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Modeling Report

WBID 28931 Sawgrass Lake
Nutrients and Dissolved Oxygen
Upper St. Johns River Basin

May 22, 2013



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Watershed Description

Sawgrass Lake lies in southern Osceola County just west of the city of Melbourne. It is an element of the upper St. Johns River, being located upstream of where US Highway 192 crosses the Upper St Johns River.

The Sawgrass Lake WBIDs (Figure 1) is located in Osceola County and eventually drains to the St. Johns River.

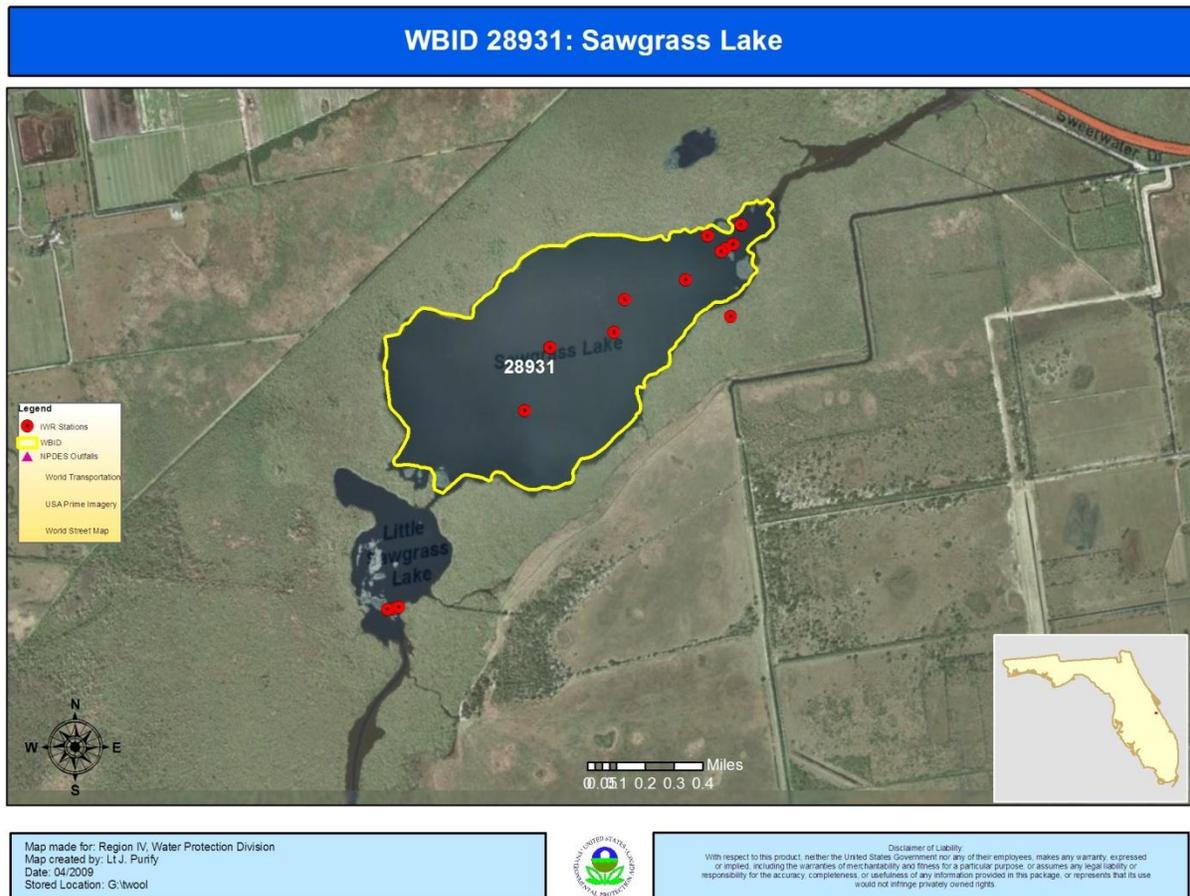


Figure 1 Location of Sawgrass Lake Watershed and WBID

The landuse distributions for the Sawgrass Lake watersheds are presented in Figure 2. The predominant landuse in the watershed is agriculture.

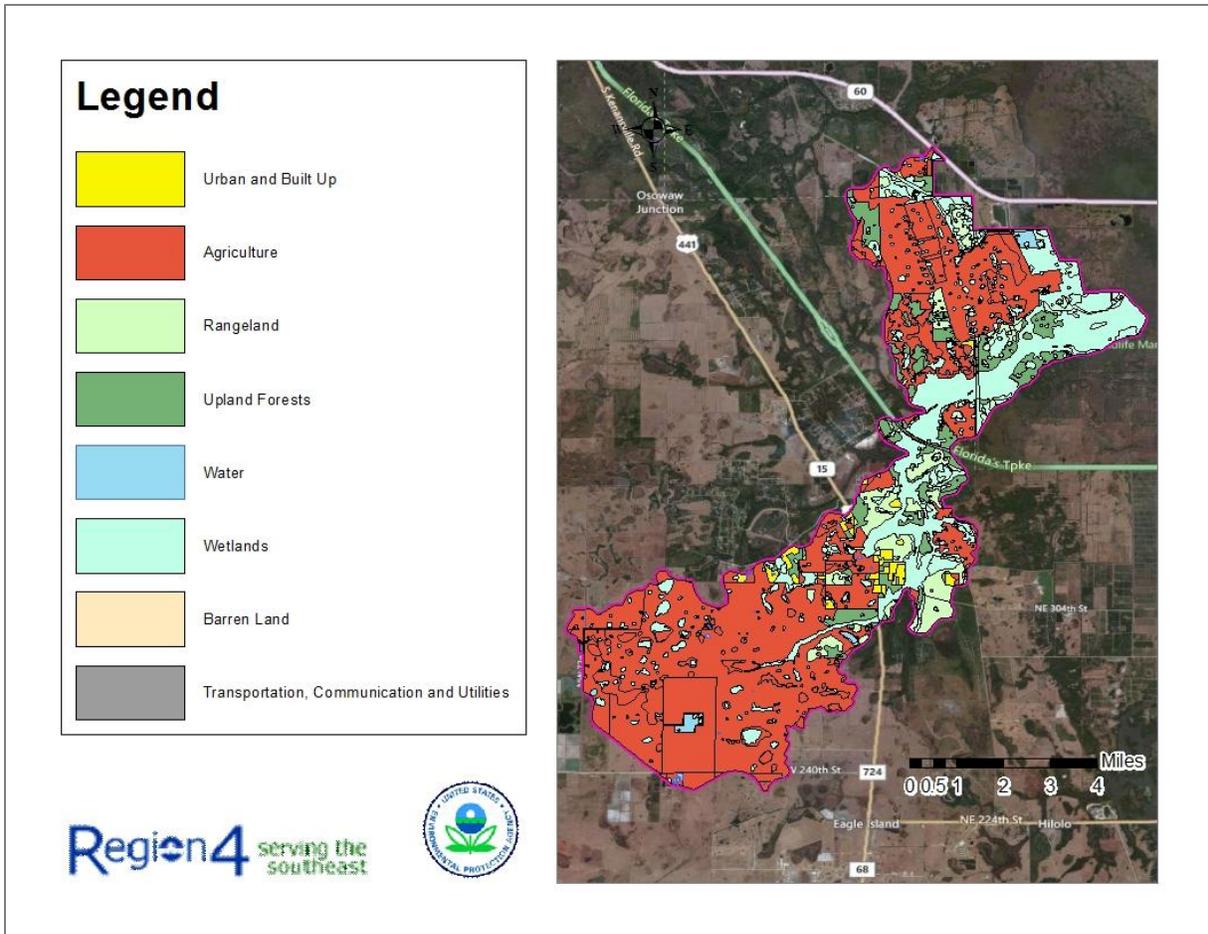


Figure 2 Landuse Distribution for Sawgrass Lake Watershed

TMDL Targets

The TMDL reduction scenarios will be done to achieve Florida’s dissolved oxygen concentration of 5 mg/L and insure balanced flora and fauna within Sawgrass Lake or if the dissolved oxygen standard cannot be achieved the TMDL will be done to be consistent with a natural condition.

The Sawgrass Lake WBID is a Class I Freshwater system designated as a potable water supply. For nutrients and dissolved oxygen the Class III freshwater standards apply, with a designated use of Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife. Designated use classifications are described in Florida’s water quality standards. See Section 62-302.400, F.A.C. Water quality criteria for protection of all classes of waters are established in Section 62-302.530, F.A.C. Individual criteria should be considered in conjunction with other provisions in water quality standards, including Section 62-302.500 F.A.C., which established minimum criteria that apply to all waters unless alternative criteria are specified. Section 62-302.530, F.A.C. Several of the WBIDs addressed in this report were listed due to elevated concentrations of chlorophyll *a*. While FDEP does not have a streams water

quality standard specifically for chlorophyll *a*, elevated levels of chlorophyll *a* are frequently associated with a violation of the narrative nutrient standard, which is described below.

