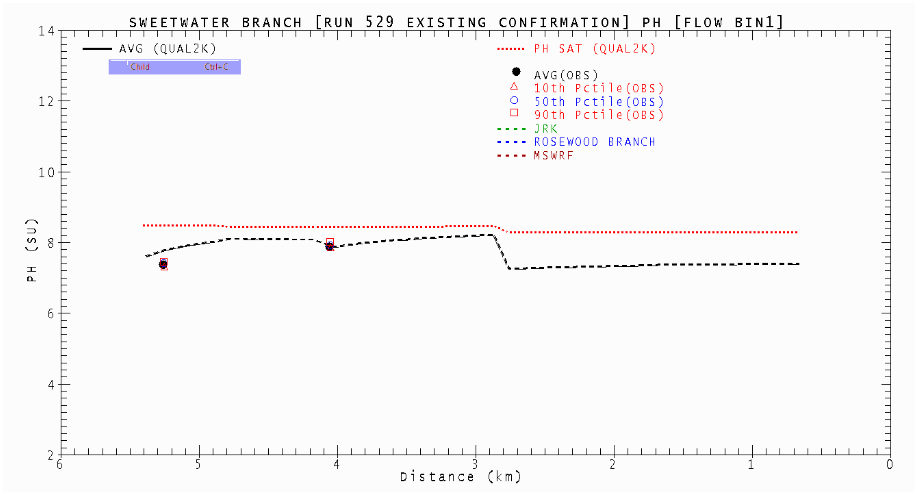
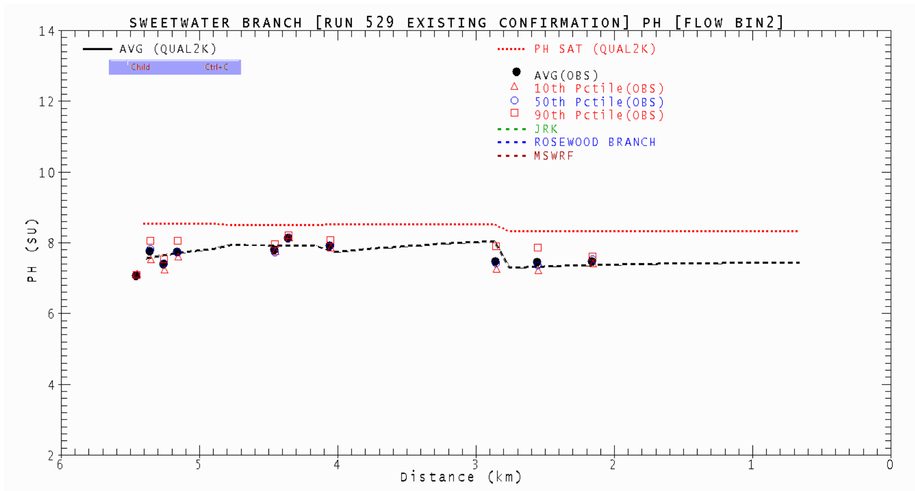


PH_BIN1_RUN529.BMP



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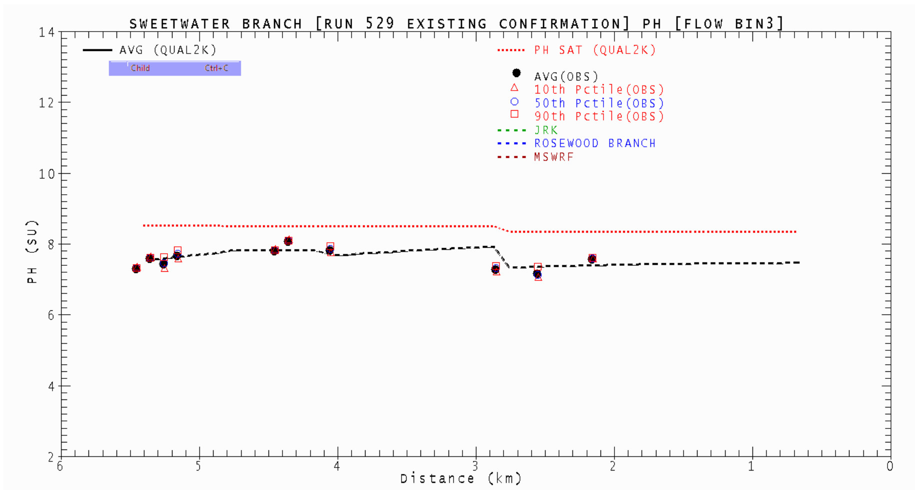

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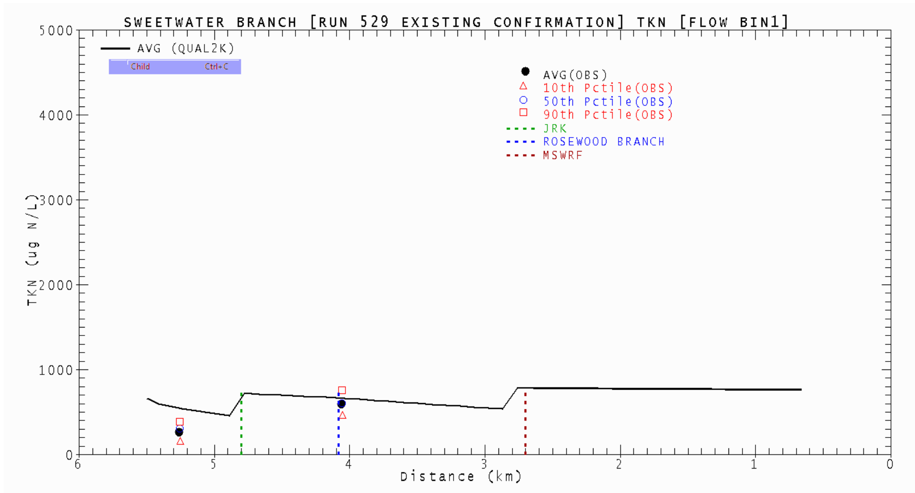
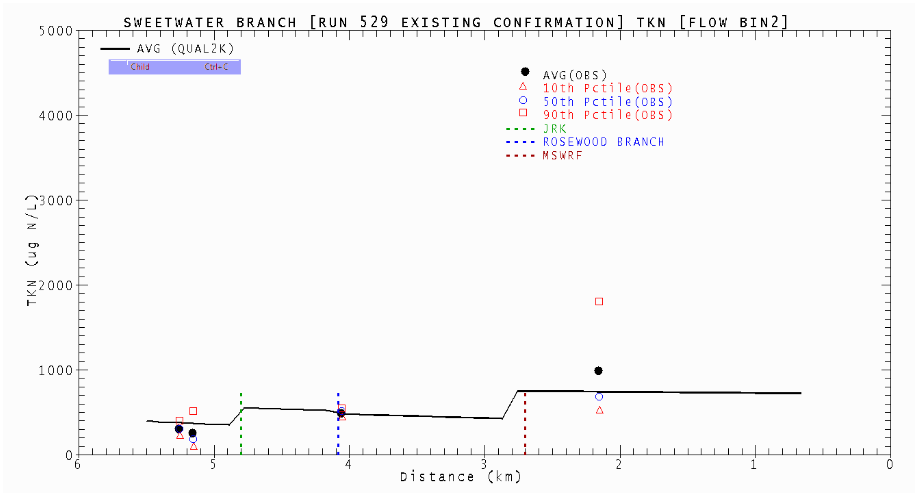


TKN_BIN1_RUN529.BMP



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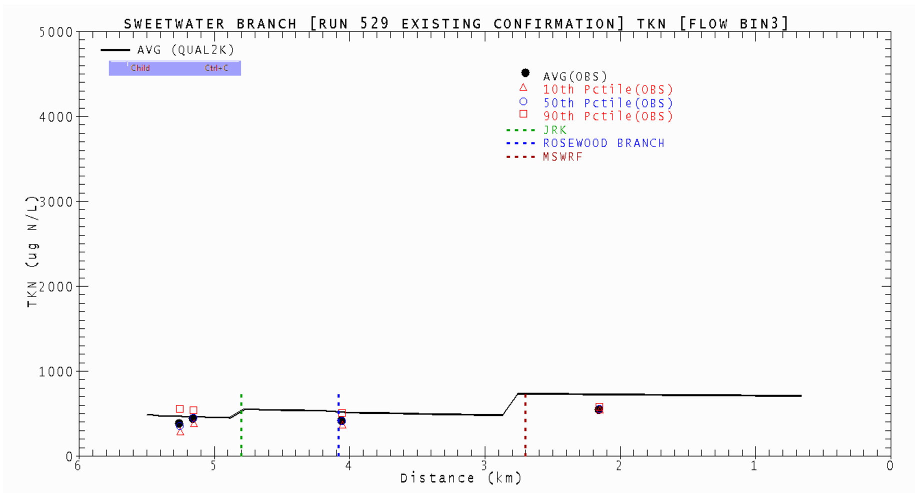

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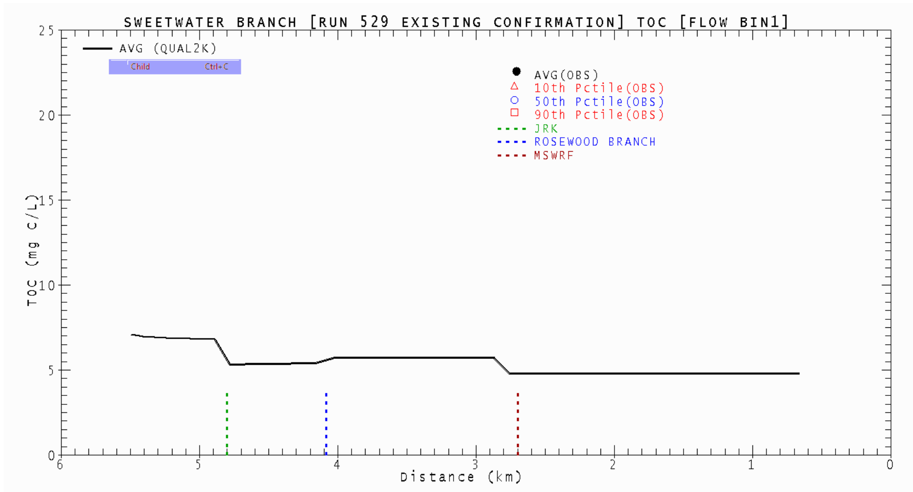

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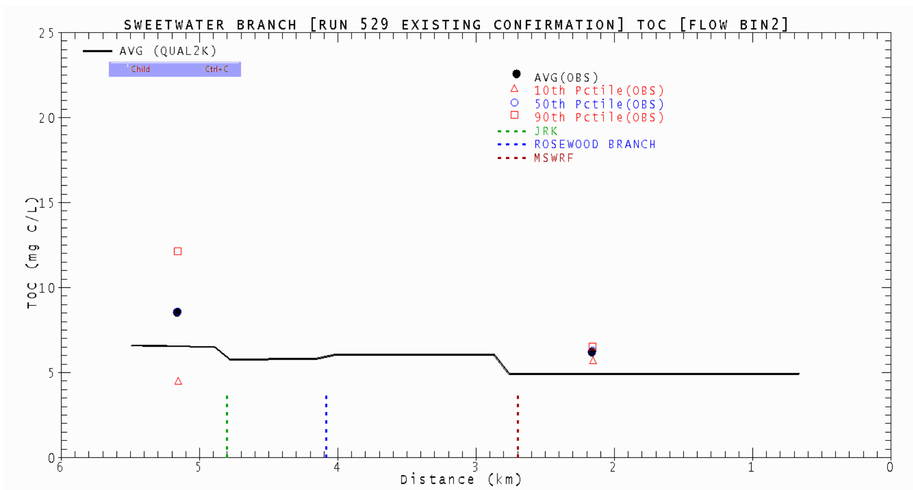

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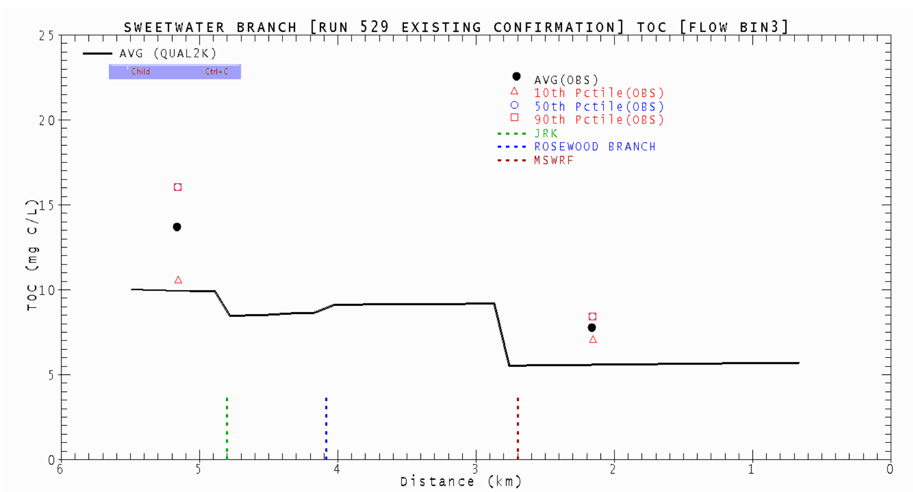

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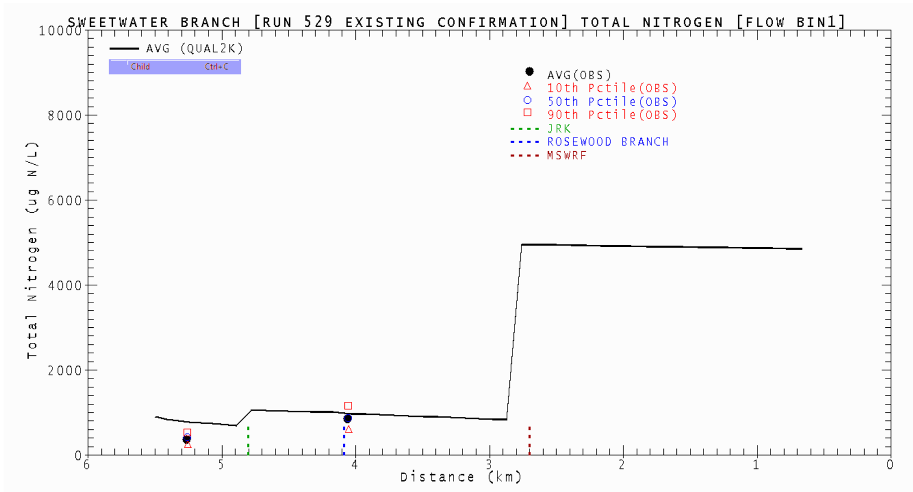

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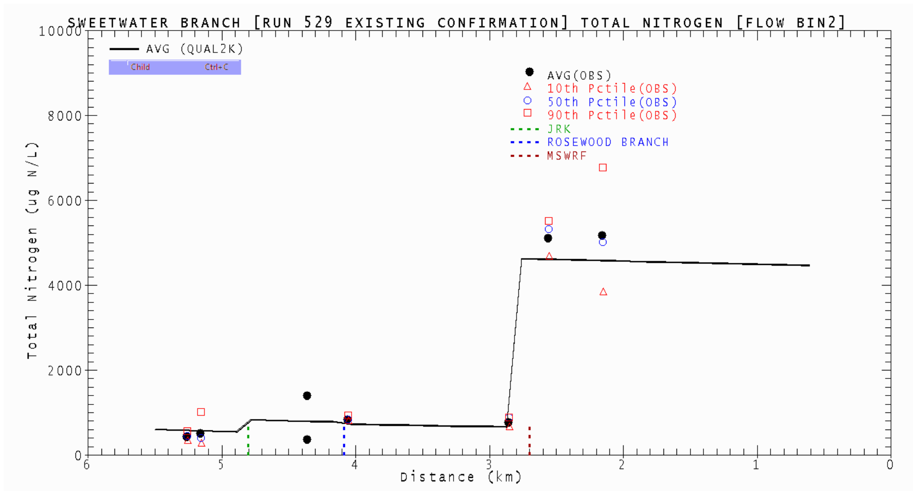

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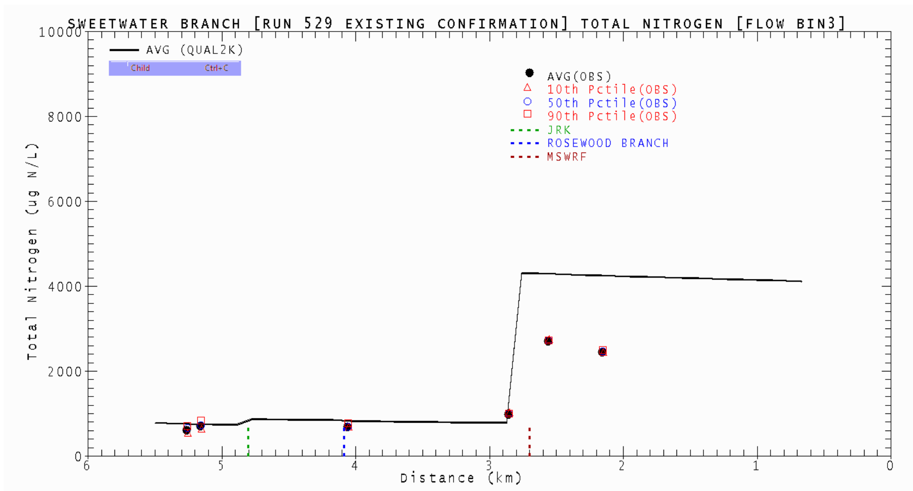

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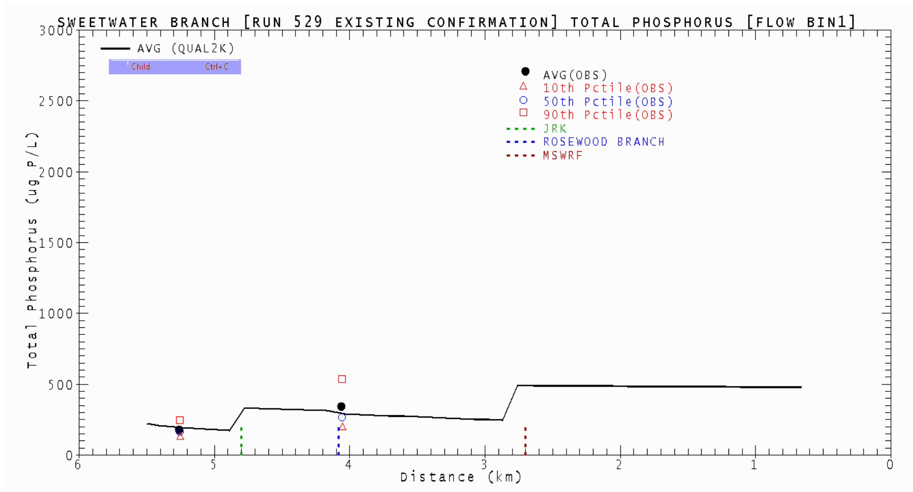

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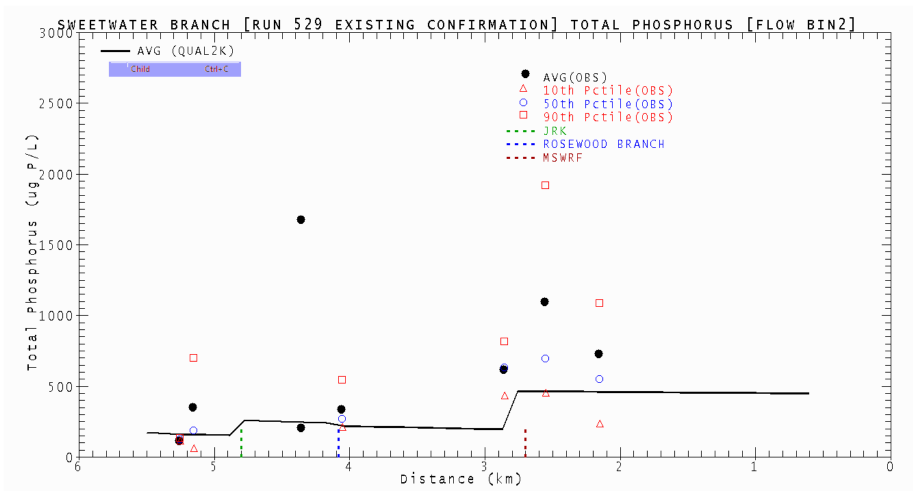
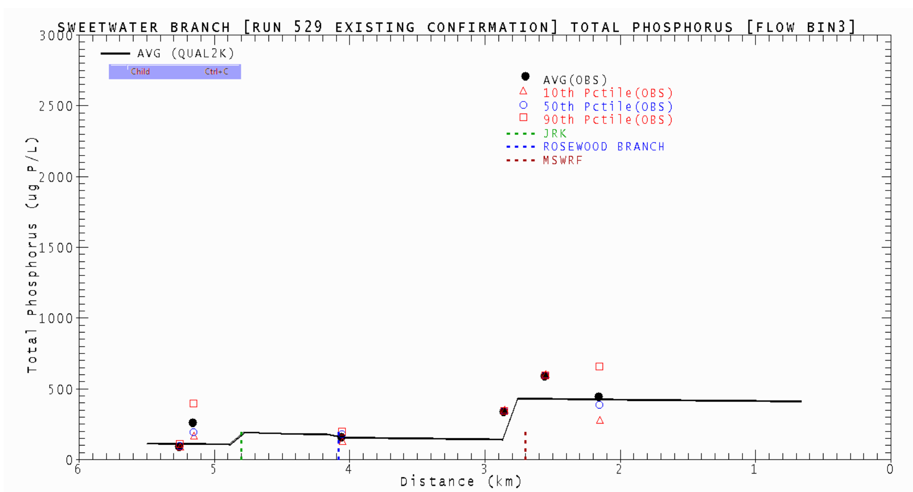


TOTP_BIN2_RUN529.BMP



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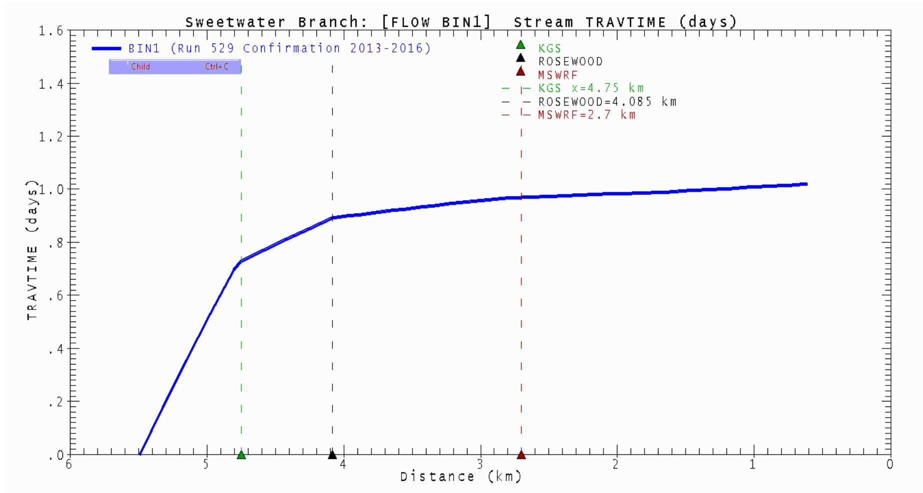
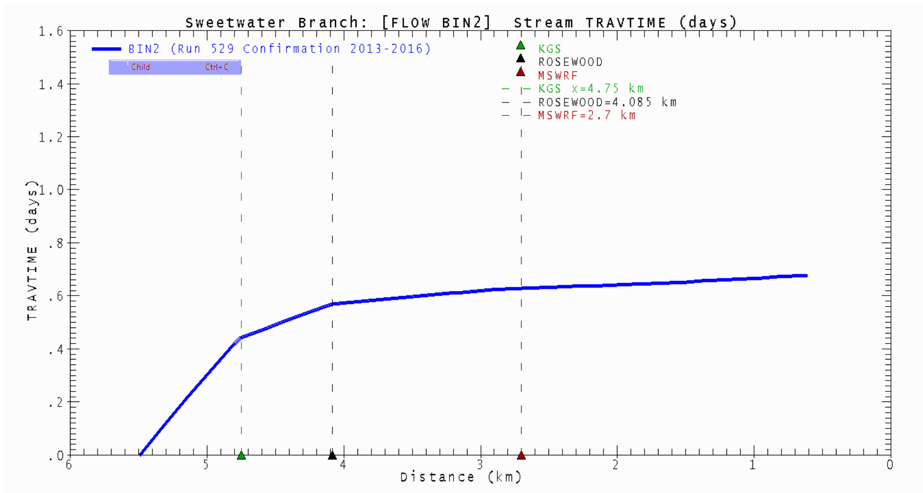


TRAVTIME_BIN1_RUN529.BMP



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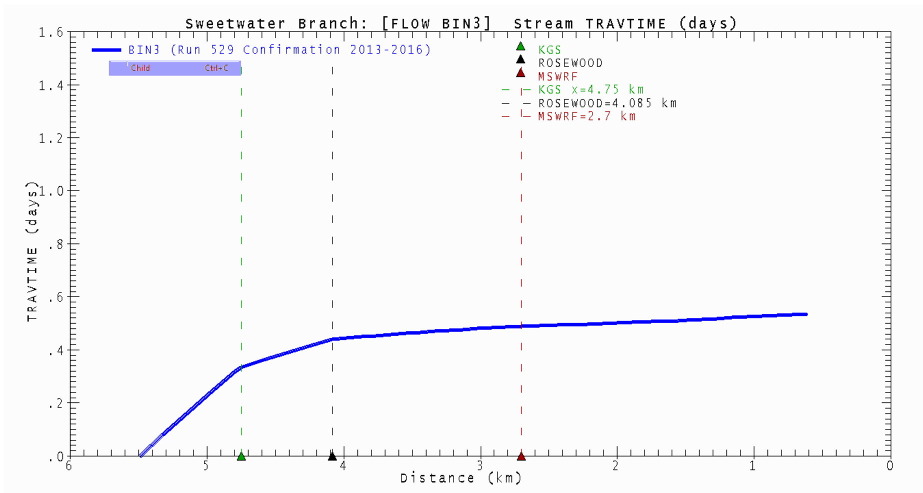

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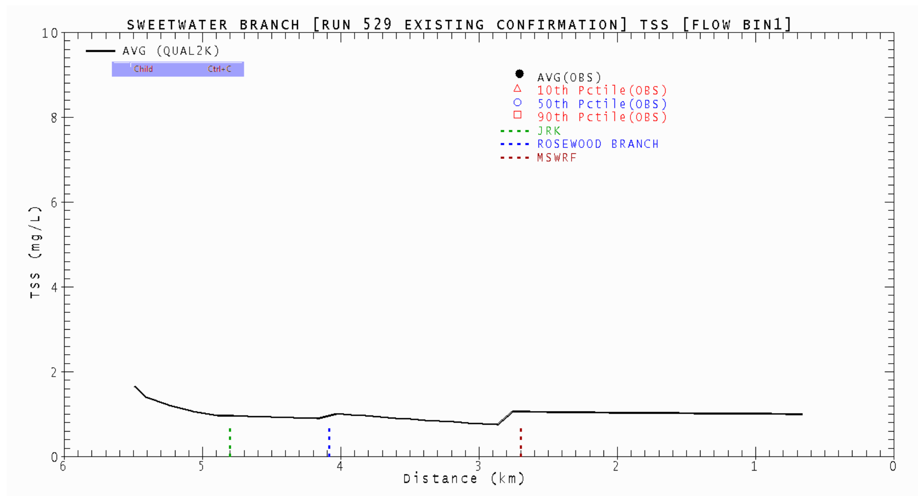

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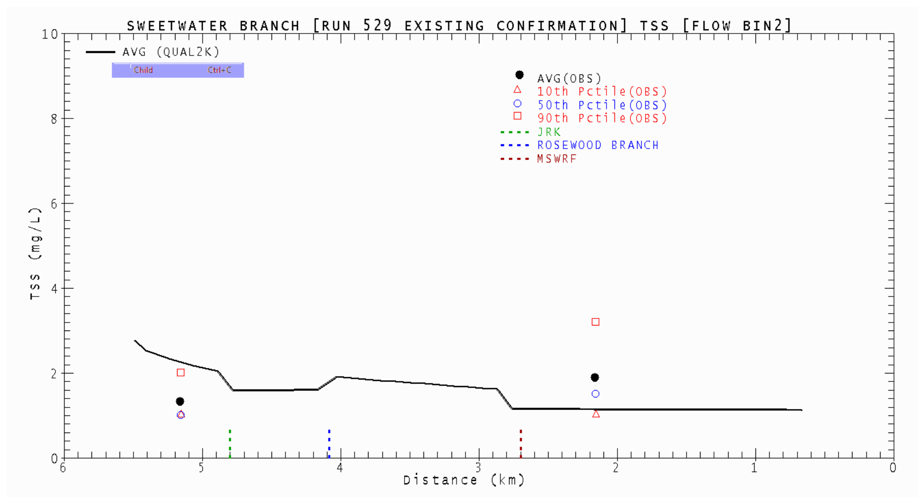
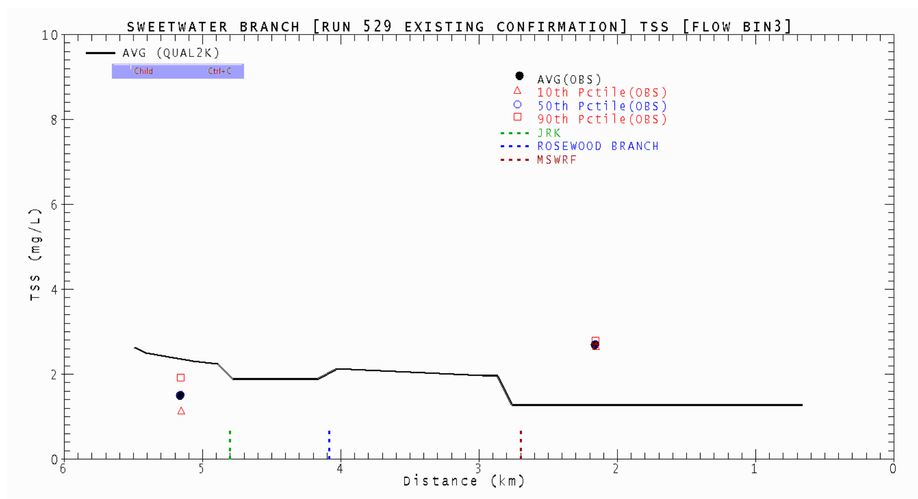


TSS_BIN2_RUN529.BMP



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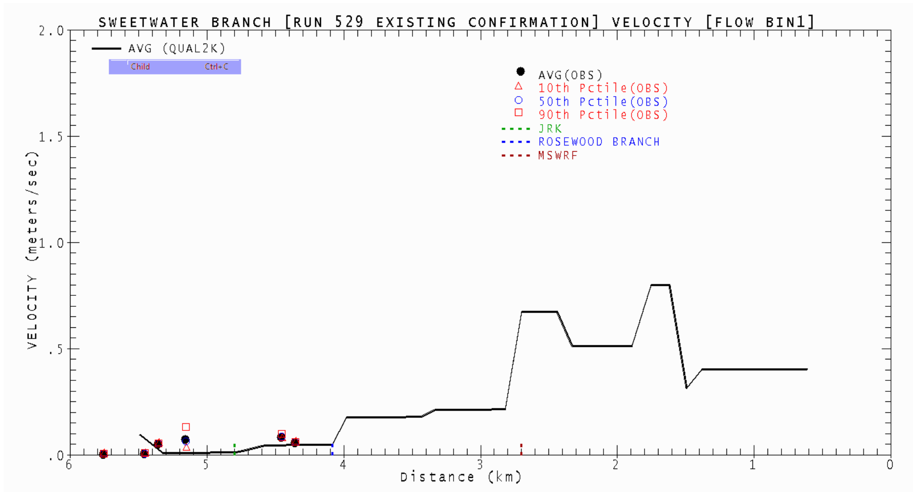
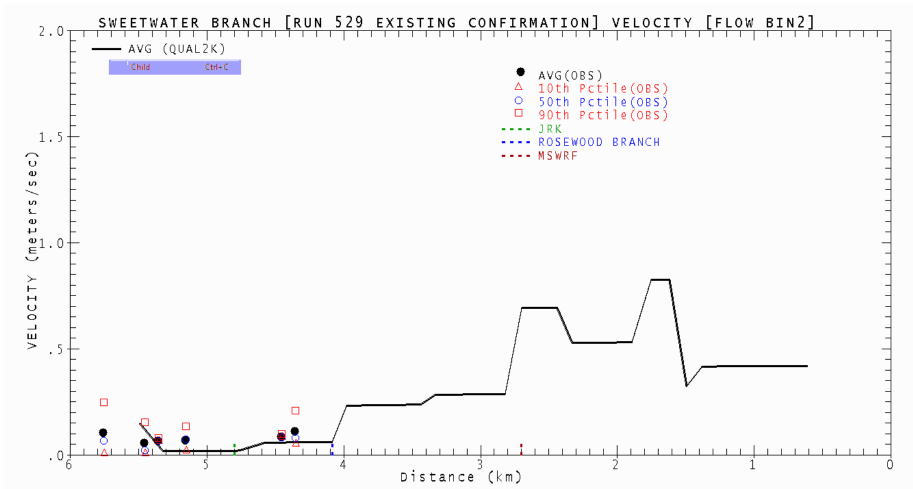


VELOCITY_BIN1_RUN529.BMP



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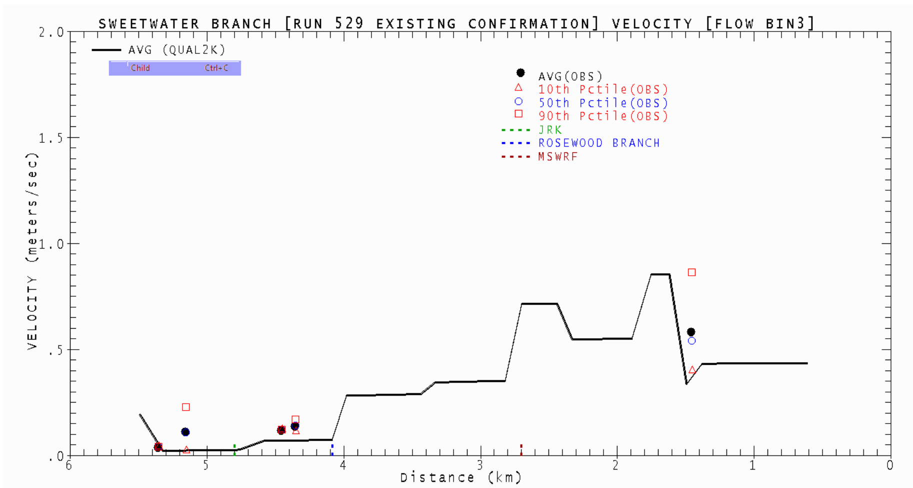
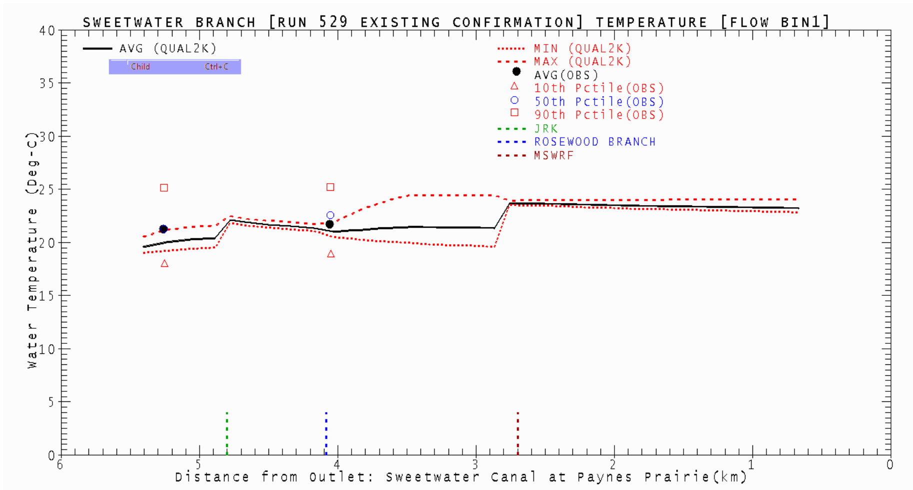
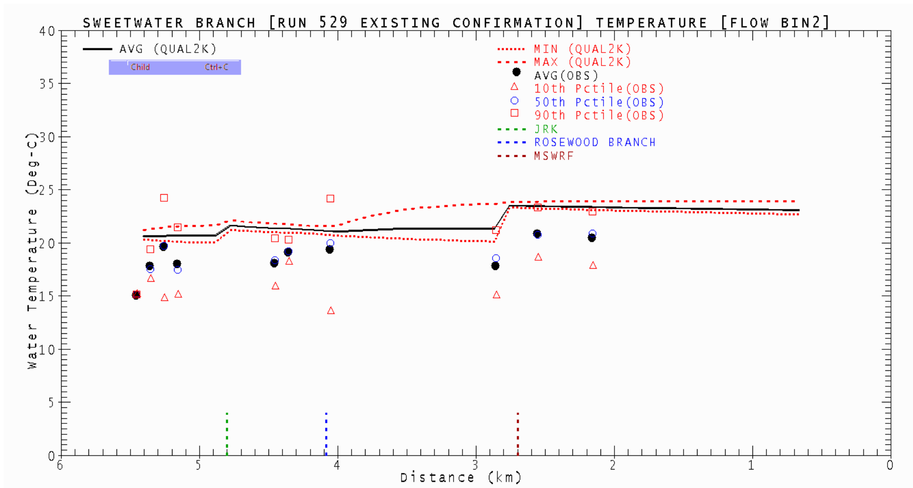


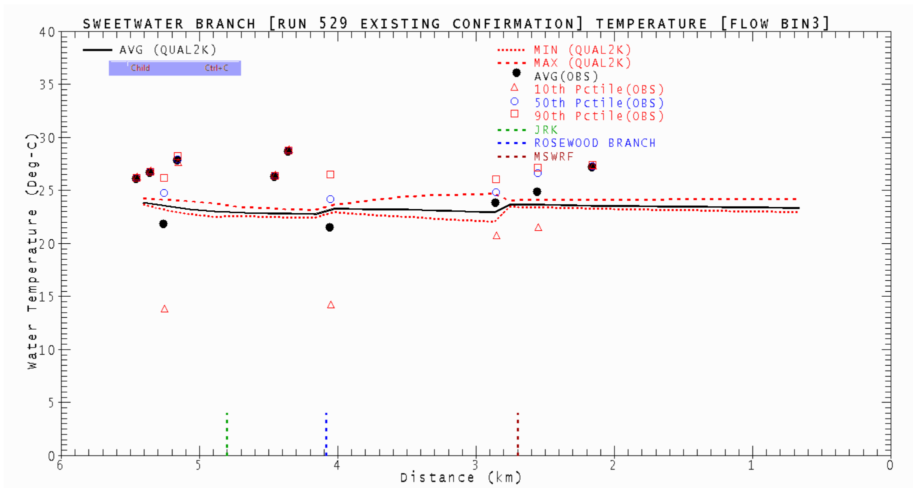
VELOCITY_BIN3_RUN529.BMP



WTEMP_BIN1_RUN529.BMP



WTEMP_BIN2_RUN529.BMP



WTEMP_BIN3_RUN529.BMP

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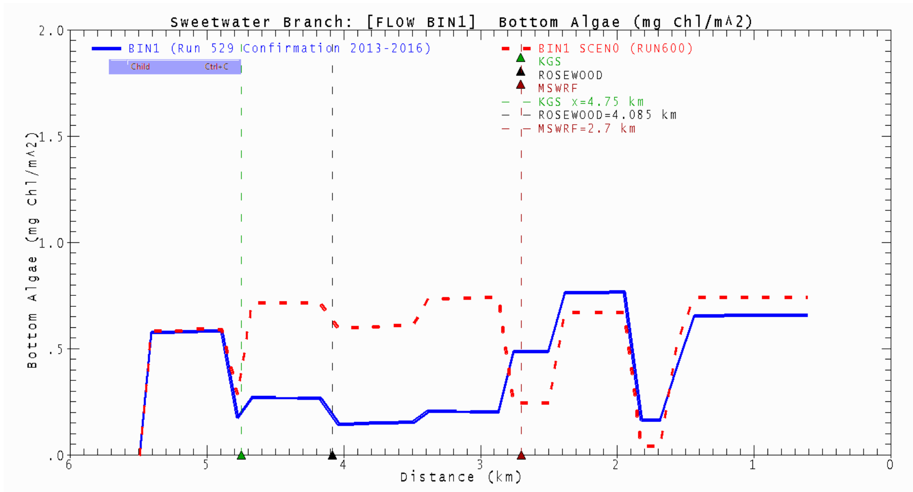
Appendix C

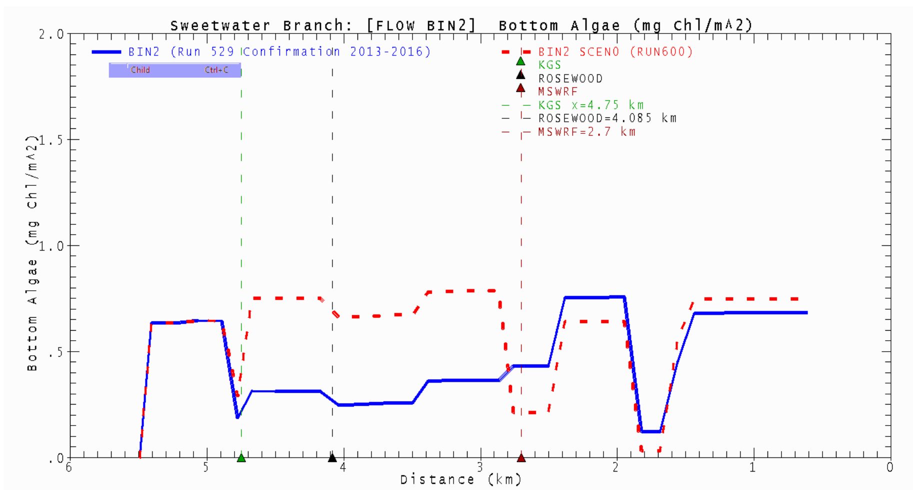
Scenario #0, Run 600

Run 600: Scenario #0
Existing NPDES Permits
(KGS and MSWRF)

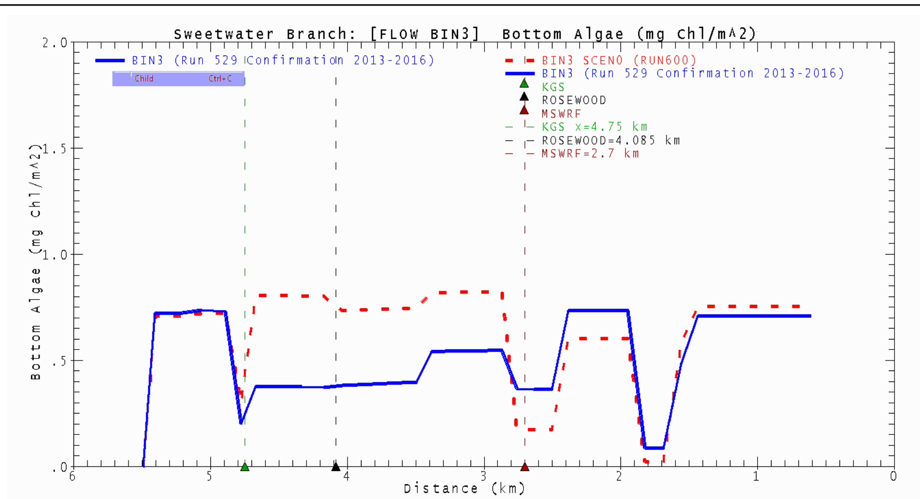
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
BOTALG_	Bottom Algae Chlorophyll-a	mg Chl-a/m^2	2		✓	✓	✓
CHL_	Sestonic Algae Chlorophyll-a	µg Chl-a/L	3		✓	✓	✓
FLOW_	Streamflow	m^3/sec	4		✓	✓	✓
TRAVTIME_	Travel Time	days	5		✓	✓	✓
VEL_	Stream Velocity	m/sec	6		✓	✓	✓
XPERIPHYTON_	Empirical Velocity Function	Multiplier	7			✓	



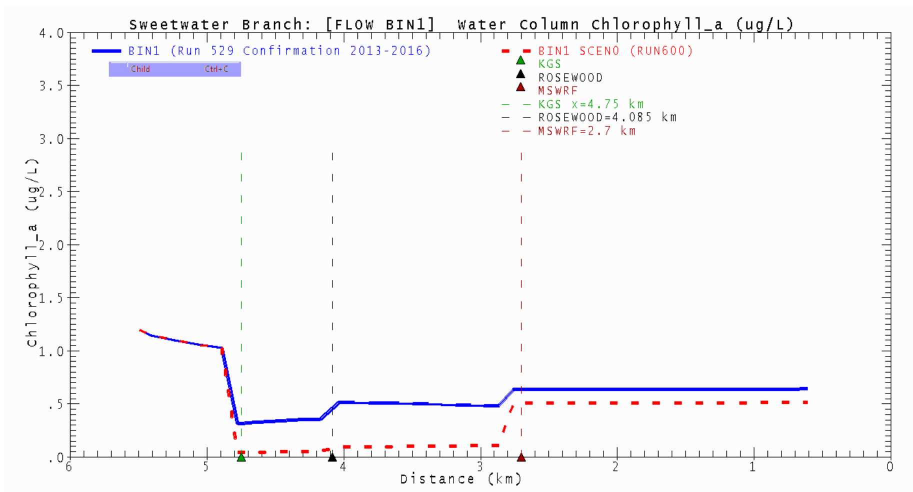
BOTALG_BIN1SCEN0_RUN600.BMP



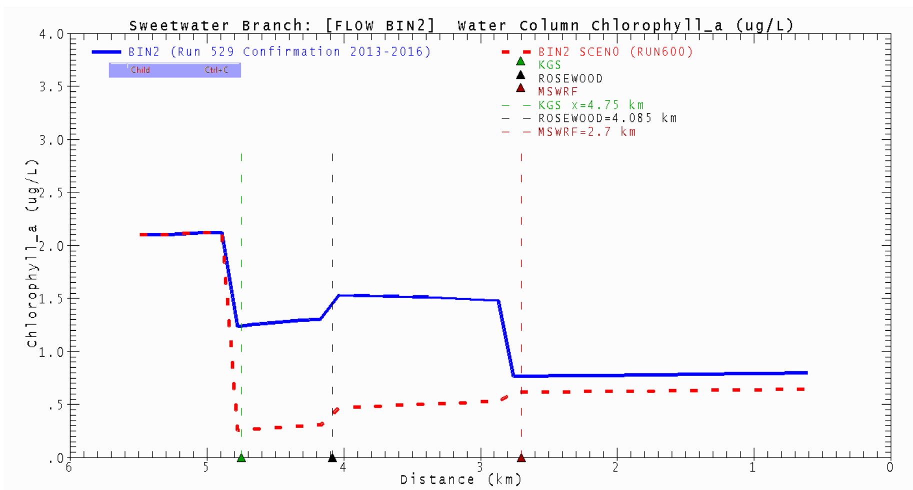
BOTALG_BIN2SCEN0_RUN600.BMP



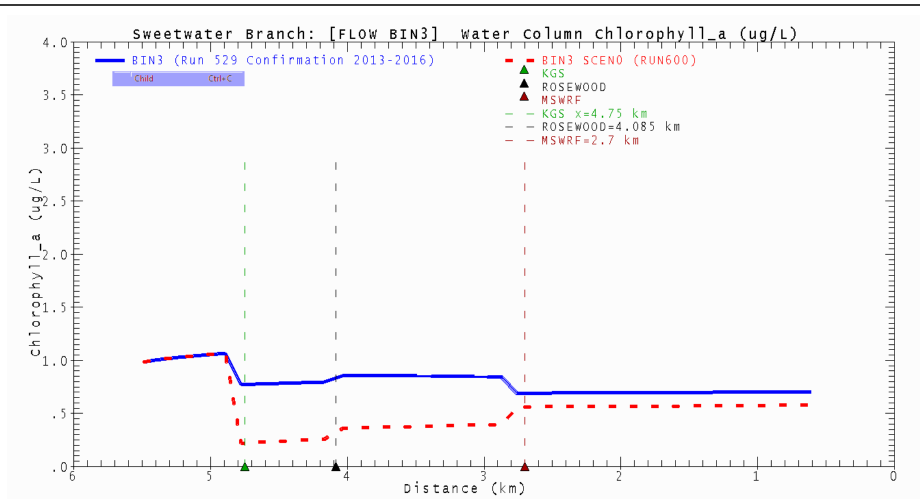
BOTALG_BIN3SCEN0_RUN600.BMP



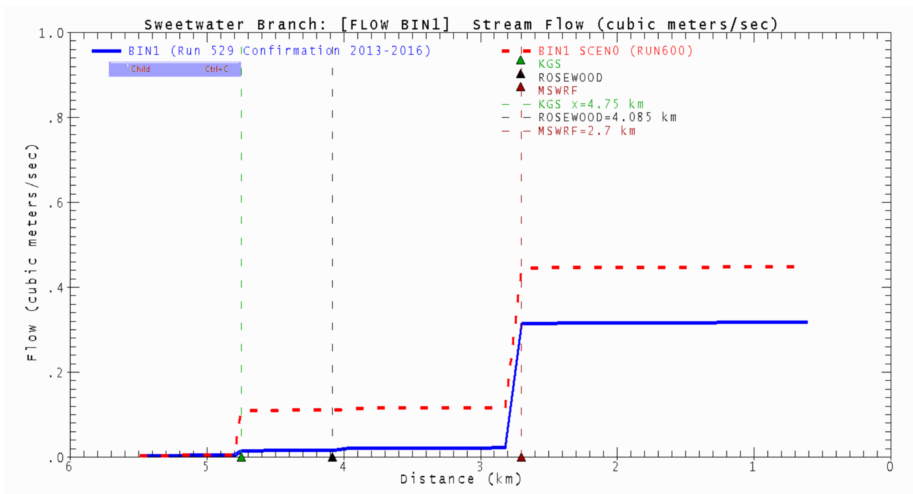
CHL_BIN1SCEN0_RUN600.BMP



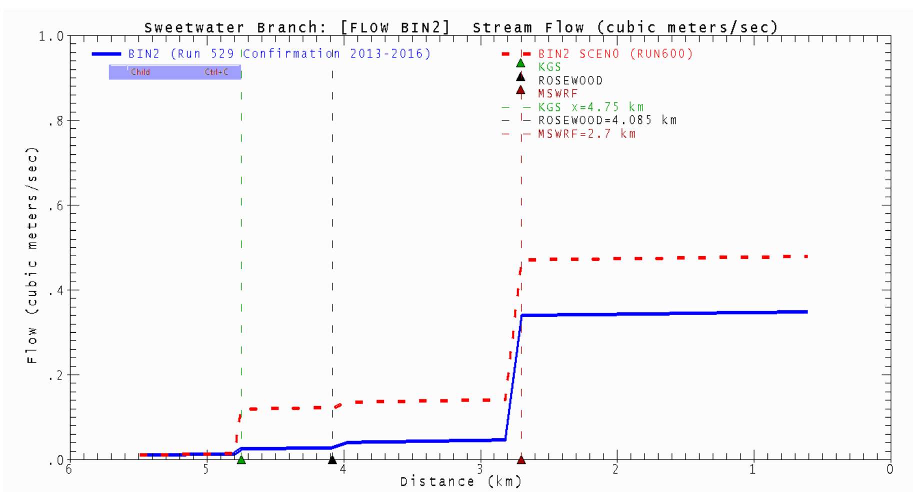
CHL_BIN2SCEN0_RUN600.BMP



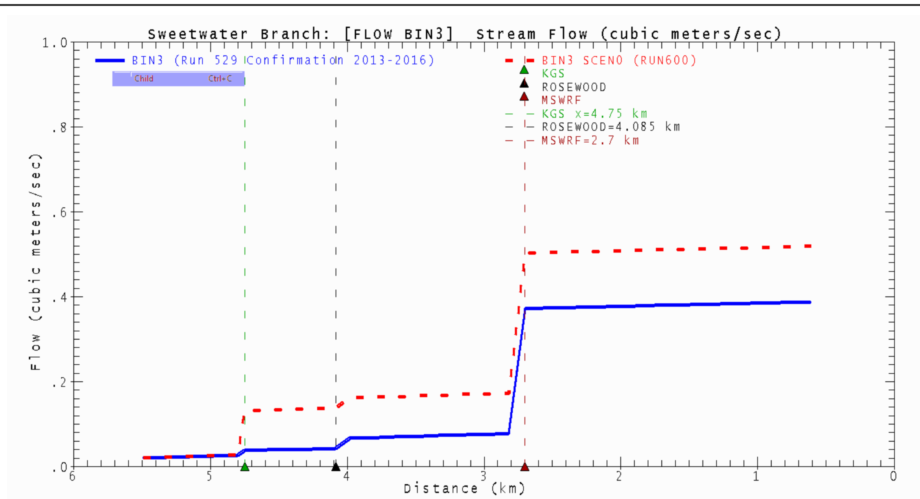
CHL_BIN3SCEN0_RUN600.BMP



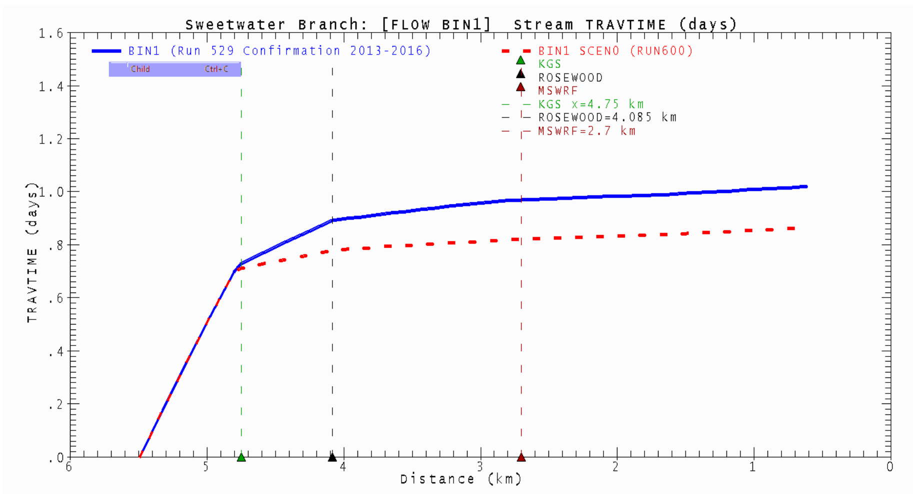
FLOW_BIN1SCEN0_RUN600.BMP



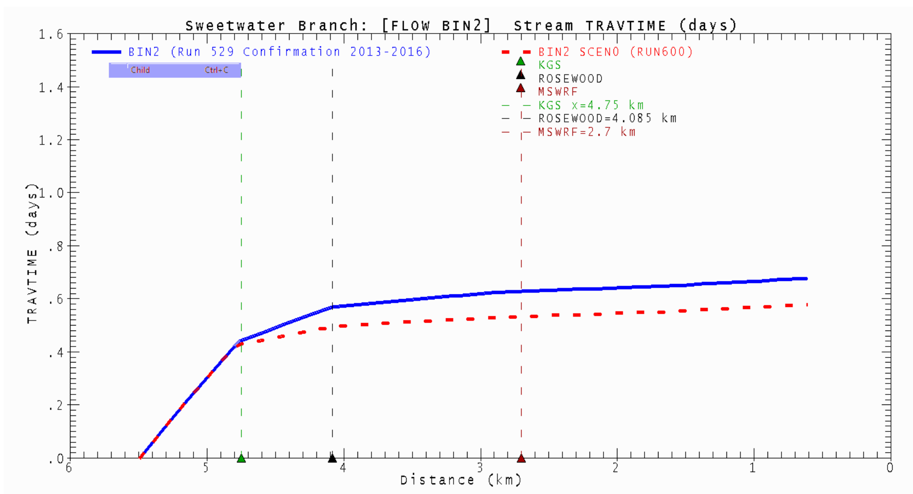
FLOW_BIN2SCEN0_RUN600.BMP



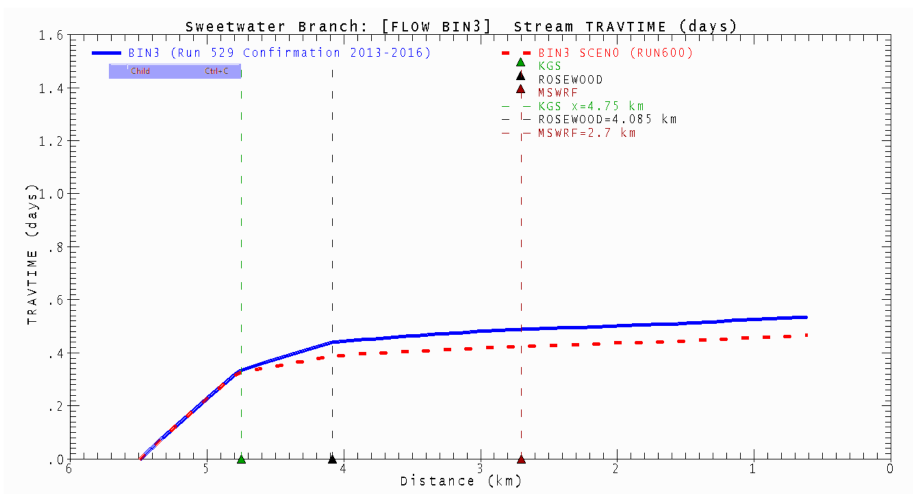
FLOW_BIN3SCEN0_RUN600.BMP



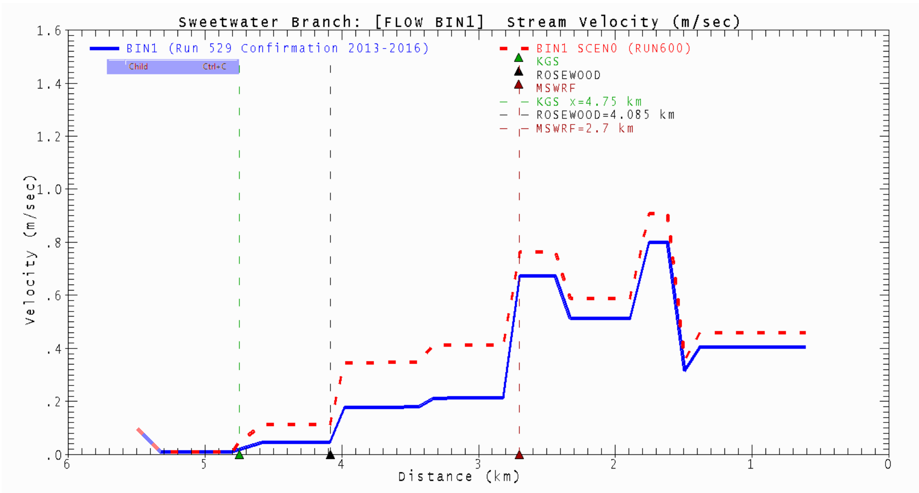
TRAVTIME_BIN1SCEN0_RUN600.BMP



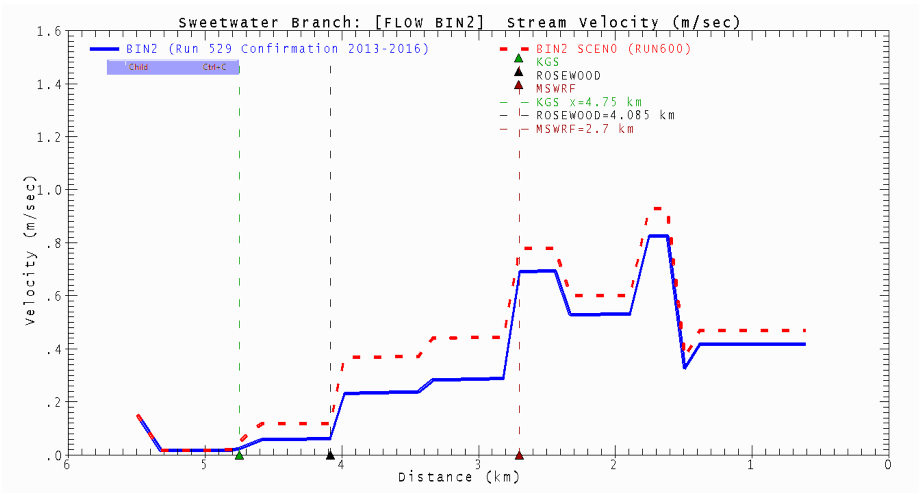
TRAVTIME_BIN2SCEN0_RUN600.BMP



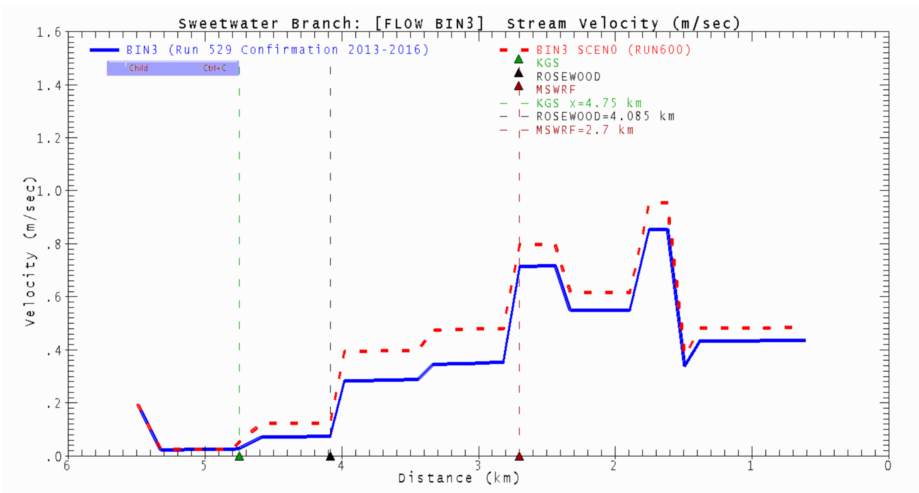
TRAVTIME_BIN3SCEN0_RUN600.BMP



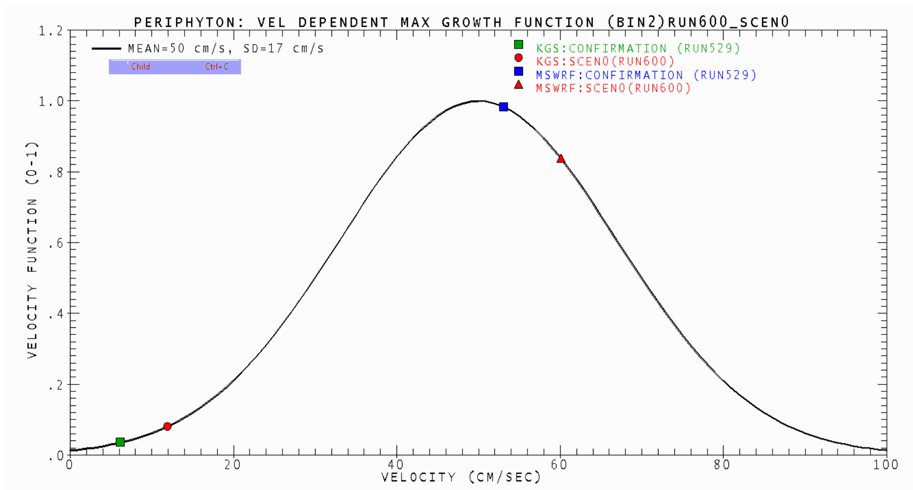
VEL_BIN1SCEN0_RUN600.BMP



VEL_BIN2SCEN0_RUN600.BMP



VEL_BIN3SCEN0_RUN600.BMP



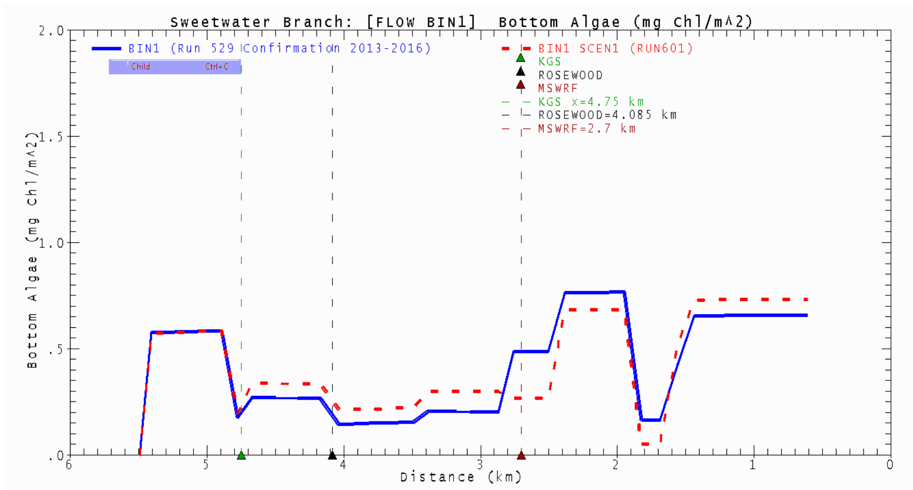
XPERIPHYTON_VEL_GROWFUNCTION(BIN2)RUN600.BMP

Appendix D

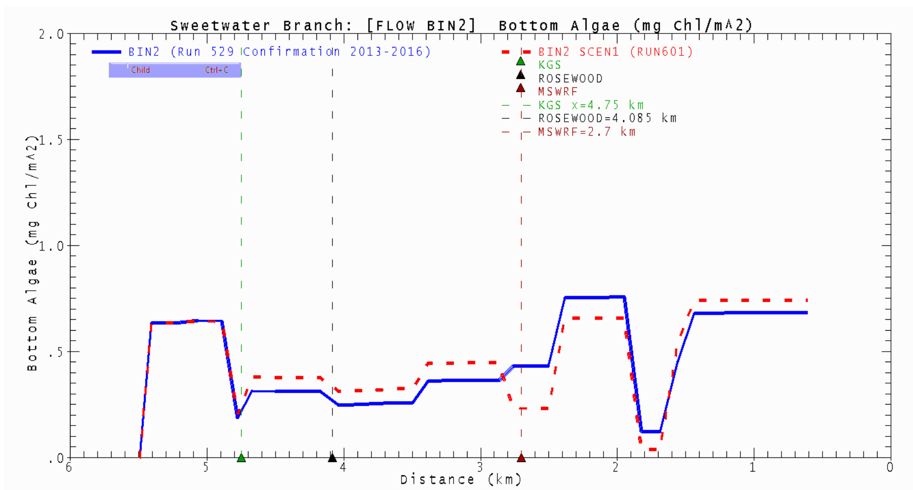
Scenario #1, Run 601

Run 601: Scenario #1
Future Build-Out PS Loads

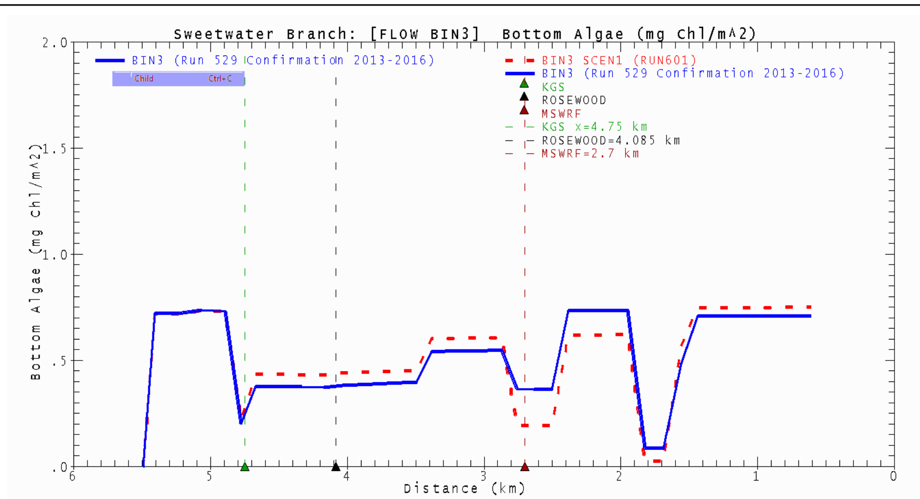
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
BOTALG_	Bottom Algae Chlorophyll-a	mg Chl-a/m^2	2		✓	✓	✓
CHL_	Sestonic Algae Chlorophyll-a	µg Chl-a/L	3		✓	✓	✓
FLOW_	Streamflow	m^3/sec	4		✓	✓	✓
TRAVTIME_	Travel Time	days	5		✓	✓	✓
VEL_	Stream Velocity	m/sec	6		✓	✓	✓
XPERIPHYTON_	Empirical Growth as f(Velocity)	Multiplier	7			✓	



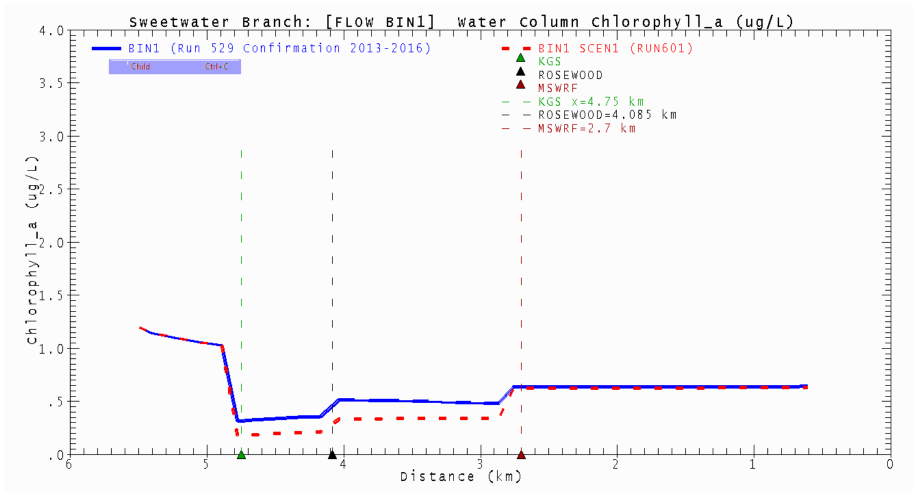
BOTALG_BIN1SCEN1_RUN601.BMP



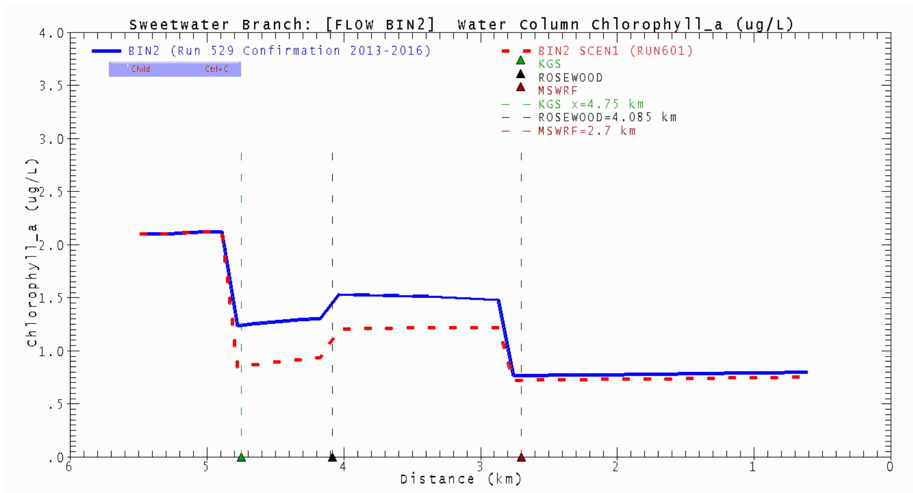
BOTALG_BIN2SCEN1_RUN601.BMP



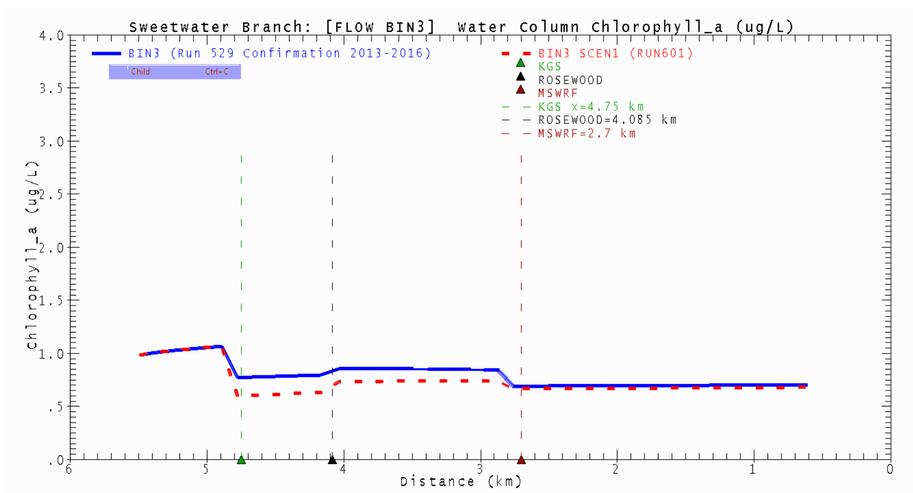
BOTALG_BIN3SCEN1_RUN601.BMP



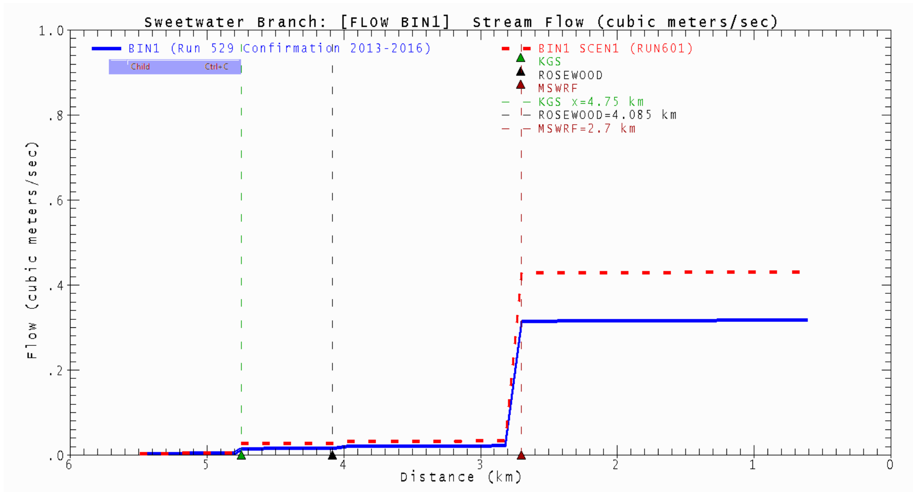
CHL_BIN1SCEN1_RUN601.BMP



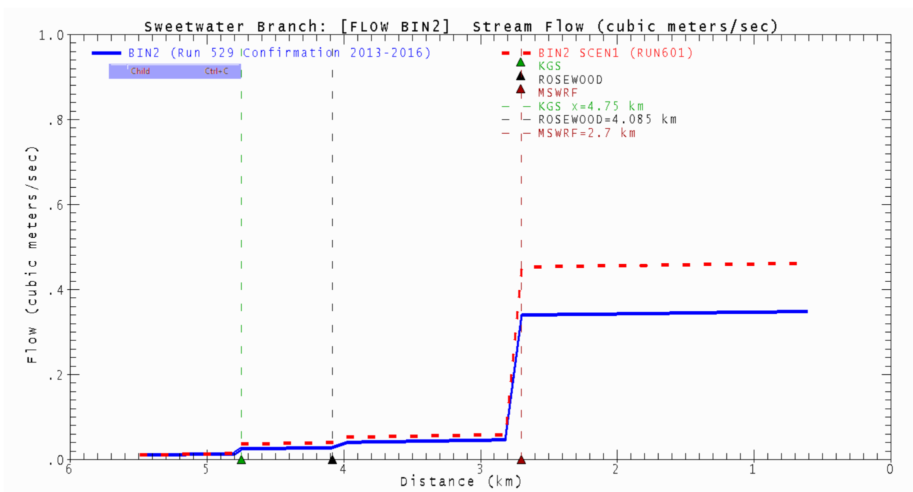
CHL_BIN2SCEN1_RUN601.BMP



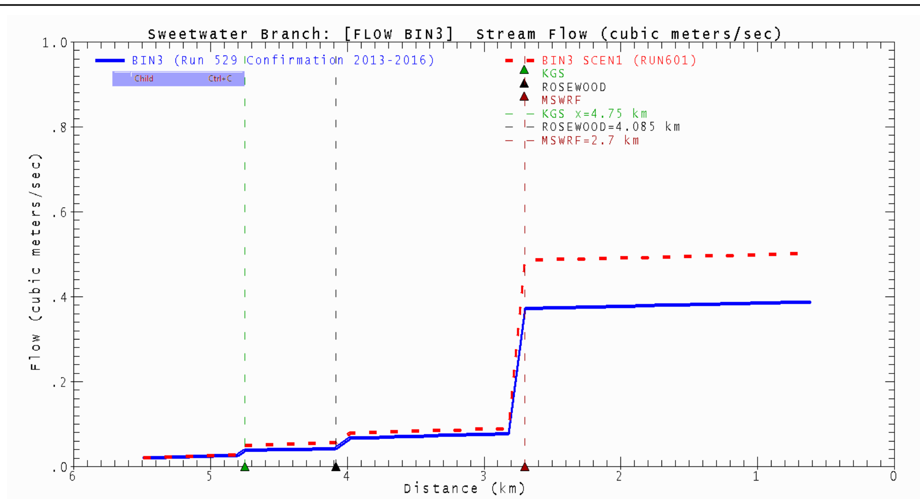
CHL_BIN3SCEN1_RUN601.BMP



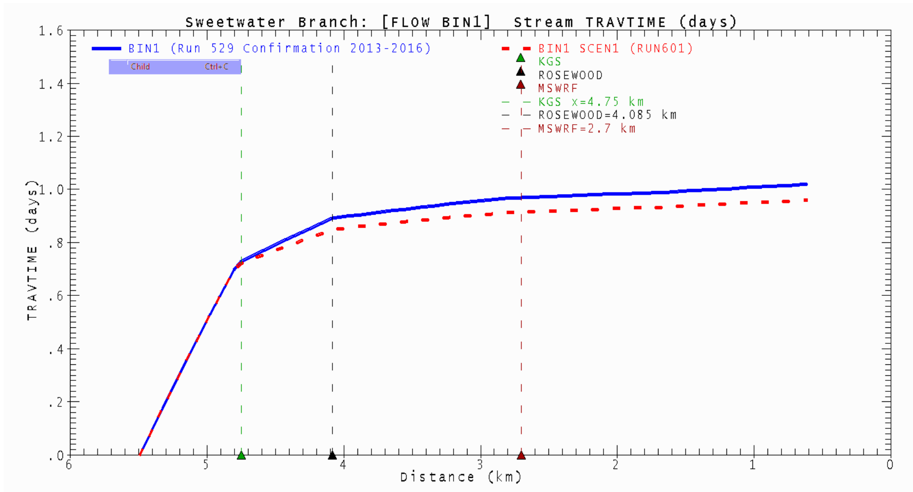
FLOW_BIN1SCEN1_RUN601.BMP



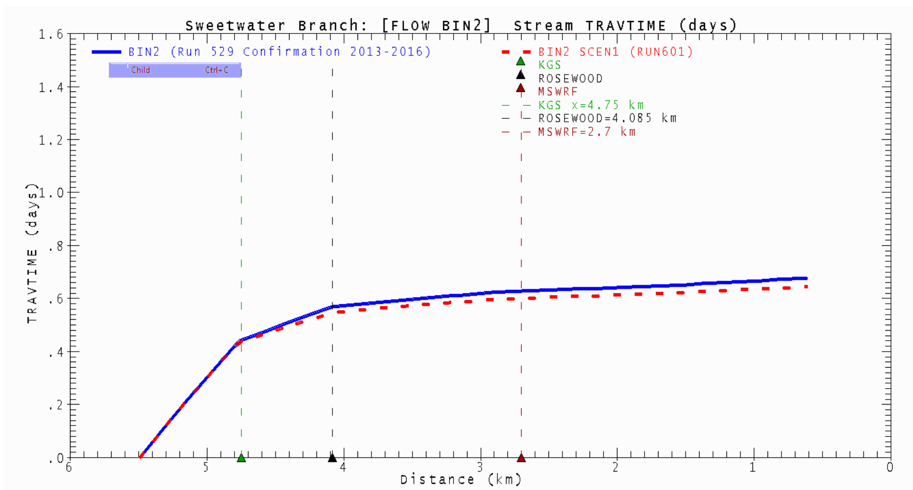
FLOW_BIN2SCEN1_RUN601.BMP



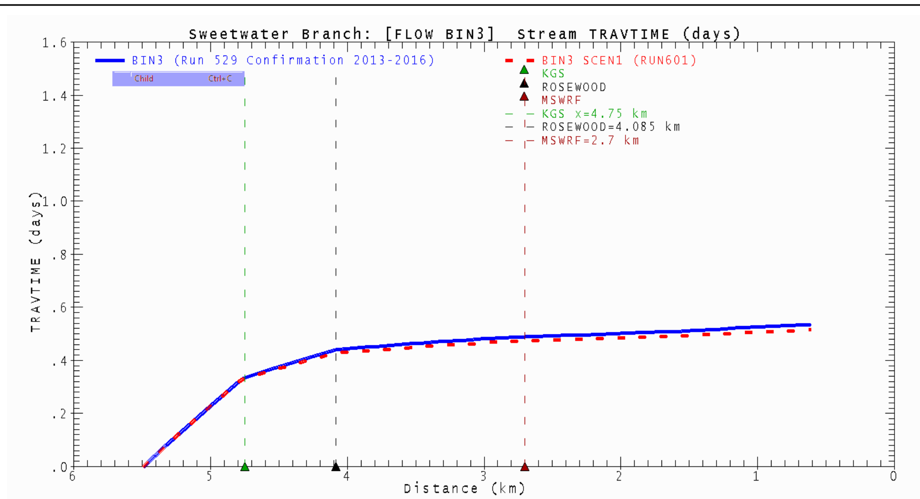
FLOW_BIN3SCEN1_RUN601.BMP



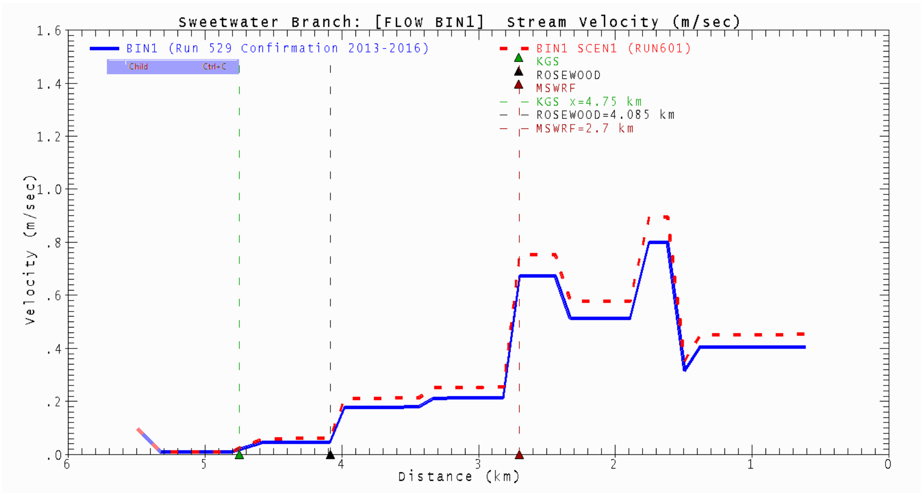
TRAVTIME_BIN1SCEN1_RUN601.BMP



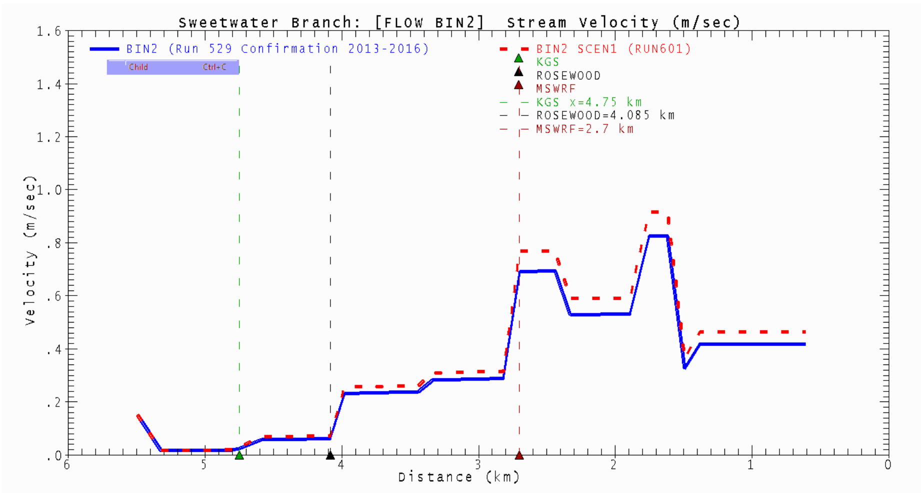
TRAVTIME_BIN2SCEN1_RUN601.BMP



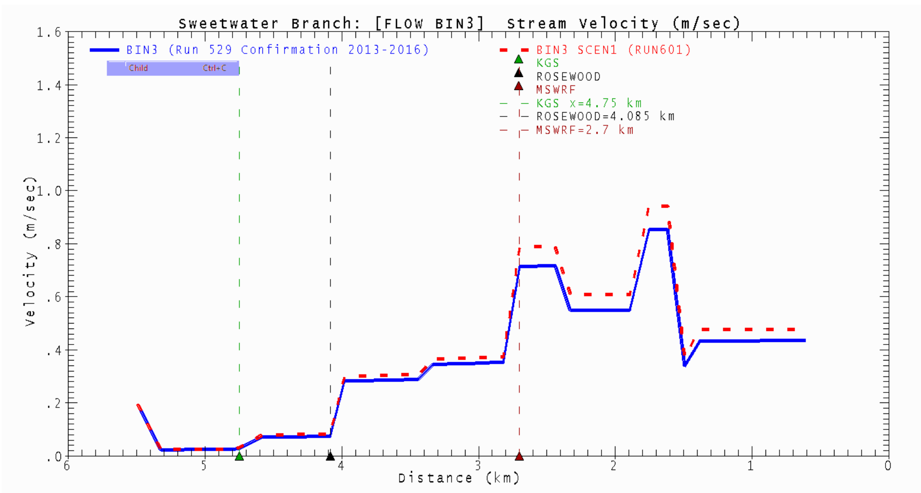
TRAVTIME_BIN3SCEN1_RUN601.BMP



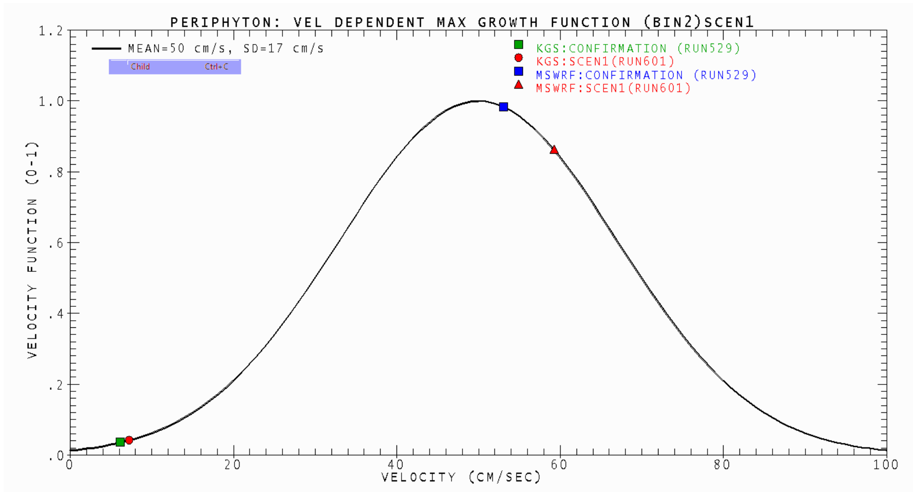
VEL_BIN1SCEN1_RUN601.BMP



VEL_BIN2SCEN1_RUN601.BMP



VEL_BIN3SCEN1_RUN601.BMP



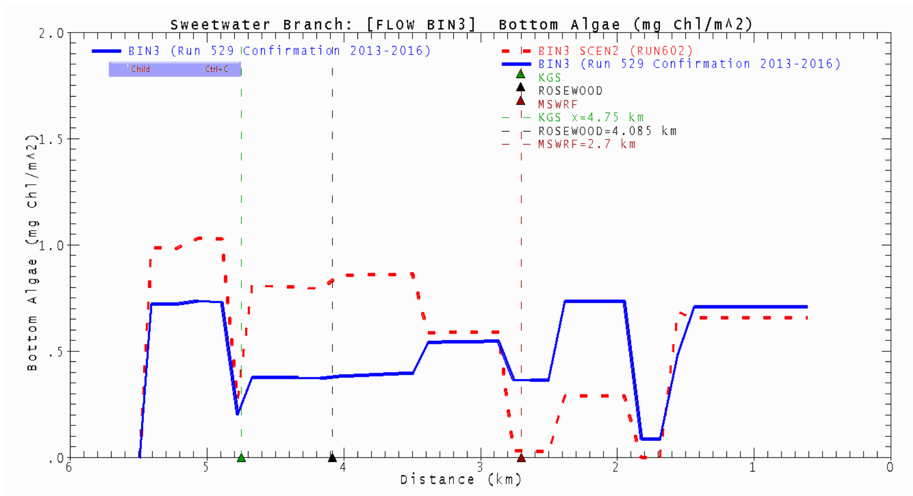
XPERIPHYTON_VEL_GROWFUNCTION(BIN2)RUN601.BMP