Nutrients

The designated use of Class I/III waters is recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. In 1979, FDEP adopted a narrative criterion for nutrients. FDEP recently adopted numeric nutrient criteria for many Class I/III waters in the state, including streams, which numerically interprets part of the state narrative criterion for nutrients. While those criteria have been submitted to EPA for review pursuant to section 303(c) of the CWA, EPA has not completed that review. Therefore, for streams in Florida, the applicable nutrient water quality standard for CWA purposes remains the Class I/III narrative criterion.

Also, in November 2010, EPA promulgated numeric nutrient criteria for Class I/III inland waters in Florida, including streams. On February 18, 2012, the streams criteria were invalidated by the U.S. District Court for the Northern District of Florida and remanded back to EPA.

Narrative Nutrient Criteria

Florida's narrative nutrient criteria provide:

The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter. Man induced nutrient enrichment (total nitrogen and total phosphorus) shall be considered degradation in relation to the provisions of Sections 62-302.300, 62-302.700, and 62-4.242. Section 62-302.530(48)(a), F.A.C.

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. Section 62-302.530(48)(b), F.A.C.

Chlorophyll and dissolved oxygen (DO) levels are often used to indicate whether nutrients are present in excessive amounts. The target for this TMDL is based on levels of nutrients necessary to prevent violations of Florida's DO criterion, set out below.

Florida's adopted numeric nutrient criteria for streams

Florida's recently adopted numeric nutrient criteria interprets the narrative water quality criterion for nutrients in paragraph 62-302.530(48)(b), F.A.C. See section 62-302.531(2). The Florida rule provides that the narrative water quality criteria for nutrients in paragraph 62-302.530(47)(a), F.A.C., continues to apply to all Class I/III waters. See section 62-302.531(1).

Florida's recently adopted rule applies to streams, including (28931). For streams that do not have a site specific criteria, Florida's rule provides for biological information to be considered together with nutrient thresholds to determine whether a waterbody is attaining 62-302.531(2)(c), F.A.C. The rule provides that the nutrient criteria are attained in a stream

segment where information on chlorophyll a levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicates there are no imbalances in flora and either the average score of at least two temporally independent SCIs performed at representative locations and times is 40 or higher, with neither of the two most recent SCI scores less than 35, or the nutrient thresholds set forth in Table 1 below are achieved. See section 62-302.531(2)(c).

Florida's rule provides that numeric nutrient criteria are expressed as a geometric mean, and concentrations are not to be exceeded more than once in any three calendar year period. Section 62-302.200 (25)(e), F.A.C.

Table 1 Inland Numeric Nutrient Criteria

Nutrient Watershed Region	Total Phosphorus Nutrient Threshold	Total Nitrogen Nutrient Threshold
Panhandle West	0.06 mg/L	0.67 mg/L
Panhandle East	0.18 mg/L	1.03 mg/L
North Central	0.30 mg/L	1.87 mg/L
Peninsular	0.12 mg/L	1.54 mg/L
West Central	0.49 mg/L	1.65 mg/L
South Florida	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.

Dissolved Oxygen Criteria

Numeric criteria for DO are expressed in terms of minimum and daily average concentrations. Section 62-302(30), F.A.C., sets out the water quality criterion for the protection of Class I/III freshwater waters as:

Shall not be less than 5.0 mg/l. Normal daily and seasonal fluctuations above these levels shall be maintained.

Natural Conditions

In addition to the standards for nutrients, DO and BOD described above, Florida's standards include provisions that address waterbodies which do not meet the standards due to natural background conditions.

Florida's water quality standards provide a definition of natural background:

“Natural Background” shall mean the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered waterbody may be based upon a similar unaltered waterbody or on historical pre-alteration data. 62-302.200(15), FAC.

Florida's water quality standards also provide that:

Pollution which causes or contributes to new violations of water quality standards or to continuation of existing violations is harmful to the waters of this State and shall not be allowed. Waters having water quality below the criteria established for them shall be protected and enhanced. However, the Department shall not strive to abate natural conditions. 62-302.300(15) FAC

Biochemical Oxygen Demand Criteria

Biochemical Oxygen Demand (BOD) shall not be increased to exceed values which would cause dissolved oxygen to be depressed below the limit established for each class and, in no case, shall it be great enough to produce nuisance conditions. [FAC 62-302.530 (11)]

Modeling Approach

The modeling approach that was used for the development of the nutrient and dissolved oxygen TMDL for Sawgrass Lake considers 13 years of meteorological and flow conditions. The selection of a longer term continuous simulation insures that average, wet and dry conditions are considered in the TMDL determination. The modeling approach uses a dynamic watershed model that predicts surface runoff of pollutants (nitrogen, phosphorus and BOD) and flow as function of landuse and meteorological information. The 13 year simulation of watershed loadings and flow are fed forward to a water quality model that predicts the impacts of the loadings and flow on water quality in waterbody. The water quality model predicts: dissolved oxygen, nitrogen (ammonia, nitrate, and organic nitrogen), phosphorus (orthophosphate, organic phosphorus), chlorophyll a, biochemical oxygen demand as a function of loads and flows provided by the watershed model.

LSPC Watershed Model

The Loading Simulation Program C++ (LSPC) was used as the watershed model. LSPC is a watershed modeling system that includes streamlined Hydrologic Simulation Program Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream fate and transport model. LSPC is derived from the Mining Data Analysis System (MDAS), which was originally developed by EPA Region 3 (under contract with Tetra Tech) and has been widely used for TMDLs. In 2003, the U.S. Environmental Protection Agency (EPA) Region 4 contracted with Tetra Tech to refine, streamline, and produce user documentation for the model for public distribution. LSPC was developed to serve as the primary watershed model for the EPA TMDL Modeling Toolbox.

WASP Water Quality Model

Water Quality Analysis Simulation Program (WASP 7.5) (USEPA, 2011) is a generalized framework for modeling contaminant fate and transport in surface waters. Its flexible, compartmental approach allows it to address problems in one, two, or three dimensions. It is designed to allow easy substitution of user-written routines into the program structure. WASP has been used to answer questions regarding biochemical oxygen demand, dissolved oxygen dynamics, nutrients and eutrophication, bacterial contamination, and organic chemical and heavy metal contamination.

The WASP model integrates the predicted flows and loads from the LSPC model to simulate water quality responses in: nitrogen, phosphorus, chlorophyll a and dissolved oxygen. Both LSPC and WASP will be calibrated to current conditions, a natural condition. The WASP model will be used to determine the percent reduction in loadings that would be needed to meet water quality standards.

LSPC Application to Sawgrass Lake Watershed

The watershed model was applied to the Sawgrass Lake watershed model for the simulation period of 1996 through 2009. The 1996 year was used to equilibrate the initial conditions in the watershed model (soil moisture, buildup and washoff), from 1997 through 2009 was used to predict flows and loads under current conditions that will be passed onto the water quality model.

Watershed Delineation and Landuse

The surrounding watershed that drains directly to Sawgrass Lake WBID was included in the watershed model. This encompasses land areas outside the delineated Sawgrass Lake WBID. The watershed was delineated into 7 sub basins (Figure 3). The LSPC model will predict flow and loads coming from each of these sub basins into Jane Green/Crabgrass Creek.

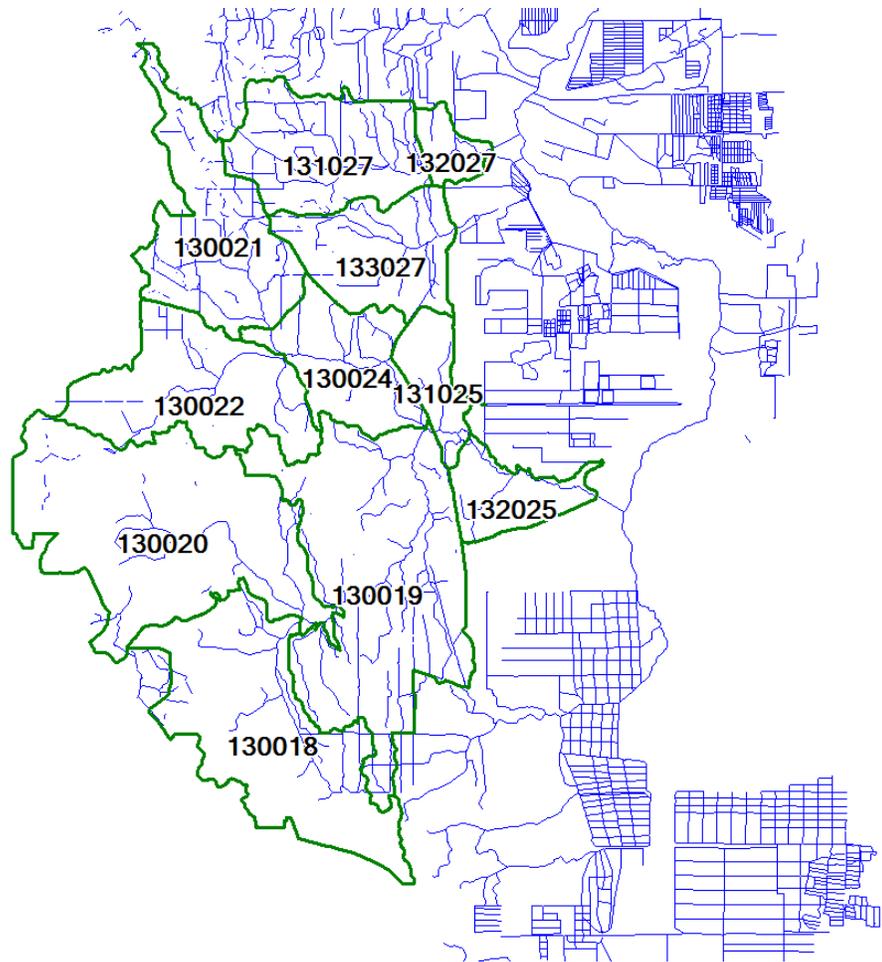


Figure 3 Sawgrass Lake Watershed Delineation

The initial model setup for Sawgrass Lake was obtained from EPA’s application of LSPC for the purposes of nutrient criteria development; the model was further refined and calibrated to all local data and gages that were available in the watershed.

Landuse coverage was obtained from the St. Johns River Water Management District (Florida Landuse Classification Code) coverage developed from 2004. Table 2 provides the landuse distribution for each of the 7 sub basins being modeled.

Table 2 Landuse Distribution for Sub Basins

Subbasin Name	Commercial	Communications	Cropland	Feeding Operations	Industrial	Low Density Residential	Mining	Open Water	Rangeland	Recreational	Transportation	Tree Crops	Upland Forest	Wetlands	Totals
130005			4658.1	13.7		15.5		7.8	324.2			140.8	124.9	1394.5	6679.6
130006	1.4		5340.9	2.2		1233		113.5	270.2			1401.5	212.8	1217.4	8683.2
130007	282.1		9591.7	2.7	5.1	2729	319.1	552	480.1		287.6	3039.7	1422.8	2404.55	40259.2
130175	8.3	0.3	6619.5	9.7		1344.2		127.5	893.1	3.1	48.7	949.1	467.9	3007.5	13478.9
130222	414	0.9	4951.9	6	182	3159		22	274.5		162.3	173.1	508.8	2349.7	8824.8
130223			164			3.8		6.3	2.2		11.5	0.1	137.5	240.7	418.6
130233			1534.7			3298		9	701.1			83.6	255.9	1310.7	4224.8

Meteorological Information

Non-point source loadings and hydrological conditions are dependent on weather conditions. Hourly data from weather stations within the boundaries of, or in close proximity to the sub-watersheds were applied to the watershed model. An ASCII file (*.air) was generated for each meteorological and precipitation station used for the hydrologic evaluations in LSPC. Each meteorological and precipitation station file contains atmospheric data used for modeling of the hydrologic processes. These data include precipitation, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation. These data are used directly, or calculated from the observed data.

Figure 4 depicts the hourly rainfall for the Sawgrass Lake (083137) meteorological station. The period of record being simulated during this TMDL development contains average, wet and dry years.

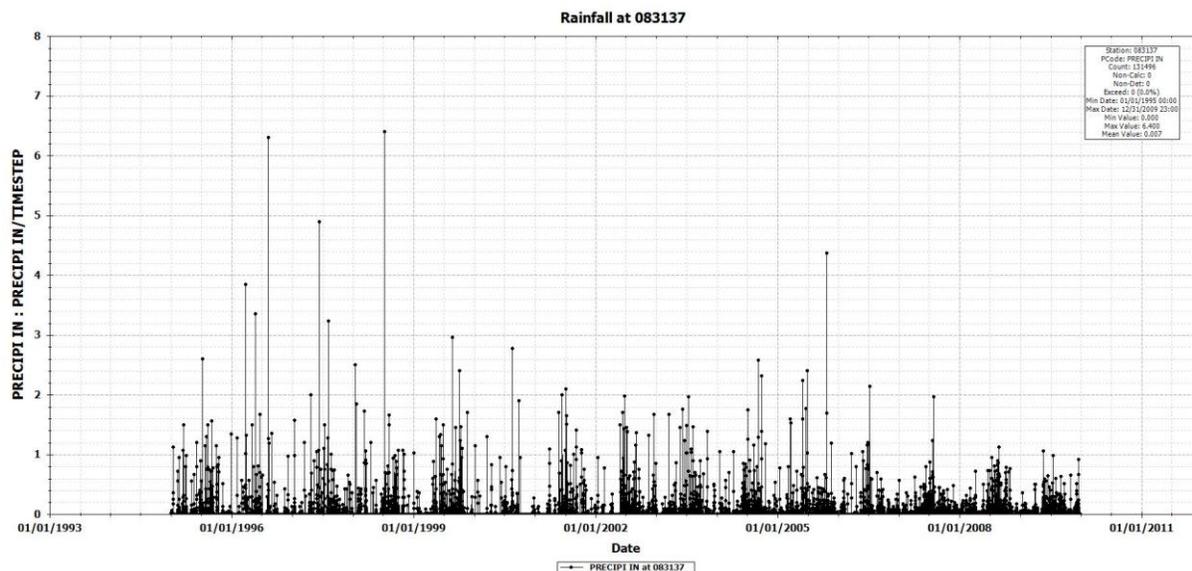


Figure 4. Hourly Rainfall Station 083137

Table 3 provides the annual rainfall for each of the simulation years.

Table 3. Annual Rainfall for Simulation Period

Year	Rainfall (inches)
1/1/1996	67
1/1/1997	62
1/1/1998	63
1/1/1999	76
1/1/2000	65
1/1/2001	30

1/1/2002	58
1/1/2003	69
1/1/2004	62
1/1/2005	72
1/1/2006	66
1/1/2007	41
1/1/2008	57
1/1/2009	67

Hydraulic Calibration

The watershed and water quality model were calibrated for flow by comparing the predict flows to the USGS gage USGS 02232155 Pennywash Creek near Deer Park, FL. While this gage is not in the direct watershed that drains to Jane Green/Crabgrass Creek, it is the closest gage in which to calibrate the model. Figure 5 illustrates both a quantitative and qualitative comparison of the model flow predictions directly compared to the measurements at the USGS gage.

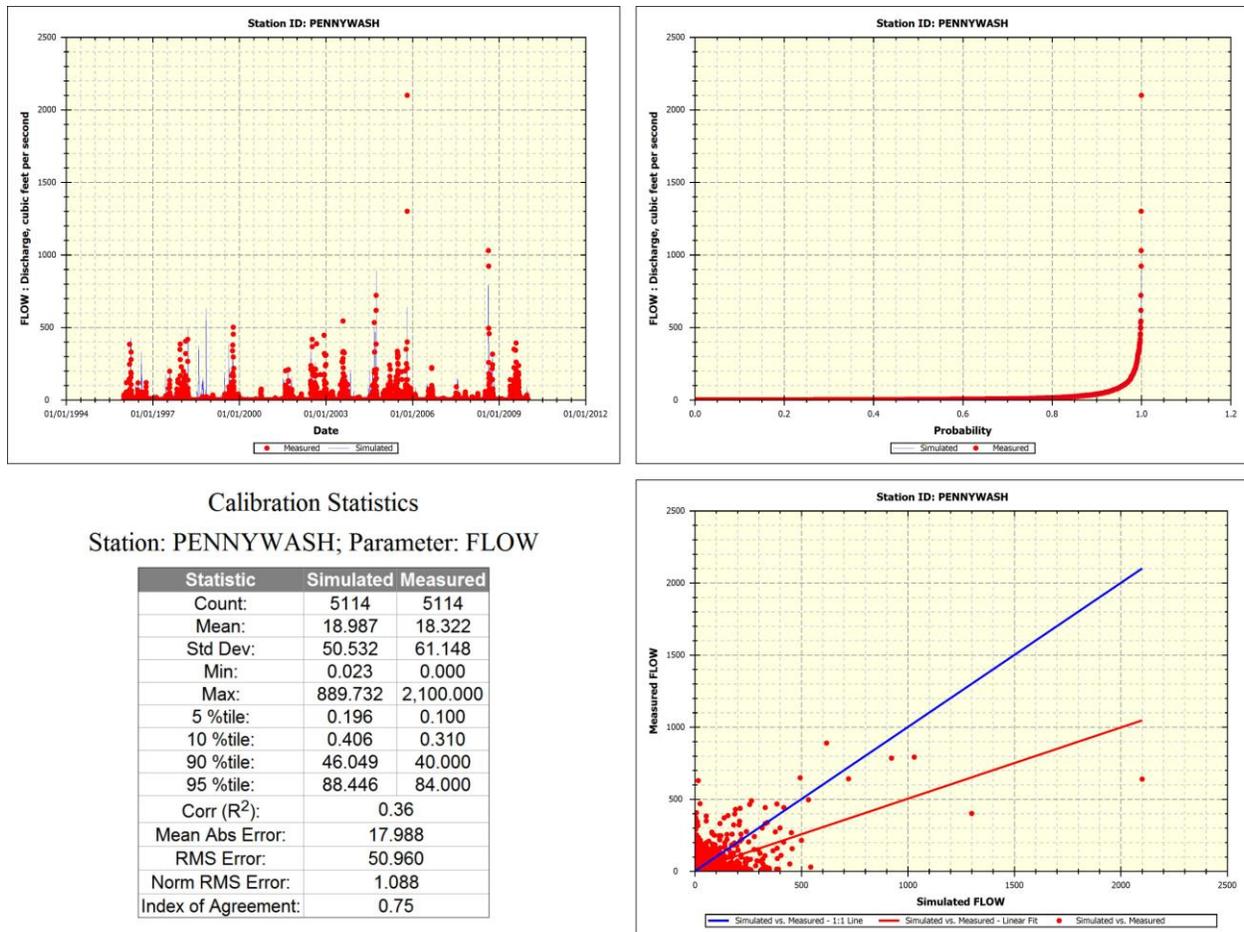


Figure 5. Flow Calibration for Sawgrass Lake Watershed

Water Quality Model Application

The WASP water quality model uses the kinematic wave equation to simulate flow and velocity and the basic eutrophication module to predict dissolved oxygen and Chlorophyll a responses to the BOD, total nitrogen and total phosphorus loadings. The waterbody geometry was determined from NHDPlus coverages of the free flowing stream sections.