Appendix E

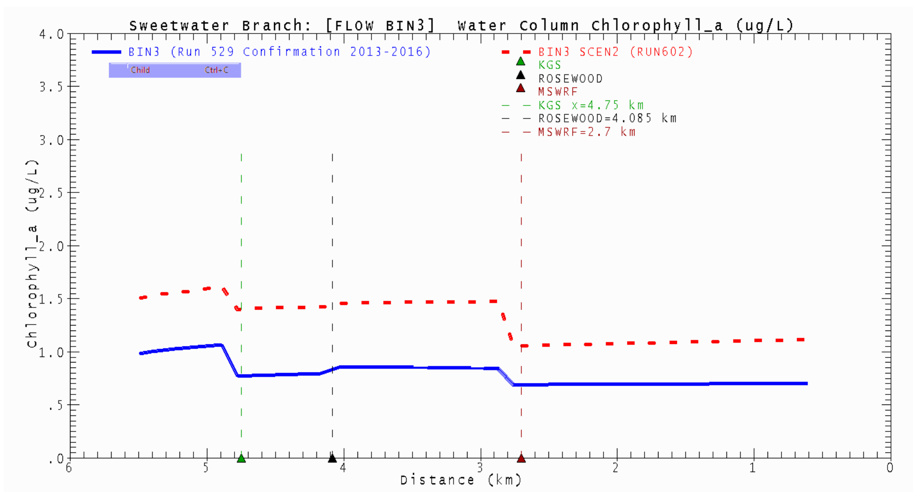
Scenario #2, Run 602

Run 602: Scenario #2
Nonpoint Source Stormwater Loads

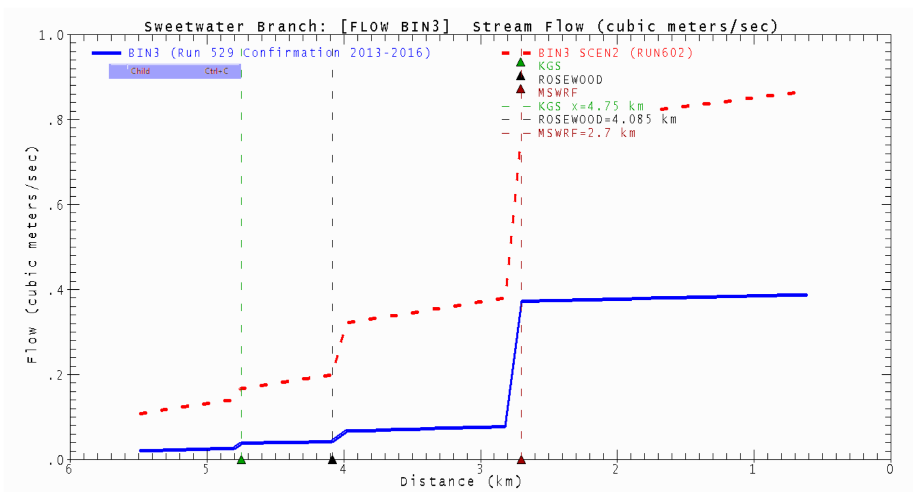
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
BOTALG_	Bottom Algae Chlorophyll-a	mg Chl-a/m^2	2		NA	NA	✓
CHL_	Sestonic Algae Chlorophyll-a	µg Chl-a/L	2		NA	NA	✓
FLOW_	Streamflow	m^3/sec	2		NA	NA	✓
TRAVTIME_	Travel Time	days	3		NA	NA	✓
VEL_	Stream Velocity	m/sec	3		NA	NA	✓
XPERIPHYTON_	Empirical Velocity Function	Multiplier	3		NA	NA	✓



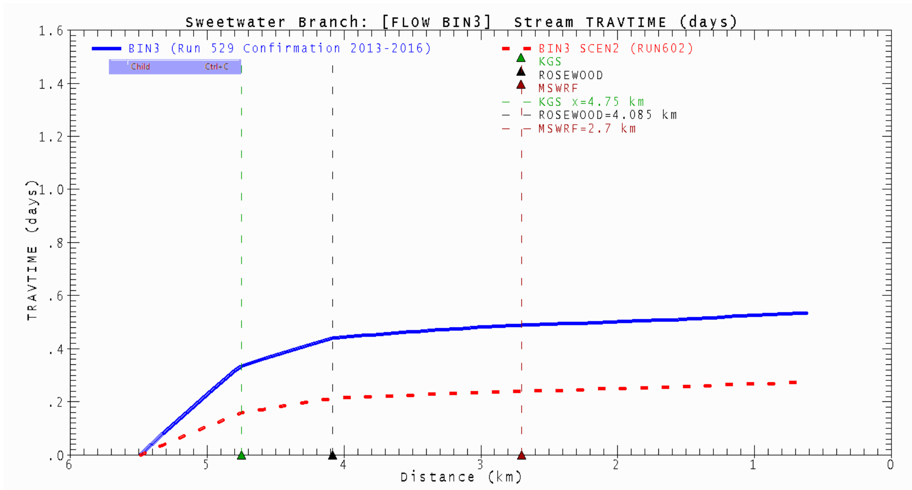
BOTALG_BIN3SCEN2_RUN602.BMP



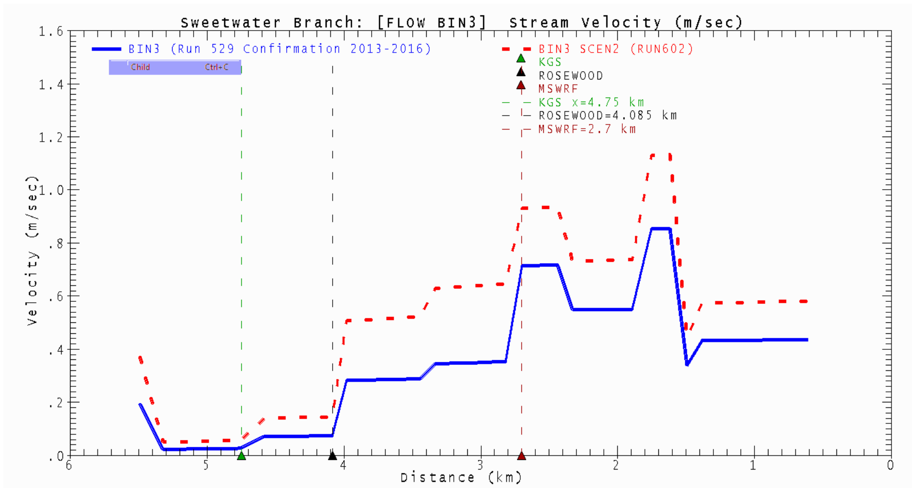
CHL_BIN3SCEN2_RUN602.BMP



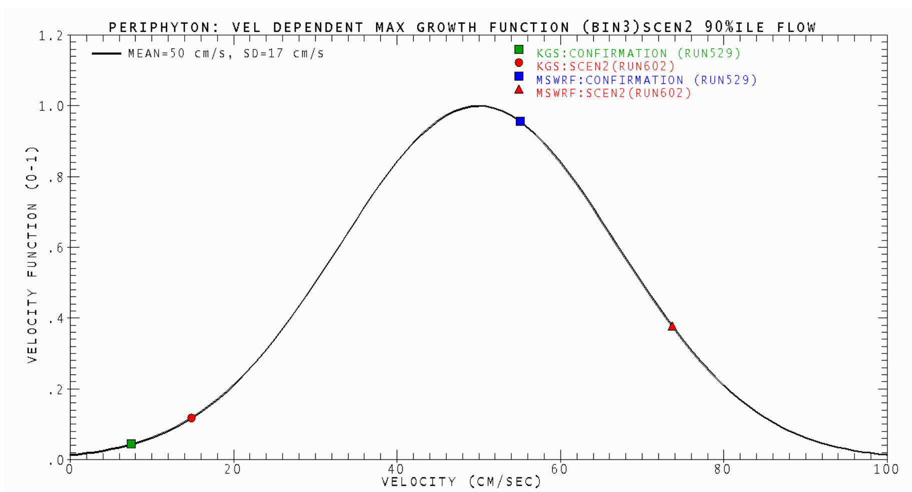
FLOW_BIN3SCEN2_RUN602.BMP



TRAVTIME_BIN3SCEN2_RUN602.BMP



VEL_BIN3SCEN2_RUN602.BMP



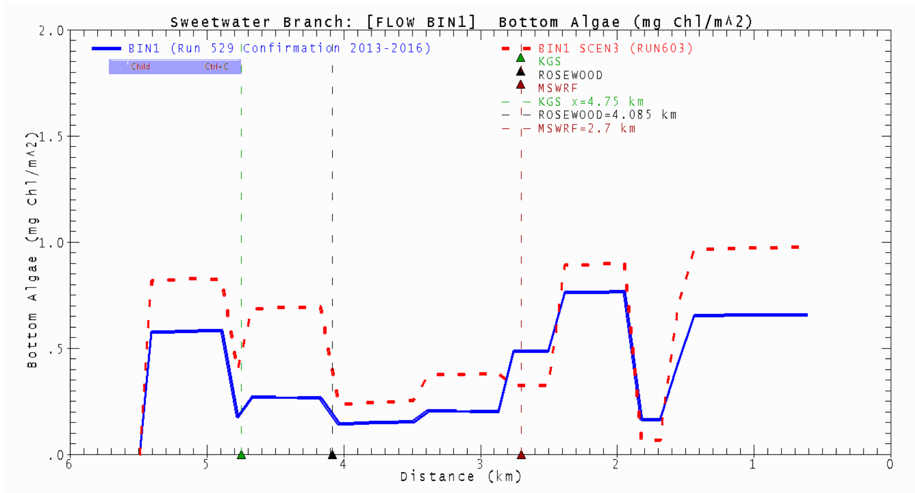
XPERIPHYTON_VEL_GROWFUNCTION(BIN3)RUN602.BMP

Appendix F

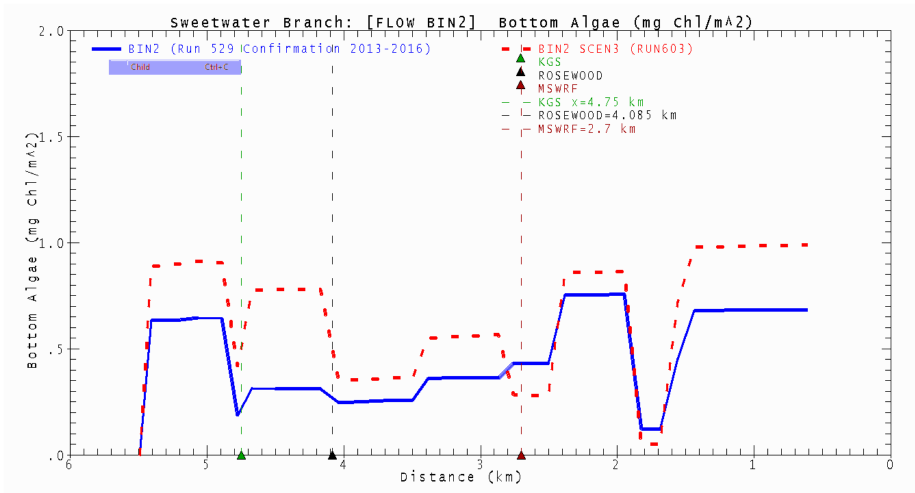
Scenario #3, Run 603

Run 603: Scenario #3
Model Sensitivity to Shade Coverage

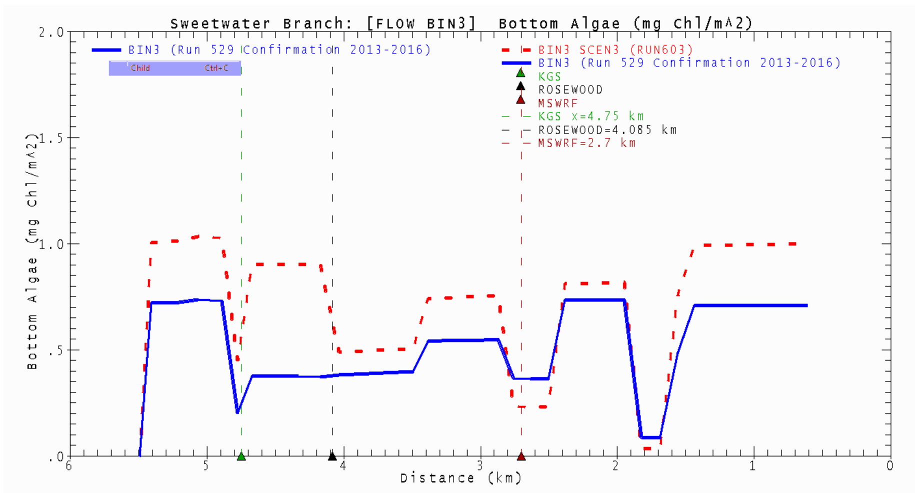
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
BOTALG_	Bottom Algae Chlorophyll-a	mg Chl-a/m^2	2		✓	✓	✓
CHL_	Sestonic Algae Chlorophyll-a	µg Chl-a/L	3		✓	✓	✓
FLOW_	Streamflow	m^3/sec	4		✓	✓	✓
TRAVTIME_	Travel Time	days	5		✓	✓	✓
VEL_	Stream Velocity	m/sec	6		✓	✓	✓
XPERIPHYTON	Empirical Growth as f(Velocity)	Multiplier	7			✓	



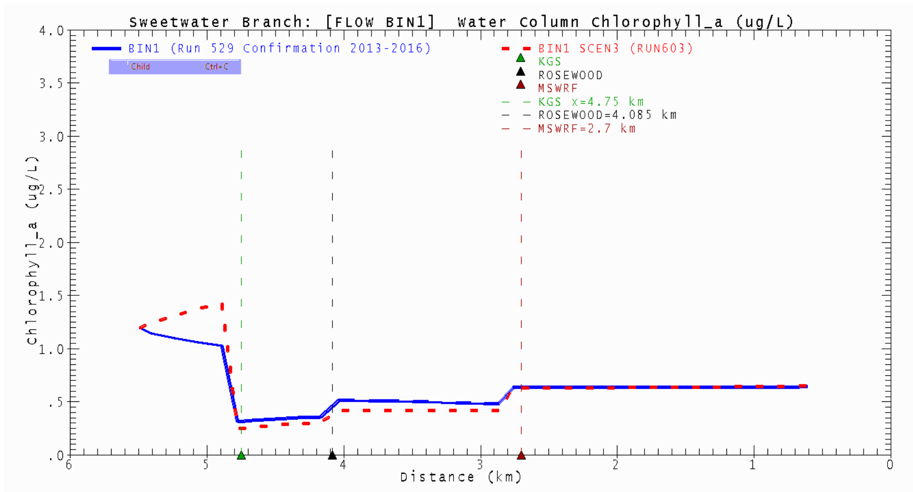
BOTALG_BIN1SCEN3_RUN603.BMP



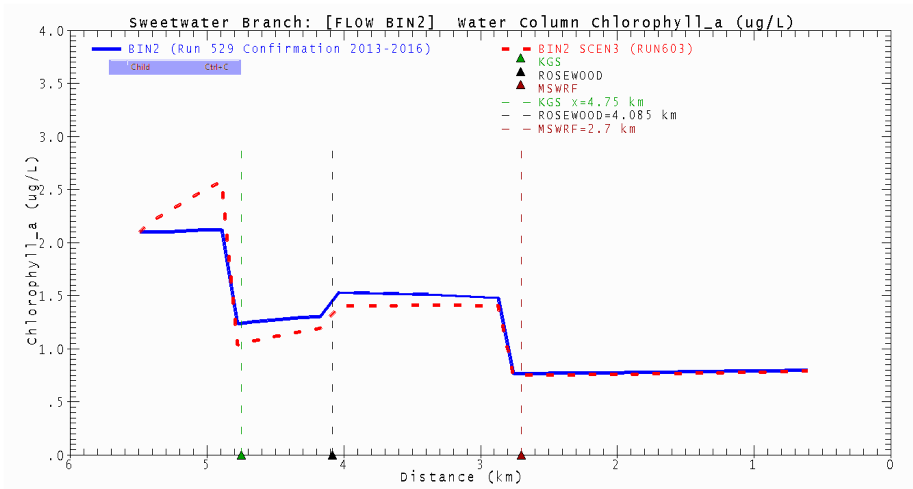
BOTALG_BIN2SCEN3_RUN603.BMP



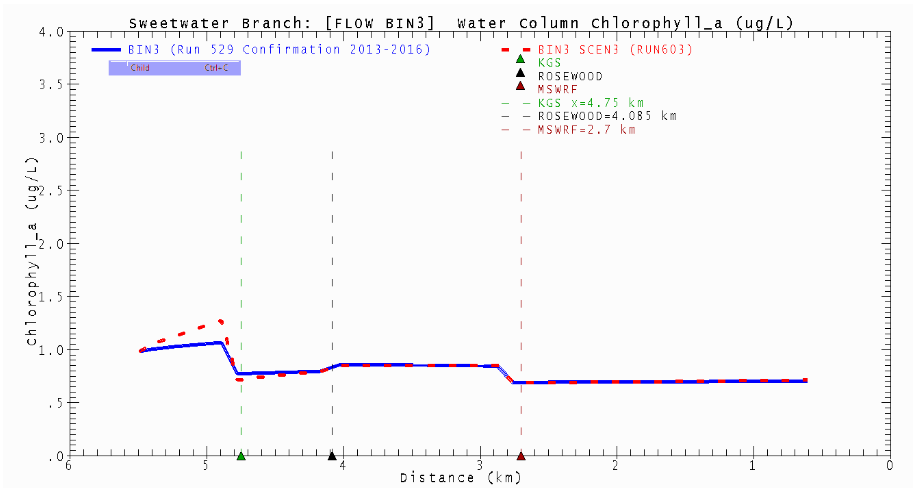
BOTALG_BIN3SCEN3_RUN603.BMP



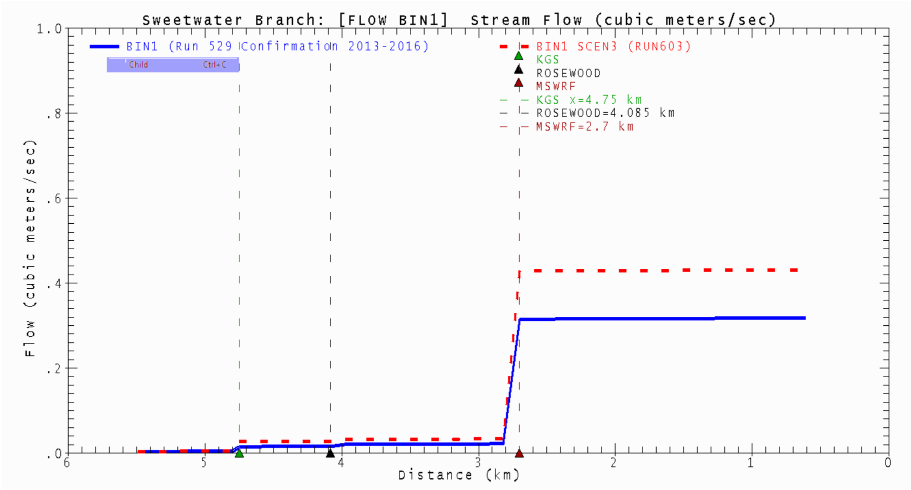
CHL_BIN1SCEN3_RUN603.BMP



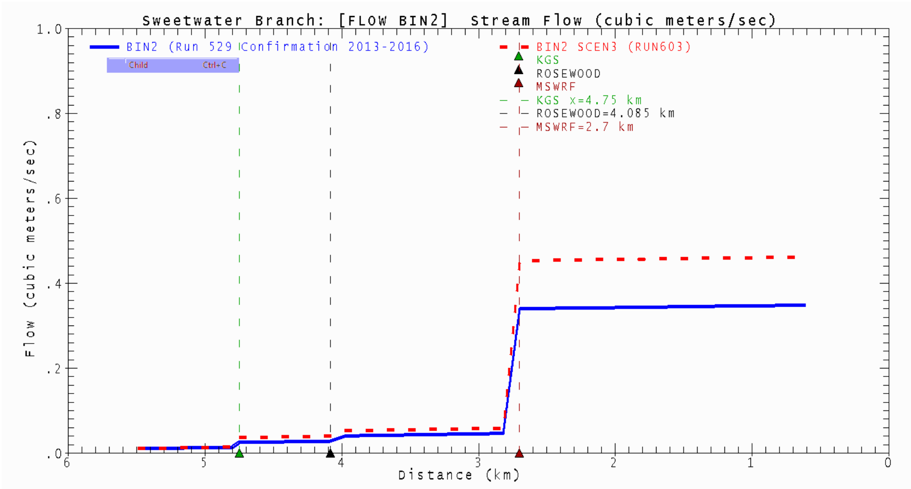
CHL_BIN2SCEN3_RUN603.BMP



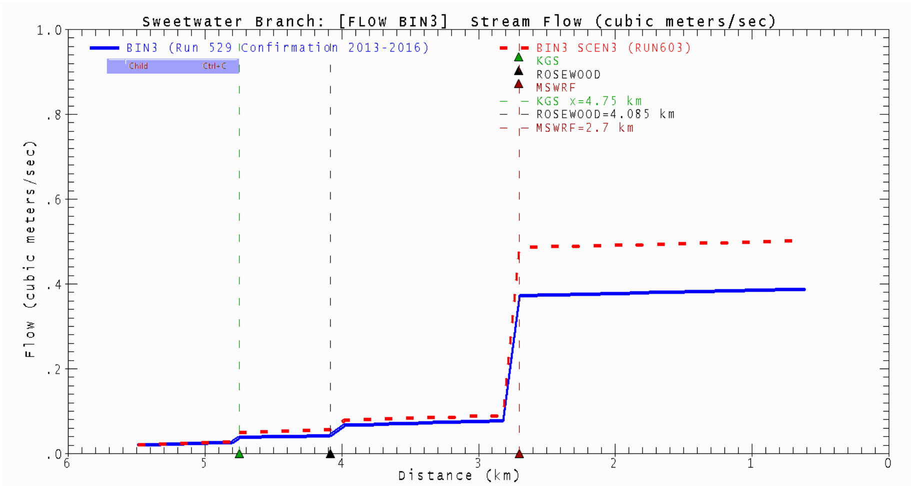
CHL_BIN3SCEN3_RUN603.BMP



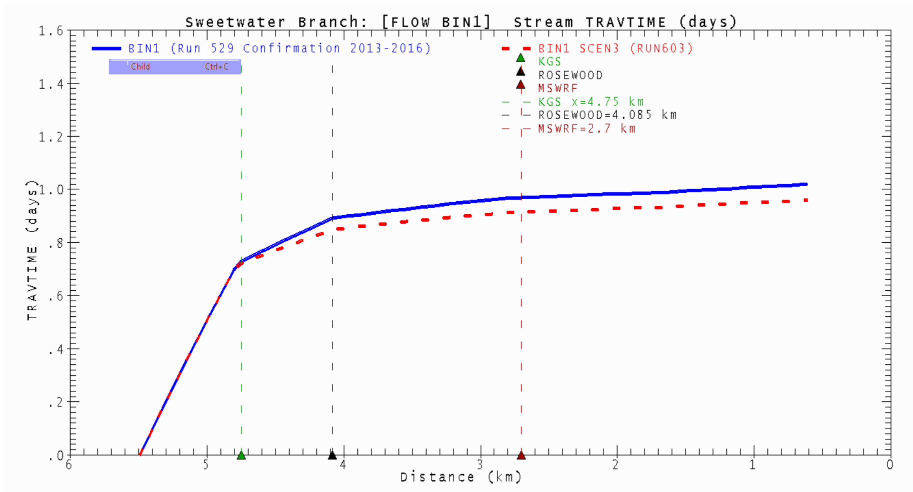
FLOW_BIN1SCEN3_RUN603.BMP



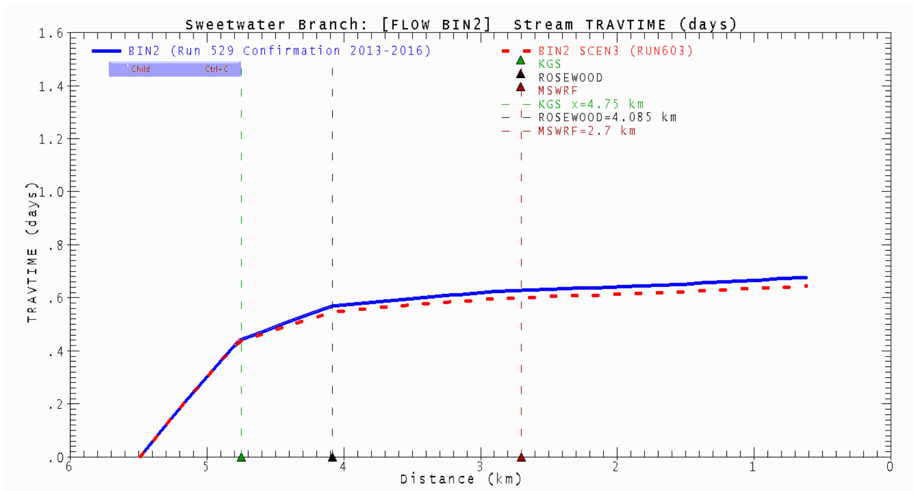
FLOW_BIN2SCEN3_RUN603.BMP



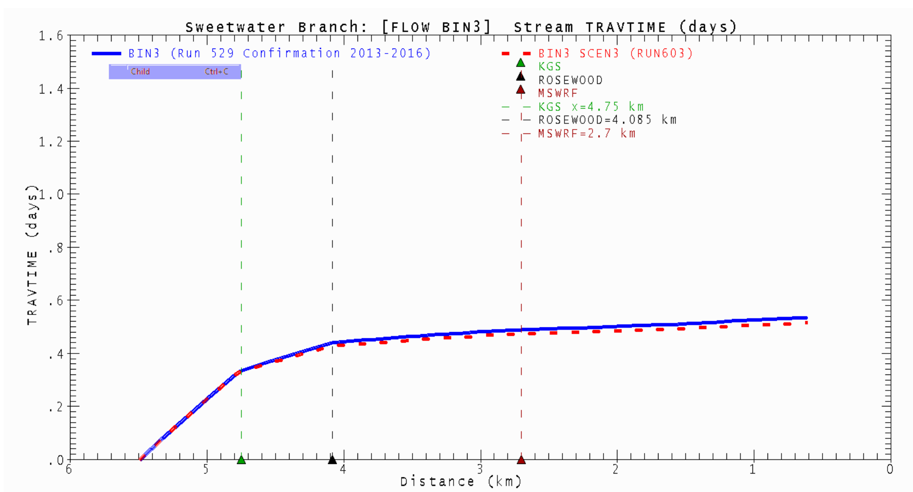
FLOW_BIN3SCEN3_RUN603.BMP



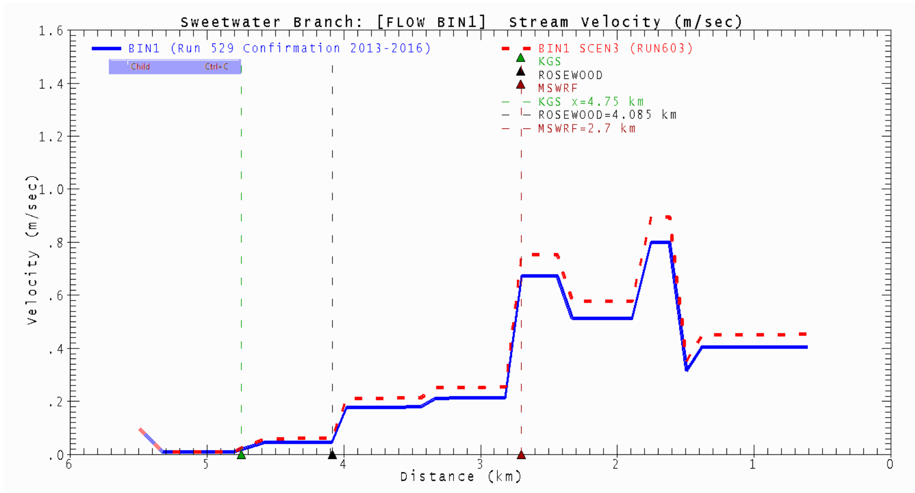
TRAVTIME_BIN1SCEN3_RUN603.BMP



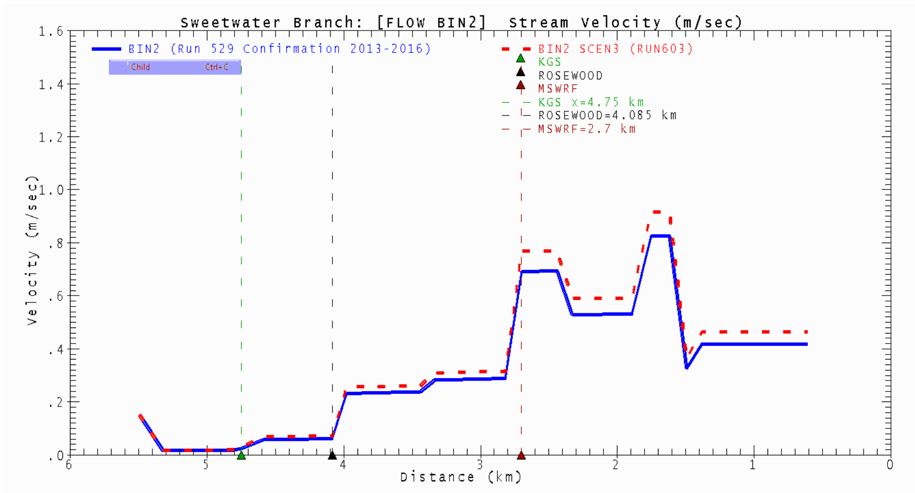
TRAVTIME_BIN2SCEN3_RUN603.BMP



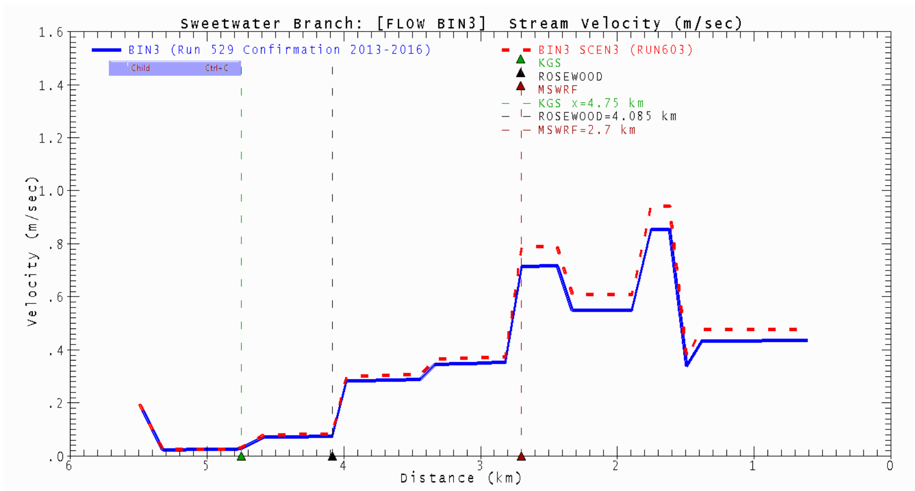
TRAVTIME_BIN3SCEN3_RUN603.BMP



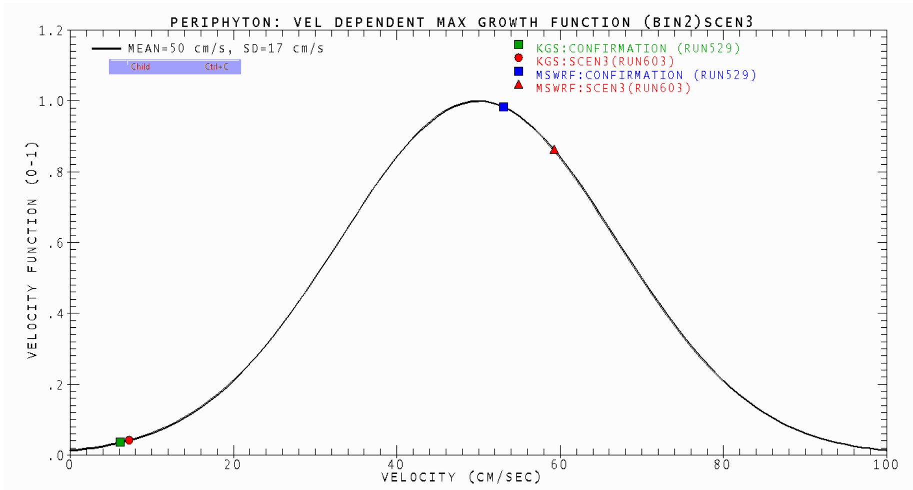
VEL_BIN1SCEN3_RUN603.BMP



VEL_BIN2SCEN3_RUN603.BMP



VEL_BIN3SCEN3_RUN603.BMP



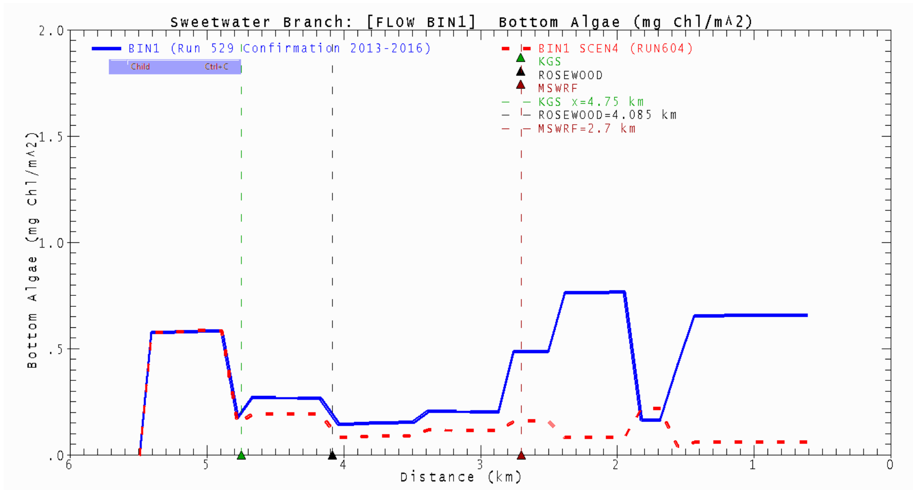
XPERIPHYTON_VEL_GROWFUNCTION(BIN2)RUN603.BMP

Appendix G

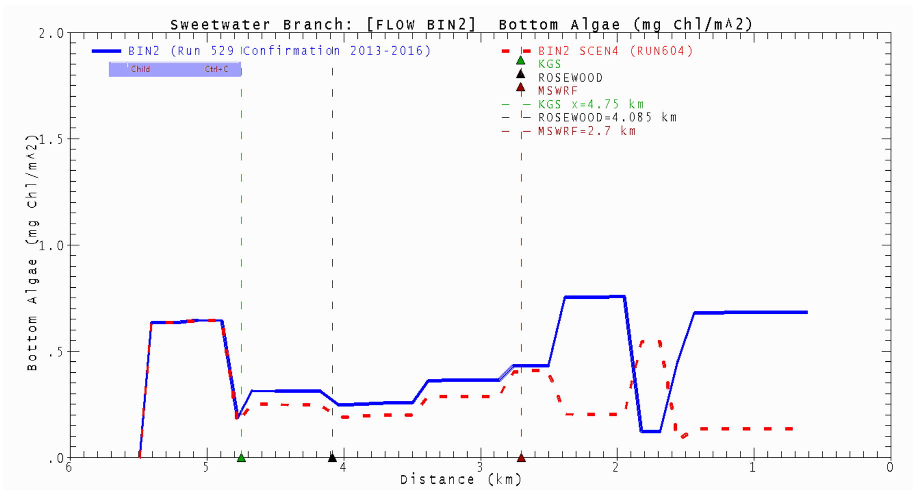
Scenario #4, Run 604

Run 604: Scenario #4
Model Sensitivity to NPDES PS Discharges

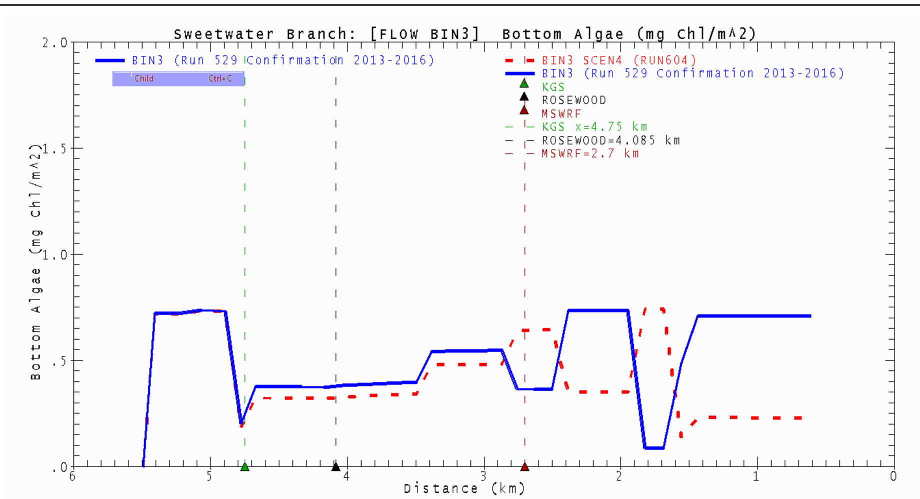
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
BOTALG_	Bottom Algae Chlorophyll-a	mg Chl-a/m^2	2		✓	✓	✓
CHL_	Sestonic Algae Chlorophyll-a	µg Chl-a/L	3		✓	✓	✓
FLOW_	Streamflow	m^3/sec	4		✓	✓	✓
TRAVTIME_	Travel Time	days	5		✓	✓	✓
VEL_	Stream Velocity	m/sec	6		✓	✓	✓
XPERIPHYTON_	Empirical Growth as f(Velocity)	Multiplier	7			✓	



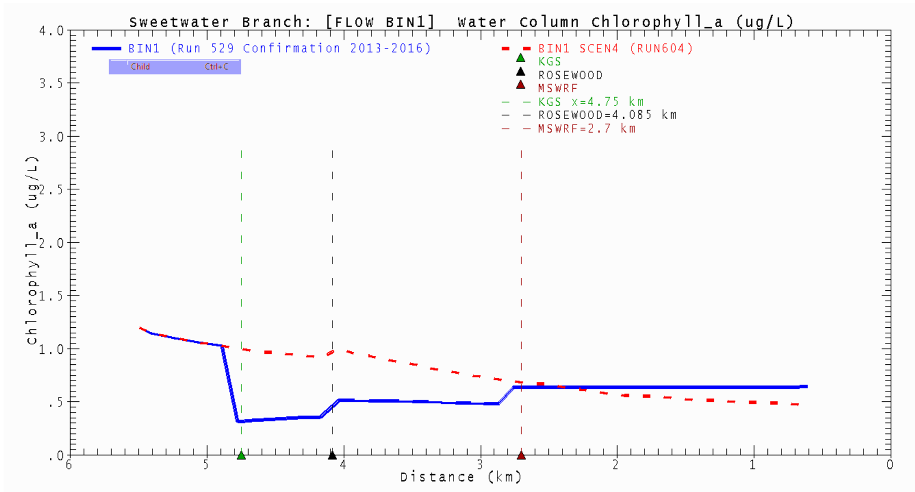
BOTALG_BIN1SCEN4_RUN604.BMP



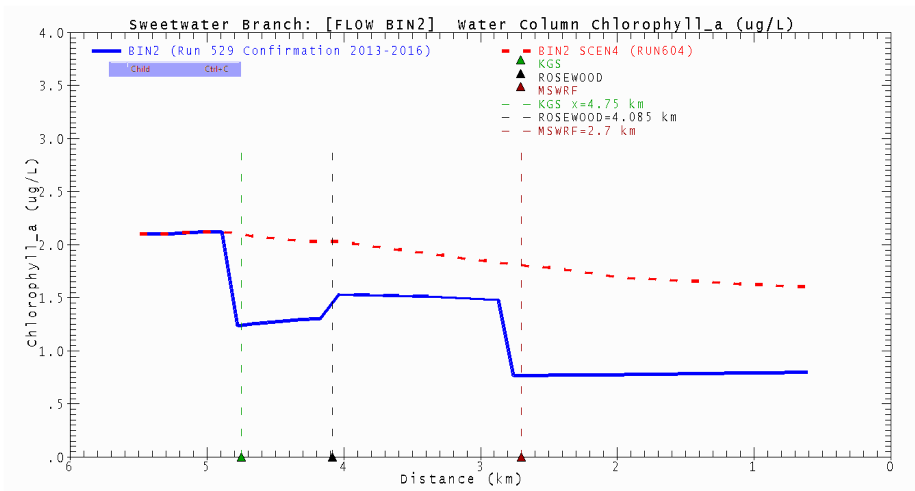
BOTALG_BIN2SCEN4_RUN604.BMP



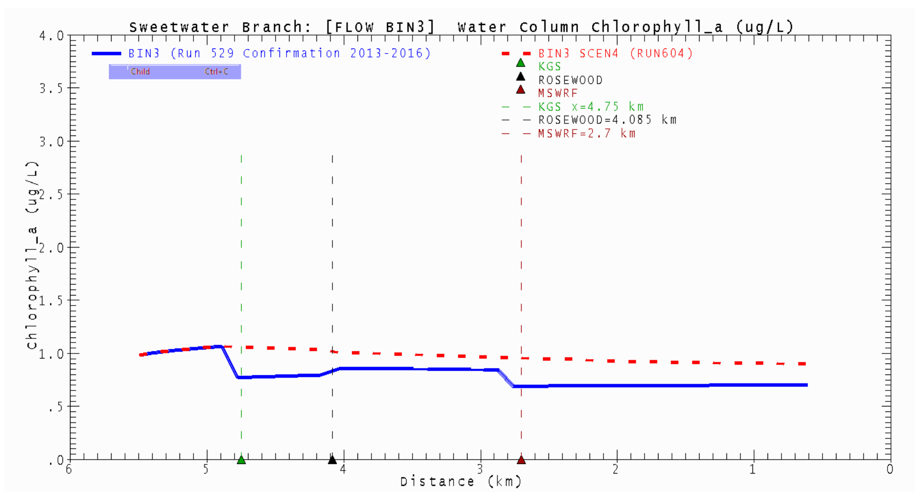
BOTALG_BIN3SCEN4_RUN604.BMP



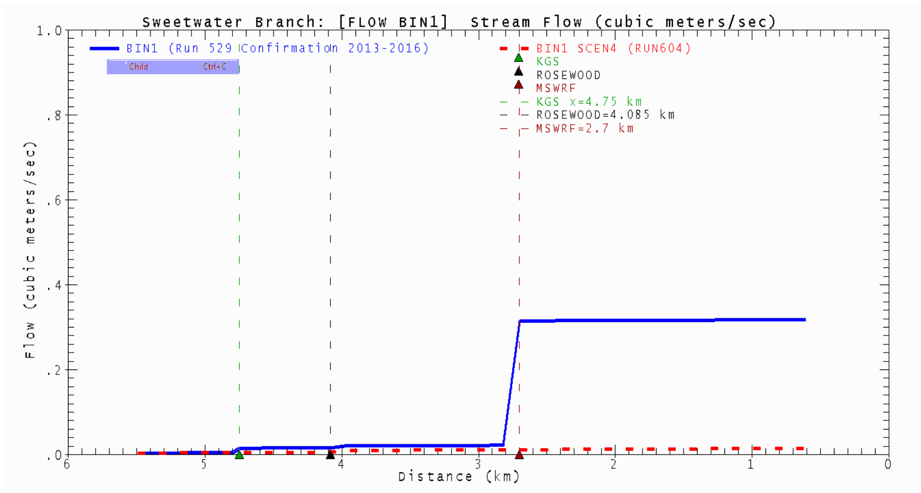
CHL_BIN1SCEN4_RUN604.BMP



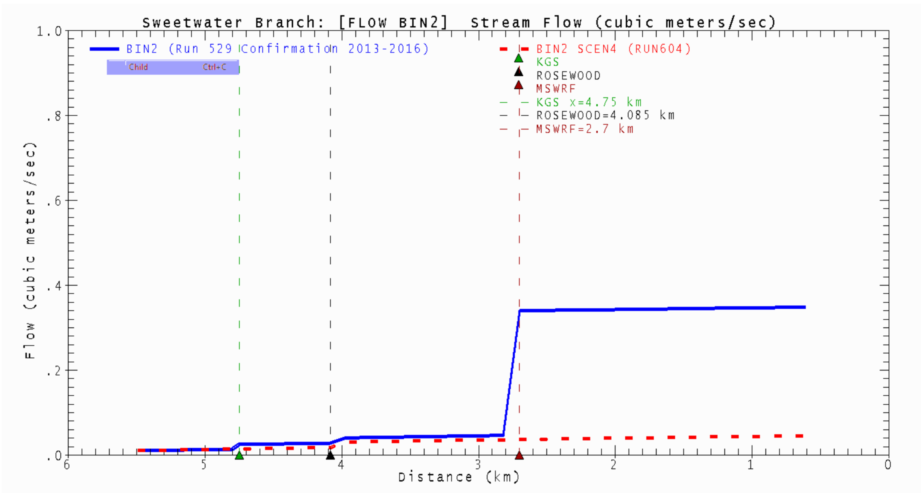
CHL_BIN2SCEN4_RUN604.BMP



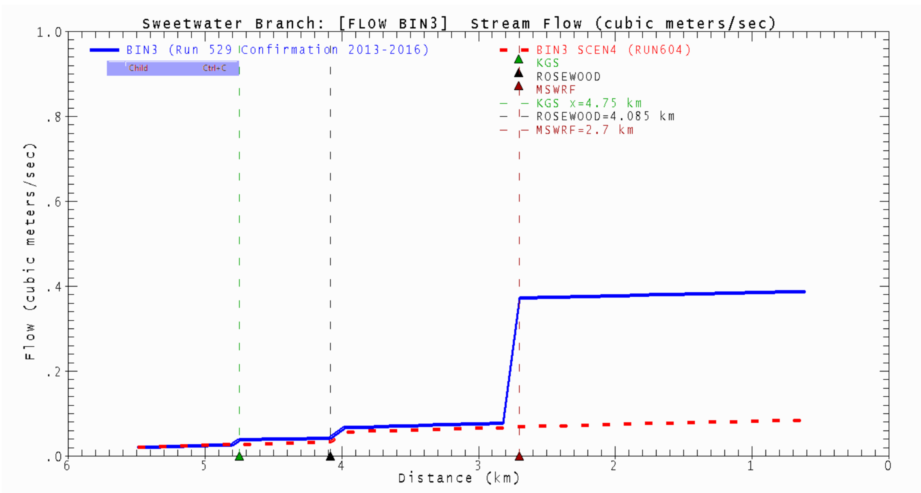
CHL_BIN3SCEN4_RUN604.BMP



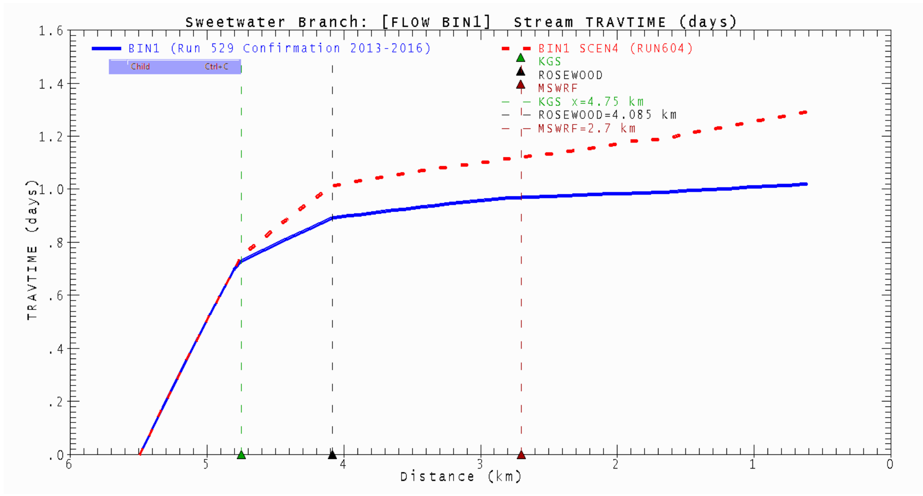
FLOW_BIN1SCEN4_RUN604.BMP



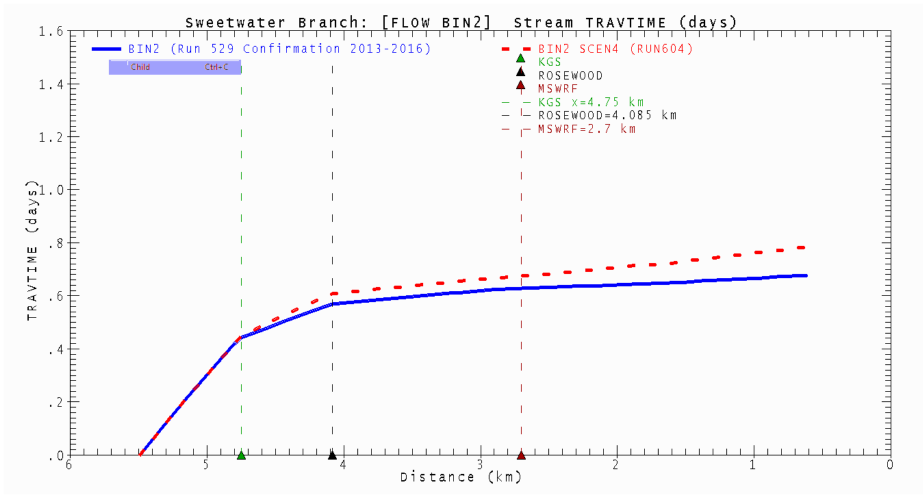
FLOW_BIN2SCEN4_RUN604.BMP



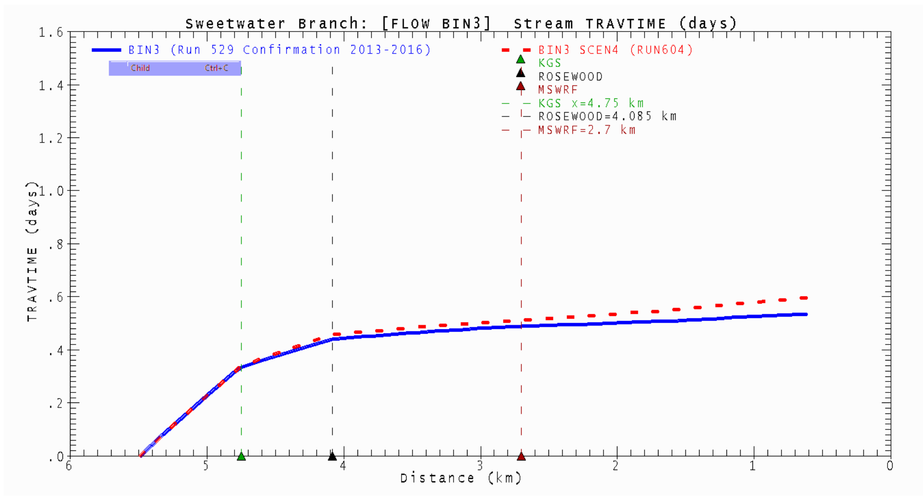
FLOW_BIN3SCEN4_RUN604.BMP



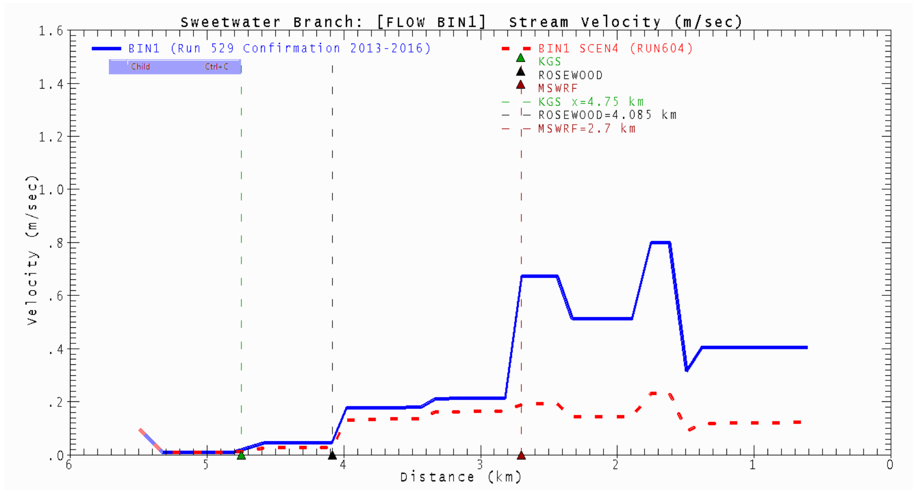
TRAVTIME_BIN1SCEN4_RUN604.BMP



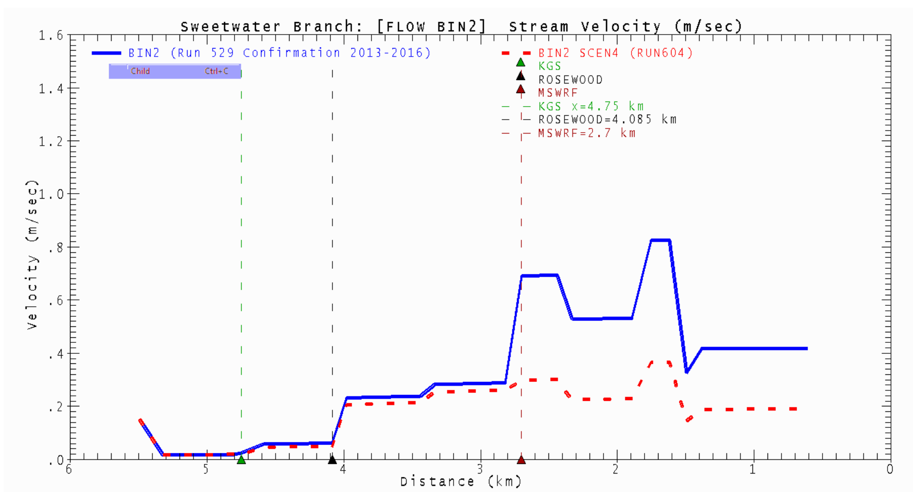
TRAVTIME_BIN2SCEN4_RUN604.BMP



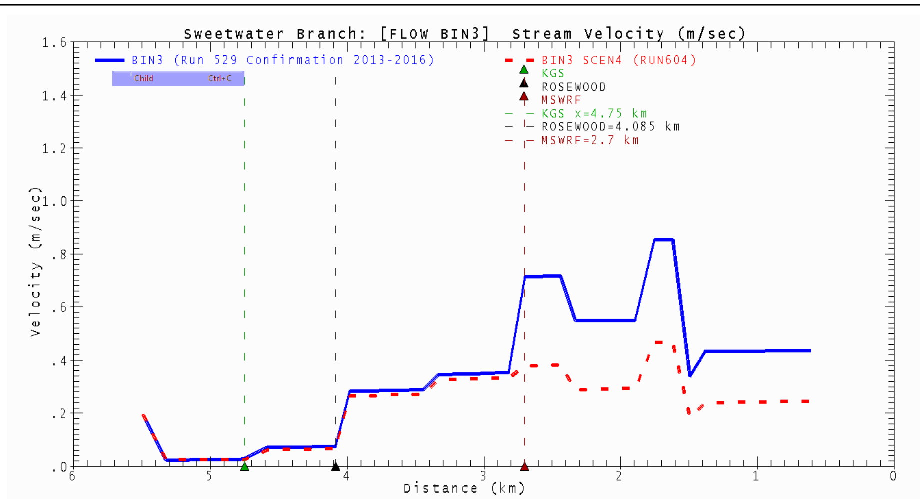
TRAVTIME_BIN3SCEN4_RUN604.BMP



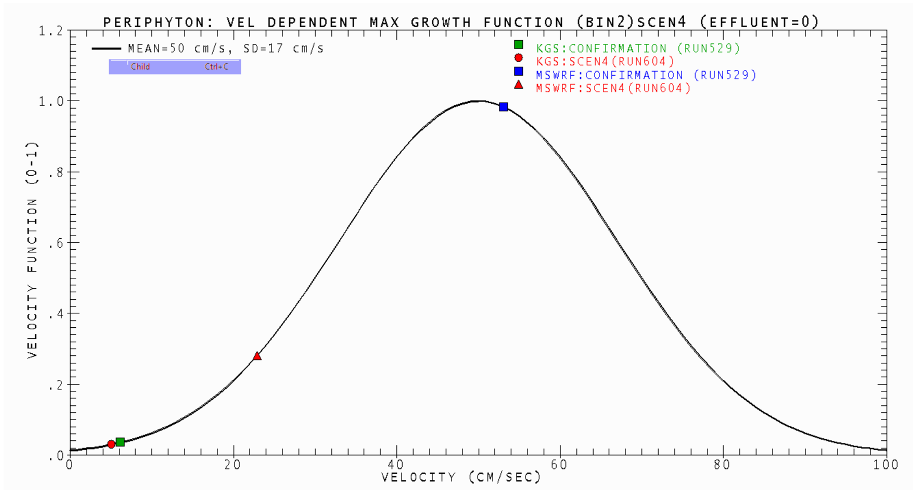
VEL_BIN1SCEN4_RUN604.BMP



VEL_BIN2SCEN4_RUN604.BMP



VEL_BIN3SCEN4_RUN604.BMP



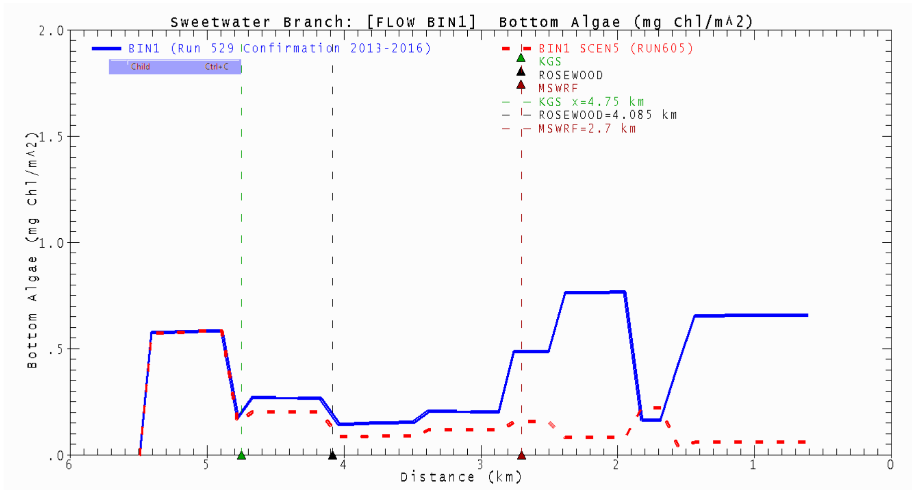
XPERIPHYTON_VEL_GROWFUNCTION(BIN2)RUN604.BMP

Appendix H

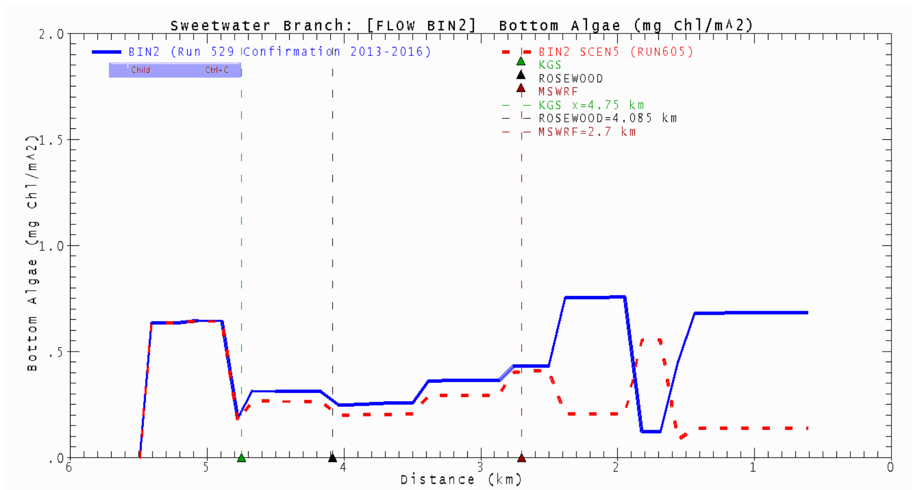
Scenario #5, Run 605

Run 605: Scenario #5
Future Build-Out PS Loads (12 MGD)

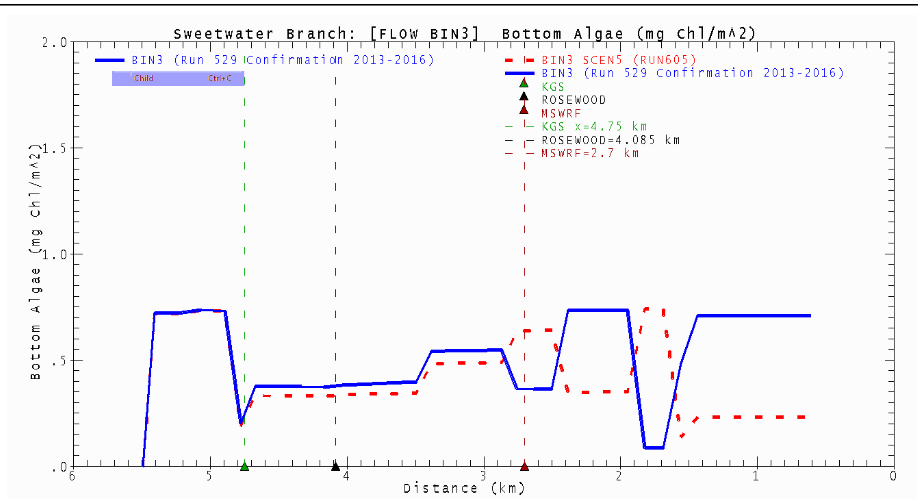
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
PERIPHYTON_ GAUSSIAN_INP	Velocity-Dependent Benthic Algae Growth Rates	mg Chl-a/$m^2 day^{-1}$	2		✓	✓	✓
BOTALG_	Bottom Algae Chlorophyll-a	mg Chl-a/m^2	4		✓	✓	✓
CHL_	Sestonic Algae Chlorophyll-a	µg Chl-a/L	5		✓	✓	✓
FLOW_	Streamflow	m^3/sec	6		✓	✓	✓
TRAVTIME_	Travel Time	days	7		✓	✓	✓
VEL_	Stream Velocity	m/sec	8		✓	✓	✓
XPERIPHYTON_	Empirical Growth as f(Velocity)	Multiplier	9			✓	



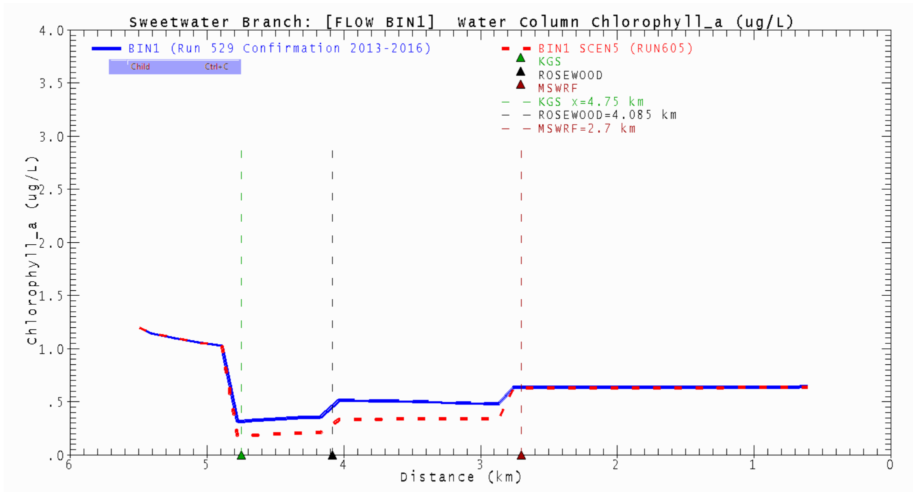
BOTALG_BIN1SCEN5_RUN605.BMP



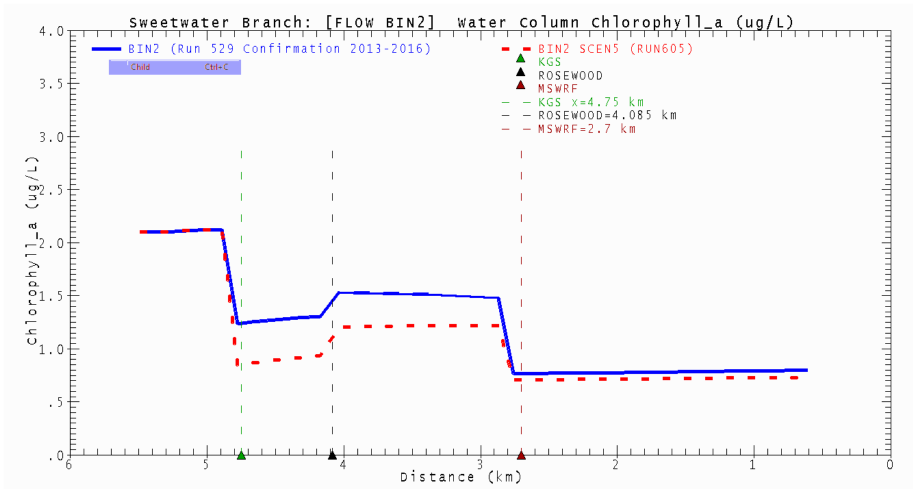
BOTALG_BIN2SCEN5_RUN605.BMP



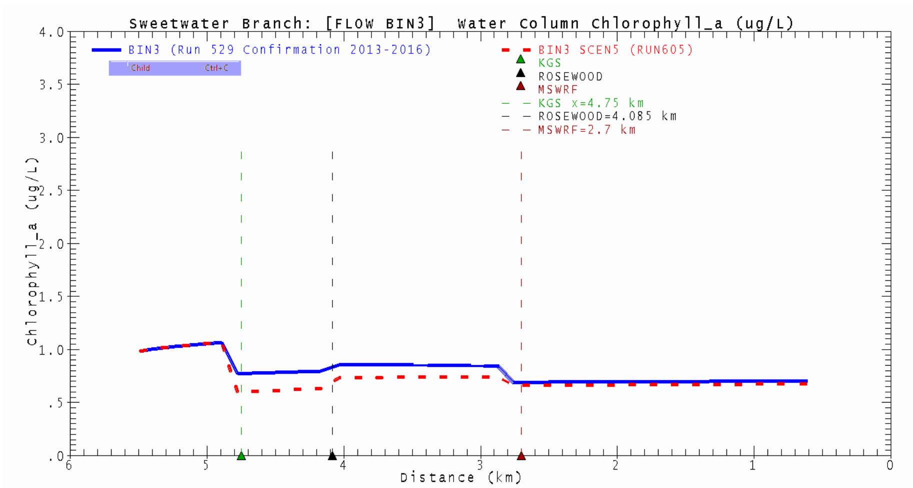
BOTALG_BIN3SCEN5_RUN605.BMP



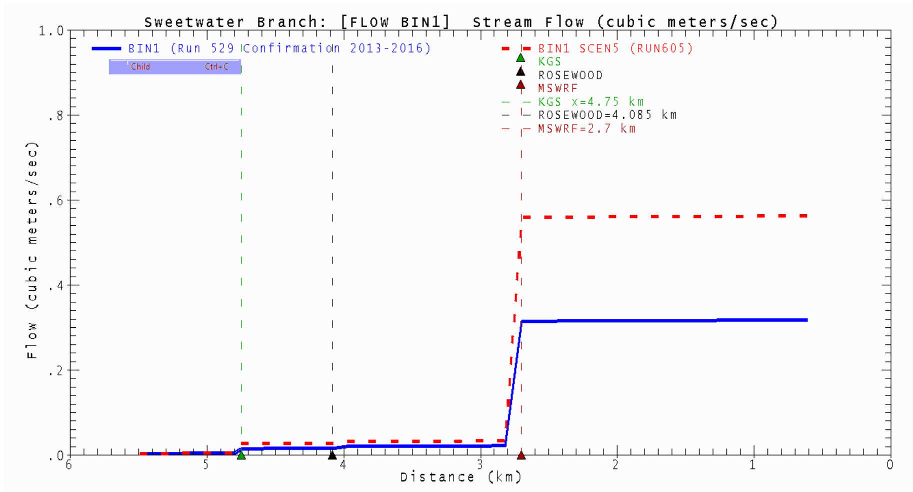
CHL_BIN1SCEN5_RUN605.BMP



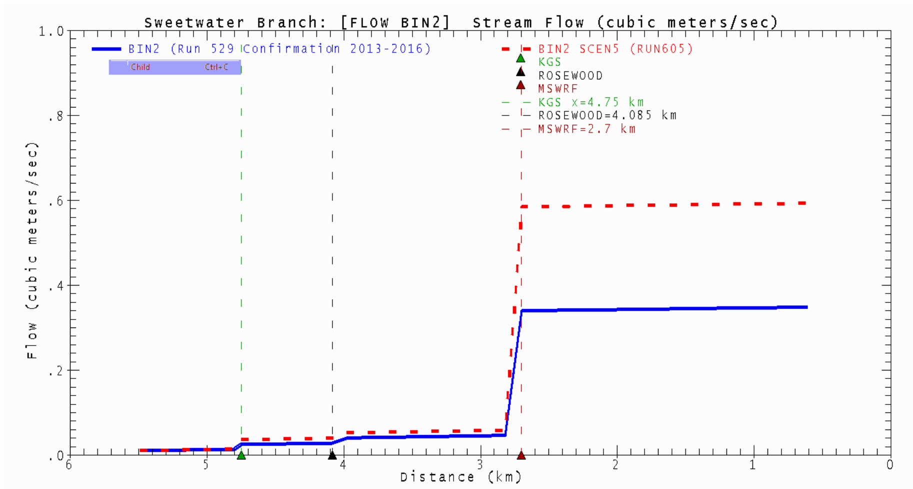
CHL_BIN2SCEN5_RUN605.BMP



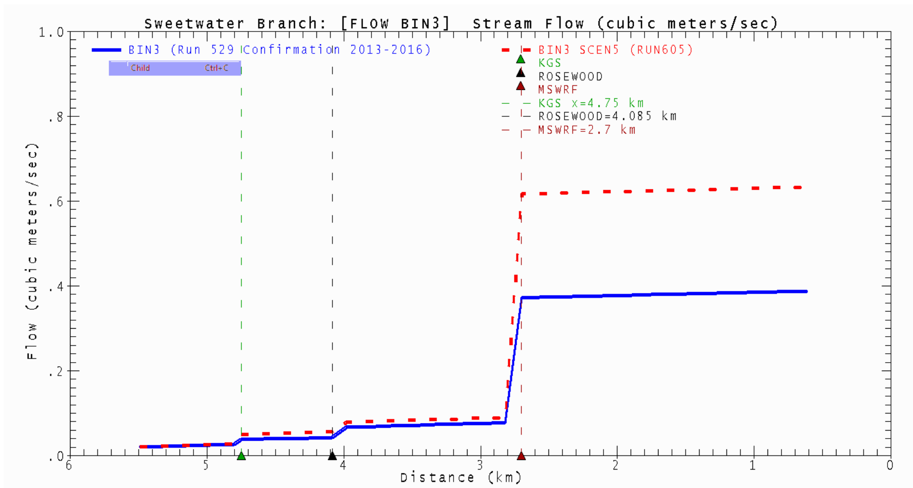
CHL_BIN3SCEN5_RUN605.BMP



FLOW_BIN1SCEN5_RUN605.BMP



FLOW_BIN2SCEN5_RUN605.BMP



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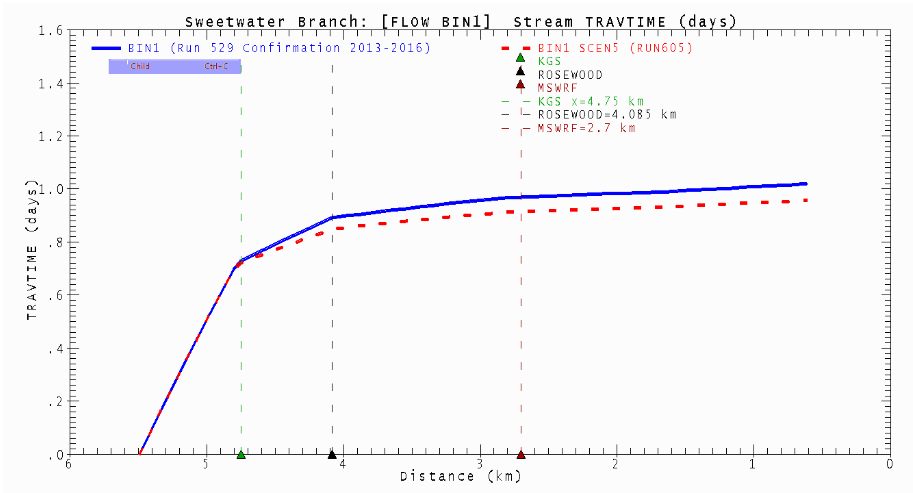

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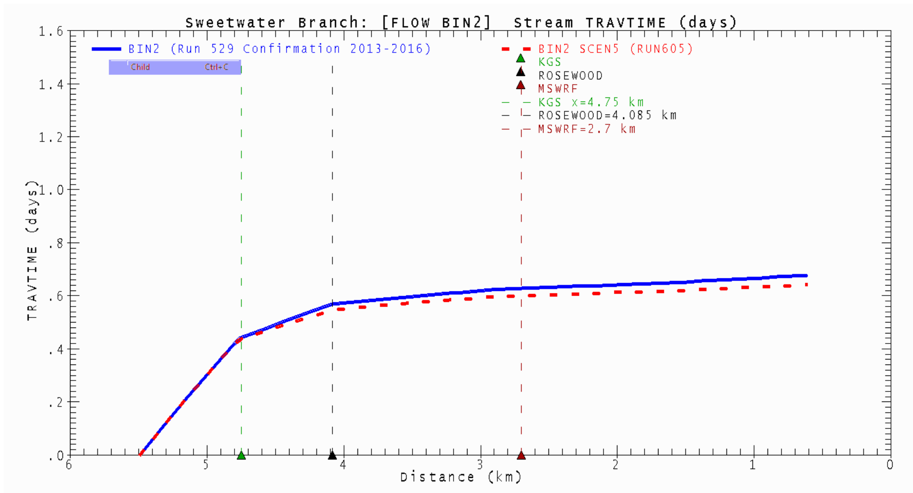

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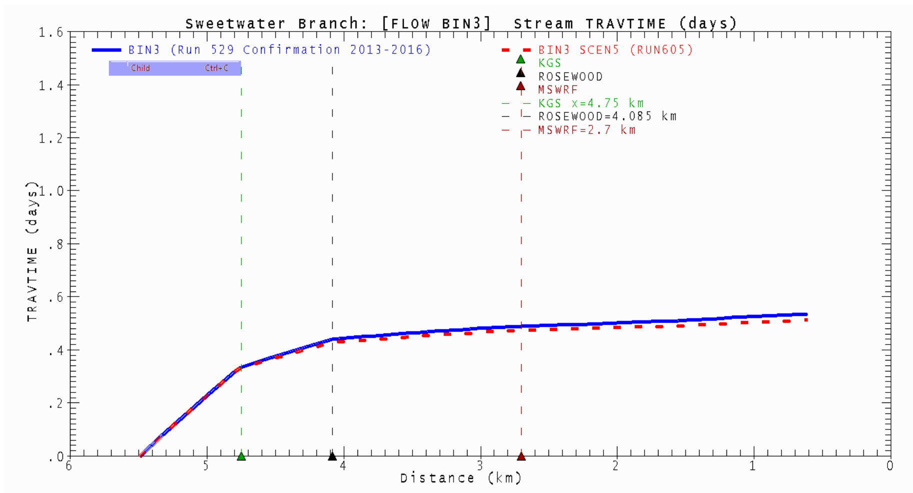

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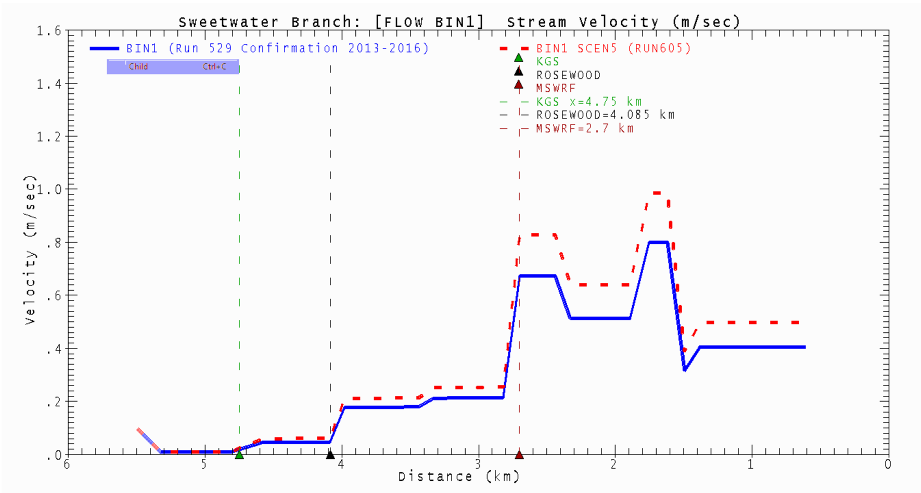

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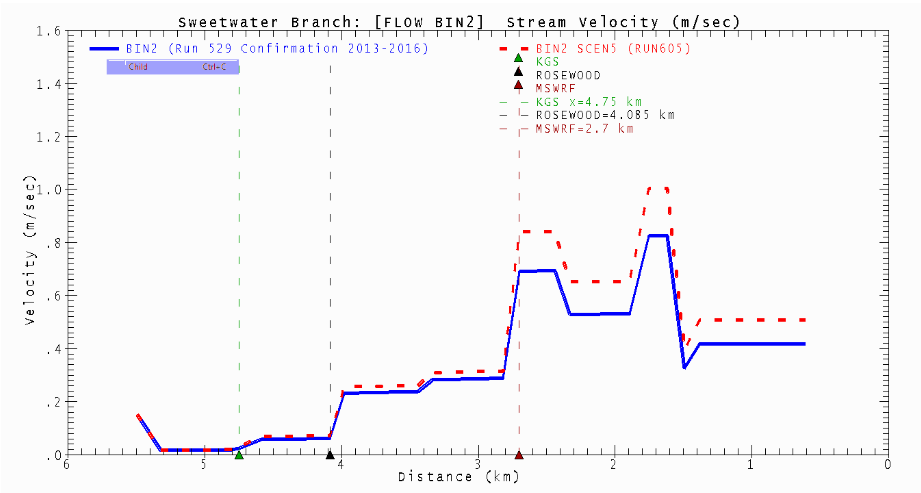

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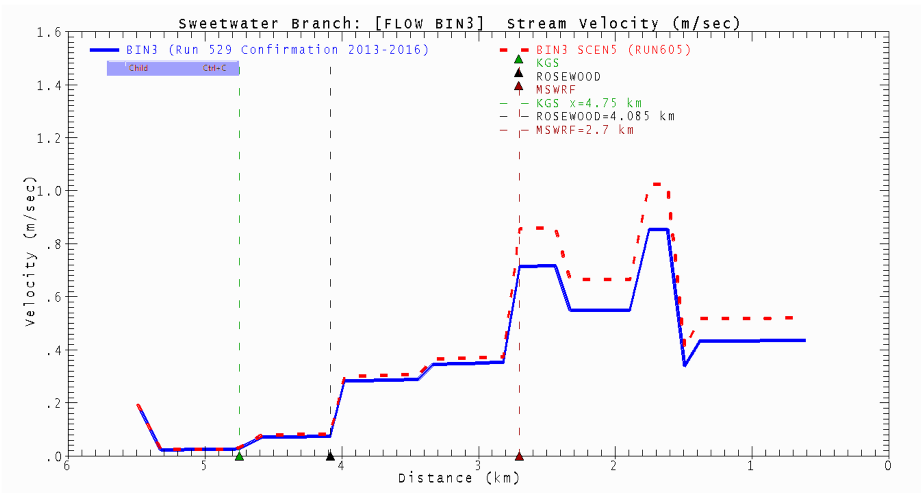

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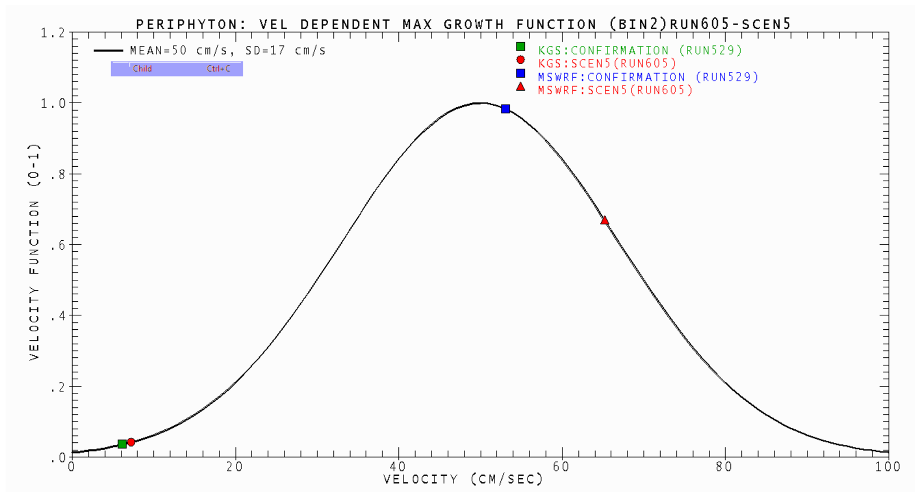


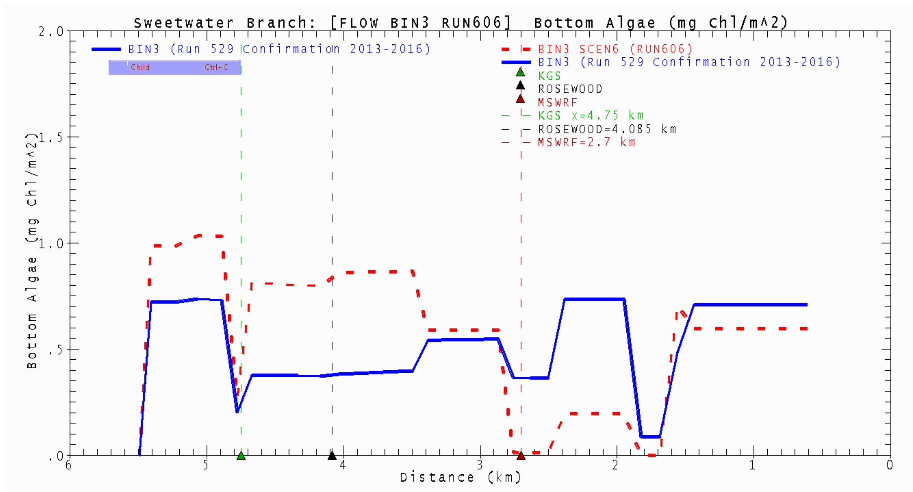
XPERIPHYTON_VEL_GROWFUNCTION(BIN2)RUN605.BMP

Appendix I

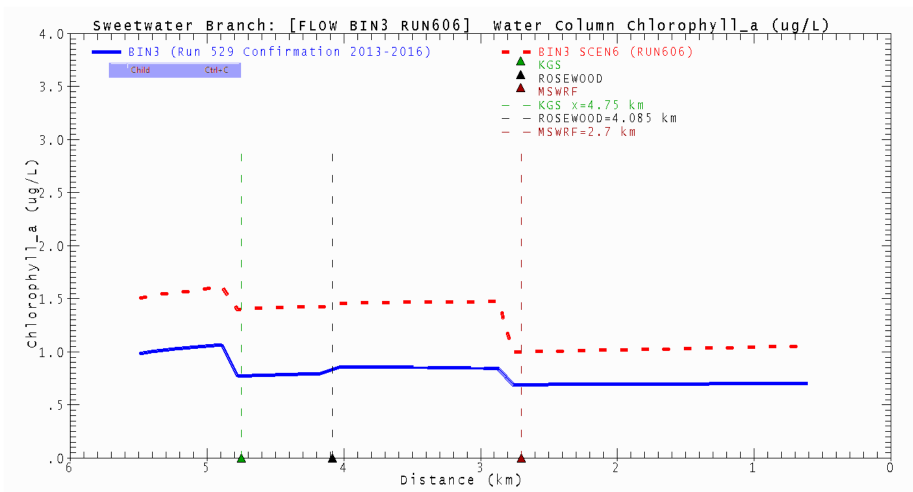
Scenario #6, Run 606

Run 606: Scenario #6
MSWRF Full Buildout (12 MGD) &
“Worst Case” 90%ile NPS Stormwater Loads (BIN3)