Model Network

The Sawgrass Lake waterbody was broken into segments for the water quality model. The model segmentation was done based upon the NHDPlus coverage taking into account travel time, pore points for the watershed model and IWR monitoring stations.

Error! Reference source not found. illustrates the 11 water quality model segments that are simulated. The LSPC model flows and loads enter the water quality model at segments 15, 14, 13, 12, 11, 8 and 7.

Water Quality Model Calibration

The water quality model was calibrated to all available data. The fine tuning of the calibration of the model utilized the IWR station located at the lower end of the WBID that most of the monitoring data.

Table 4 and **Error! Reference source not found.** provide a listing of the IWR stations that were used to calibrate the WASP model. All stations that had nutrient, BOD, dissolved oxygen and chlorophyll a measurements were used in the calibration process. The station highlighted in yellow was used for the water quality.

Table 4. Impaired Waters Rule Database Stations used in Water Quality Model Calibration Jane Green

Station	Station Name	First Date	Last Date
11COEJAX35JR10008	SAWGRASS LAKE NEAR OUTLET	9/23/1981 12:15	6/25/1984 16:15
21FLA 20010110	SAWGRASS LAKE AT CENTER OF THE LAKE	9/21/1998 9:10	9/21/1998 9:10
21FLBRA28931-A	28931 - Sawgrass Lake - btwn 2 small islands	6/22/2007 11:42	1/29/2008 9:40
21FLBRA28931-B	28931 - Sawgrass Lake - broken logs at south end	8/17/2007 7:55	8/17/2007 7:55
21FLCEN 20010110	SAWGRASS LAKE AT CENTER OF THE LAKE	2/11/2003 10:57	10/14/2003 11:00
21FLCEN 20010854	Sawgrass Lake @ NE Quad	2/11/2003 10:50	10/14/2003 10:54
21FLGFWF03080101-040	St. Johns River Station 8	2/18/1996 11:30	8/26/1996 11:25
21FLGFWFGCCR0203	ST. JOHNS RIVER EXIT OF LAKE SAWGRASS	2/18/1996 11:30	5/20/1996 11:40
21FLSJWMSGC	Big Sawgrass Lake center	10/17/1984 12:55	8/24/2004 12:20
21FLSJWMSGO	Sawgrass Lake Outlet next to Gaging station	12/4/1979 7:55	12/13/2011 10:11
21FLWQSPBRE702NL	Little Sawgrass Lake at Camp Holly (WBID 28931)	4/11/2005 9:17	1/16/2006 11:57
21FLSJWMTDRUM	Ft Drum Creek at Hog-Sick island	7/26/2011 12:50	9/23/2011 10:55
21FLWPB 26010430	FT DRUM CREEK @ US441	9/30/2009 11:05	12/8/2011 12:05
21FLWQSPOKE712LV	Fort Drum Creek at SR441 (WBID 3154)	7/7/2005 15:24	6/8/2006 10:24

Table 5 provides a comparison of predicted annual average concentrations versus the annual average concentrations of the measured data. While it is important to capture seasonal variation, duration and frequency of water quality, it is very critical to approximate average conditions in the system. It is during these periods of times that nutrients are expressed.

Table 5. Predicted vs. Observed Annual Average Concentrations

Constituent	Simulated	Observed
BOD (mg/L)	2.81	4.64
Chlorophyll a (ug/L)	13.97	12.27
DO (mg/L)	5.12	4.64
Total Nitrogen (mg/L)	1.55	1.86
Total Phosphorus (mg/L)	0.11	0.10

Figure 6 through Figure 14 provide calibration comparison for all of the major water quality constituents in which data is available.

Water Temperature

Water temperature is simulated in the water quality because of its influence on degradation, kinetic transformation, algal growth and decay rates. Because several modeling scenarios will be simulated, such as a natural condition, an estimate of water temperature under this condition could be important.

Figure 6 illustrates both a quantitative and qualitative comparison of the simulated water temperature compared to the direct measurements.

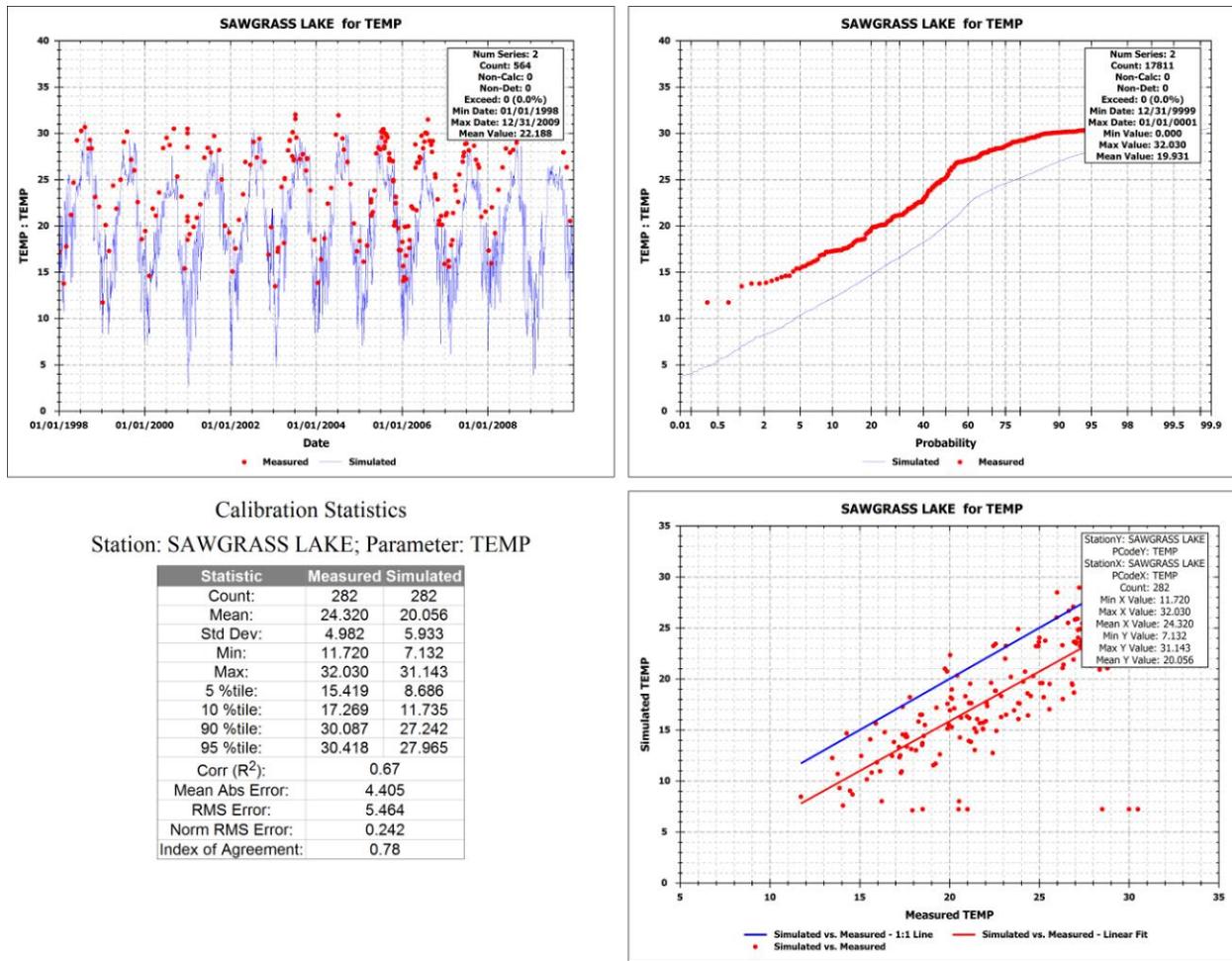


Figure 6. Water Temperature Calibration

Dissolved Oxygen

The dissolved oxygen calibration will be important in the development of this TMDL because it will be the primary response variable to determine the reductions.

Figure 7 illustrates both a quantitative and qualitative comparison of the predicted dissolved oxygen concentrations compared to the direct measurements.