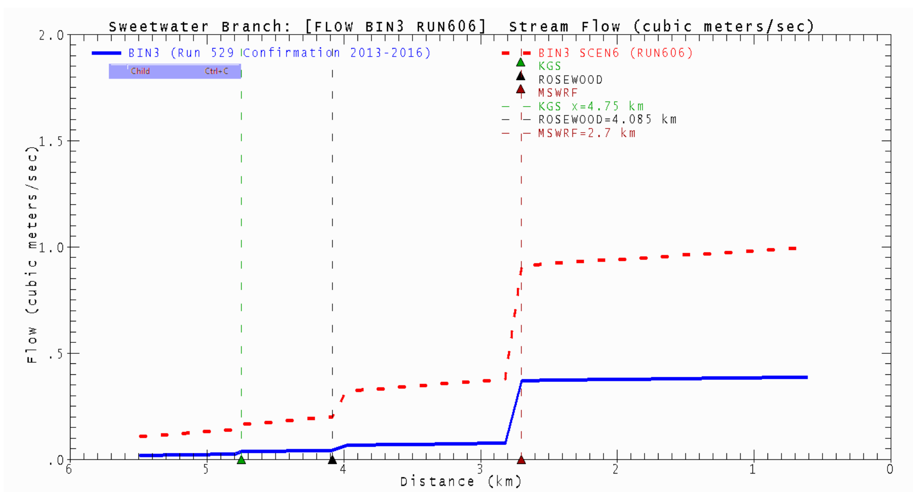
Filename	Water Quality Variable	Units	Page		BIN1	BIN2	BIN3
BOTALG_	Bottom Algae Chlorophyll-a	mg Chl-a/m^2	2		NA	NA	✓
CHL_	Sestonic Algae Chlorophyll-a	µg Chl-a/L	2		NA	NA	✓
FLOW_	Streamflow	m^3/sec	2		NA	NA	✓
TRAVTIME_	Travel Time	days	3		NA	NA	✓
VEL_	Stream Velocity	m/sec	3		NA	NA	✓
XPERIPHYTON_	Empirical Velocity Function	Multiplier	3		NA	NA	✓



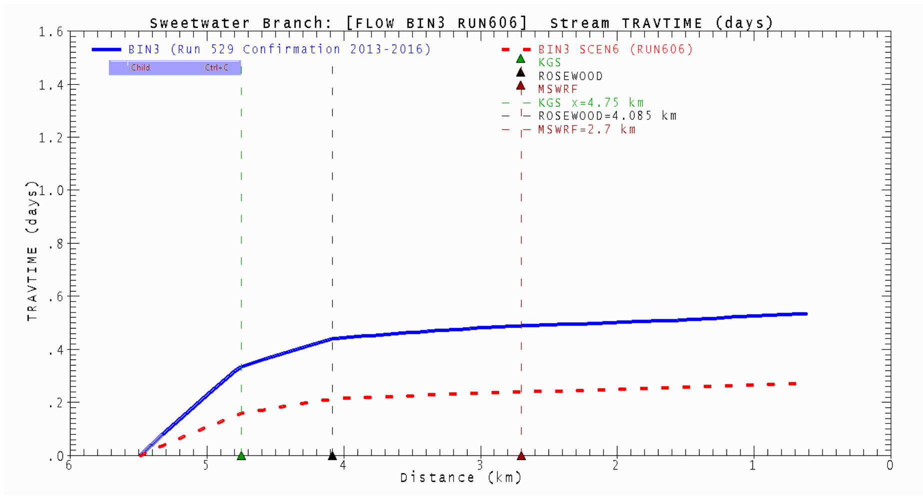
BIN3SCEN6_RUN606_BOTALG.BMP



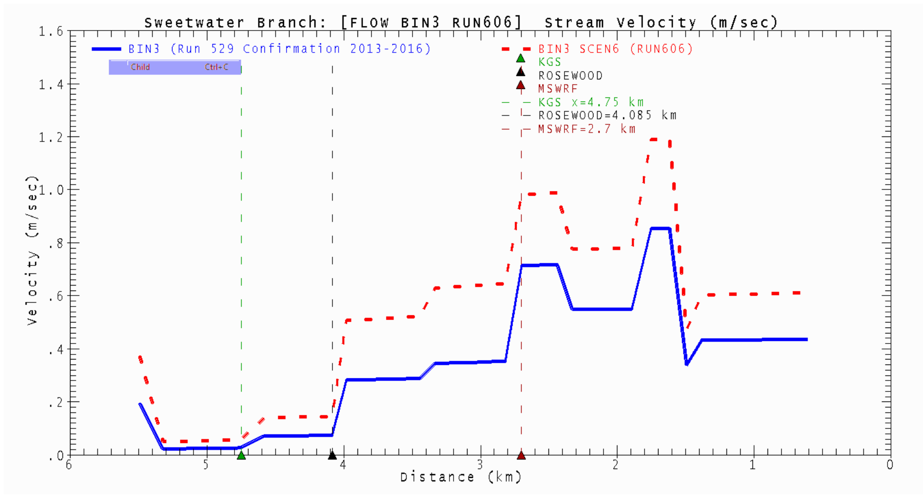
BIN3SCEN6_RUN606_CHL.BMP



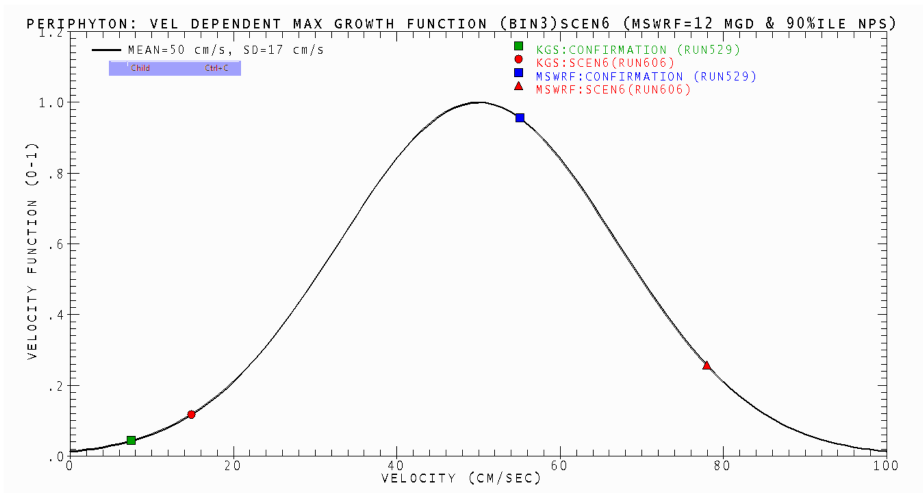
BIN3SCEN6_RUN606_FLOW.BMP



BIN3SCEN6_RUN606_TRAVTIME.BMP



BIN3SCEN6_RUN606_VEL.BMP



PERIPHYTON_VEL_GROWFUNCTION(BIN3)Run606.BMP

APPENDIX J

Maximum Daily Load Methodology for KGS Effluent Flow and Nutrient Loading

GAINESVILLE REGIONAL UTILITIES
200 SE 16TH AVENUE
GAINESVILLE, FLORIDA 32601

Purchase Order No. 4510047537

March 31, 2020

DYNAMIC SOLUTIONS, LLC
6421 DEANE HILL DRIVE
KNOXVILLE, TENNESSEE 37919

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1.0 BACKGROUND

1.1 Model Confirmation

Under the model confirmation conditions described in Section 5.4.4, effluent data has been compiled for the period of record from 2013-2016 to compute summary statistics for effluent flow and nutrient levels for Main Street Water Reclamation Facility (MSWRF) and J.R. Kelly Generating Station (KGS) (see Table J-1). Input data for model confirmation used median values to characterize KGS effluent flow and nutrient concentrations and loads as shown in Table J-1 and Figure J-2 and Figure J-3 for Total Nitrogen (TN) and Total Phosphorus (TP).

Table J-1 Summary of MSWRF and KGS Effluent Flow and Nutrients for Model Confirmation

Model Confirmation Run 529	MSWRF Median	KGS CTBD8 Median	KGS LVW Median	KGS CTBD8+LVW Median
Annual Flow (MGD)	6.68	0.221	0.0182	0.2392
Total Nitrogen (mg N/L)	5.27	1.29	0.57	1.235
Total Phosphorus (mg P/L)	0.51	0.435	0.11	0.410
Total Nitrogen (lbs N/yr)	107,227.5	868.4	31.6	900.0
Total Phosphorus (lbs P/yr)	10,376.9	292.8	6.1	298.9

1.2 NPDES Permits for MSWRF and KGS

As described in Section 5.6.1 for management applications of the confirmed QUAL2K stream model, Scenario#0 was developed as a hypothetical effluent loading to examine "what if" GRU's Main Street Water Reclamation Facility (MSWRF) and Kelly Generating Station (KGS) discharged flow and nutrient loads to Sweetwater Branch based on their existing NPDES permits.

The existing NPDES permit for MSWRF (FL0027251) allows an effluent flow rate of 7.5 MGD with effluent nutrient levels of 8.0 mg/L for Total Nitrogen and 0.454 mg/L for Total Phosphorus. The existing NPDES permit for KGS (FL0026646) allows for an effluent flow rate of 1.958 MGD for the Unit 8 Cooling Tower Blowdown (CTBD8) outfall and 0.444 MGD for the Low Volume Waste (LVW) outfall. As is typical for steam electric generating stations, however, effluent limits are not specified in the KGS permit for either nitrogen or phosphorus. In the absence of permit limits, Scenario#0 upper bound estimates for KGS effluent concentrations of TN and TP were based on 95th percentile statistics compiled from KGS effluent records for the period of record from 2013-2016. Under Scenario#0, KGS permitted effluent 95th percentile levels of TN and TP effluent concentrations and computed loads are shown in Figure J-2 and Figure J-3 for Total Nitrogen (TN) and Total Phosphorus (TP). MSWRF and KGS effluent flow and nutrient data for Scenario#0 are summarized in Table J-2.

Table J-2 Existing NPDES Permit Conditions for MSWRF and KGS Effluent Discharges and 95th Percentile TN and TP Estimates

	MSWRF	KGS CTBD8	KGS LVW	KGS CTBD8+LVW
NPDES Permit- ID	**FL0027251**	**FL0026646**	**FL0026646**	**FL0026646**
Annual Flow (MGD)	7.5	1.958	0.444	2.402
Total Nitrogen (mg N/L)	8.0	None	None	None
Total Phosphorus (mg P/L)	0.45	None	None	None
	NPDES Permit	**Permit Flow & 95%ile TN,TP**	**Permit Flow & 95%ile TN,TP**	**Permit Flow & Flow-Wt TN,TP**
Annual Flow (MGD)	7.5	1.958	0.444	2.402
Total Nitrogen (mg N/L)	8	2.712	2.641	2.699
Total Phosphorus (mg P/L)	0.45	0.983	0.22	0.842
Total Nitrogen (lbs N/yr)	182,755.5	16,174.2	3,571.7	19,745.8
Total Phosphorus (lbs P/yr)	10,280.0	5,862.5	297.5	6,160.1

As can be seen by comparison of the data presented in the bar charts for model confirmation with Scenario#0, permitted effluent flow increased by 10X and the 95th percentile estimates for TN and TP concentrations increased by a factor of two. The combination of the 10X increase in the permitted flow rate and the doubling of nutrient concentrations resulted in TN and TP loading rates for Scenario#0 that are more than 20X greater than nutrient loading estimates developed for model confirmation to existing conditions. The KGS effluent flow and nutrient loading rates developed for Scenario#0 clearly do not provide realistic estimates of potential "what-if" nutrient loading conditions. In retrospect, the methodology used to assign KGS effluent flow and nutrient loading for Scenario#0 was determined to be flawed and a more robust methodology was needed to characterize management scenarios for future flow and nutrient loading conditions from KGS.

1.3 MSWRF Full Build-Out and Upper Bound Estimates for KGS Flow and Nutrient Loads

A methodology based on EPA's Maximum Daily Load (MDL) technical guidance for NPDES permits has been developed to properly characterize KGS effluent flow and nutrient loading for management scenario applications of the confirmed QUAL2K stream model. As described for Scenario#1, upper bound estimates for KGS effluent flow and nutrient loads were derived from the EPA MDL methodology. MDL estimates for KGS nutrients are shown in Figure J-2 (TN) and Figure J-3 (TP). MSWRF Full Build-Out (Scenario#6) and KGS effluent data (Scenario#1) is summarized in Table J-3.

Table J-3 MSWRF Full Build-Out and Maximum Daily Load Estimates for KGS Effluent Flow and Nutrient Loads

Future Conditions	MSWRF Full Build-Out & Upgrade	KGS CTBD8 EPA MDL	KGS LVW EPA MDL	KGS CTBD8+LVW EPA MDL
Annual Flow (MGD)	12.0	0.418	0.087	0.505
Total Nitrogen (mg N/L)	8.0	2.2	0.984	1.991
Total Phosphorus (mg P/L)	0.30	0.636	0.125	0.548
Total Nitrogen (lbs N/yr)	292,408.8	2,801.0	260.8	3,061.8
Total Phosphorus (lbs P/yr)	10,965.3	809.8	33.1	842.9

1.4 Objectives of Appendix J

Appendix J has been prepared to document the data sources and EPA's MDL methodology used to estimate KGS effluent flow and nutrient loading data for management scenario applications of the confirmed stream model.

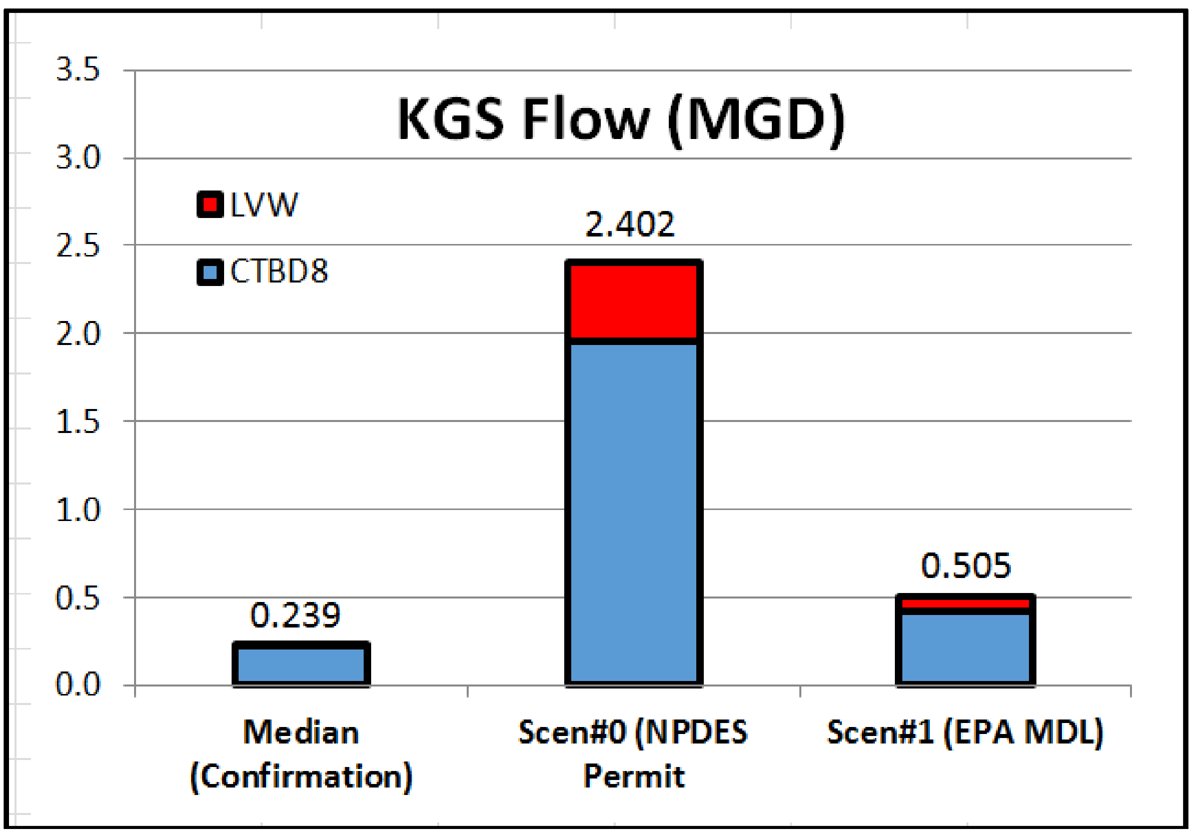
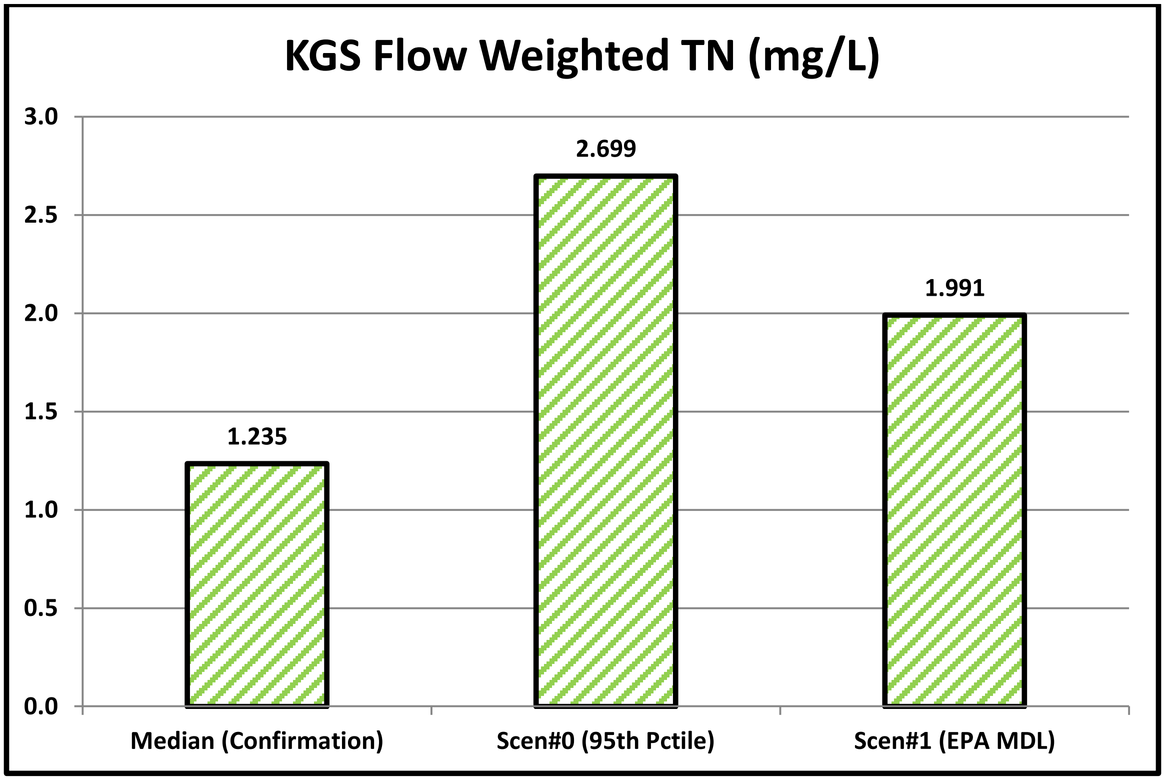


Figure J-1 KGS Effluent Flow



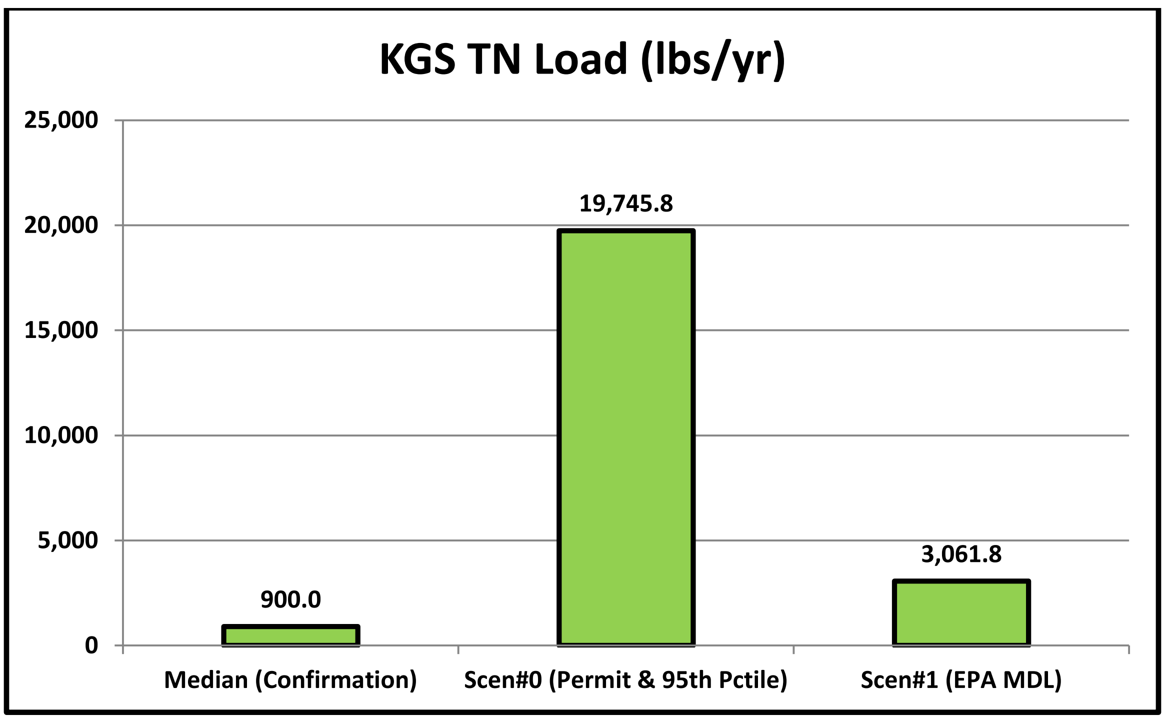
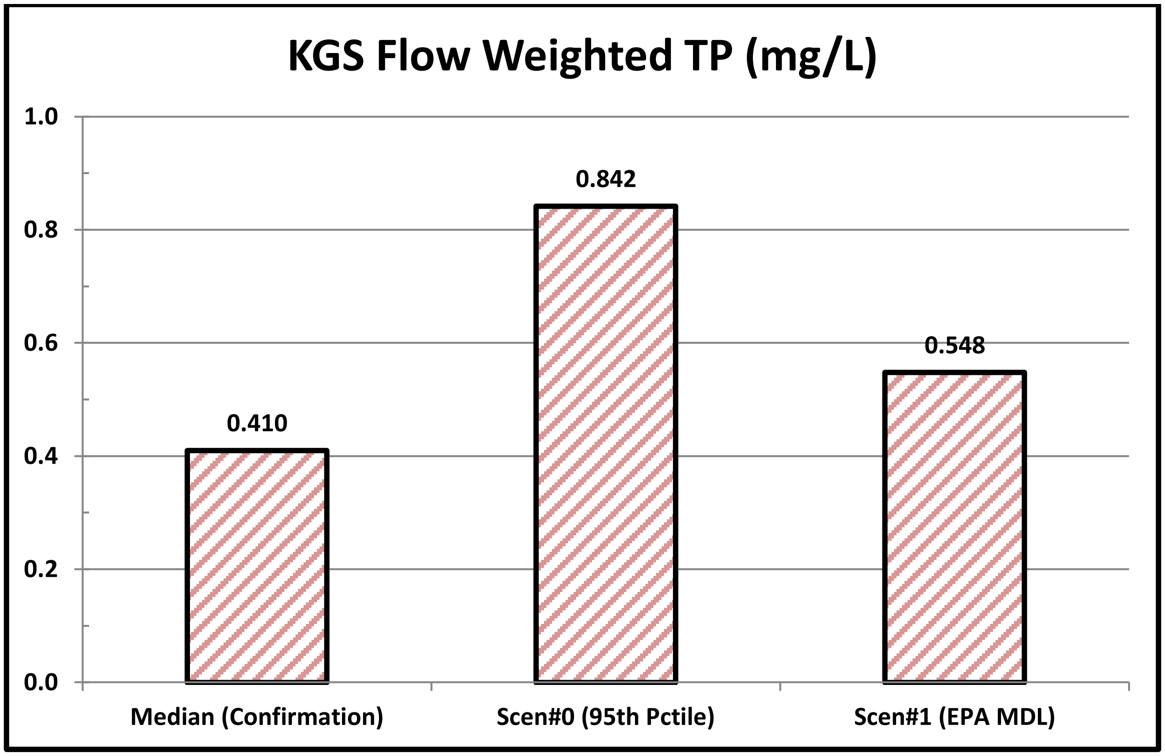


Figure J-2 KGS Effluent Total Nitrogen Concentration and Load



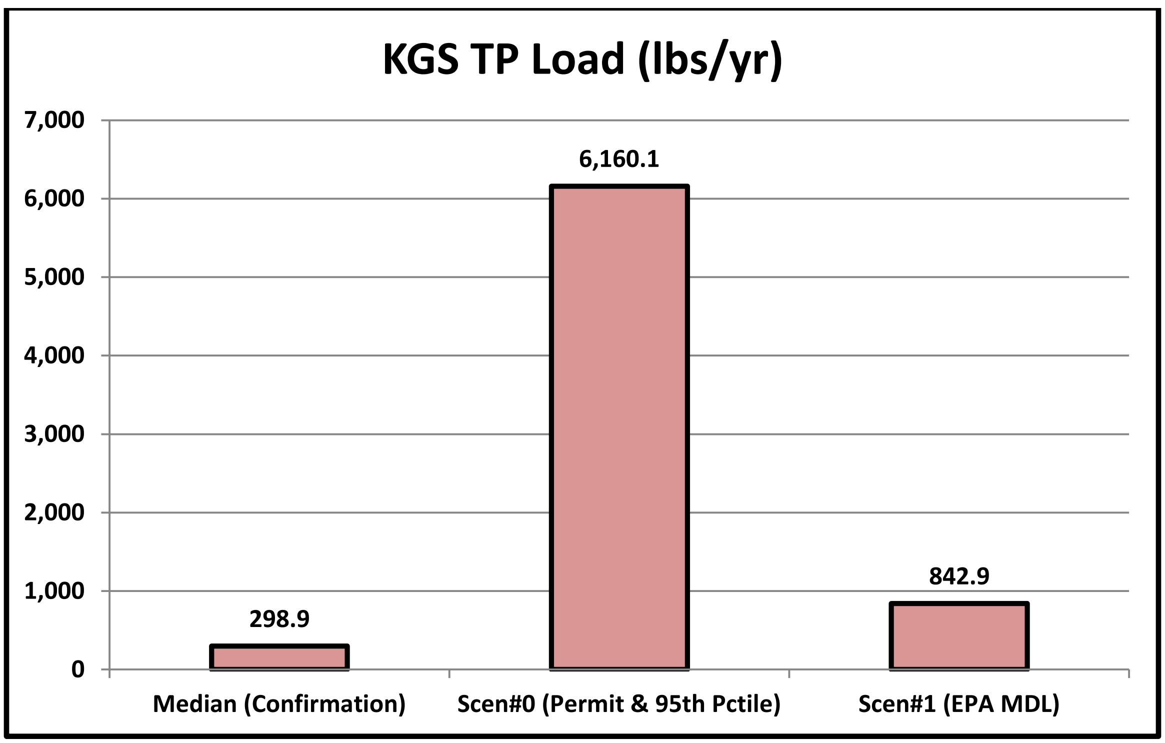


Figure J-3 KGS Effluent Total Phosphorus Concentration and Load

2.0 KGS Data Sources

2.1 Updates to Effluent Records for Nutrients

Effluent records for nutrient measurements for the CTBD8 and LVW discharges were updated based on a careful review of effluent nutrient measurements provided by KGS to ensure that data used for developing the model are representative of current operating conditions at KGS. Effluent nitrogen and phosphorus records for the CTBD8 and LVW outfalls provided by KGS as the most current version of effluent data records were obtained from a spreadsheet file [*Copy of 2017 May Copy of Kelly Nutrient Data (2012 - Current) embry edits.xlsx*] (Regina Embry, personal communication, 2017).

Phosphorus records for the CTBD8 effluent were deleted from the project database for the period from June 7, 2012 through December 1, 2014. Effluent phosphorus levels were reduced dramatically during this period by a modification of treatment processes for cooling water blowdown. Effluent phosphorus data collected at the CTBD8 outfall after December 1, 2014, however, were considered to be representative of current KGS operating conditions.

2.2 Effluent Flow

Discharge records used to derive upper bound estimates for effluent flow are based on daily records compiled from January 1, 2013 through June 30, 2016 for the Unit 8 Cooling Tower Blowdown (CTBD8) (n=1,307) and Low Volume Waste (LVW) (n=1,295) discharges. A subset of effluent flow records was used to derive effluent loading rates for phosphorus and nitrogen. Effluent flow records were extracted from daily flow records to compile paired effluent flow rates that matched effluent sampling dates for the LVW and CTBD8 discharges for phosphorus (Figure J-4 and Figure J-5) and nitrogen (Figure J-6 and Figure J-7) measurements.

2.3 Effluent Nutrients

Sample dates for TP and TN measurements are shown as solid red markers in the effluent flow time series plots for the LVW and CTBD8 discharges (Figure J-4 through Figure J-7). Time series plots for TP (Figure J-8 and Figure J-9) and TN (Figure J-10 and Figure J-11) show marker lines as quartiles and estimates of outliers computed from the quartiles. Data table listings of the TP and TN sample dates with paired effluent flow, effluent concentration, and computed loads are documented in Attachment #1 (TP) and Attachment #2 (TN) at the end of Appendix J.

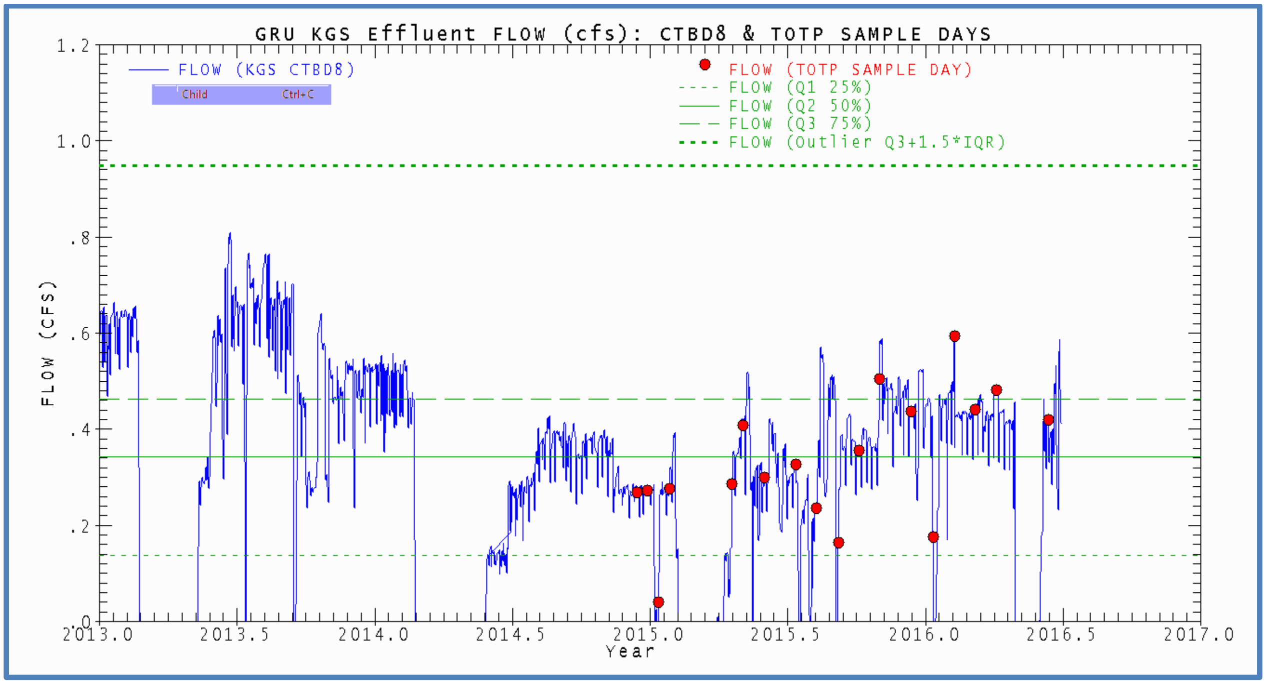


Figure J-4 CTBD8: Daily Flow and Sample Dates for TP

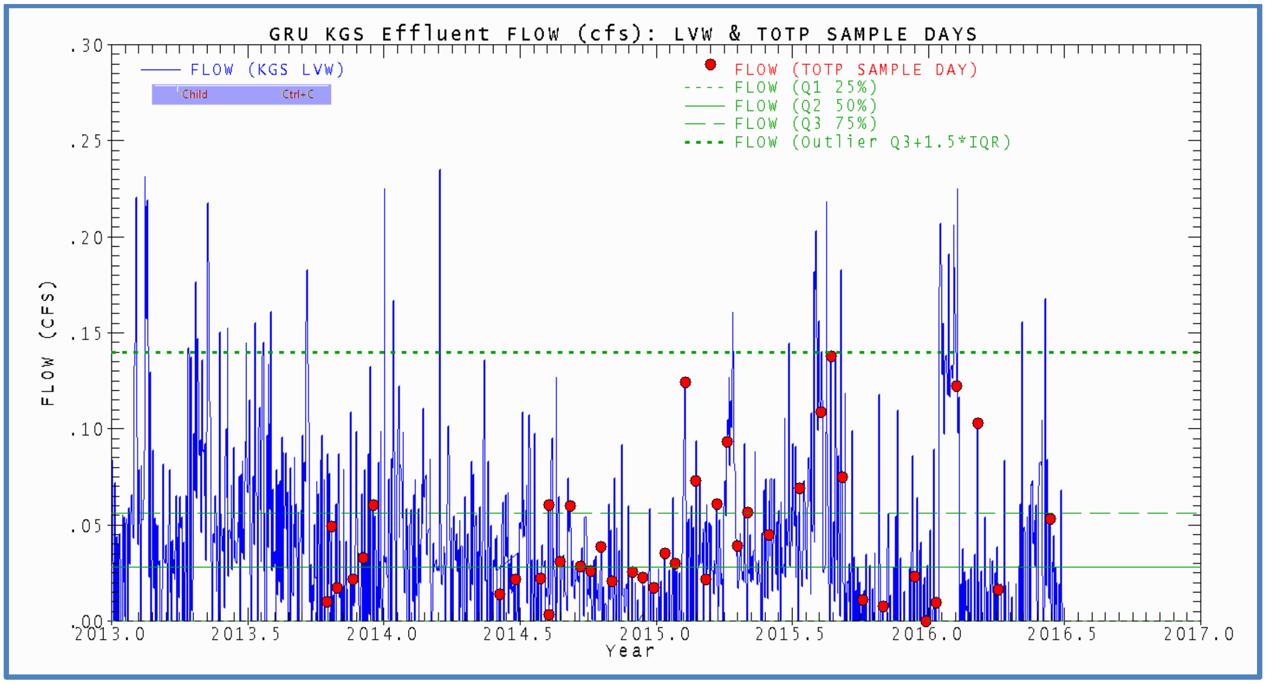


Figure J-5 LVW: Daily Flow and Sample Dates for TP

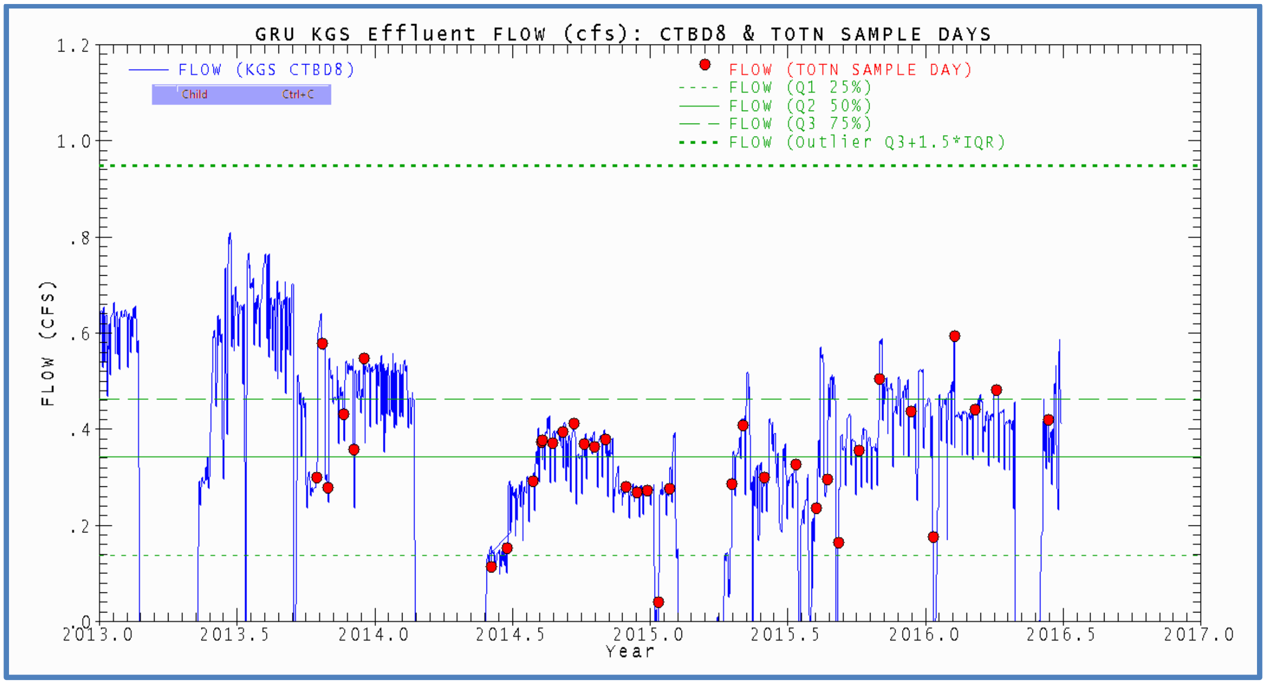


Figure J-6 CTBD8: Daily Flow and Sample Dates for TN

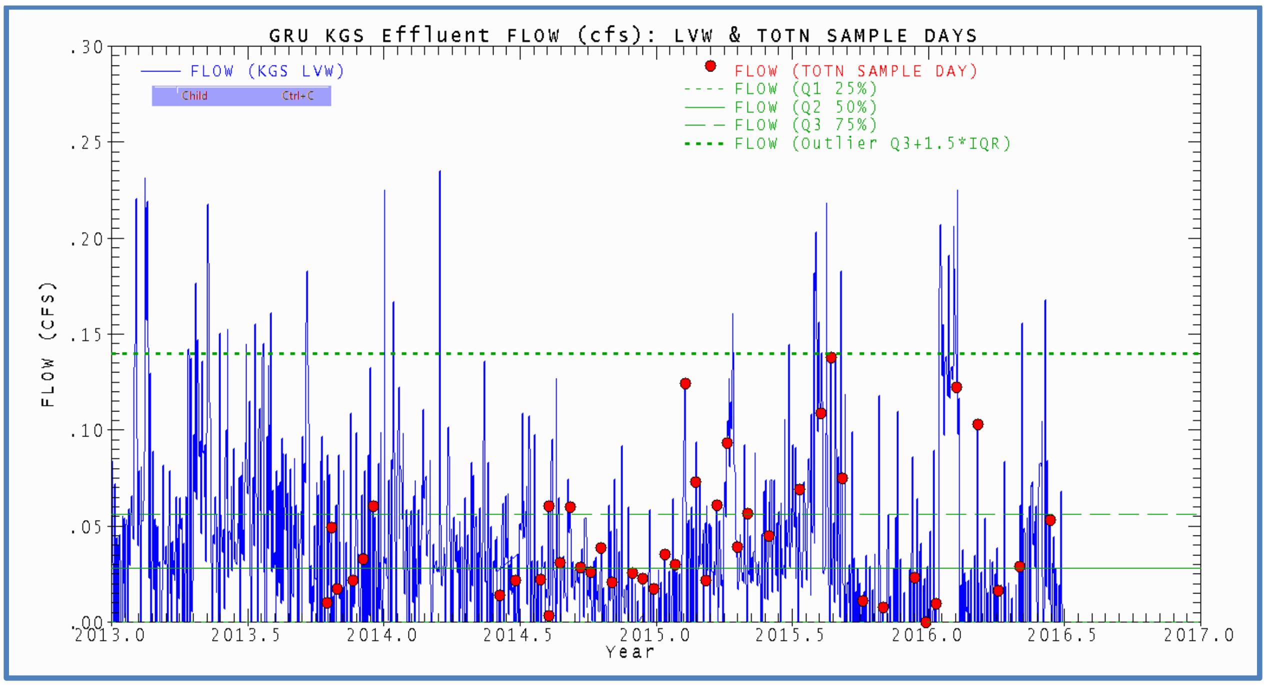


Figure J-7 LVW: Daily Flow and Sample Dates for TN

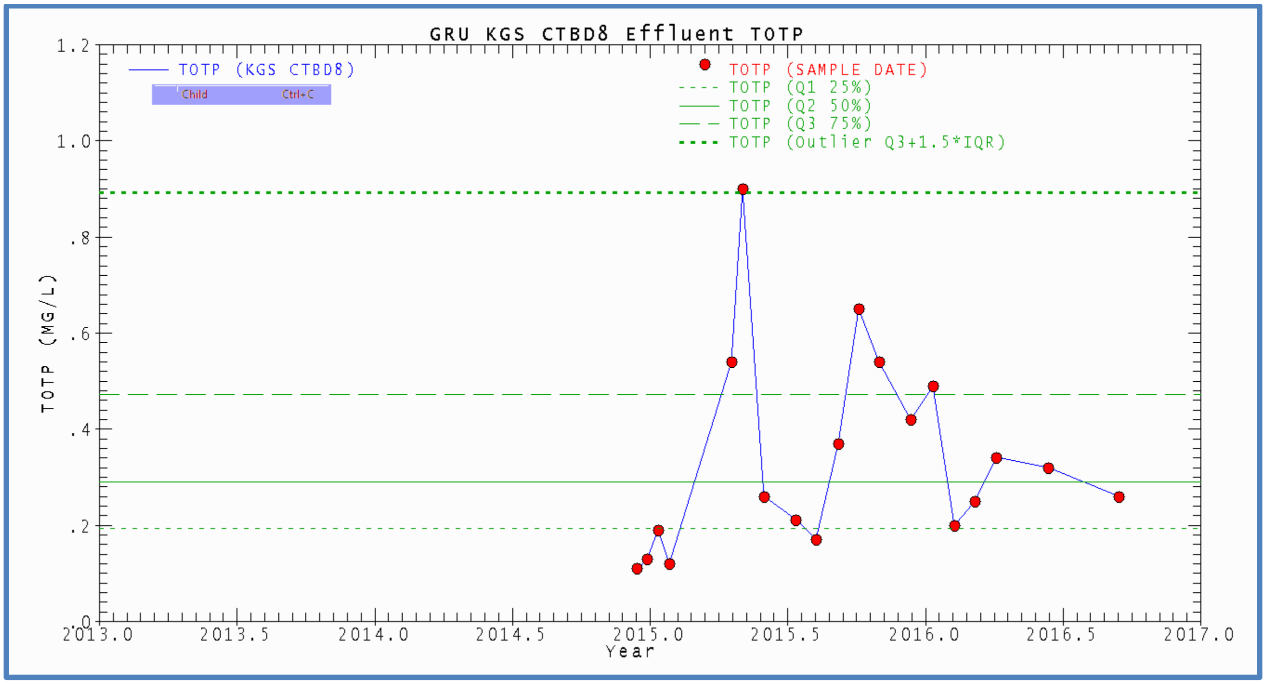


Figure J-8 CTBD8: Summary Statistics as Quartiles and TP Sample Dates, 2013-2016

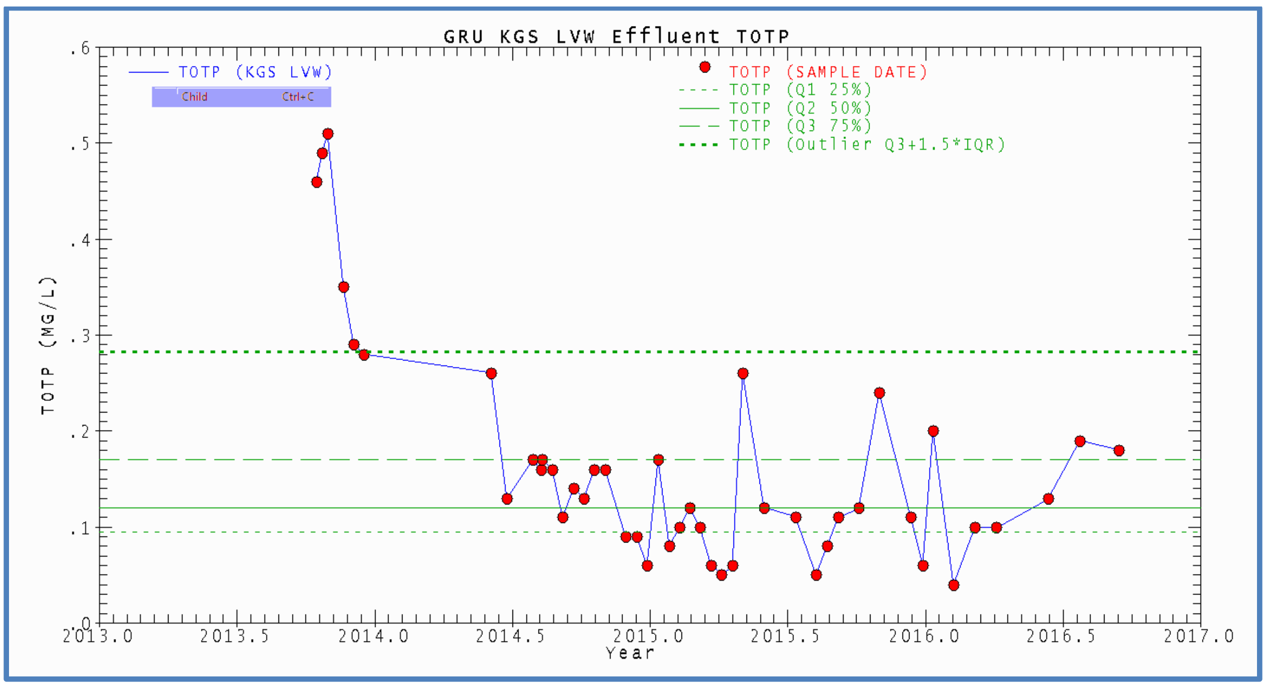


Figure J-9 LVW: Summary Statistics as Quartiles and TP Sample Dates, 2013-2016

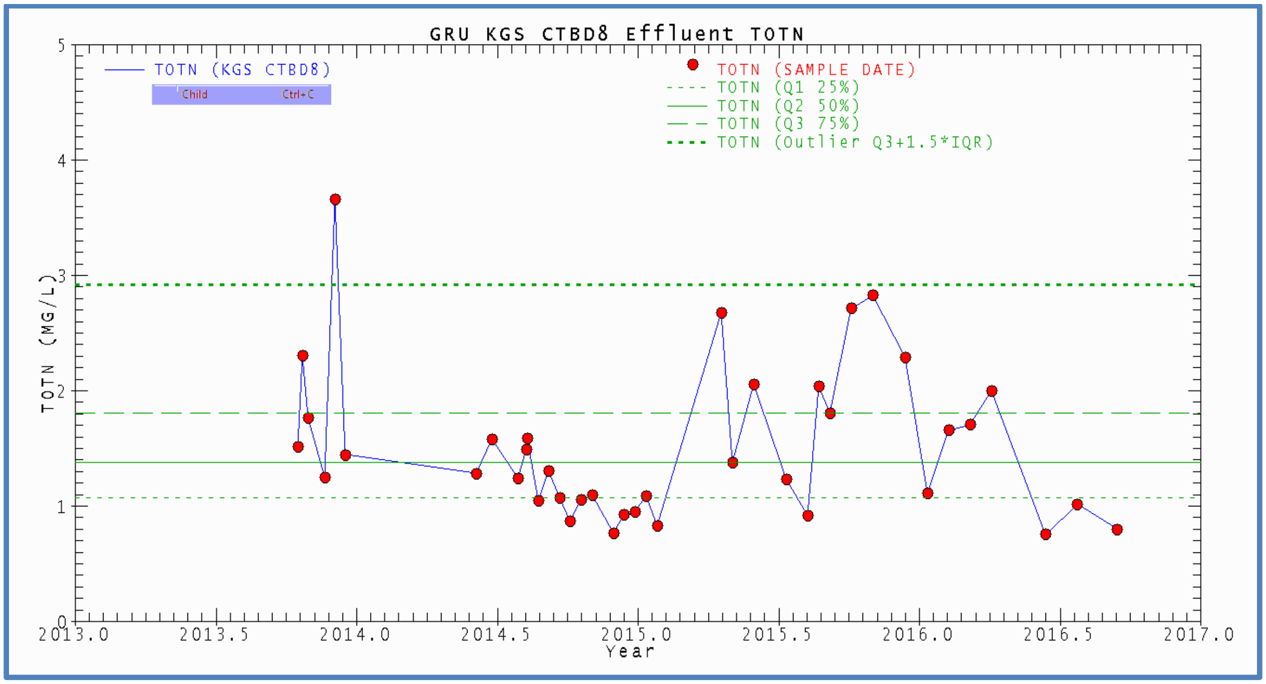


Figure J-10 CTBD8: Summary Statistics as Quartiles and TN Sample Dates, 2013-2016