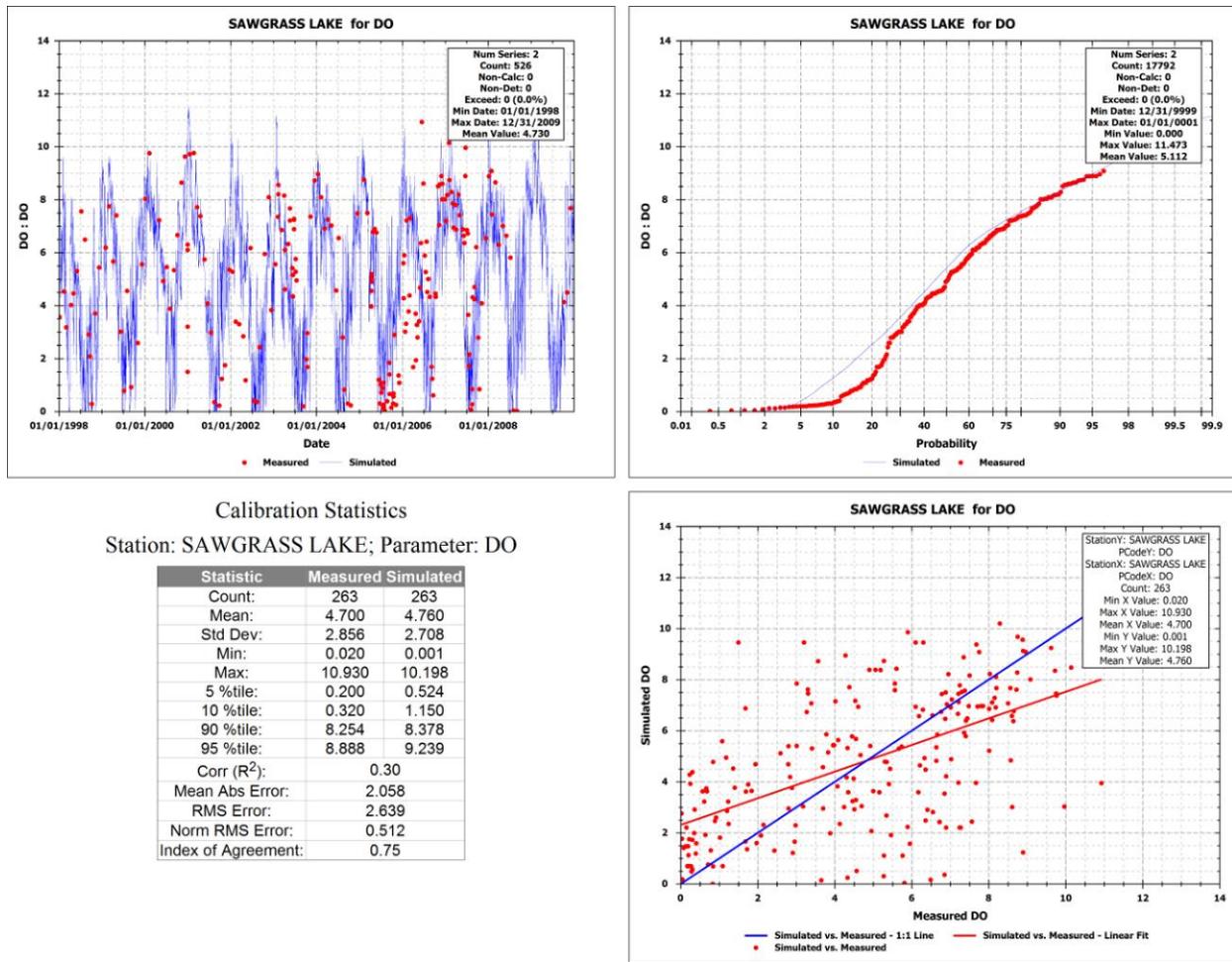


Figure 7. Dissolved Oxygen Calibration

Biochemical Oxygen Demand

There is very little BOD data available for the Sawgrass Lake WBID. The following presents BOD data that is available from the IWR Station Sawgrass Lake Creek at Florida Turnpike.

Figure 8 illustrates both a quantitative and qualitative comparison of the predicted dissolved oxygen concentrations compared to the direct measurements.



Figure 8 BOD Calibration

Chlorophyll a

There is very little BOD data available for the Sawgrass Lake WBID. The following presents chlorophyll a data that is available from the IWR Station Sawgrass Lake Creek at Florida Turnpike.

Figure 9 illustrates both a quantitative and qualitative comparison of the predicted dissolved oxygen concentrations compared to the direct measurements.

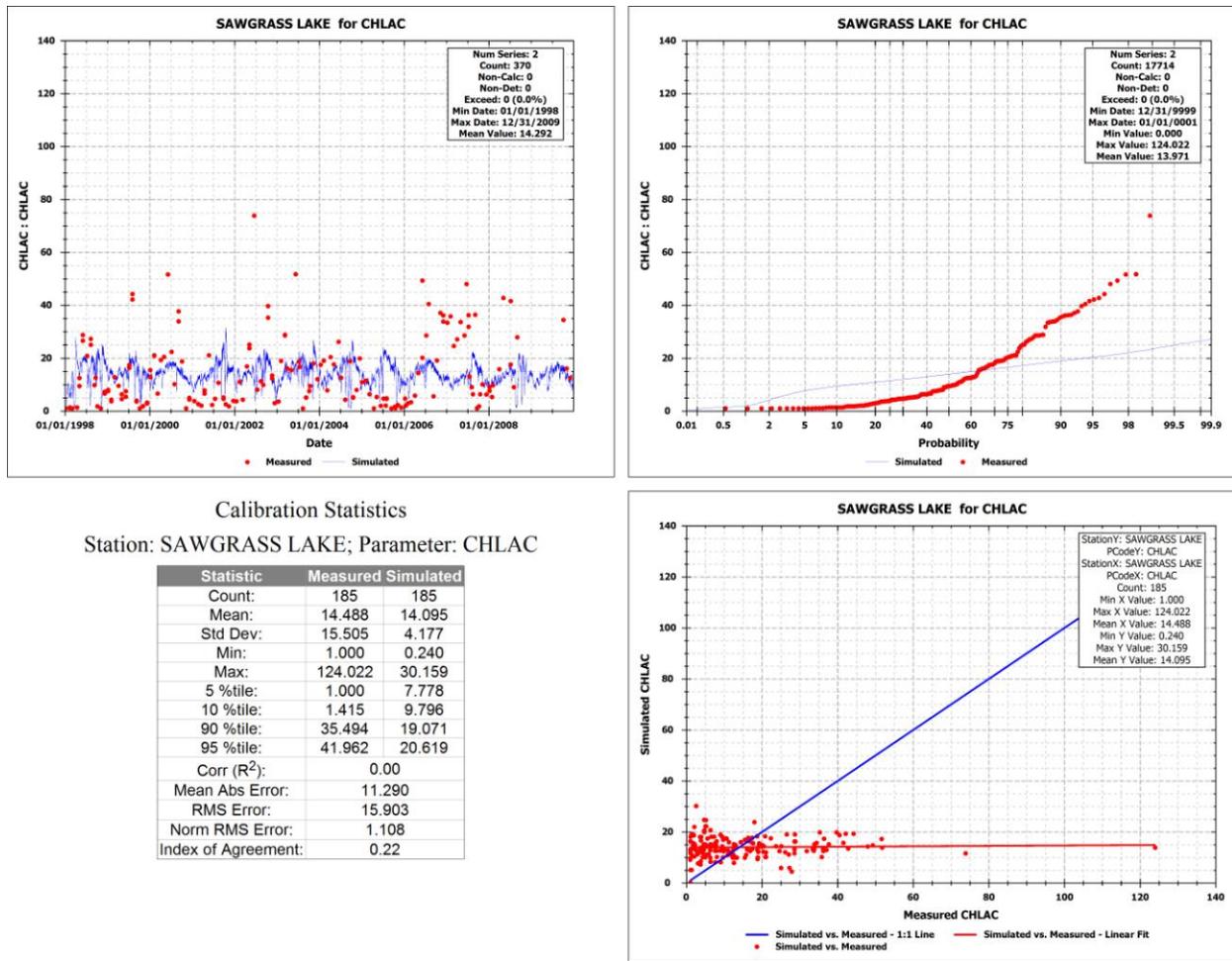


Figure 9. Chlorophyll a Calibration

Nitrogen

Figure 10 illustrates both a quantitative and qualitative comparison of the model predictions for total nitrogen to direct measurements.