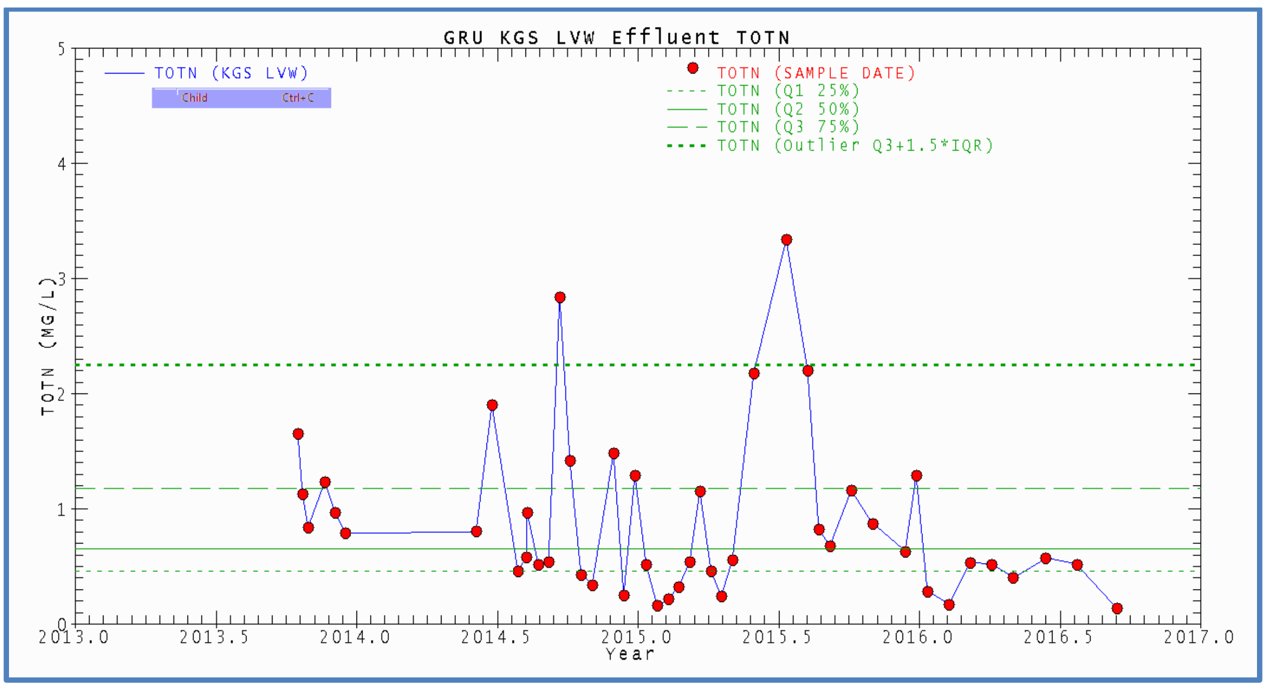


Figure J-11 LVW: Summary Statistics as Quartiles and TN Sample Dates, 2013-2016

3.0 MAXIMUM DAILY LOAD ESTIMATES FOR EFFLUENT FLOW AND EFFLUENT NUTRIENT LOADS

The methodology used for deriving Maximum Daily Loads from long-term average loads is based on the assumption that flow and water quality concentration and loading data for streams, rivers, and point source wastewater discharges can be described by lognormal distributions. It has been well documented in numerous studies that a two-parameter lognormal distribution defined by the mean and variance of a log transformed time series data set provides a useful approximation to the probabilistic distribution of streamflow (Nash, 1994; Limbrunner et al., 2000; Vogel et al., 2005). Van Buren et al., (1997) and Di Toro (1984) have also determined that water quality analyses based on the assumption of a lognormal probability distribution for both streamflow and water quality concentration are quite realistic for many streams, rivers and wastewater discharges.

Three documents available from EPA's Office of Water provide the statistical basis for determination of NPDES permit limits based on Maximum Daily Loading (MDL) rates that can be derived from annual loading rate data sets. In 2007, EPA published "*Options for Expressing Daily Loads in TMDLs*" (EPA, 2007) in response to the "Anacostia Decision" (Grumbles, 2006). The statistical basis for the calculation of a daily loading rate from an annual average load was previously documented by EPA in two technical guidance documents: "*Technical Guidance Manual for Performing Wasteload Allocations, Book VII: Permit Averaging Periods*" EPA (1984); and *"Technical Support Document for Water Quality-Based Toxics Control"* EPA (1991). These EPA documents provide the assumptions and statistical methods for the equations, parameters, and calculation of maximum daily load limits based on long-term average loads and temporal variability of the pollutant load time series datasets. EPA (1991: Appendix E] and EPA (1984: Section 2) present the rationale, equations and parameters based on normal and lognormal distributions that can be used to calculate Maximum Daily Loads. The methodology is based on the well-known "bell shaped" curve of the normal distribution as shown conceptually in Figure J-12.

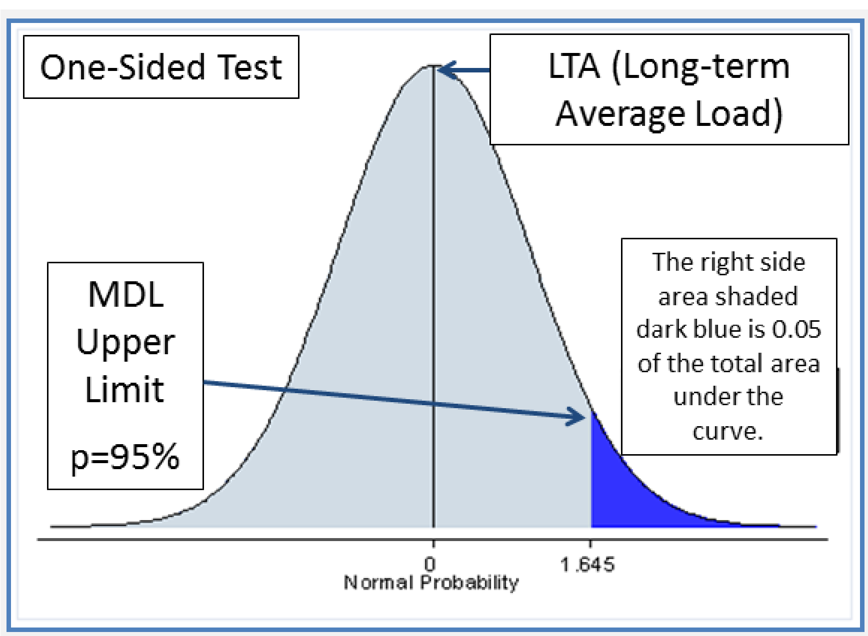


Figure J-12 Conceptual Representation of Maximum Daily Load Methodology

3.1 Upper Bound Estimates of Effluent Flow and Nutrient Loading

As permit limits have not been established for TN and TP for the KGS effluent discharges and the permit limits for effluent flow are 10X larger than existing operating conditions, it is appropriate to use the statistical methods developed by EPA as technical guidance for NPDES permits to derive upper bound estimates for effluent flow, and TN and TP loads for KGS's LVW and CTBD8 discharges. Daily effluent loading rates for TP and TN were computed from measured effluent concentrations and the paired effluent flow rate recorded for the sampling dates when effluent was collected for nutrient analyses. Attachment#1 presents a table of paired samples for TP and Attachment#2 presents a table of paired samples for TN. The lognormal distribution, described in Section 3.2 of this Appendix J, was used to derive upper bound estimates of KGS nitrogen and phosphorus loading rates for the Cooling Tower Blowdown Unit 8 (CTBD8) and the Low Volume Waste (LVW) discharges.

Based on operating conditions of the J.R. Kelly Generating Station, daily effluent flows of zero were recorded for 21% of the CTBD8 period of record (n=277 of 1,307 days) and 26% of the LVW period of record (n=331 of 1,295 days) (see Figure J-4 and Figure J-5). Kahn and Rubin (1989) developed the Delta lognormal distribution as a special case of the lognormal distribution for data sets that can be characterized by a mix of censored data sets (i.e., less than detection limit) and non-censored data sets (i.e., above detection limit). The equations for the Delta lognormal distribution, given in EPA's technical guidance document [EPA (1991: Appendix E], were used to treat the large number of zero flow records as "censored" data records for the KGS discharges. The Delta lognormal distribution, described in Section 3.4 of this Appendix J, was used to derive upper bound estimates of KGS effluent flow for the Cooling Tower Blowdown Unit 8 (CTBD8) and the Low Volume Waste (LVW) discharges.

Consistent with EPA guidance, the KGS effluent time series data sets for flow and nutrients discharged by the LVW and CTBD8 outfalls have been log transformed to derive upper bound Maximum Daily Load estimates based on the 95% Confidence Interval for effluent flow and TP and TN loads (Table J-4). Simple arithmetic mean values are also shown in the table for comparison to the upper bound MDL estimates derived for flow and nitrogen and phosphorus loads. Flow-weighted effluent concentrations of TN and TP were derived from the MDL estimates of nutrient loads and effluent flow for the 95% Confidence Interval. High values of the regression coefficients for effluent flow and TN and TP loads (r^2 = 0.940 to 0.989) demonstrate the strong linear relationships of the lognormal distributions developed for the CTBD8 and LVW effluent discharges (Table J-4).

Table J-4 Arithmetic Mean and Upper Bound MDL Estimates for Lognormal Distributions of Effluent Flow, Total Nitrogen and Total Phosphorus for 95% Confidence Interval

Probability, p=	**0.95**		**Z(p)=**	**1.645**	
		Total Nitrogen			
LVW		**Count**	**Mean**	**MDL**	**R^2**
Flow	**(MGD)**	953	0.02634	0.086457	0.988
Load	**(kg/day)**	37	0.102052	0.322091	0.987
Load	**(lbs/yr)**	37	82.11855	259.178	
Concentration	**(mg/L)**	37	1.023529	0.984186	
CTBD8		**Count**	**Mean**	**MDL**	**R^2**
Flow	**(MGD)**	943	0.223877	0.418176	0.989
Load	**(kg/day)**	37	1.402475	3.482682	0.94
Load	**(lbs/yr)**	37	1128.535	2802.422	
Concentration	**(mg/L)**	37	1.65495	2.200163	
Probability, p=	**0.95**		**Z(p)=**	**1.645**	
		Total Phosphorus			
LVW		**Count**	**Mean**	**MDL**	**R^2**
Flow	**(MGD)**	953	0.02634	0.086457	0.988
Load	**(kg/day)**	45	0.015159	0.040785	0.987
Load	**(lbs/yr)**	45	12.19809	32.81837	
Concentration	**(mg/L)**	37	0.152038	0.124622	
CTBD8		Count	Mean	MDL	R^2
Flow	**(MGD)**	943	0.223877	0.418176	0.989
Load	**(kg/day)**	18	0.329797	1.006685	0.947
Load	**(lbs/yr)**	18	265.3787	810.0526	
Concentration	**(mg/L)**	37	0.389167	0.635967	

Load (kg/day) = MGD x mg/L x 3.7853   Load (lbs/yr) = MGD x mg/L x 8.345 x 365

3.2 Equations and Parameters of the Lognormal Distribution

Existing pollutant loading data sets are defined by a set of time series measurements of a random variable 'X' where 'y' is defined as the set of natural log transformation of loading data:

$X =$ existing pollutant load data set defined by time series

$y = \ln(X) =$ natural log transformation of pollutant load data, X

Equations for the log transformed data are presented in this section for the lognormal distribution to define the lognormal parameters used to calculate NPDES permit limits based on maximum daily loads for pollutant loading. The expected value (E_x) (e.g., existing mean), variance (V_x), and upper percentile limit (X_p) of the random variable distribution of 'X' expressed in the measured units of the original untransformed existing time series data set (e.g., kg/day, lbs/day etc.) are given as follows:

$E(X) = \exp(\mu + 0.5\sigma^2)$ -- Equation 1
$V(X) = \exp(2\mu + \sigma^2)\,[\exp(\sigma^2) - 1]$ -- Equation 2
$X_p = \exp(\mu + Z\sigma)]$--- Equation 3

Estimates of these parameters are derived from substitution of the values for the sample mean (μ) and sample variance (σ^2) calculated from the natural log transformed observed data set [y=ln (X)] where:

μ = mean of log transformed data set, y=ln(X)

σ^2=variance of log transformed data set, y=ln(X)

σ = standard deviation of log transformed data set, y=ln(X)

z_p = pth percentile of 1-sided standard normal distribution (z_p=1.645 for 95th percentile and z_p=2.326 for 99th percentile)

The daily maximum variability factor (VF_p) for the pth percentile of the standard normal distribution is based on the ratio of the high value to average value of a lognormal distribution. Kahn and Rubin (1989) and EPA (1991) in Appendix E define the variability factor as:

$VF_p = \frac{X_p}{E_x}$--- Equation 4
$VF_p = \exp(z_p\sigma - 0.5\sigma^2)$ --- Equation 5

In EPA (1991), the variability factor (VF_p) is defined as the ratio of X_p (the upper limit of the confidence interval of the log transformed data) and the expected mean value E_x of the log transformed flow or pollutant loading data. As shown in EPA (1991: Table 5-2), the equation for the variability factor ratio is used with the Coefficient of Variation (CV) to compute the table of Long-Term Average (LTA) "LTA multipliers" to derive the Maximum Daily Load (MDL) based on reduction of the long-term average flow or load needed to meet water quality targets, criteria or standards.

The Coefficient of Variation (CV_x) for the untransformed load data set (X) is computed from the log transformed parameter value for variance (σ^2):

$CV_x = [\exp(\sigma^2) - 1]^{1/2}$-- Equation 6

The variability factor is then used to calculate the MDL from the reduced long-term average needed to attain compliance with water quality targets as follows:

$$MDL = LTA * VF_p = LTA * LTA\ Multiplier$$ ---------- Equation 7

Substitution of the exponential term for VF_p from above yields the lognormal distribution equation for the MDL given in EPA's *Options for Expressing Daily Loads in TMDLs* (EPA, 2007):

$$MDL = LTA\ \exp(z_p\sigma - 0.5\sigma^2)$$ ---------- Equation 8

The long-term average reduced load (LTA) is computed from the existing long-term average load [E(X)] computed from the log transformation of the observed load data and the estimated percent removal of existing loading (%R=0 for KGS analysis) expected to meet water quality targets in the waterbody.

$$LTA = E(X)(1 - \%R)$$ ---------- Equation 9

3.3 Parameters of the Lognormal Distribution

Parameter values determined for the MDL analysis of KGS total nitrogen and total phosphorus loading from the CTBD8 and LVW outfalls are summarized below in data tables for TN (Table J-5 and Table J-6), and TP (Table J-7 and Table J-8). MDL estimates for effluent TN and TP are based on assignment of the mean and variance of the log transformed time series for TN and TP loads and the Z-score value assigned for the 95% probability Confidence Interval.

Table J-5 Summary of Lognormal Parameter Values for KGS Effluent TN Load from CTBD8 Outfall

	KGS Discharge	**WQ_VAR ## TOTN**	**CTBD8 Value**	**Units KG/DAY**
	Input Parameters			
N=	Total N_Observations		37	
α	1-Sided, α		0.05	
p=	Probability, Confidence Interval		0.95	
	Log Transformed Statistics			
μ=	Mean (log transformed)	AVERAGE()	0.090883	kg/day
Var=	Variance (log transformed)	VAR()	0.494712	
	Results (original untransformed units)			
E(x) =	Expected value (Long Term Avg, LTA)	Eq. 10	1.402475	kg/day
V(x)=	Variance	Eq. 11	1.258889	
X(p) =	Upper p^{th} percentile limit of distribution	Eq. 12	3.482682	kg/day
Z(p)=	Z-Score	Eq. 13	1.644854	
VF(p)=	Variability Factor	Eq. 14	2.48324	
%R=	% Removal of Long Term Average (LTA)		0%	
MDL=	Max Daily Load	Eq. 15	3.482682	kg/day

Table J-6 Summary of Lognormal Parameter Values for KGS Effluent TN Load from LVW Outfall

	KGS Discharge	WQ_VAR ## TOTN	LVW Value	Units KG/DAY
	<u>Input Parameters</u>			
N=	Total N_Observations		37	
α	1-Sided, α		0.05	
p=	Probability, Confidence Interval		0.95	
	<u>Log Transformed Statistics</u>			
µ=	Mean (log transformed)	AVERAGE()	-2.78931	kg/day
Var=	Variance (log transformed)	VAR()	1.014075	
	<u>Results (original untransformed units)</u>			
E(x) =	Expected value (Long Term Avg, LTA)	Eq. 10	0.102052	kg/day
V(x)=	Variance	Eq. 11	0.018297	
X(p) =	Upper p^{th} percentile limit of distribution	Eq. 12	0.322091	kg/day
Z(p)=	Z-Score	Eq. 13	1.644854	
VF(p)=	Variability Factor	Eq. 14	3.156145	
%R=	% Removal of Long Term Average (LTA)		0%	
MDL=	Max Daily Load	Eq. 15	0.322091	kg/day

Table J-7 Summary of Lognormal Parameter Values for KGS Effluent TP Load from CTBD8 Outfall

	KGS Discharge	WQ_VAR ## TOTP	CTBD8 Value	Units KG/DAY
	<u>Input Parameters</u>			
N=	Total N_Observations		18	
α	1-Sided, α		0.05	
p=	Probability, Confidence Interval		0.95	
	<u>Log Transformed Statistics</u>			
µ=	Mean (log transformed)	AVERAGE()	-1.56684	kg/day
Var=	Variance (log transformed)	VAR()	0.915129	
	<u>Results (original untransformed units)</u>			
E(x) =	Expected value (Long Term Avg, LTA)	Eq. 10	0.329797	kg/day
V(x)=	Variance	Eq. 11	0.162833	
X(p) =	Upper p^{th} percentile limit of distribution	Eq. 12	1.006685	kg/day
Z(p)=	Z-Score	Eq. 13	1.644854	
VF(p)=	Variability Factor	Eq. 14	3.052441	
%R=	% Removal of Long Term Average (LTA)		0%	
MDL=	Max Daily Load	Eq. 15	1.006685	kg/day

Table J-8 Summary of Lognormal Parameter Values for KGS Effluent TP Load from LVW Outfall

	KGS Discharge	**WQ_VAR TOTP**	**## LVW Value**	**Units KG/DAY**
	Input Parameters			
N=	Total N_Observations		42	
α	1-Sided, α		0.05	
p=	Probability, Confidence Interval		0.95	
	Log Transformed Statistics			
μ=	Mean (log transformed)	AVERAGE()	-4.50336	KG/DAY
Var=	Variance (log transformed)	VAR()	0.628412	
	Results (original untransformed units)			
E(x) =	Expected value (Long Term Avg, LTA)	Eq. 10	0.015159	KG/DAY
V(x)=	Variance	Eq. 11	0.000201	
X(p) =	Upper p^{th} percentile limit of distribution	Eq. 12	0.040785	KG/DAY
Z(p)=	Z-Score	Eq. 13	1.644854	
VF(p)=	Variability Factor	Eq. 14	2.690453	
%R=	% Removal of Long Term Average (LTA)		0%	
MDL=	Max Daily Load	Eq. 15	0.040785	KG/DAY

3.4 Equations and Parameters of the Delta Lognormal Distribution

The delta lognormal distribution is a straight forward extension of the lognormal distribution, where the data set is represented as a mix of non-censored data and zeros (or censored data). Observations greater than the detection limit for censored data are described by the lognormal distribution and the proportion of records lower than the detection limit is represented with a discrete probability of recording a measurement at, or below, the detection limit. Owen and De Rouen (1980) recommended use of the delta lognormal distribution for pollutant data sets that included zero values and censored data (i.e., measurements reported as less than the detection limit). The methodology was first adopted by EPA for the development of effluent guidelines for the Organic Chemicals, Plastics and Synthetic Fibers industry (EPA, 1987) and subsequently applied for effluent guidelines for other industry groups (e.g., Iron and Steel: EPA, 2002). The methodology, equations, and parameters used for the delta lognormal distribution to derive maximum daily loads, briefly described in EPA (1991: Appendix E), are described in detail by Kahn and Rubin (1989). The equations for the delta lognormal distribution are presented herein with the parameters used to develop maximum daily load calculations.

For a data set of size (N) characterized by a mix of censored and non-censored load data, two new parameters are required for MDL calculations based on the delta lognormal distribution. The first new parameter (D) is defined as the censored value (or detection limit) of the data set. The second new parameter (δ) is defined as the proportion of the number of data records (r), where the observed value is less than or equal to the censored value ($\delta = r/N$).

Following the notation of Kahn and Rubin and EPA (1991), X^* is used to define the random variable for the modified delta lognormal distribution. The mean $E(X^*)$, variance $V(X^*)$, and upper percentile limit (X^*_p) of the modified random variable 'X^*' expressed in the measured units of the original untransformed data set are given as follows:

$E(X^*) = \delta D + (1-\delta)\exp(\mu + 0.5\sigma^2)$ -- Equation 10
$V(X^*) = (1-\delta)\exp(2\mu + \sigma^2)\,[\exp(\sigma^2) - (1-\delta)] + \delta(1-\delta)D[D - 2\exp(\mu + 0.5\sigma^2)]$ Equation 11
${X_p}^* = \max[D, \exp(\mu + Z^*\sigma)]$ --- Equation 12
$Z^* = \emptyset^{-1}[(p-\delta)/(1-\delta)]$ --- Equation 13

The probability value of the argument for the function $\emptyset^{-1}(\,)$ is based on the censored proportion of the input data set and the desired probability for the confidence interval of the distribution. The function $\emptyset^{-1}(\,)$ is the inverse of the standard normal cumulative distribution function. The probability value of the argument can be input to the Microsoft Excel function NORMSINV ( ) to obtain the parameter value for the Z-score (Z^*) as a function of the desired percentile (p) for the confidence interval of the distribution.

Note that for the case where $\delta = 0$ the value for $Z^* = 2.326$ for p=0.99 and the value for $Z^* = 1.645$ for p=0.95. As an example of the calculation of the argument and the Z-score parameter based on the 95th percentile (p=0.95) and a data set where 80% of the records are marked as censored data ($\delta = 0.8$), the argument for the function $\emptyset^{-1}(\,)$ is $[(0.95-0.8)/(1-0.8)] = 0.75$ and the value returned from NORMSINV (0.75) is $Z^* = 0.6745$.

The daily maximum variability factor (VF_p) for the p^{th} percentile of the standard normal distribution, based on the ratio of high values to average values of the non-censored lognormal distribution, is defined by Kahn and Rubin (1989) and EPA (1991) as:

$VF_p^* = X_p^*/E(X^*)$ -- Equation 14

Following the methodology for the lognormal distribution, the variability factor is used to calculate the MDL from the expected value of the existing average flow or load [$E(X^*)$] and the percent reduction (%R) of the existing flow or pollutant load needed to attain compliance with water quality targets. $E(X^*)$ accounts for the minimum value for the censored limit, the proportion of the total flow or load data set that is defined as censored and non-censored data, and the parameter values of the distribution of the log transformed load censored load data. The MDL is computed from the expected value of the existing flow or pollutant load, the required removal percentage (%R=0 for KGS analysis) for compliance with water quality targets, and the temporal variability factor as follows:

$MDL = E(X^*)(1 - \%R)VF_p$ --- Equation 15

3.5 Parameters of the Delta Lognormal Distribution

Parameter values determined for the MDL analysis of KGS flow from the CTBD8 and LVW outfalls are summarized below in data tables for flow (Table J-9 and Table J-10). MDL estimates for effluent flow are based on assignment of non-zero values of parameters (D, ð) determined for the Delta lognormal distribution, the mean and variance of the log transformed time series for effluent flow, and the Z-score value computed from Eq. 13 for the 95% probability Confidence Interval.

Table J-9 Summary of Delta Lognormal Parameter Values for Effluent Flow from CTBD8 Outfall

	KGS Discharge	WQ_VAR FLOW	CTBD8 Value	Units MGD
	Censored Input Parameters			
N=	Total N_Observations		1307	
D =	Minimum Detection Value		0.1	MGD
r=	N_Obs <= D (Min Value)		364	
k=N-r	N_Obs > D (Min Value)		943	
ð=r/N	Fraction censored data		0.2785	
	Non-Censored Input Parameters			
α	1-Sided, α		0.05	
p=	Probability, Confidence Interval		0.95	
	Log Transformed Statistics			
μ=	Mean (log transformed)	AVERAGE()	-1.35665	MGD
Var=	Variance (log transformed)	VAR()	0.107152	
	Results (original untransformed units)			
E(x*) =	Expected value (Long Term Avg, LTA)	Eq. 10	0.223877	MGD
V(x*)=	Variance	Eq. 11	0.011947	
X*(p) =	Upper p^{th} percentile limit of distribution	Eq. 12	0.418176	MGD
Z*(p)=	Arg ($Ø^{-1}$)=(p-ð)/(1-ð) = Z-Score	Eq. 13	1.481024	
VF*(p)=	Variability Factor	Eq. 14	1.867878	
%R=	% Removal of Long Term Average (LTA)		0%	
MDL=	Max Daily Load	Eq. 15	0.418176	MGD

Table J-10 Summary of Delta Lognormal Parameter Values for Effluent Flow from LVW Outfall

	KGS Discharge	**WQ_VAR FLOW**	**LVW Value**	**Units MGD**
	Censored Input Parameters			
N=	Total N_Observations		1295	
D =	Minimum Detection Value		0.001	MGD
r=	N_Obs <= D (Min Value)		342	
k=N-r	N_Obs > D (Min Value)		953	
ð=r/N	Fraction censored data		0.264093	
	Non-Censored Input Parameters			
α	1-Sided, α		0.05	
p=	Probability, Confidence Interval		0.95	
	Log Transformed Statistics			
μ=	Mean (log transformed)	AVERAGE()	-3.68285	MGD
Var=	Variance (log transformed)	VAR()	0.685539	
	Results (original untransformed units)			
E(x*) =	Expected value (Long Term Avg, LTA)	Eq. 10	0.02634	MGD
V(x*)=	Variance	Eq. 11	0.00114	
X*(p) =	Upper p^{th} percentile limit of distribution	Eq. 12	0.086457	MGD
Z*(p)=	Arg ($Ø^{-1}$)=(p-ð)/(1-ð) = Z-Score	Eq. 13	1.491285	
VF*(p)=	Variability Factor	Eq. 14	3.282312	
%R=	% Removal of Long Term Average (LTA)		0%	
MDL=	Max Daily Load	Eq. 15	0.086457	MGD

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Attachment #1 Total Phosphorus Sampling Dates for KGS CTBD8 and LVW Outfalls

Sample Dates for TP, Effluent Flow and Load: CTBD8

TOTP CTBD8 TOTP MG/L	TOTP CTBD8 FLOW MGD	TOTP CTBD8 FLOW CFS	TOTP CTBD8 FLOW GAL/DAY	TOTP CTBD8 LOAD kg/day	TOTP CTBD8 LOAD lbs/day	TOTP CTBD8 DATE SAMPLE
0.11	0.173378	0.268256	173378.2	0.072192	0.159057	2014-12-15
0.13	0.176105	0.272475	176105	0.086659	0.190933	2014-12-29
0.19	0.026083	0.040356	26083	0.018759	0.041331	2015-01-12
0.12	0.178671	0.276445	178670.9	0.081159	0.178814	2015-01-26
0.54	0.185257	0.286635	185256.9	0.378677	0.834323	2015-04-20
0.9	0.263548	0.407769	263547.8	0.897847	1.978189	2015-05-04
0.26	0.194025	0.300201	194024.8	0.190955	0.420723	2015-06-01
0.21	0.211015	0.326489	211015.2	0.167739	0.369572	2015-07-13
0.17	0.153205	0.237043	153204.8	0.098587	0.217214	2015-08-10
0.37	0.106095	0.164153	106094.8	0.148592	0.327387	2015-09-08
0.65	0.23051	0.356652	230510	0.567157	1.249595	2015-10-05
0.54	0.325966	0.504344	325965.8	0.666294	1.468019	2015-11-02
0.42	0.282162	0.43657	282162.3	0.448589	0.988358	2015-12-14
0.49	0.113869	0.176182	113869.3	0.211204	0.465338	2016-01-11
0.2	0.384392	0.594743	384392.1	0.291008	0.641166	2016-02-08
0.25	0.285483	0.441708	285483.1	0.27016	0.595232	2016-03-07
0.34	0.311899	0.482579	311898.7	0.401414	0.88442	2016-04-04
0.32	0.271344	0.419832	271344.3	0.328678	0.724164	2016-06-13
0.26	#N/A	#N/A	#N/A	#N/A	#N/A	2016-09-15

Sample Dates for TP, Effluent Flow and Load: LVW

TOTP LVW TOTP MG/L	TOTP LVW FLOW MGD	TOTP LVW FLOW CFS	TOTP LVW FLOW GAL/DAY	TOTP LVW LOAD KG/DAY	TOTP LVW LOAD LB/DAY	TOTP LVW DATE SAMPLE
0.46	0.00644	0.009964	6439.999	0.011214	0.024706	2013-10-17
0.49	0.031782	0.049174	31782.02	0.058949	0.12988	2013-10-24
0.51	0.011403	0.017643	11403.02	0.022014	0.048502	2013-10-31
0.35	0.014167	0.02192	14167	0.018769	0.041353	2013-11-21
0.29	0.021255	0.032886	21255.02	0.023332	0.051407	2013-12-05
0.28	0.03899	0.060327	38990	0.041325	0.091049	2013-12-18
0.26	0.009173	0.014193	9172.974	0.009028	0.019891	2014-06-05
0.13	0.014176	0.021934	14175.98	0.006976	0.01537	2014-06-26
0.17	0.014275	0.022087	14274.99	0.009186	0.020239	2014-07-30
0.16	0.038954	0.060271	38954	0.023592	0.05198	2014-08-10
0.17	0.002125	0.003288	2124.998	0.001367	0.003013	2014-08-11
0.16	0.020132	0.031149	20131.98	0.012193	0.026864	2014-08-25
0.11	0.038629	0.059768	38628.97	0.016084	0.035438	2014-09-08
0.14	0.018504	0.02863	18503.97	0.009806	0.021605	2014-09-22
0.13	0.016969	0.026255	16968.97	0.00835	0.018398	2014-10-06
0.16	0.024992	0.038668	24992.02	0.015136	0.033349	2014-10-20
0.16	0.013475	0.020849	13474.98	0.008161	0.017981	2014-11-03
0.09	0.016611	0.025701	16610.98	0.005659	0.012468	2014-12-01
0.09	0.014691	0.02273	14691.03	0.005005	0.011027	2014-12-15
0.06	0.011362	0.01758	11361.98	0.002581	0.005686	2014-12-29
0.17	0.022742	0.035187	22742	0.014634	0.032244	2015-01-12
0.08	0.019346	0.029933	19345.99	0.005858	0.012908	2015-01-26
0.1	0.080517	0.124578	80516.79	0.030478	0.067151	2015-02-09
0.12	0.047113	0.072895	47112.97	0.0214	0.047151	2015-02-23
0.1	0.014147	0.021889	14147.02	0.005355	0.011799	2015-03-09
0.06	0.039291	0.060792	39290.99	0.008924	0.019661	2015-03-23
0.05	0.060251	0.093222	60251.03	0.011403	0.025125	2015-04-06
0.06	0.025315	0.039168	25314.98	0.005749	0.012668	2015-04-20
0.26	0.036652	0.056709	36652.02	0.036072	0.079476	2015-05-04
0.12	0.028968	0.04482	28968.03	0.013158	0.028991	2015-06-01
0.11	0.044766	0.069263	44766	0.01864	0.041068	2015-07-13
0.05	0.070427	0.108967	70427.15	0.013329	0.029368	2015-08-10
0.08	0.089117	0.137884	89116.68	0.026987	0.059459	2015-08-24
0.11	0.048322	0.074765	48321.97	0.02012	0.044331	2015-09-08
0.12	0.0072	0.01114	7200.028	0.003271	0.007206	2015-10-05
0.24	0.004873	0.00754	4872.999	0.004427	0.009754	2015-11-02
0.11	0.015097	0.023359	15096.98	0.006286	0.01385	2015-12-14
0.06	0	0	0	0	0	2015-12-29
0.2	0.006331	0.009796	6330.998	0.004793	0.01056	2016-01-11
0.04	0.078997	0.122227	78997.3	0.011961	0.026354	2016-02-08
0.1	0.066645	0.103115	66644.91	0.025227	0.055582	2016-03-07
0.1	0.010684	0.016531	10684	0.004044	0.00891	2016-04-04
0.13	0.034354	0.053154	34353.97	0.016905	0.037247	2016-06-13
0.19	#N/A	#N/A	#N/A	#N/A	#N/A	2016-07-25
0.18	#N/A	#N/A	#N/A	#N/A	#N/A	2016-09-15

Attachment #2 Total Nitrogen Sampling Dates for KGS CTBD8 and LVW Outfalls

Sample Dates for TN, Effluent Flow and Load; CTBD8

TOTN CTBD8 TOTN MG/L	TOTN CTBD8 FLOW MGD	TOTN CTBD8 FLOW CFS	TOTN CTBD8 FLOW GAL/DAY	TOTN CTBD8 LOAD kg/day	TOTN CTBD8 LOAD lbs/day	TOTN CTBD8 DATE SAMPLE
1.52	0.193405	0.299242	193405	1.112786	2.451756	2013-10-17
2.31	0.374412	0.579301	374411.7	3.273872	7.213191	2013-10-24
1.77	0.180531	0.279323	180531	1.209554	2.664963	2013-10-31
1.25	0.278902	0.431526	278902.3	1.319661	2.907556	2013-11-21
3.66	0.230837	0.357158	230837	3.198062	7.046162	2013-12-05
1.44	0.353705	0.547263	353705	1.927987	4.247856	2013-12-18
1.28	0.074153	0.114732	74153.16	0.359286	0.7916	2014-06-05
1.58	0.098657	0.152645	98656.95	0.590045	1.300022	2014-06-26
1.24	0.188827	0.292159	188827.1	0.886311	1.952775	2014-07-30
1.49	0.241041	0.372946	241041.1	1.359495	2.995321	2014-08-10
1.59	0.243991	0.37751	243990.9	1.46849	3.235465	2014-08-11
1.05	0.239616	0.370741	239616	0.952369	2.098317	2014-08-25
1.31	0.255345	0.395077	255344.7	1.266189	2.789743	2014-09-08
1.07	0.266409	0.412196	266409	1.079029	2.377381	2014-09-22
0.87	0.2388	0.369479	238800.3	0.78642	1.732687	2014-10-06
1.06	0.235367	0.364167	235367.1	0.944391	2.080739	2014-10-20
1.1	0.245047	0.379144	245047	1.020334	2.248061	2014-11-03
0.77	0.181294	0.280504	181294.3	0.528415	1.164236	2014-12-01
0.93	0.173378	0.268256	173378.2	0.610348	1.344756	2014-12-15
0.95	0.176105	0.272475	176105	0.63328	1.39528	2014-12-29
1.09	0.026083	0.040356	26083	0.107618	0.23711	2015-01-12
0.83	0.178671	0.276445	178670.9	0.561348	1.236796	2015-01-26
2.68	0.185257	0.286635	185256.9	1.879358	4.140714	2015-04-20
1.38	0.263548	0.407769	263547.8	1.376698	3.033224	2015-05-04
2.06	0.194025	0.300201	194024.8	1.512951	3.333424	2015-06-01
1.23	0.211015	0.326489	211015.2	0.98247	2.164636	2015-07-13
0.92	0.153205	0.237043	153204.8	0.533532	1.175509	2015-08-10
2.04	0.191975	0.297029	191974.7	1.482431	3.266181	2015-08-24
1.81	0.106095	0.164153	106094.8	0.726897	1.601543	2015-09-08
2.72	0.23051	0.356652	230510	2.373335	5.229073	2015-10-05
2.83	0.325966	0.504344	325965.8	3.491875	7.693509	2015-11-02
2.29	0.282162	0.43657	282162.3	2.445878	5.388905	2015-12-14
1.11	0.113869	0.176182	113869.3	0.478443	1.054134	2016-01-11
1.66	0.384392	0.594743	384392.1	2.415365	5.321678	2016-02-08
1.71	0.285483	0.441708	285483.1	1.847893	4.071389	2016-03-07
2	0.311899	0.482579	311898.7	2.36126	5.20247	2016-04-04
0.76	0.271344	0.419832	271344.3	0.780611	1.719889	2016-06-13
1.02	#N/A	#N/A	#N/A	#N/A	#N/A	2016-07-25
0.8	#N/A	#N/A	#N/A	#N/A	#N/A	2016-09-15

Sample Dates for TN, Effluent Flow and Load: LVW

TOTN LVW TOTN MG/L	TOTN LVW FLOW MGD	TOTN LVW FLOW CFS	TOTN LVW FLOW GAL/DAY	TOTN LVW LOAD kg/day	TOTN LVW LOAD lbs/day	TOTN LVW DATE SAMPLE
1.65	0.00644	0.009964	6439.999	0.040223	0.088621	2013-10-17
1.13	0.031782	0.049174	31782.02	0.135944	0.29952	2013-10-24
0.84	0.011403	0.017643	11403.02	0.036258	0.079885	2013-10-31
1.23	0.014167	0.02192	14167	0.06596	0.145328	2013-11-21
0.97	0.021255	0.032886	21255.02	0.078043	0.171949	2013-12-05
0.79	0.03899	0.060327	38990	0.116595	0.25689	2013-12-18
0.81	0.009173	0.014193	9172.974	0.028125	0.061967	2014-06-05
1.9	0.014176	0.021934	14175.98	0.101955	0.224633	2014-06-26
0.46	0.014275	0.022087	14274.99	0.024856	0.054765	2014-07-30
0.58	0.038954	0.060271	38954	0.085522	0.188428	2014-08-10
0.97	0.002125	0.003288	2124.998	0.007802	0.017191	2014-08-11
0.52	0.020132	0.031149	20131.98	0.039627	0.087308	2014-08-25
0.54	0.038629	0.059768	38628.97	0.07896	0.173969	2014-09-08
2.84	0.018504	0.02863	18503.97	0.198922	0.438278	2014-09-22
1.42	0.016969	0.026255	16968.97	0.09121	0.20096	2014-10-06
0.43	0.024992	0.038668	24992.02	0.040679	0.089626	2014-10-20
0.34	0.013475	0.020849	13474.98	0.017342	0.03821	2014-11-03
1.48	0.016611	0.025701	16610.98	0.093059	0.205033	2014-12-01
0.25	0.014691	0.02273	14691.03	0.013902	0.030631	2014-12-15
1.29	0.011362	0.01758	11361.98	0.055481	0.122239	2014-12-29
0.52	0.022742	0.035187	22742	0.044764	0.098627	2015-01-12
0.16	0.019346	0.029933	19345.99	0.011717	0.025815	2015-01-26
0.22	0.080517	0.124578	80516.79	0.067052	0.147732	2015-02-09
0.32	0.047113	0.072895	47112.97	0.057068	0.125735	2015-02-23
0.54	0.014147	0.021889	14147.02	0.028917	0.063713	2015-03-09
1.15	0.039291	0.060792	39290.99	0.171037	0.37684	2015-03-23
0.46	0.060251	0.093222	60251.03	0.104911	0.231147	2015-04-06
0.24	0.025315	0.039168	25314.98	0.022998	0.05067	2015-04-20
0.56	0.036652	0.056709	36652.02	0.077694	0.17118	2015-05-04
2.18	0.028968	0.04482	28968.03	0.239043	0.526673	2015-06-01
3.34	0.044766	0.069263	44766	0.565972	1.246984	2015-07-13
2.2	0.070427	0.108967	70427.15	0.586493	1.292197	2015-08-10
0.82	0.089117	0.137884	89116.68	0.276613	0.609451	2015-08-24
0.68	0.048322	0.074765	48321.97	0.124381	0.274044	2015-09-08
1.16	0.0072	0.01114	7200.028	0.031615	0.069656	2015-10-05
0.87	0.004873	0.00754	4872.999	0.016048	0.035358	2015-11-02
0.63	0.015097	0.023359	15096.98	0.036002	0.079323	2015-12-14
1.29	0	0	0	0	0	2015-12-29
0.28	0.006331	0.009796	6330.998	0.00671	0.014784	2016-01-11
0.17	0.078997	0.122227	78997.3	0.050835	0.112002	2016-02-08
0.53	0.066645	0.103115	66644.91	0.133704	0.294584	2016-03-07
0.52	0.010684	0.016531	10684	0.02103	0.046334	2016-04-04
0.4	0.018665	0.028879	18664.97	0.028261	0.062266	2016-05-02
0.57	0.034354	0.053154	34353.97	0.074123	0.163312	2016-06-13
0.52	#N/A	#N/A	#N/A	#N/A	#N/A	2016-07-25
0.14	#N/A	#N/A	#N/A	#N/A	#N/A	2016-09-15

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Appendix K

Periphyton Density and Biomass Data

Lough Gill, Sligo, Ireland

Table K-1 Periphyton Measurements in Lough Gill, Ireland. Source (Feeney, 1998)

Feeney, D. (1998). *Development of a lake pollution monitoring system using periphyton in the littoral zone of Lough Gill.* Sligo, Ireland: Institute of Technology.