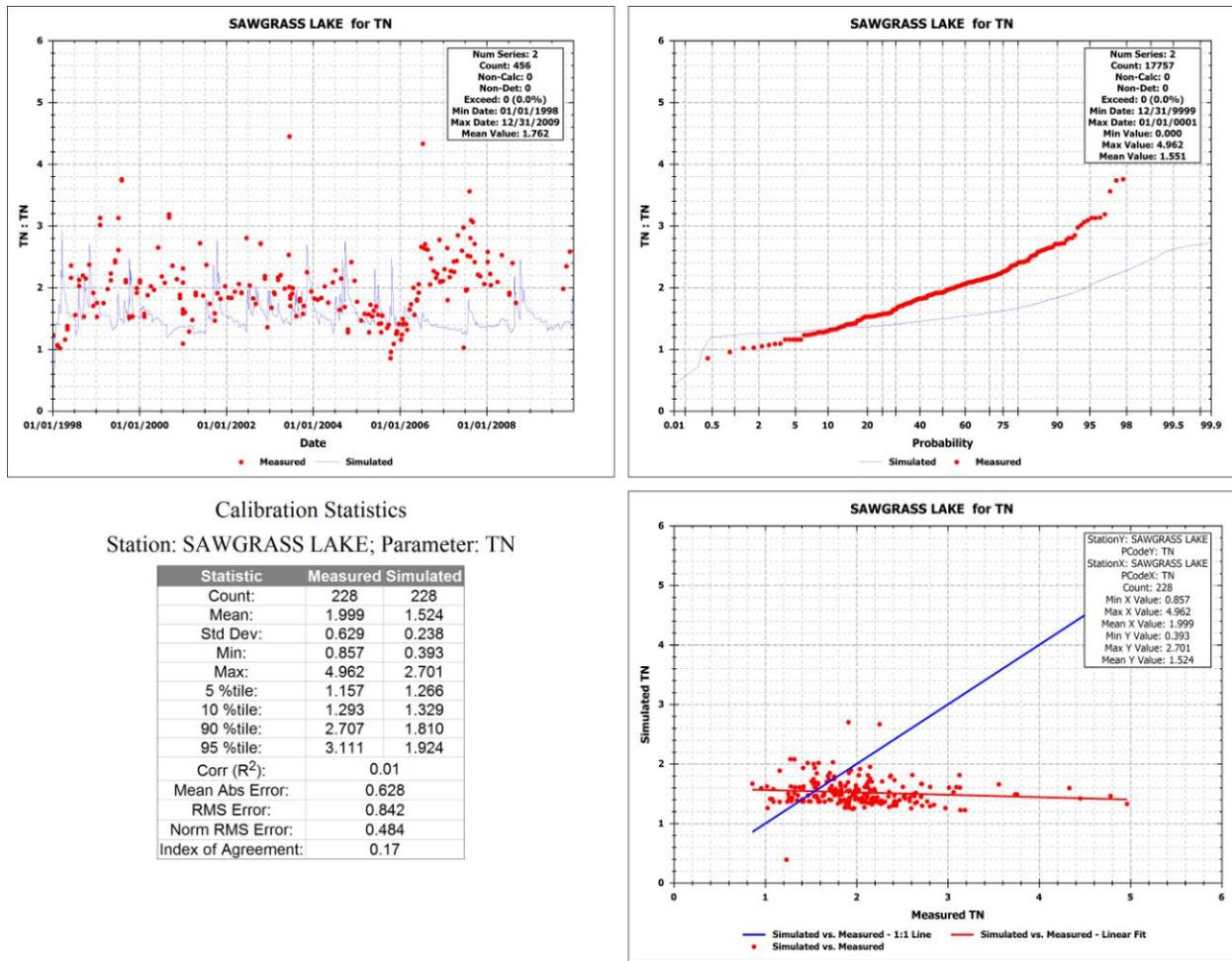


Figure 10. Total Nitrogen Calibration

Figure 11 illustrates both a quantitative and qualitative comparison of the model predictions for ammonia to direct measurements.

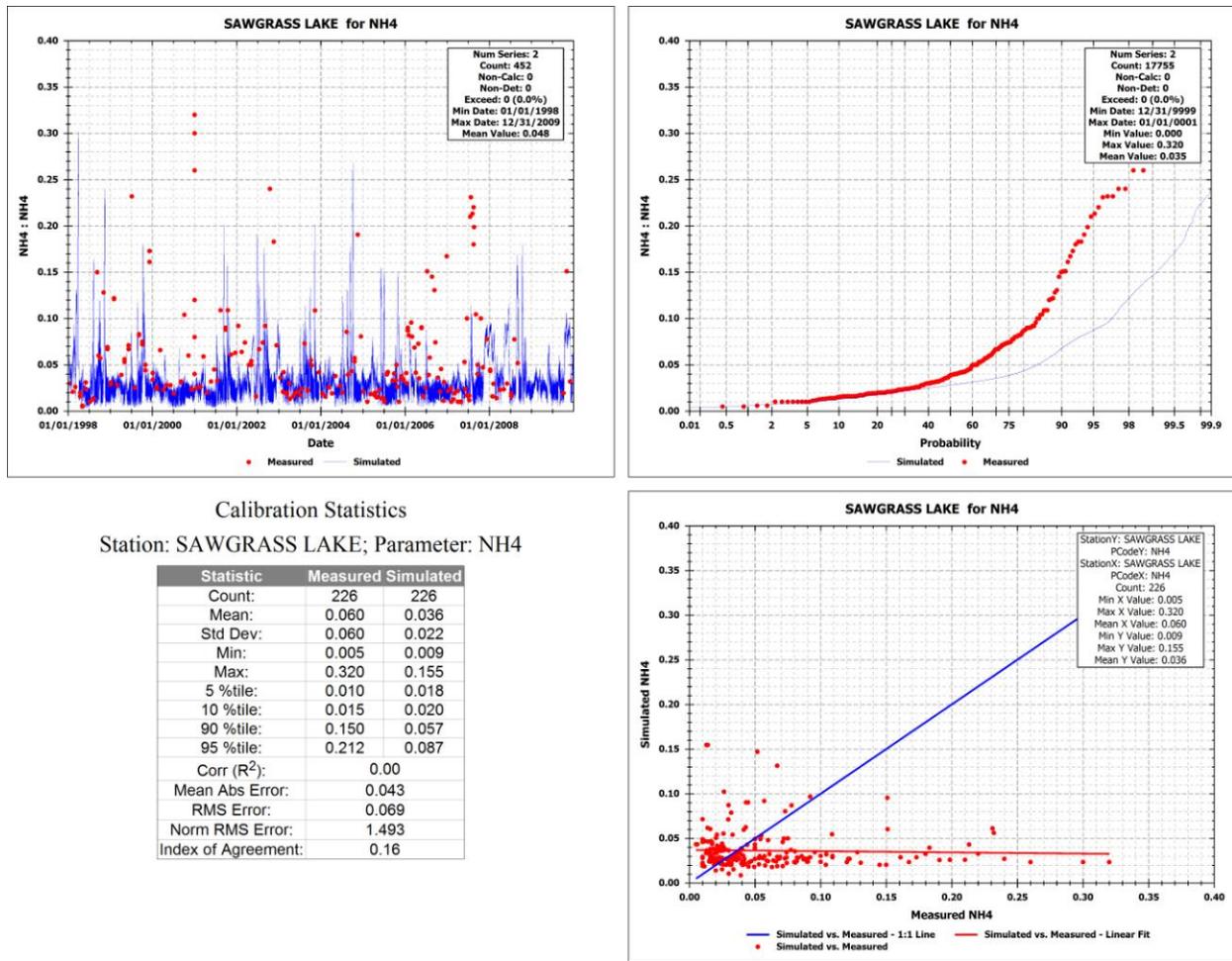


Figure 11 Ammonia Calibration

Figure 12 illustrates both a quantitative and qualitative comparison of the model predictions for nitrate to direct measurements.

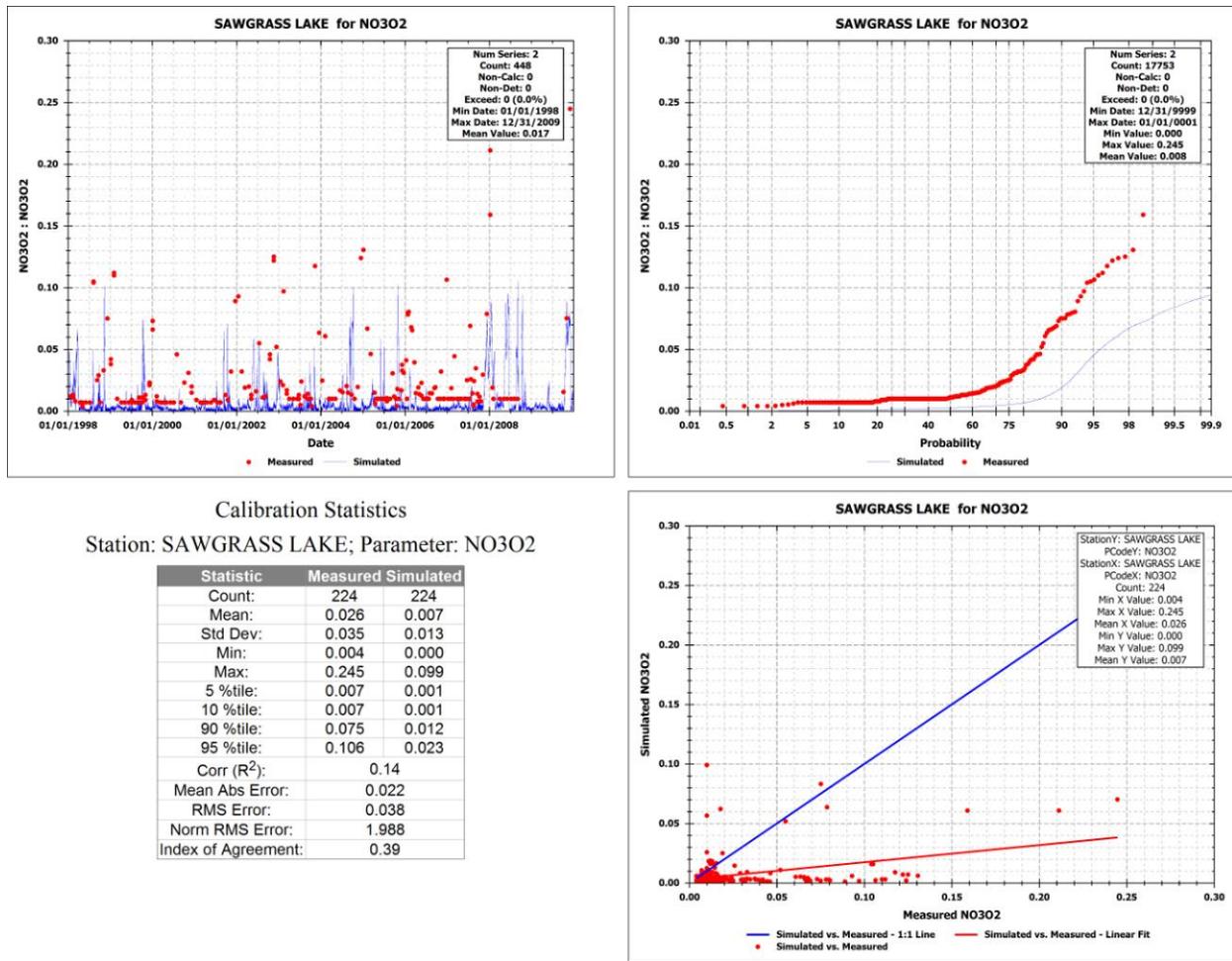


Figure 12 Nitrate Calibration

Phosphorus

Figure 13 illustrates both a quantitative and qualitative comparison of the model predictions for total phosphorus to direct measurements.

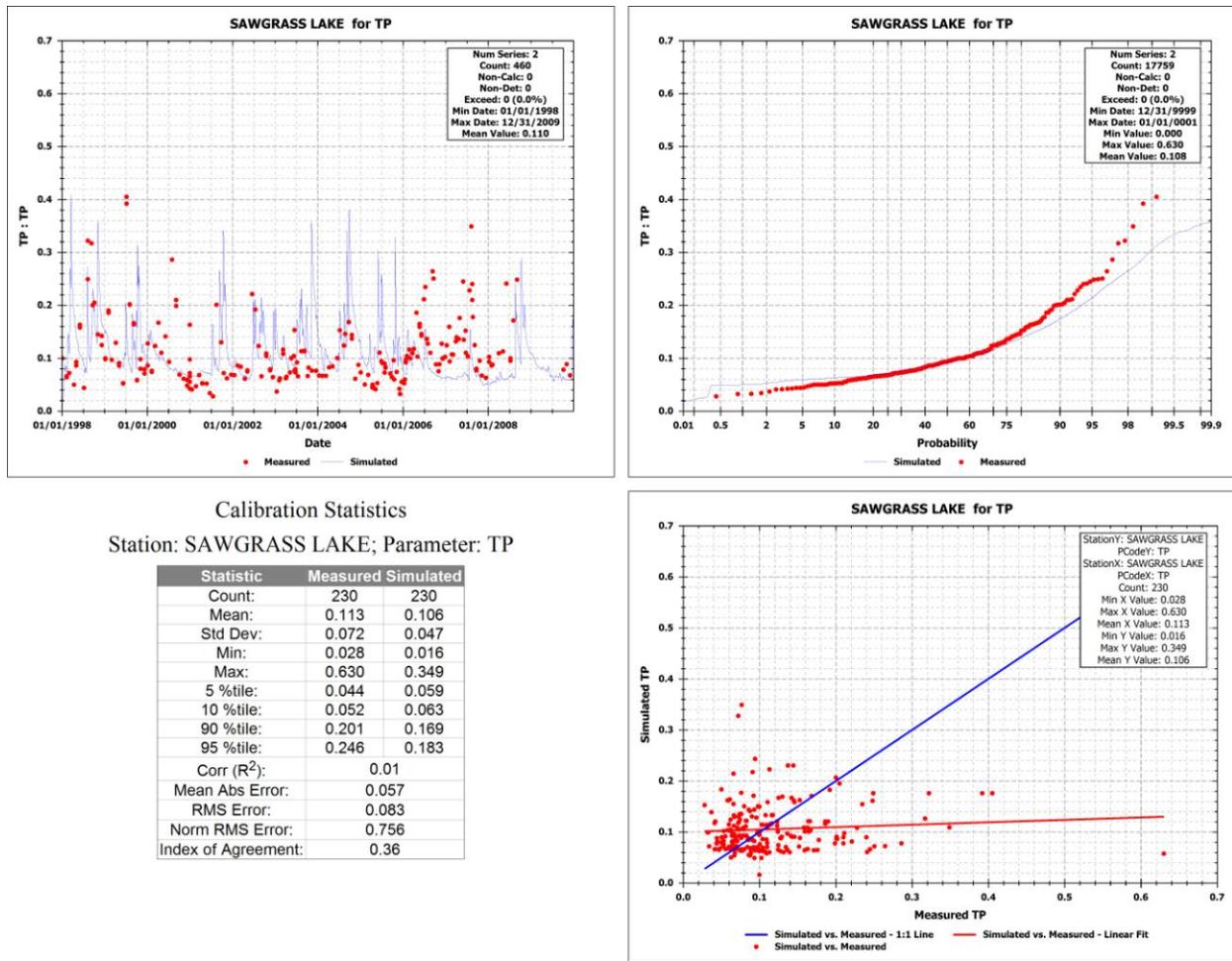


Figure 13. Total Phosphorus Calibration

Figure 14 illustrates both a quantitative and qualitative comparison of the model predictions for orthophosphate to direct measurements.

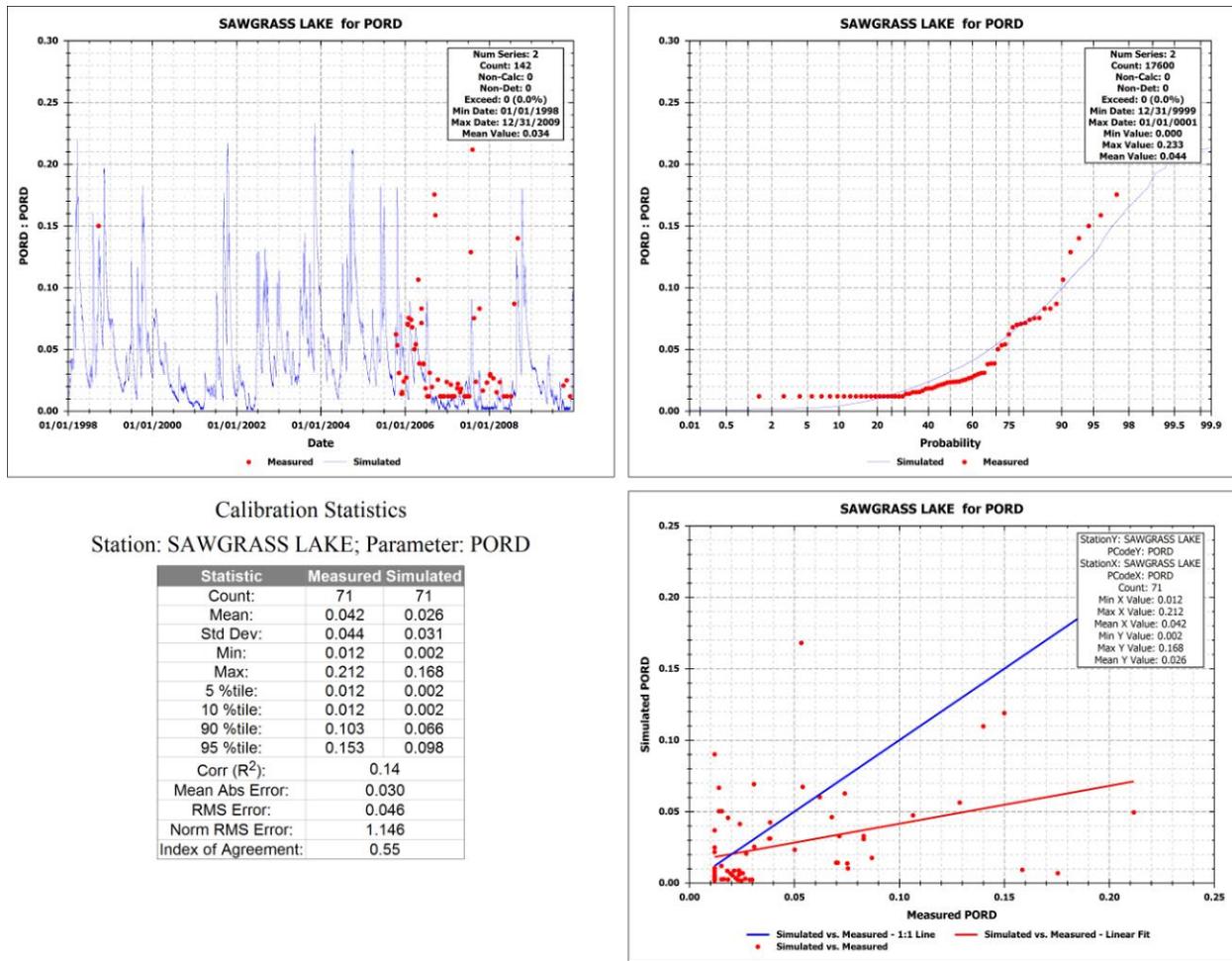


Figure 14 Orthophosphate Calibration

Current Loads

Table 4 provides the annual average total nitrogen, total phosphorus and BOD loads for the period of record 1997 through 2009. It is these loadings that the TMDL load reduction will be calculated from.