Summary Statistics	**Biomass g AFDW m^{-2}**	**Chl-a mg Chl m^{-2}**	**DENSITY Cells mm^{-2}**
COUNT	98	98	98
MIN	0.1	0.6	62
10th%ile	0.47	2.74	477.4
25%ile	1.1	7.925	1488.25
50th%ile	1.75	22.6	4159
75%ile	4.15	42.1	7257
90%ile	7.86	66.99	14738.4
MAX	18.8	168.1	41276
AVERAGE	3.47	29.19	6332.61

STA	**SITE**	**DATE**	**INDEX #**	**Raw_Data** **Biomass g AFDW m^{-2}**	**Raw_Data** **Chl-a mg Chl m^{-2}**	**Raw_Data** **DENSITY Cells mm^{-2}**
S1	M1	Mar-97	1	4	42	1696
S1	M2	Apr-97	2	2.1	27.3	2736
S1	W1	10-Apr-97	3	1.6	19.1	1239
S1	W2	24-Apr-97	4	1.3	18.3	1754
S1	M3	May-97	5	1.2	2	5492
S1	W3	06-May-97	6	1.2	7.9	2509
S1	W4	28-May-97	7	0.4	3	693
S1	M4	Jun-97	8	1.1	7.1	2315
S1	M5	Jul-97	9	1	8	1531
S1	M6	Aug-97	10	1.7	32.7	1474
S1	M7	Sep-97	11	2.4	22.1	4168
S1	M8	Oct-97	12	0.8	7	1133
S1	M9	Nov-97	13	0.3	2.8	476
S1	M12	Feb-98	14	0.3	2.6	329
S1	M13	Mar-98	15	1.2	21.1	3026
S1	M14	Apr-98	16	12.5	36.5	27638
S1	M15	May-98	17	5.3	66.6	13290
S2	M1	Mar-97	18	6.7	67.9	8152
S2	M2	Apr-97	19	2.6	52.8	4341
S2	W1	10-Apr-97	20	1.5	18.3	2120
S2	W2	24-Apr-97	21	6.3	168.1	9132
S2	M3	May-97	22	5.4	43.8	13885
S2	W3	06-May-97	23	2.9	33.3	3720

S2	M5	Jul-97	24	2.6	28.9	5372
S2	M6	Aug-97	25	1.4	14.6	2733
S2	M7	Sep-97	26	1.3	21.9	2692
S2	M8	Oct-97	27	0.7	7.8	904
S2	M9	Nov-97	28	0.2	0.8	124
S2	M12	Feb-98	29	0.9	7.6	870
S2	M13	Mar-98	30	3.5	65.7	6779
S2	M14	Apr-98	31	18.8	69.6	25844
S2	M15	May-98	32	8.7	70.6	15822
S3	M1	Mar-97	33	7.5	75.2	9723
S3	M2	Apr-97	34	6.9	74.4	9191
S3	W1	10-Apr-97	35	1.8	31.5	3259
S3	W2	24-Apr-97	36	3.3	45.4	8059
S3	M3	May-97	37	13.8	42.1	16193
S3	W3	06-May-97	38	3.8	42	4489
S3	M4	Jun-97	39	3.8	31.6	6909
S3	M5	Jul-97	40	1.2	17.2	4150
S3	M7	Sep-97	41	2.3	23.7	5293
S3	M8	Oct-97	42	0.3	1	337
S3	M9	Nov-97	43	0.3	1.3	166
S3	M12	Feb-98	44	0.7	6	947
S3	M13	Mar-98	45	6	35.4	7373
S3	M14	Apr-98	46	10.9	75.1	18864
S3	M15	May-98	47	12.7	67.9	12429
S4	M1	Mar-97	48	3.6	42.1	5811
S4	M2	Apr-97	49	1.6	14.7	1883
S4	W1	10-Apr-97	50	0.7	2.6	415
S4	W2	24-Apr-97	51	1.5	20.7	5554
S4	M3	May-97	52	12.7	28	31327
S4	W3	06-May-97	53	2.7	13.1	4744
S4	W4	28-May-97	54	1	8.8	3597
S4	M4	Jun-97	55	5.5	46.7	9776
S4	M5	Jul-97	56	1.5	19	3426
S4	M6	Aug-97	57	0.6	2.9	564
S4	M7	Sep-97	58	1.4	27.6	3867
S4	M8	Oct-97	59	1	7.1	782
S4	M9	Nov-97	60	0.4	2.3	291
S4	M12	Feb-98	61	0.2	2.1	420
S4	M13	Mar-98	62	1.2	21	4301
S4	M14	Apr-98	63	15.9	55.4	41276
S4	M15	May-98	64	7.4	60.4	20197
S5	M1	Mar-97	65	4.2	47.9	5997
S5	M2	Apr-97	66	5.5	68.1	6034

S5	W1	10-Apr-97	67	2.2	24.8	3972
S5	W2	24-Apr-97	68	3.2	37.1	5544
S5	M3	May-97	69	4.7	50.2	12213
S5	W3	06-May-97	70	3.4	28.8	5166
S5	W4	28-May-97	71	1.6	23.1	5430
S5	M4	Jun-97	72	6.3	88.2	14274
S5	M5	Jul-97	73	1.6	11.2	2878
S5	M6	Aug-97	74	1.3	8.8	2935
S5	M7	Sep-97	75	1.8	21.3	4301
S5	M8	Oct-97	76	1.6	26.9	4181
S5	M9	Nov-97	77	0.5	8.2	841
S5	M12	Feb-98	78	0.1	0.6	76
S5	M13	Mar-98	79	3.2	53.4	7928
S5	M14	Apr-98	80	14.8	41.3	28532
S5	M15	May-98	81	4.5	52.3	6550
S6	M1	Mar-97	82	1.3	5.5	1046
S6	M2	Apr-97	83	1.5	27.5	2507
S6	W1	10-Apr-97	84	1.1	6.9	1148
S6	W2	24-Apr-97	85	1	12.8	1563
S6	M3	May-97	86	4	29.6	9558
S6	W3	06-May-97	87	2	15.7	5932
S6	W4	28-May-97	88	1.8	9.6	1612
S6	M4	Jun-97	89	1.8	5	1662
S6	M5	Jul-97	90	1.5	15.6	5077
S6	M6	Aug-97	91	1	4.8	1230
S6	M7	Sep-97	92	2.1	23.3	4656
S6	M8	Oct-97	93	1	8.3	1076
S6	M9	Nov-97	94	0.7	6.4	478
S6	M12	Feb-98	95	0.1	1	62
S6	M13	Mar-98	96	1.7	57.3	5515
S6	M14	Apr-98	97	14.7	37.1	31849
S6	M15	May-98	98	5.7	59.8	9171

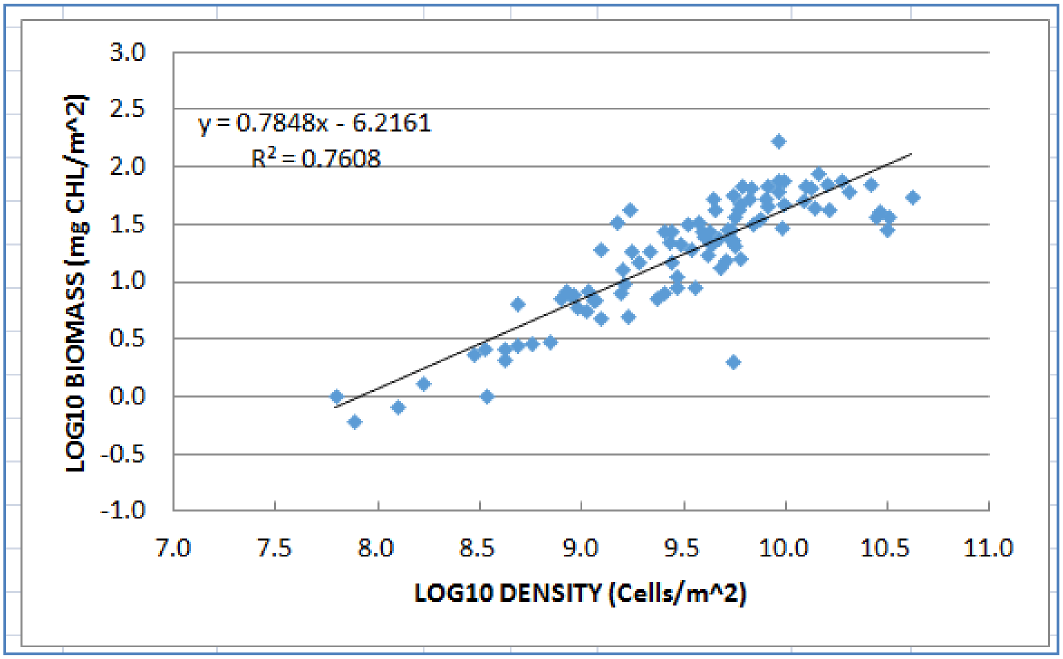

Figure K-1 Log-log plot of Periphyton cell density vs. biomass as Chlorophyll-a

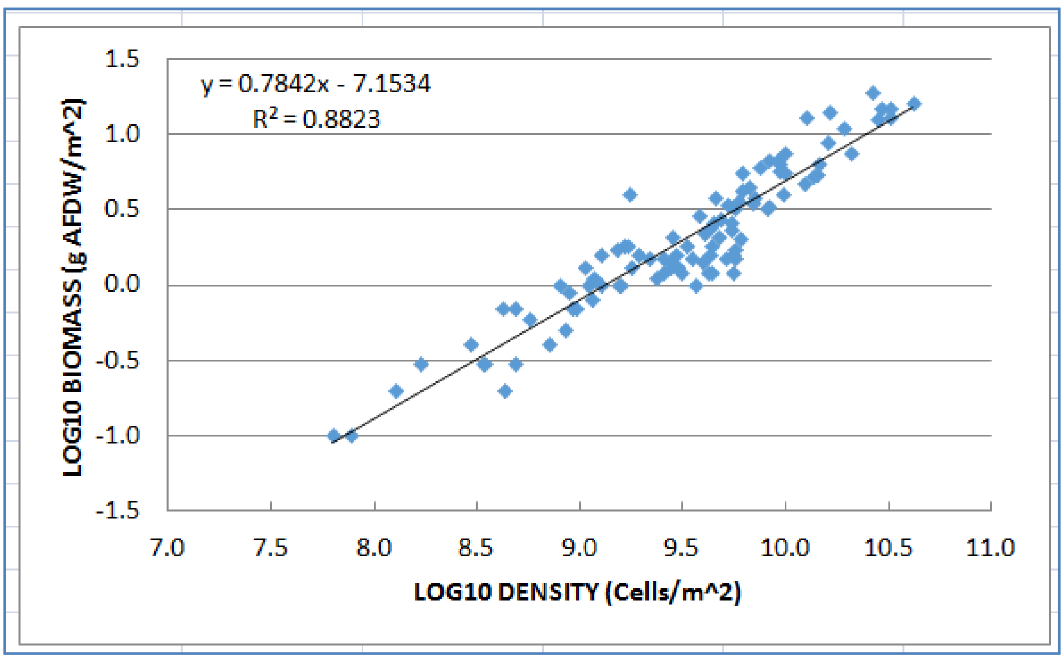

Figure K-2 Log-log plot of Periphyton cell density vs. biomass as Ash-Free Dry Weight (AFDW)

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Sweetwater Branch Level II Water Quality-Based Effluent Limits Report

Section 6 – Joint Report

Sweetwater Wetlands and Restoration Area Performance Modeling

Prepared for

Gainesville Regional Utilities

March 2021

Prepared by

Wetland Solutions Inc

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Background

The Sweetwater Wetlands Park, formerly referred to as the Sweetwater Branch/Paynes Prairie Sheetflow Restoration Project (Project), was completed in mid-2015 and was implemented as the least-cost alternative to comply with the Alachua Sink Total Maximum Daily Load (TMDL) for total nitrogen (TN) that was established by the Florida Department of Environmental Protection (FDEP) in 2006. The TMDL set wasteload allocations (WLAs) for the Main Street Water Reclamation Facility (MSWRF) and Kelly Generating Station (KGS), both of which are operated by Gainesville Regional Utilities (GRU). The TMDL also required a 45 percent reduction in non-point source (NPS) nitrogen loads to Alachua Sink. Figure 1 shows the Project area with the location of point source discharges.

GRU is requesting the establishment of Water Quality Based Effluent Limitations for (WQBELs) for the MSWRF and KGS. Documentation presented in Sections 1-5 of this joint report describe the results of stressor identification studies and nutrient modeling within Sweetwater Branch (Frydenborg Ecologic and Dynamic Solutions 2019). Those sections include a summary of the water quality modeling that was conducted for the 125-acre Enhancement Wetlands and 1,300-acre Sheetflow Restoration Area during the permitting and design phase for the Project. Since the design phase was completed, additional wetland water quality modeling has been conducted in support of the WQBEL process (Wetland Solutions 2016). This memorandum has also been prepared in support of the WQBEL process for the following specific purposes:

- To demonstrate, using the same modeling approach used during the design phase which was presented in the Preliminary Engineering Report for the project, that long-term average nutrient concentrations of 3 mg/L for TN and 0.3 mg/L (as 5-year rolling averages) for total phosphorus (TP) are achieved at the outlet from the Enhancement Wetlands in compliance with the conditions of the Environmental Resource Permit (ERP);
- To demonstrate that water quality improvement continues in the Sheetflow Restoration Area and achieves background nutrient concentrations (1.4 mg/L for TN and 0.1 mg/L for TP); and
- To demonstrate compliance with the TMDL for Alachua Sink.

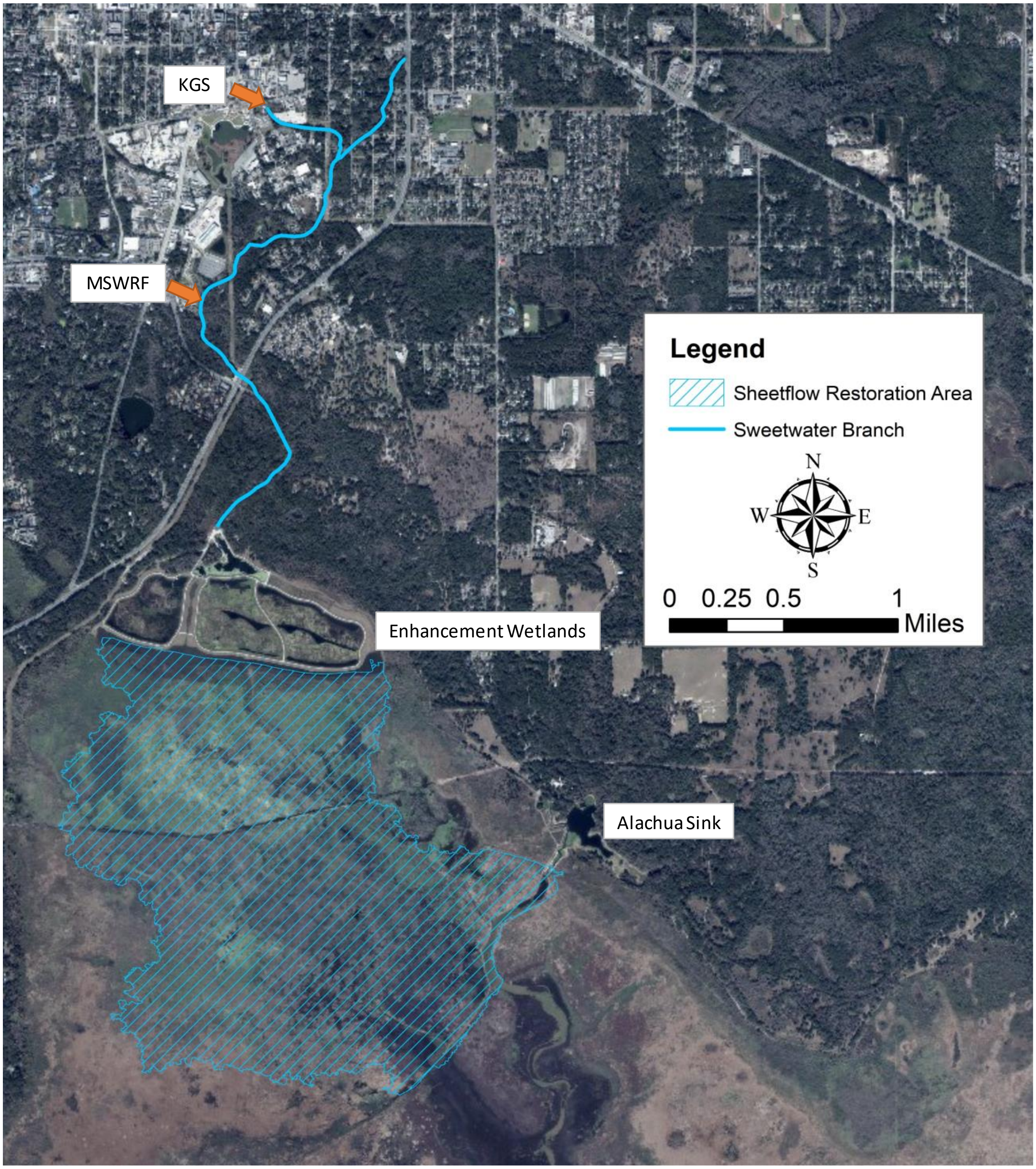

Figure 1. Project Location Map

The Kelly Generating Station and Main Street Water Reclamation Faciltty discharge treated effluent to Sweetwater Branch, which also conveys urban watershed runoff. Most stream flow is routed through the Enhancement Wetlands for polishing, while high flows bypass the Enhancement Wetlands. All flow is collected and discharged to the Sheetflow Restoration Area and Alachua Sink.

Wetland Water Quality Performance Modeling Approach

An empirical wetland water quality model was used to provide performance estimates for the Enhancement Wetlands and the Sheetflow Restoration Area. The tanks-in-series formulation of the k-C* model (Kadlec and Knight, 1996) is a first-order, steady-state algorithm that estimates long-term average performance based on long-term average inflow conditions. The k-C* model was used for the project design, is widely accepted for this purpose, has been extensively peer reviewed, and has been calibrated with data from hundreds of wetland systems.

P-k-C Model*

Kadlec and Wallace (2009) promote the P-k-C* model as the preferred tool for sizing constructed wetlands and determining removal rate parameters from operational data. This model is an improved variant of the previously published tanks-in-series (TIS) formulation of the first-order k-C* model (Kadlec and Knight, 1996). The model equation is given below and incorporates the following key principles:

- Wetland removal processes are area-based and follow first-order kinetics.
- For some parameters, internal cycling results in non-zero background concentrations (C*).
- Physical factors that influence the hydraulic efficiency of wetlands, including topography, wetland geometry, vegetation density and spatial distribution, and wind fetch lead to non-plug-flow conditions and should be included in calculations.
- Factors that describe pollutant mixtures or contaminant "weathering" should also be included in the model.

$$\left(\frac{C_2 - C^*}{C_1 - C^*}\right) = \left(1 + \frac{k}{Pq}\right)^{-P} \qquad \text{[EQ-1]}$$

Where

C_1	=	average inlet concentration, mg/L
C_2	=	average outlet concentration, mg/L
C^*	=	background concentration, mg/L
k	=	first-order, area-based rate constant, m/y
q	=	average hydraulic loading rate, m/y
P	=	apparent number of tanks-in-series

In the earlier TIS model, the effects of hydraulic efficiency were described by the parameter N, the number of TIS. In the updated model, N has been replaced by P and combines the effects of hydraulic efficiency and pollutant mixtures or weathering such that $P \leq N$ (Kadlec and Wallace, 2009).

For certain parameters where removal mechanisms are correlated with temperature or season, it is necessary to correct the value of k for the ambient water temperature:

$$k_T = k_{20}\theta^{T-20} \qquad \text{[EQ-2]}$$

Where

k_{20} = removal rate constant at 20°C

θ = dimensionless constant

k_T = removal rate constant at temperature T

The hydraulic loading rate term (q) in Equation 1 incorporates the effective wetland treatment area as follows:

$$q = \frac{Q}{A} \qquad \text{[EQ-3]}$$

Where

Q = inflow rate, m^3/y

A = effective wetland area, m^2

Depending on the site, the reported nominal system area and the effective area can be different. For example, internal areas (topographic highs) that are not inundated but may be included in the nominal area do not treat water and should be excluded from the calculations. At Sweetwater, Cell 1 includes upland islands that do not contribute to treatment. All reported calculations used an effective area of 120 acres within the Enhancement Wetlands to account for upland island area.

Using equations EQ-1 and EQ-3, the concentration profile between the wetland inlet and outlet can be described based on the fractional distance downstream as follows:

$$\left(\frac{C_2 - C^*}{C_1 - C^*}\right) = \left(1 + \frac{yk}{Pq}\right)^{-P} \qquad \text{[EQ-4]}$$

Where

y = fractional distance through the wetland, dimensionless

General Behavior of the P-k-C* Model

Figure 2 shows the general behavior of the first-order P-k-C* model for a hypothetical test case with a 100-acre wetland receiving a flow of 5 MGD at an inflow concentration of 20 mg/L. The value of C* was assumed to be 1.0 mg/L and P was assigned a value of 3. The figure shows the longitudinal profile of concentration change between the wetland inlet and outlet for three different removal rate coefficients (k = 50 m/yr; 2k = 100 m/yr; and 0.5k = 25 m/yr). The model represents treatment performance in the following ways:

- Pollutant concentrations decline exponentially with linear distance (increasing area) through the wetland.
- Pollutant concentrations decrease more rapidly at higher removal rate coefficients but still approach the same background concentration.
- For pollutants with high inflow concentrations and low background concentrations, an appropriately sized wetland can exhibit concentration or mass removal efficiencies in excess of 95 percent. Removal efficiencies reported in the literature for stormwater or

lightly loaded systems are typically much lower than those observed for more heavily loaded systems that receive municipal or industrial wastewaters.

- When the removal rate coefficient is high enough, or the pollutant load (combination of inflow concentration and hydraulic loading rate) is low enough, the estimated outlet concentration will essentially be at the background concentration.
- A conservatively sized wetland will approximately reach the background concentration before the end of the wetland is reached. This means that the same wetland has additional capacity for future growth.
- If the outlet concentration is not close to the background concentration (or the regulatory target outlet concentration), then either the inflow load must be reduced, or the wetland area must be expanded.

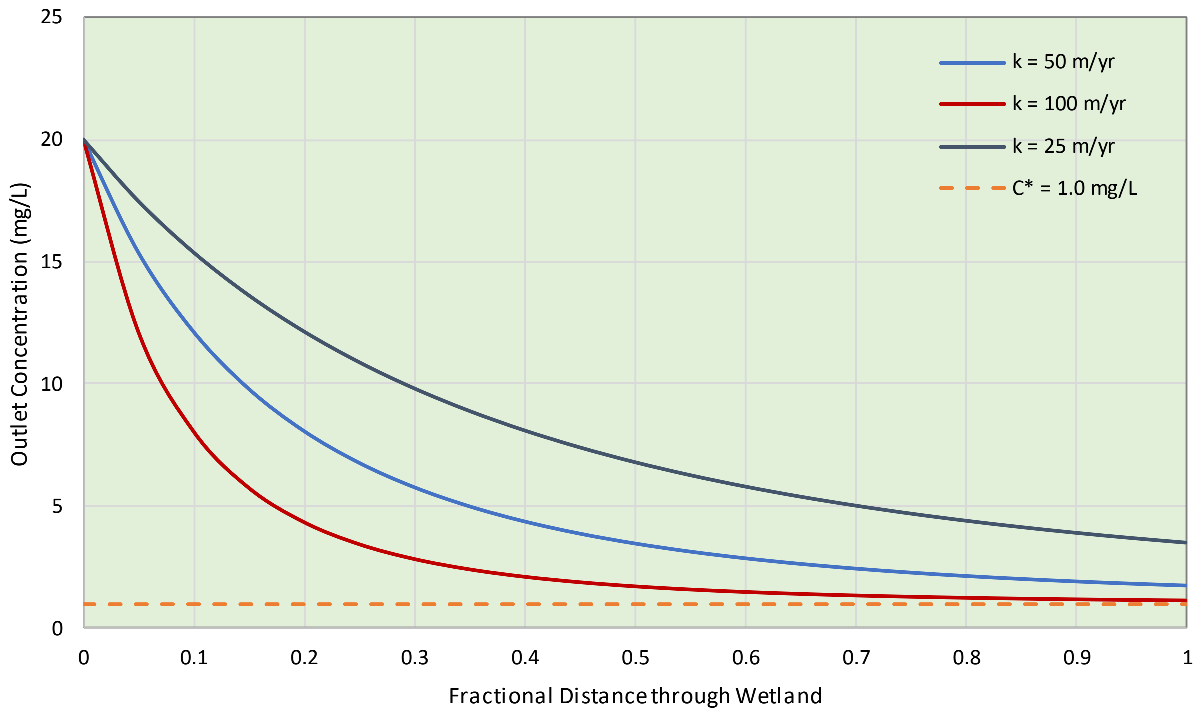

Figure 2. General Behavior of the P-k-C* Model
For this example, Q = 5 MGD, A = 100 ac, C1 = 20 mg/L, C = 1.0 mg/L, and P = 3*

Sequential Nitrogen P-k-C* Model

Because nitrogen occurs in a number of different oxidation states in wetlands and numerous biological and physical-chemical processes can transform nitrogen between these different forms, a more complex version of the model is required to predict nitrogen-removal performance (Kadlec and Knight, 1996).

Organic nitrogen (ON), ammonia nitrogen (AN), nitrate+nitrite nitrogen (NN), and nitrogen gasses are the primary nitrogen forms found in surface waters. A fraction of ON is mineralized to AN in aquatic and wetland systems. The reduction in ON using the P-k-C* model is given by the following equation:

$$C_{ON} = C^*_{ON} + \left(C_{ONi} - C^*_{ON}\right)\left[1 + \frac{k_{ON}}{Pq}\right]^{-P} \quad \text{[EQ-5]}$$

Where

C_{ONi} = inlet concentration of organic nitrogen, mg/L

C^*_{ON} = background concentration of organic nitrogen, mg/L

C_{ON} = outlet concentration of organic nitrogen, mg/L

k_{ON} = first-order area-based organic nitrogen rate constant, m/yr

Water temperature and pH determine the extent to which AN is distributed between ammonium (ionized form) and its volatile form (un-ionized ammonia). AN can in turn be oxidized to NN through aerobic microbial processes (nitrification). Depending on the amount of ON found in the source water, AN can be both produced and consumed in wetlands. The following two-step reaction model from Kadlec and Knight (1996) can be used to estimate the concentration of AN:

$$C_{AN} = C^*_{AN} + \left(C_{ANi} - C^*_{AN}\right)\left[1 + \frac{k_{AN}}{Pq}\right]^{-P} + \left(\frac{k_{ON}}{k_{AN} - k_{ON}}\right)\left(C_{ONi} - C^*_{ON}\right)\left(\left[1 + \frac{k_{ON}}{Pq}\right]^{-P} - \left[1 + \frac{k_{AN}}{Pq}\right]^{-P}\right) \quad \text{[EQ-6]}$$

Where

C_{ANi} = inlet concentration of ammonium nitrogen, mg/L

C^*_{AN} = background concentration of ammonium nitrogen, mg/L

k_{AN} = first-order area-based ammonium nitrogen rate constant, m/yr

Oxidized nitrogen presents the same difficulty as ammonium: it is produced (nitrification) as well as consumed (nitrate reduction) in wetlands. Oxidized nitrogen may also be utilized in plant growth in the absence of significant ammonium nitrogen. The three-step equation from Kadlec and Knight (1996) was used to estimate the combined effects of all processes on NN concentrations:

$$C_{NN} = (C_{NNi})\left[1 + \frac{k_{NN}}{Pq}\right]^{-P} + \psi \left\{ \begin{array}{l} \left(\dfrac{k_{AN}}{k_{NN} - k_{AN}}\right)(C_{ANi})\left(\left[1 + \dfrac{k_{AN}}{Pq}\right]^{-P} - \left[1 + \dfrac{k_{NN}}{Pq}\right]^{-P}\right) \\ + \left(\dfrac{k_{ON}}{k_{AN} - k_{ON}}\right)\left(\dfrac{k_{AN}}{k_{NN} - k_{ON}}\right)\left(C_{ONi} - C^*_{ON}\right)\left(\left[1 + \dfrac{k_{ON}}{Pq}\right]^{-P} - \left[1 + \dfrac{k_{NN}}{Pq}\right]^{-P}\right) \\ - \left(\dfrac{k_{ON}}{k_{AN} - k_{ON}}\right)\left(\dfrac{k_{AN}}{k_{NN} - k_{AN}}\right)\left(C_{ONi} - C^*_{ON}\right)\left(\left[1 + \dfrac{k_{AN}}{Pq}\right]^{-P} - \left[1 + \dfrac{k_{NN}}{Pq}\right]^{-P}\right) \end{array} \right\} \quad \text{[Eq. 7]}$$

Where

C_{NNi} = inlet concentration of nitrate nitrogen, mg/L

C^*_{NN} = background concentration of nitrate nitrogen, mg/L

k_{NN} = first-order area-based nitrate nitrogen rate constant, m/yr

Ψ = fraction of ammonium nitrified (1 – fraction volatilized)

Model Parameter Selection

Values for the model parameters k, C*, and P used for this analysis are modified from Kadlec and Knight (1996) and summarized in Table 1. These model parameters are typical of Florida treatment wetlands receiving elevated nutrient concentrations. It should be noted that the value of C* for ON is variable and depends to some extent on local site conditions (soil nitrogen storages and TN in precipitation), while C* values for AN and NN are theoretically zero. A C* value for ON of 1.0 mg/L appears to be realistic based on ambient nitrogen levels observed on Paynes Prairie. A P value of 3 is a reasonable assumption for individual constructed wetland cells (Kadlec and Wallace, 2009).

Table 1. P-k-C* Model Parameters used for the Sweetwater Wetlands Analysis

Parameter	Organic N	Ammonia N	Nitrate N	TP
k (m/yr)	17	18	50	11.5
C* (mg/L)	1.0	0.005	0.005	0.02

The model was run using measured inflow conditions for 2018 to compare predicted and observed results. Inflow TN to the wetlands (Forebay outflow concentration that integrates point and non-point sources) averaged 3.34 mg/L during 2018 (ON = 0.65 mg/L, AN = 0.12 mg/L, and NN = 2.57 mg/L). Combined inflows to the wetland averaged 14.5 cfs (9.4 MGD) between January and December 2018. Using the model parameters shown in the PER and this report, the model predicted outflow TN concentration under these conditions was 1.4 mg/L, which is substantially greater than the measured value (average of three wetland cell discharges) of 0.9 mg/L (see Figure 3). This indicates that the system's capacity for TN removal was higher than estimated during the design phase, that the model is appropriately conservative in predicting outflow TN concentrations, and that the project can be expected to provide adequate protection of downstream waters under both current and projected future conditions.

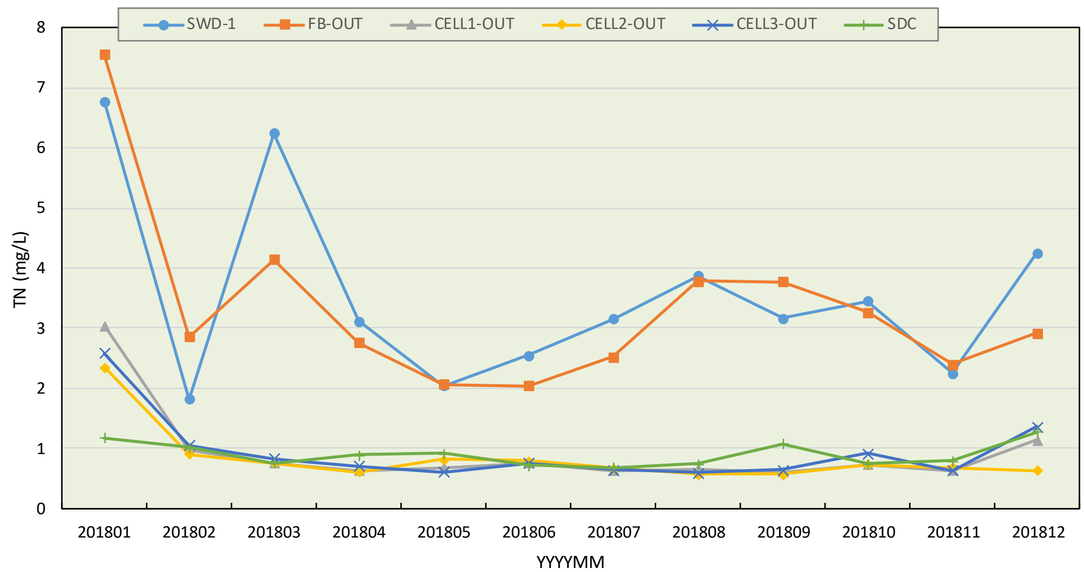

Figure 3. Measured Inflow and Outflow Total Nitrogen Concentrations at the Sweetwater Wetlands Park in 2018

SWD-1: Sweetwater Branch stream below MSWRF discharge.

FB-OUT: Outlet from forebay and inlet to the three enhancement wetland cells.

CELL#-OUT: Outlet from designated enhancement wetland cell at discharge to the Sweetwater Distribution Channel.

SDC: Sweetwater Distribution Channel (recombined enhancement wetland cell outflows and bypassed flow) at point of discharge to the Sheetflow Restoration Area.

Modeled Loading Conditions

Modeling scenarios were developed for dry-year and wet-year conditions to compare Project performance against the combined WLAs defined in Table 48 of the TMDL (Gao, Gilbert, and Magley 2006). The TMDL established a dry-year TN limit of 55,258 lbs/yr for the combined sources that contribute flow to Alachua Sink from Sweetwater Branch (40,380 lbs/yr for the MSWRF, 623 lbs/yr for KGS, and 14,255 lbs/yr for the watershed). The corresponding wet year condition is 61,114 lbs/yr (40,380 lbs/yr for the MSWRF, 623 lbs/yr for KGS, and 20,111 lbs/yr for the watershed). These wetland performance scenarios differ from those used to evaluate the stream response to various nutrient loads described in Section 5. Because the stream dimensions are relatively small and stream biology can be expected to potentially change significantly in response to short-term perturbations, the modeling described in Section 5 appropriately demonstrated protection of the resource under extreme conditions. In contrast, the combined effects and scale of the Project features (e.g., the sediment basin, forebay, Enhancement Wetlands, overflow and distribution channels, and Sheetflow Restoration Area) buffer extreme conditions. Therefore, it is not appropriate to model the effectiveness of either the Enhancement Wetlands or Sheetflow Restoration Area under extreme conditions, particularly with respect to stream discharge. The performance estimation modeling scenarios for the Enhancement Wetlands and Sheetflow Restoration Area include nutrient load inputs from the following sources:

- The MSWRF operating at the current permitted design capacity of 7.5 MGD, and at estimated future capacities of 10.0 and 12.0 MGD;
  - Effluent MSWRF TN concentrations of 8.0 mg/L and an effluent TP concentration of 0.3 mg/L for a flow of 7.5 MGD,
  - Effluent MSWRF TN concentrations of 6.0 mg/L and an effluent TP concentration of 0.3 mg/L for a flow of 10.0 MGD,
  - Effluent MSWRF TN concentrations of 5.0 mg/L and an effluent TP concentration of 0.3 mg/L for a flow of 12.0 MGD,
- The KGS operating at 0.505 MGD, with an effluent TN concentration of 1.99 mg/L and an effluent TP concentration of 0.55 mg/L, and
- Non-point source loads at the flows and concentrations as further described below.

The MSWRF future scenarios (10 and 12 MGD) were developed with reduced TN concentrations so that there is no increase in discharged TN load over the current condition. In all cases, with MSWRF flows ranging from 7.5 to 12.0 MGD, the discharged load is 182,646 lbs/yr. In discussions with the FDEP during development of the WQBEL modeling efforts, GRU has agreed to meet an annual average TP concentration at the discharge from the MSWRF of 0.3 mg/L.

Development of Non-Point Source Loads

Several data sources were evaluated to develop the dry-year and wet-year non-point source loads used for this modeling effort. The sources included the loading estimates prepared by the FDEP and reported in the TMDL report (Gao, Gilbert, and Magley 2006), a review of ambient water quality and discharge data in Sweetwater Branch, and a review of limited storm-event data reported by the Alachua County Environmental Protection Department (ACEPD 2007). As a point of reference, the estimated dry-year and wet-year TN loads reported by the FDEP and included in the TMDL for Alachua Sink were 24,642 lbs/yr and 29,910 lbs/yr, respectively (Gao, Gilbert, and Magley 2006 – Table 47). Similarly, the FDEP's estimated TP loads were 2,928 lbs/yr (dry-year) and 3,551 lbs/yr (wet-year). These loads could not be reproduced based on analyses of measured stream discharges (corrected for the point-source inputs) and measured in-stream nutrient concentration. WSI's alternative approach to developing non-point source loads is described in the next two paragraphs.

Daily average stream discharge for Sweetwater Branch at Williston Road was estimated after subtracting daily average effluent discharge from the MSWRF and KGS for the same period used in the TMDL report (2000-2004). The FDEP's dry-year rainfall condition was 46.6 inches (Gao, Gilbert, and Magley 2006) and closely matches the conditions measured in 2003. The wet-year condition was 56.7 inches and can be conservatively approximated using the conditions measured in 2004. Accordingly, WSI assigned average flows of 3.38 cfs for the dry-year and 5.85 cfs for the wet-year to represent the non-point source contributions to the Project.

To be conservative, and to be consistent with the wet-year non-point source loads referenced in the TMDL (Gao, Gilbert, and Magley 2006), WSI assigned non-point source TN and TP concentrations of 2.60 mg/L and 0.309 mg/L respectively. While these values do not correspond to a particular statistic, they are within the range of measured values. Further, the combination of these concentrations with the assigned average wet-year flow of 5.85 cfs equals the wet-year

TMDL loads of 29,910 lbs/yr for TN and 3,551 lbs/yr for TP. The same concentrations were used with the selected dry-year average flow of 3.38 cfs to yield loads of 17,281 lbs/yr for TN and 2,052 lbs/yr for TP. The dry year estimated loads are lower than those reported by Gao et al. (2006). The difference is not of significant concern as the TMDL is based on wet-year loads for non-point sources.

Nitrogen Speciation

To facilitate use of the sequential nitrogen equations with the P-k-C* model, the TN for each source was fractionated between the ON, AN, and NN species as shown in Table 2. Nitrogen speciation for the MSWRF was estimated based on a review of historical effluent data that indicated an average ON concentration of 0.71 mg/L and AN of about 0.09 mg/L. As the MSWRF does not fully denitrify the effluent, the balance of the TN can reasonably be assumed to be in the form of NN, whether the facility is operated at current or permitted design flows. MSWRF TN was estimated to be 8.0 mg/L (7.20 mg/L NN) for a flow of 7.5 MGD. As noted above, GRU has agreed to maintain a maximum annual TN discharge load from the MSWRF of 182,646 lbs/yr, which translates to a TN concentration of 6.0 mg/L (5.2 mg/L NN) at 10.0 MGD, and 5.0 mg/L (4.2 mg/L NN) at 12.0 MGD. Upgrades to the MSWRF process will be necessary to ensure lower TN outlet concentrations in the future. GRU has undertaken a progressive design-build project to evaluate, design, and construct the necessary improvements. Assumed nitrogen speciation for the KGS was based on the data summarized in Tables 23 and 24 of Section 5 (Dynamic Solutions 2018). Flow-weighting the cooling tower and low volume waste streams resulted in estimated concentrations of 1.27 mg/L for ON, 0.13 mg/L for AN, and 0.59 mg/L for NN (TN = 1.99 mg/L). Non-point source nitrogen (TN = 2.60 mg/L as described above) was assumed to be comprised of 1.0 mg/L ON, with the remainder evenly split between AN (0.80 mg/L) and NN (0.80 mg/L).