Table 6. Current Loads (1997-2009)

Constituent	Current Condition	
	WLA (kg/yr)	LA (kg/yr)
BOD	NA	2,397,360
Total Nitrogen	NA	1,888,931
Total Phosphorus	NA	242,037

Modeling Scenarios

Using the calibrated watershed and water quality models, up to two potential modeling scenarios will be developed. The first scenario will be to predict water quality conditions under a natural condition (remove point sources and returning landuses back to upland forests and wetlands). A second scenario will be developed if water quality standards can be met under natural conditions (balanced flora and fauna, dissolved oxygen greater than 5 mg/L); loads would be reduced from the current conditions until standards are met (balanced flora and fauna, dissolved oxygen greater than 5 mg/L)

Natural Condition Analysis

The purpose of the natural condition scenario is to determine the water quality in the Sawgrass Lake watershed without the influences of man. Because of Florida's regulation of not allowing abating of a natural condition, this scenario determines the maximum reduction that could be required. The natural condition scenario makes the following assumptions:

1. All man induced landuses in the watershed model are transformed back to wetlands and upland forest (50:50 & 75:25 ratio).
2. New hydrology is predicted under natural landuse assumption.
3. All point sources are removed (if any).
4. Water quality is predicted using the new flows and loads from the natural condition run from the watershed model.
5. Sediment oxygen demand is reduced based upon the percent reduction in nutrient loads.

Table 7 presents the predicted annual average concentrations under natural conditions. Without the impacts of anthropogenic sources the dissolved oxygen concentration in the Sawgrass Lake watershed. It should be noted that under natural conditions the dissolved oxygen standard of 5 mg/l would not be achieved. The natural condition scenario will be used to set the maximum loads for the TMDL.

Table 7. Natural Condition Annual Average Model Predictions

Constituent	Natural
BOD (mg/L)	2.06
Chlorophyll a (ug/L)	10.28
DO (mg/L)	6.42
Total Nitrogen (mg/L)	1.17
Total Phosphorus (mg/L)	0.05

Table 8 provides the annual average model predictions for total nitrogen, total phosphorus, and dissolved oxygen under a natural condition.

Table 8 Annual Average Loadings for Natural Condition

Natural Condition		
Constituent	WLA (kg/yr)	LA (kg/yr)
BOD	NA	1,487,055
Total Nitrogen	NA	949,730
Total Phosphorus	NA	54,552

Figure 15 shows the probability distribution for dissolved oxygen concentration in Sawgrass Lake under current and the natural condition scenario.

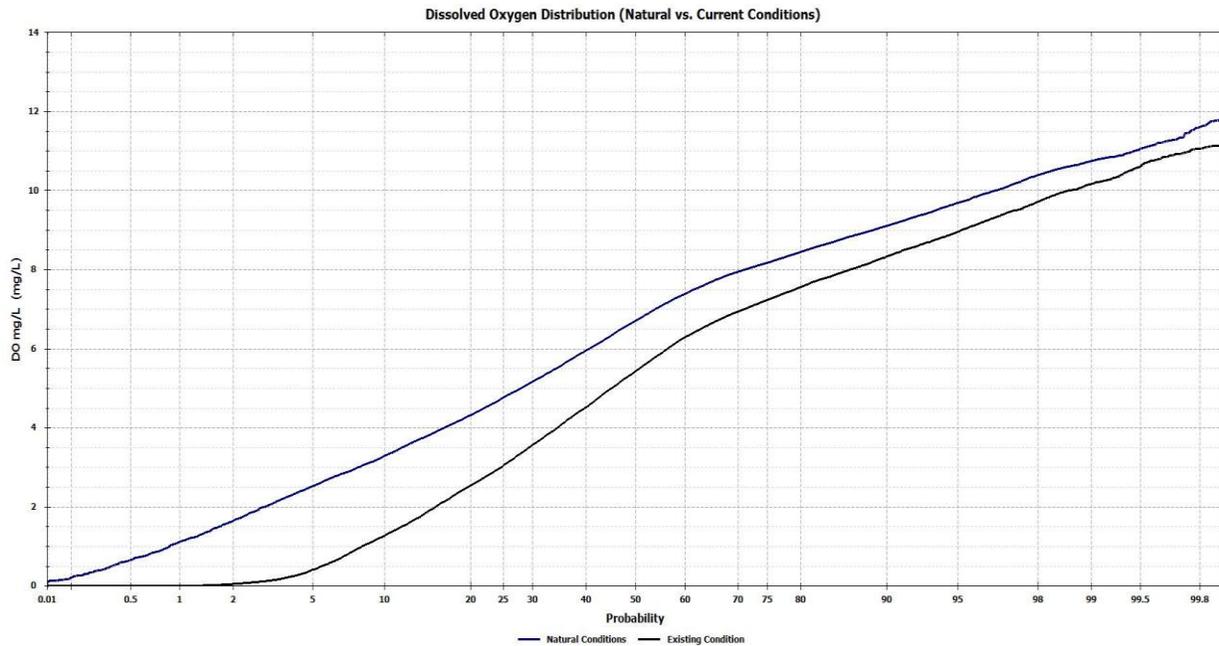


Figure 15 Dissolved Oxygen Concentration Probability Current vs. Natural Condition

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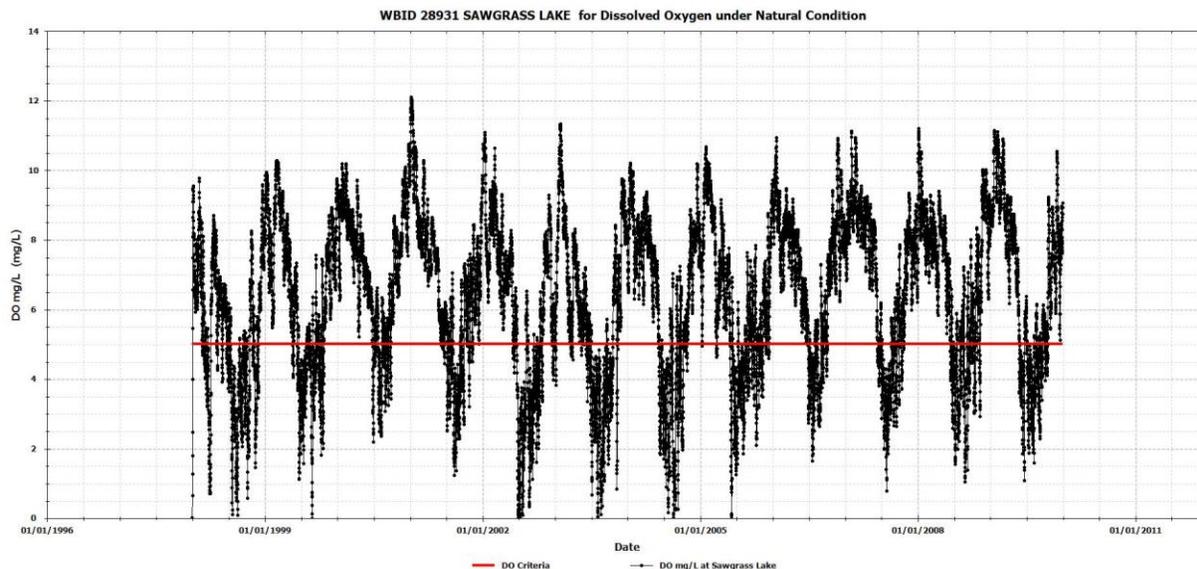


Figure 16 Dissolved Oxygen Time Series for Natural Conditions

TMDL Load Reductions

Because water quality standards cannot be met under natural conditions no other scenarios were conducted. The TMDL will be set to the natural conditions.

TMDL Determination

The TMDL load reduction was determined by reducing the current conditions to the natural conditions. The annual average loadings are given in Table 9 along with the prescribed load reductions.

Table 9 TMDL Determination

Constituent	Current Condition		TMDL Condition		MS4	LA
	WLA (kg/yr)	LA (kg/yr)	WLA (kg/yr)	LA (kg/yr)	% Reduction	% Reduction
BOD	NA	2,397,360	NA	1,487,055	NA	38%
Total Nitrogen	NA	1,888,931	NA	949,730	NA	50%
Total Phosphorus	NA	242,037	NA	54,552	NA	77%

Note: Both the watershed and water quality models including calibration and scenario input files are available upon request.