Table 2. Assumed Nitrogen Fractionation for Sweetwater Wetlands Modeling Analysis

Source	Parameter	Concentration		
NPS	ON (mg/L)	1.0		
	AN (mg/L)	0.80		
	NN (mg/L)	0.80		
	TN (mg/L)	2.60		
KGS	ON (mg/L)	1.27		
	AN (mg/L)	0.13		
	NN (mg/L)	0.59		
	TN (mg/L)	1.99		
MSWRF	Flow	7.5 MGD	10.0 MGD	12.0 MGD
	ON (mg/L)	0.71		
	AN (mg/L)	0.09		
	NN (mg/L)	7.20	5.20	4.20
	TN (mg/L)	8.00	6.00	5.00

Bypassed Loads

As designed and constructed, all flow in Sweetwater Branch enters the Project and flows through the sediment basin and forebay. The forebay routes flow to the Enhancement Wetland and two bypass flow-ways, the Forested Slough and the Overflow Channel. The routing of flows between the Enhancement Wetland cells and bypass channels is stage dependent. The minimum inflow stage to the Enhancement Wetlands is 61.0 feet (NAVD88). At forebay stages between 61.0 and 63.0 feet, all inflow is routed to the Enhancement Wetland cells through openings in the inlet structures which function as rectangular weirs. When forebay stages exceed 63.0 feet, the inlet structures transition to orifice flow and a portion of the flow begins to discharge over two broad-crested spillways (the Forested Slough is 100-ft wide and the Overflow Channel is 130-ft wide) which bypass the wetland cells. There is a 2’x2’ slide gate in the Forested Slough overflow weir that can be temporarily removed to increase flow through the Forested Slough for vegetation management or other purposes. That structure is normally closed, maintaining the control elevation at 63.0 feet. The system was designed with this control elevation to allow bypassing of a portion of the flow when flows exceed 25 cfs.

As described in the Preliminary Engineering Report (Jones Edmunds and Wetland Solutions 2009), the Enhancement Wetland cells were designed to capture approximately 97 percent of the total annual watershed nitrogen load by accepting inflow rates up to 25 cfs, which equates to the 95th percentile average daily discharge. Figure 4 shows the Project process flow diagram. The MSWRF, KGS, and non-point source inflows combine in the forebay with flows up to about 25 cfs being routed through the Enhancement Wetlands, and excess flow bypassing the Enhancement Wetlands. All flow from Sweetwater Branch recombines in the Sheetflow Distribution Channel prior to discharging to the Sheetflow Restoration Area. It was estimated that about 3 percent of the combined annual inflow load would bypass the Enhancement Wetland cells. It should be noted that while a small portion of the annual load bypasses the Enhancement Wetland cells, it cannot bypass treatment in the Sheetflow Restoration Area prior to reaching Alachua Sink. Thus, no water that enters Alachua Sink from Sweetwater Branch should be considered untreated. It should be noted that the average flows used for the contributing sources include conditions during which bypass would occur.

A dry-year analysis based on estimated loads described earlier in this document was completed using daily data. Based on data summarized in the TMDL report, the year 2003 was selected as a representative dry year. Daily discharge data for Sweetwater Branch at Williston Road and MSWRF were compiled. KGS daily flows were small and were set equal to the 2003 annual average of 0.165 cfs. For some days, subtraction of the MSWRF and KGS flow from the daily average downstream at Williston Road to estimate the non-point source flow resulted in a negative number due to compounded measurement errors. Upstream data for Sweetwater Branch at Depot Avenue show that the 25% value (which likely still includes KGS) was 0.35 cfs. Any subtracted daily estimate for non-point source flows that was less than 0.35 cfs was set to equal 0.35 cfs. MSWRF flows were then scaled to an annual average of 7.5 MGD, 10 MGD, and 12 MGD. Daily total combined flows that would be delivered to the project were compared to the bypass threshold established in the PER of 25 cfs. Scaling the MSWRF AADF to 7.5 MGD resulted in an estimated load capture efficiency of 96.3% and bypass frequency of 5.2% of days (Table 3). At a MSWRF flow of 10 MGD, the load capture was 94.9% and the bypass frequency was 9.9% of days. At 12 MGD the load capture was 92.7% and the bypass frequency was 19.2% of days. Under all MSWRF flow scenarios, the total bypassed volume was estimated to be less than 9.0% of the

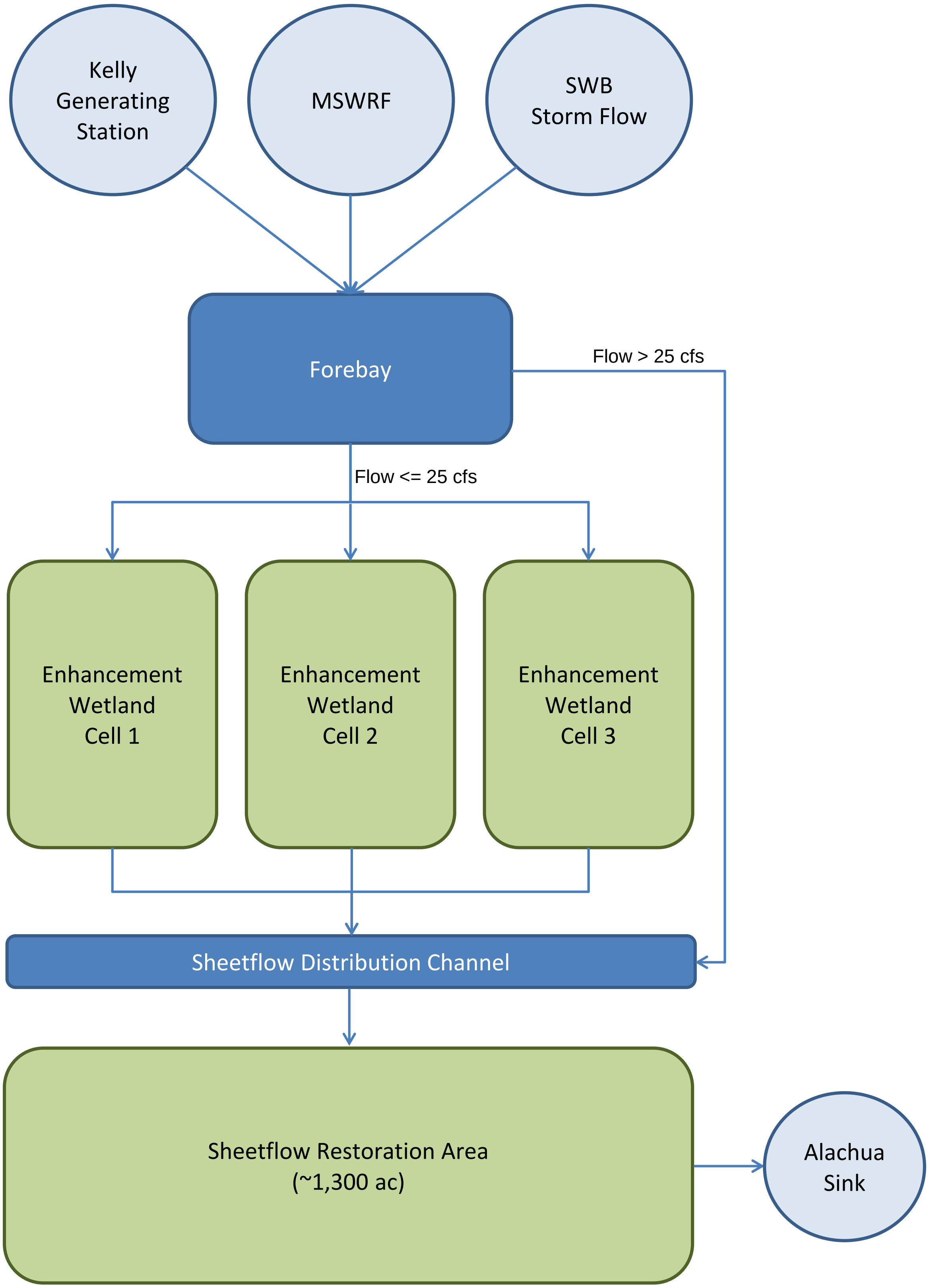

Figure 4. Process Flow Diagram

total volume conveyed by Sweetwater Branch based on 2003 dry-year flows. As described above, the load capture efficiency through the wetland cells was not significantly affected by increasing the MSWRF flow.

A similar analysis was completed for wet year conditions using 2004 flow data from Sweetwater Branch and a 2004 average flow from the KGS of 0.296 cfs. At a MSWRF flow of 7.5 MGD, the load capture was 86.9% and the bypass frequency was 8.5% of days (Table 3). At a MSWRF flow of 10 MGD, the load capture was 84.4% and the bypass frequency was 13.4% of days. At 12 MGD the load capture was 82.2% and the bypass frequency was 18.0% of days. Under all MSWRF flow scenarios, the total bypassed volume was estimated to be less than 22.5% of the total volume conveyed by Sweetwater Branch based on 2004 wet-year flows. Again, these estimated bypasses occur only around the Enhancement Wetlands and do not bypass treatment in the overflow channels, Sheetflow Distribution Channel, or Sheetflow Restoration Area. Detailed flow and mass balances are included in the results section.

Longer-term bypass estimates for the period from January 1998 through August 2006 are also summarized in Table 3. For the multi-year analysis, bypass events were estimated to increase from 180 days out of 3,165 days in the data record (5.7% of days and 10.1% of total inflow) at currently permitted MSWRF flows to 572 days (18.1% of days and 11.4% of total inflow) for a MSWRF capacity of 12 MGD.

Table 3. Estimated Bypass Frequencies for the Paynes Prairie Sheetflow Restoration Project at Current and Buildout Conditions

Scenario	Period	Days	Days with Bypass	% Time with Bypass	% Volume Bypassed
Current (7.5 MGD)	2003 Dry Year	365	19	5.2	6.7
	2004 Wet Year	365	31	8.5	22.5
	1/1998 – 8/2006	3165	180	5.7	10.1
MSWRF @ 10 MGD	2003 Dry Year	365	36	9.9	7.3
	2004 Wet Year	365	49	13.4	22.0
	1/1998 – 8/2006	3165	320	10.1	10.2
MSWRF @ 12 MGD	2003 Dry Year	365	70	19.2	9.0
	2004 Wet Year	365	66	18.0	22.5
	1/1998 – 8/2006	3165	572	18.1	11.4

Actual bypass estimates for the operational period from 2016 through 2019 are shown in Figure 5. For the years 2016-2019, total flows in Sweetwater Branch averaged 14.5 cfs. Over the same period, an average of 14.3 cfs was routed through the Enhancement Wetlands and 1.2 cfs bypassed the Enhancement Wetlands. The operational period-of-record bypass was about 5.0% of the total flow in Sweetwater Branch. Of the total volume of flow that was bypassed between 2016 and 2019, 12.8% was associated with increased stormwater flows during Hurricane Irma in September 2017. There was a higher frequency of bypasses during 2016 than during the remaining period-of-record as a fraction of the total incoming flow was routed through the Forested Slough to support vegetation establishment.

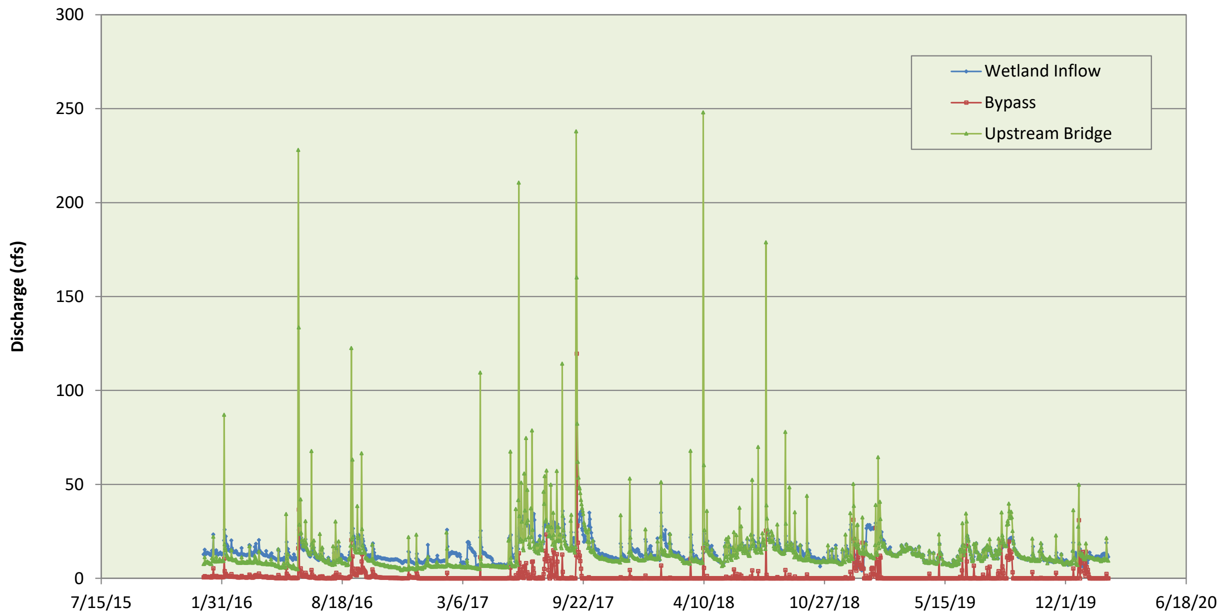

Figure 5. Paynes Prairie Sheetflow Restoration Project Historical Bypass Estimates (2016-2019)

The modeling results described below estimates TN and TP loads at the outflow of the enhancement wetland and at the outflow of the restoration area (entering Alachua Sink) account for flow bypassing. Additionally, the compliance monitoring station (SF1) is located in the enhancement wetland distribution channel which includes outflows from the wetland cells and the two bypass channels. Because flow bypassing occurs during wet weather events, the TN and TP concentrations are low due to dilution. Additionally, the modeling for the project is conservative because it does not account for TN attenuation through the two by-pass channels, which is likely to be significant.

Final Modeled Loads

Table 4 summarizes the individual and combined flows, concentrations, and loads used to estimate the water quality performance of the Project and to determine compliance with the TMDL for Alachua Sink with the MSWRF capacity ranging between 7.5 and 12 MGD. Because the MSWRF discharge TN load will be maintained at 182,646 lbs/yr, the estimated dry-year combined inflow TN loads were 202,988 lbs/yr regardless of the MSWRF capacity. Similarly, the estimated wet-year combined inflow TN loads were 215,616 lbs/yr.

Table 4. Inflow Assumptions for Sweetwater Wetlands Modeling

Source	Parameter	Dry Year			Wet Year		
		MSWRF @ 7.5 MGD	MSWRF @ 10 MGD	MSWRF @ 12 MGD	MSWRF @ 7.5 MGD	MSWRF @ 10 MGD	MSWRF @ 12 MGD
MSWRF	Flow (MGD [cfs])	7.5 [11.6]	10.0 [15.5]	12.0 [18.6]	7.5 [11.6]	10.0 [15.5]	12.0 [18.6]
	TN (mg/L)	8.0	6.0	5.0	8.0	6.0	5.0
	TN Load (lb/yr)	182,646	182,646	182,646	182,646	182,646	182,646
	TP (mg/L)	0.3	0.3	0.3	0.3	0.3	0.3
	TP Load (lb/yr)	6,849	9,132	10,959	6,849	9,132	10,959
KGS	Flow (MGD [cfs])	0.505 [0.78]			0.505 [0.78]		
	TN (mg/L)	1.99			1.99		
	TN Load (lb/yr)	3,060			3,060		
	TP (mg/L)	0.55			0.55		
	TP Load (lb/yr)	843			843		
NPS	Flow (MGD [cfs])	2.18 [3.38]			3.78 [5.85]		
	TN (mg/L)	2.60			2.60		
	TN Load (lb/yr)	17,281			29,910		
	TP (mg/L)	0.309			0.309		
	TP Load (lb/yr)	2,052			3,551		
Combined	Flow (MGD [cfs])	10.2 [15.8]	12.7 [19.6]	14.7 [22.7]	10.8 [18.2]	14.3 [22.1]	16.3 [25.2]
	TN (mg/L)	6.54	5.25	4.54	6.01	4.96	4.35
	TN Load (lb/yr)	202,988	202,988	202,988	215,616	215,616	215,616
	TP (mg/L)	0.314	0.311	0.310	0.320	0.311	0.310
	TP Load (lb/yr)	9,744	12,027	13,854	11,244	13,527	15,353

Wetland Modeling Results

The combined inflows summarized in Table 4, with the nitrogen speciation summarized in Table 2 were used as inputs for the P-k-C* model to estimate outflow concentrations and loads from the Enhancement Wetlands and the Sheetflow Restoration Area. For each MSWRF flow scenario, the bypassed volumes/loads were removed from the enhancement wetland model, non-bypassed flows were routed through the enhancement wetland model, enhancement wetland output was blended with untreated bypass, and the recombined flows were then routed through the Sheetflow Restoration Area model. Table 5 summarizes the modeling results. Figures 6 through 11 show mass balance diagrams for each model case.

Across the range of MSWRF flows, the estimated long-term average concentrations delivered from the Enhancement Wetlands to the Sheetflow Distribution Channel averaged about 1.4 mg/L for TN and 0.28 mg/L for TP. With the bypass flows added, and conservatively assuming no treatment in either of the vegetated bypass channels, the recombined flow entering the Sheetflow Restoration Area averaged between 1.7 and 2.4 mg/L for TN and 0.28 mg/L for TP. In either case, these values meet the conditions of the ERP (3.0 mg/L for TN and 0.3 mg/L for TP as 5-year rolling averages). Additional nutrient assimilation was estimated to occur within the Sheetflow Restoration Area. It is expected that the Sheetflow Restoration Area can achieve similar minimum concentrations as was documented for the Enhancement Wetlands during 2018 (0.9 mg/L), however a lower limit final TN concentration of 1.2 mg/L was applied to provided added conservatism to model estimates. Similarly, final TP concentrations were limited to 0.1 mg/L, even if the model predicted lower concentrations. The 1300-acre Sheetflow Restoration Area is approximately 5,000 feet in width and 11,300 feet in length. These lower limits were estimated to be reached within 1,800 feet (TN) and 6,000 feet (TP) into the Sheetflow Restoration Area.

Table 5. Sweetwater Wetlands and Sheetflow Restoration Area Performance Estimates

Location	Performance Metric	Dry Year			Wet Year		
		7.5 MGD	10 MGD	12 MGD	7.5 MGD	10 MGD	12 MGD
Watershed Inflow	TN (mg/L)	6.54	5.25	4.54	6.01	4.96	4.35
	TN Load (lb/yr)	202,988	202,988	202,988	215,616	215,616	215,616
	TP (mg/L)	0.31	0.31	0.31	0.31	0.31	0.31
	TP Load (lb/yr)	9,744	12,027	13,854	11,244	13,527	15,353
Enhancement Wetland Outflow	TN (mg/L)	1.40	1.43	1.42	1.39	1.41	1.41
	TN Load (lb/yr)	40,691	51,207	58,057	39,047	48,243	54,508
	TP (mg/L)	0.27	0.28	0.28	0.27	0.27	0.28
	TP Load (lb/yr)	7,891	9,911	11,365	7,568	9,373	10,705
Outflow from Sheetflow Restoration Area	TN (mg/L)	1.20	1.20	1.20	1.20	1.20	1.20
	TN Load (lb/yr)	37,223	46,355	53,661	43,055	52,187	59,493
	TP (mg/L)	0.10	0.10	0.10	0.10	0.10	0.10
	TP Load (lb/yr)	2,903	3,589	4,082	2,801	3,414	3,866
	TN Load Reduction	165,765	156,633	149,327	172,561	163,429	156,123
	TN Efficiency (%)	81.7	77.2	73.6	80.0	75.8	72.4
	TP Load Reduction	6,841	8,438	9,772	8,443	10,113	11,487
	TP Efficiency (%)	70.2	70.2	70.5	75.1	74.8	74.8

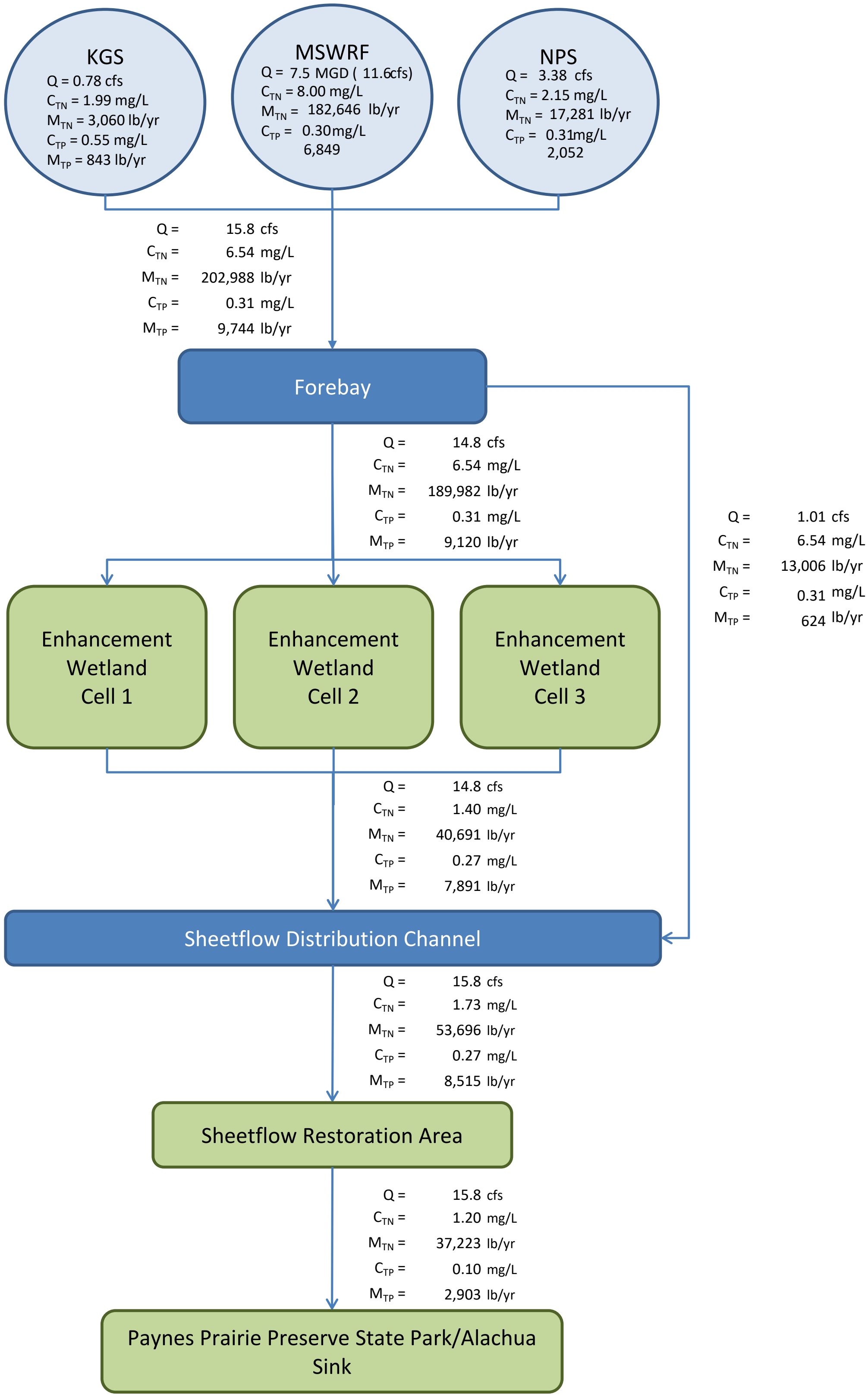

Figure 6. Estimated TN and TP Mass Balances with MSWRF at 7.5 MGD for Dry Year Condition

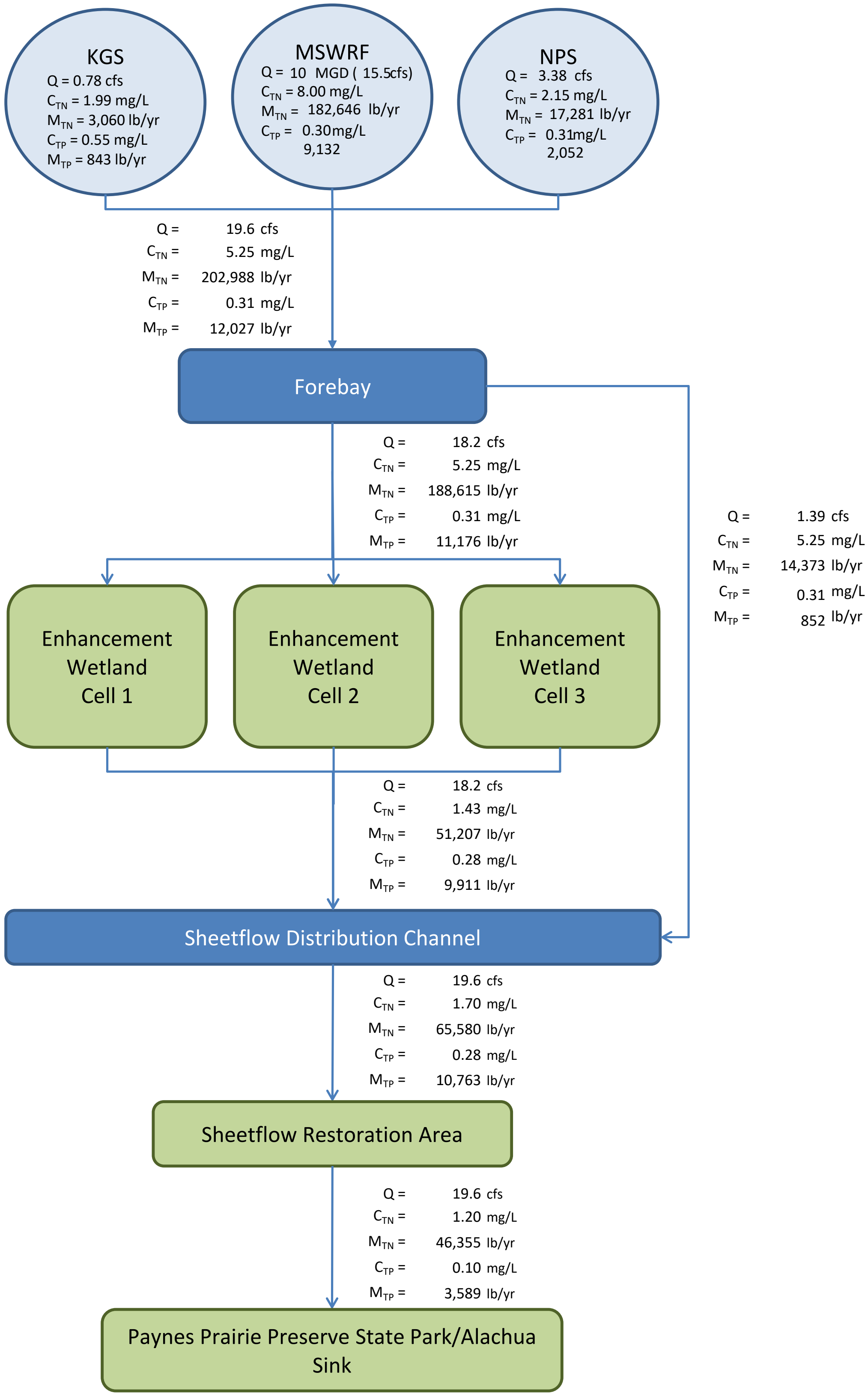

Figure 7. Estimated TN and TP Mass Balances with MSWRF at 10.0 MGD for Dry Year Condition

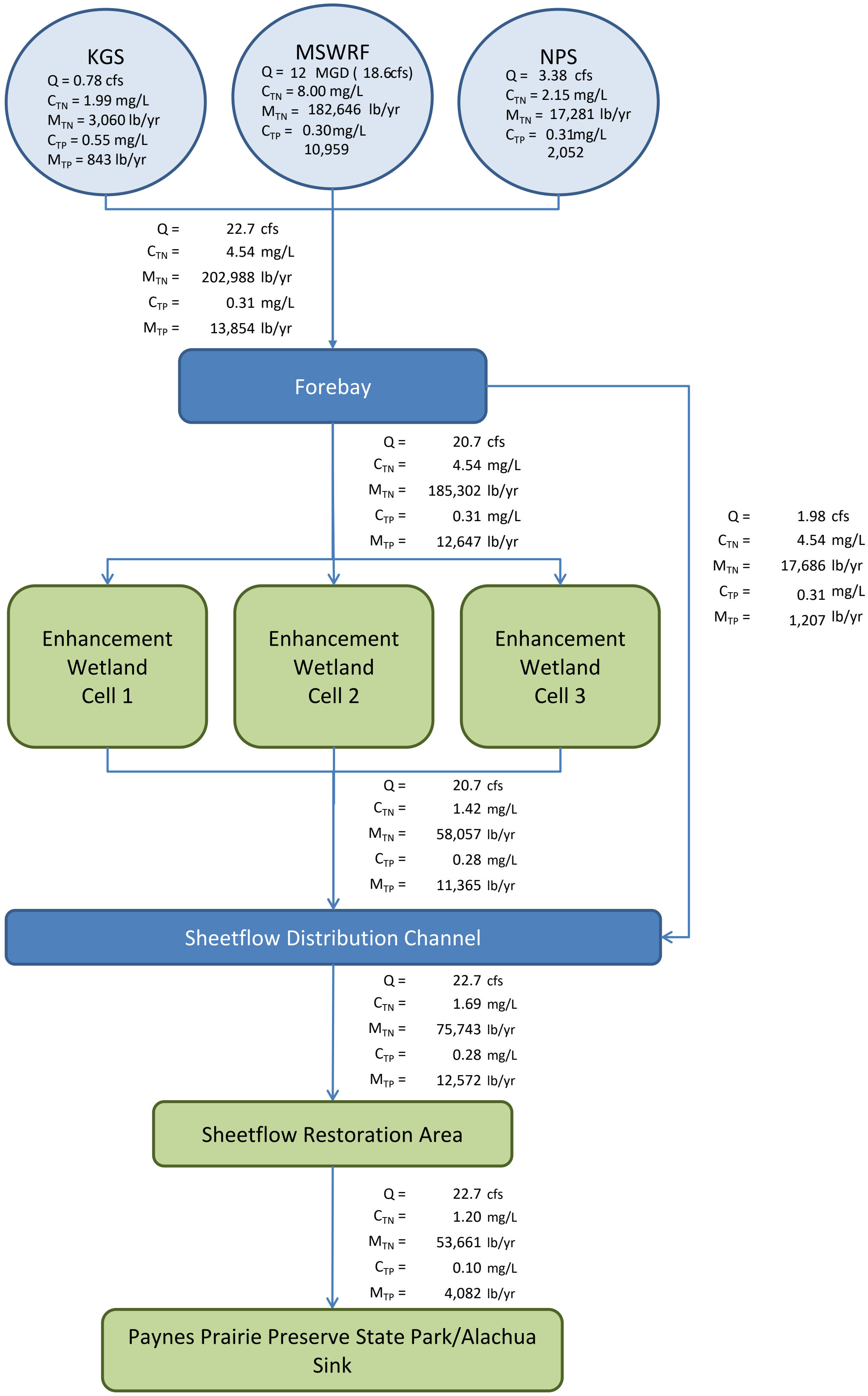

Figure 8. Estimated TN and TP Mass Balances with MSWRF at 12.0 MGD for Dry Year Condition

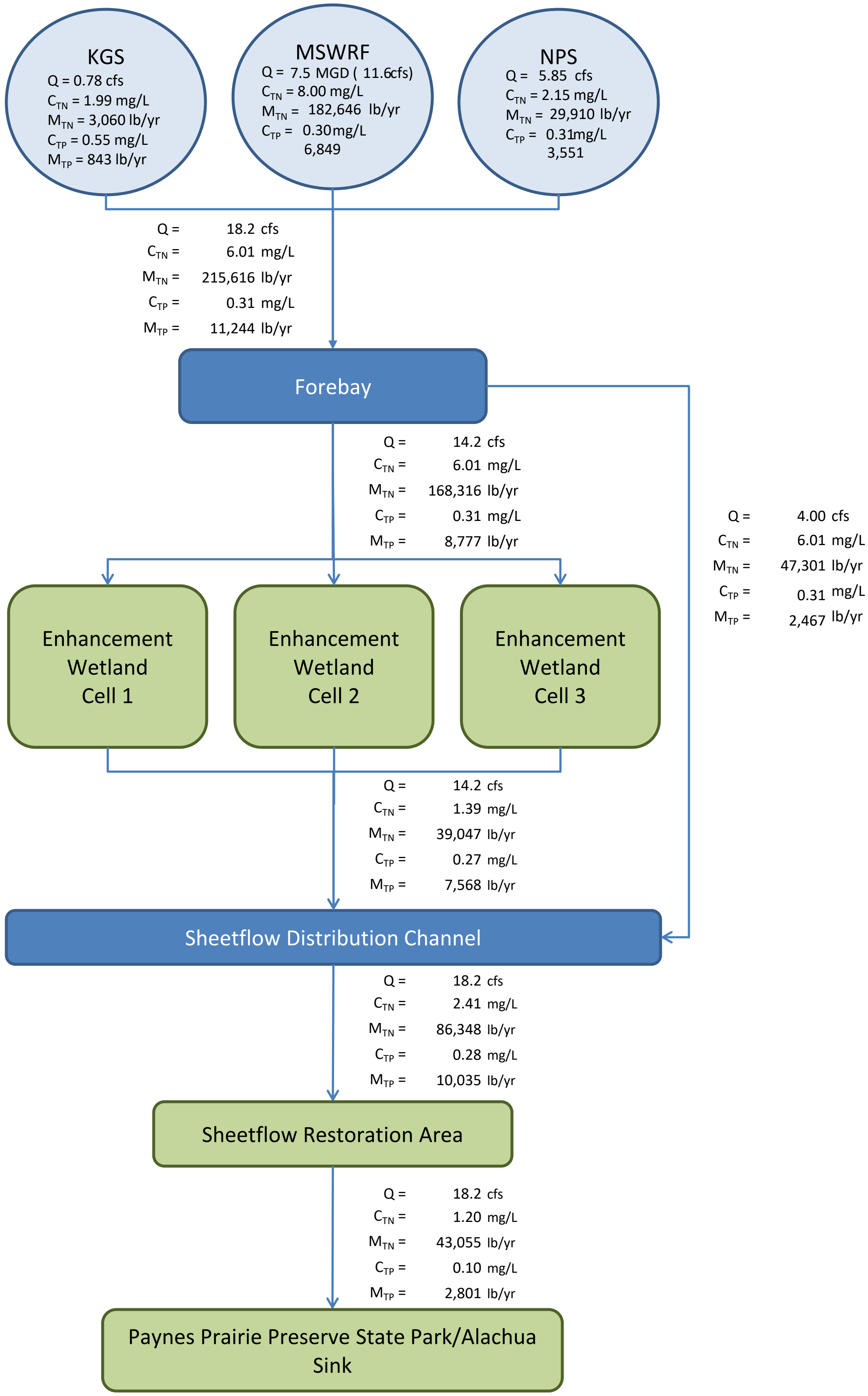

Figure 9. Estimated TN and TP Mass Balances with MSWRF at 7.5 MGD for Wet Year Condition

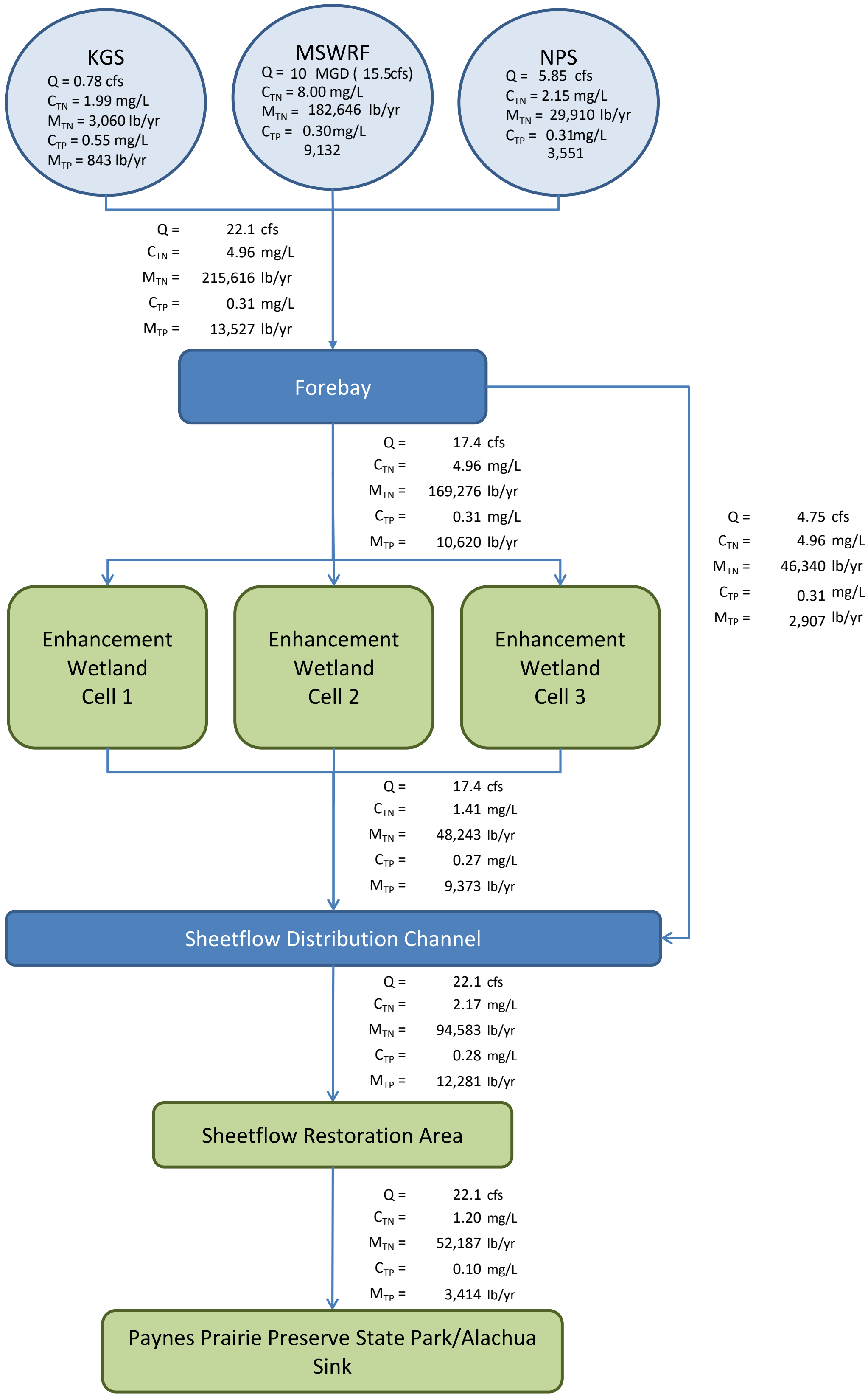

Figure 10. Estimated TN and TP Mass Balances with MSWRF at 10.0 MGD for Wet Year Condition

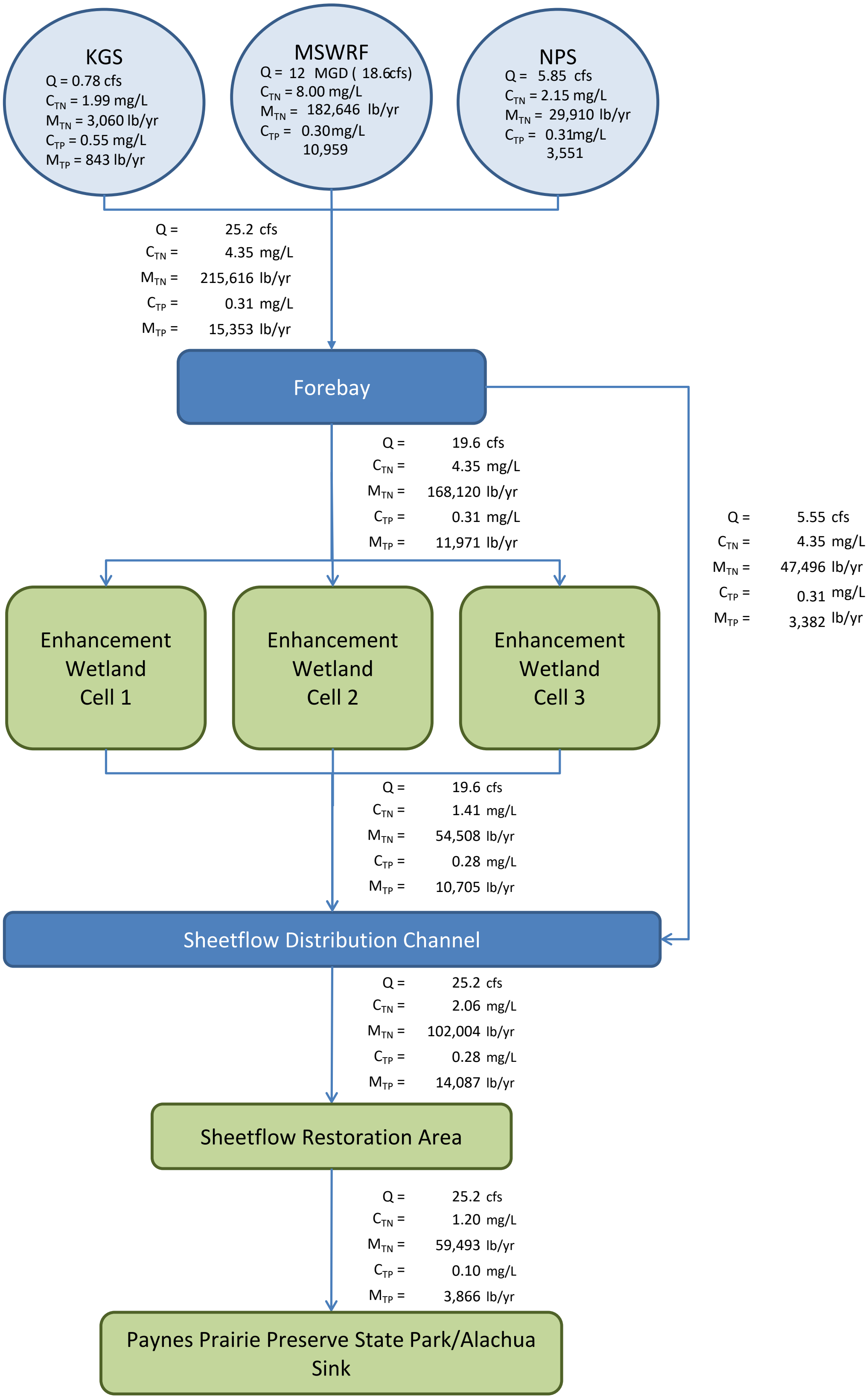

Figure 11. Estimated TN and TP Mass Balances with MSWRF at 12.0 MGD for Wet Year Condition

Conclusions

The performance estimates summarized above (Table 5, Figures 6-11) demonstrate that the Enhancement Wetlands (Sweetwater Wetlands Park) and Sheetflow Restoration Area have the capacity to reduce watershed nutrient concentrations to low levels, thus providing adequate protection of downstream waterbodies. Table 6 shows that the constructed Project is expected to comply with the TN load reduction required by the Alachua Sink TMDL under all modeled conditions. The dry-year allowable TN load, considering the WLAs for the MSWRF and KGS and the 45% reduction required for non-point sources is 55,258 lbs/yr, while the wet-year allowable load is 61,114 lbs/yr. Based on dry-year conditions, the Project is estimated to discharge between 37,223 and 53,661 lbs/yr of TN depending on the ultimate capacity of the MSWRF, leaving a buffer between 1,597 to 18,035 lb/yr. In wet years, the Project is estimated to discharge between 43,055 and 59,493 lbs/yr of TN depending on the ultimate capacity of the MSWRF, leaving a buffer between 1,621 to 18,059 lb/yr.

Table 6. Comparison of Modeled Results with TMDL Requirements

TMDL Wasteload Allocations	Dry Year TN Load (lbs/yr)	Wet Year TN Load (lbs/yr)
MSWRF	40,380	40,380
KGS	623	623
Non-Point (Table 48: Gao, Gilbert, and Magley 2006)	14,255	20,111
Combined WLA	**55,258**	**61,114**
Modeled Load to Alachua Sink with MSWRF at 7.5 MGD	**37,223**	**43,055**
Modeled Load to Alachua Sink with MSWRF at 10.0 MGD	**46,355**	**52,187**
Modeled Load to Alachua Sink with MSWRF at 12.0 MGD	**53,661**	**59,493**

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