Hydrology and Water Quality Modeling Report

for the

Caloosahatchee River and Estuary, Florida

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Cover photograph from https://www.sfwmd.gov/our-work/caloosahatchee-river

LIST OF ACRONYMS AND ABBREVIATIONS

ADCP	Acoustic Doppler Current Profilers
AFSIRS	Agricultural Field-Scale Irrigation Requirements Simulation
BENOD	Benthic Oxygen Demand
BMAP	Basin Management Action Plan
BOD	Biochemical Oxygen Demand
CASTNET	Clean Air Status and Trends Network
CBOD	Carbonaceous Biochemical Oxygen Demand
CBOD5	Carbonaceous Biochemical Oxygen Demand 5-Day
CBODU	Carbonaceous Biochemical Oxygen Demand Ultimate
DAFL	Daily Average Fraction of Light
Department	Florida Department of Environmental Protection
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
DW	Domestic Wastewater
EFDC	Environmental Fluid Dynamics Code (model)
EIA	Effective Impervious Area
EMC	Event Mean Concentrations
ET	Evapotranspiration
FDACS	Florida Department of Agriculture and Consumer Services
FDOH	Florida Department of Health
FDOT	Florida Department of Transportation
FSAID	Florida Statewide Agricultural Irrigation Demand
F-TABLE	Function Table
GIS	Geographic Information System
GVC	Generalized Vertical Coordinate
HSPF	Hydrologic Simulation Program – FORTRAN (model)
IA	Index of Agreement
ISD	Integrated Surface Database
IW	Industrial Wastewater
IWR	Impaired Waters Rule
LiDAR	Light Detection and Ranging (data)
LPOC	Labile Particulate Organic Carbon
LULC	Land Use/Land Cover
MAE	Mean Absolute Error
MetADAPT	Meteorological Data Analysis and Preparation Tool
MG	Million Gallons
MGD	Million Gallons per Day
MIA	Mapped Impervious Area
MSL	Mean Sea Level
NADP	National Atmospheric Deposition Program
NAVD 88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center

NEXRAD	Next-Generation Radar
NH3	Ammonia
NH4	Ammonium
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NO3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NRMSE	Normalized Root Mean Square Error
NS	Nash-Sutcliffe (coefficient)
NTN	National Trends Network
OAT-SA	One at a Time Sensitivity Analysis
OrgC	Organic Carbon
OrgN	Organic Nitrogen
OrgP	Organic Phosphorus
PAR	Photosynthetically Available Radiation
PE	Percent Error
PET	Potential Evapotranspiration
PO4	Orthophosphate
POC	Particulate Organic Carbon
RETo	Reference Evapotranspiration
RMSE	Root Mean Squared Error
RPOC	Refractory Particulate Organic Carbon
SA	Surface Airways
SCCF	Sanibel-Captiva Conservation Foundation
SFWMD	South Florida Water Management District
SOD	Summary of the Day
SOFIA	South Florida Information Access
SSURGO	Soil Survey Geographic Database
SWET	Soil and Water Engineering Technology
SWFWMD	Southwest Florida Water Management District
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WBAN	Weather-Bureau-Army-Navy
WBID	Waterbody Identification (number)
WRDB	Water Resources Database
WSE	Water Surface Elevation

EXECUTIVE SUMMARY

The Caloosahatchee River Watershed encompasses approximately 1,339 square miles and covers significant portions of four counties. The 75-mile-long Caloosahatchee River originates as the C-43 Canal at the southwest corner of Lake Okeechobee at the structure S-77, and then flows predominantly east to west, eventually discharging into the Gulf of Mexico at San Carlos Bay. The Caloosahatchee Estuary extends from the Franklin Lock (S-79) to Shell Point, adjacent to San Carlos Bay, with Pine Island Sound to the northwest and Estero Bay to the southeast. The Caloosahatchee River receives flow from Lake Okeechobee, tributaries and canals that discharge to the Caloosahatchee River upstream of S-79, and streams and large tributaries that discharge directly to the estuary below S-79. Approximately half of the volume of water that reaches S-79 is water that has passed through S-77 from Lake Okeechobee.

The Florida Department of Environmental Protection (department) identified the tidal Caloosahatchee River and Estuary as impaired for nutrients and dissolved oxygen (DO). To address these impairments, the department adopted a total maximum daily load (TMDL) in 2009, which limits the amount of total nitrogen (TN) that the tidal portion of the river and the estuary can receive and still meet water quality standards. The ultimate goal of the TMDL is to increase light penetration in the estuary to allow for seagrass growth.

The department worked with local stakeholders to develop a basin management action plan (BMAP) to implement projects to start working towards meeting the TMDL. The BMAP was adopted in 2012. During BMAP development, the stakeholders raised concerns about the existing TMDL and the models used to develop the TMDL. To address these concerns and to update the Hydrologic Simulation Program – FORTRAN (HSPF) watershed model and Environmental Fluid Dynamics Code (EFDC) estuary model for use in additional TMDL development, the department contracted with Tetra Tech, Inc. and Amec Foster Wheeler, Inc. in 2016. The overall goals of this project were to revise the models so that the department had the necessary tools to update the BMAP, reevaluate and potentially refine the existing TMDL, and develop TMDLs for impaired waterbodies in the watershed.

In updating the models, Tetra Tech focused on addressing major department and stakeholder comments, as well as issues that Tetra Tech identified with the original models that would limit the ability to provide the information needed for TMDL and BMAP updates and/or revisions. The simulation period was extended through 2014, and Tetra Tech processed all new data input files for both models for the full model simulation period of January 1, 1996 – December 31, 2014.

The major modifications and changes made to the HSPF watershed model were as follows:

- Updated the model subbasin delineations.
- Adjusted reach function tables to represent ponding that occurs behind weirs in the watershed.
- Processed the rainfall, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation data for use in the model.
- Updated the model land use to the 2008-2009 South Florida Water Management District (SFWMD) and Southwest Florida Water Management District (SWFWMD) coverages.
- Added additional land use classifications to better represent the land uses in the watershed.
- Updated effective impervious land use representation.

- Adjusted model parameterization to ensure parameters were within suggested literature ranges and to improve model calibration.
- Developed new agricultural irrigation demand time series for five different crop classifications to address stakeholder comments.
- Revised the representation of National Pollutant Discharge Elimination System (NPDES) facilities in the watershed.
- Processed reuse facilities data for explicit inclusion in the model to more accurately simulate the flows and loads from these sources.
- Processed septic systems for explicit inclusion in the model and to reflect the septic system loadings in the watershed.
- Reduced the upland simulation to four upland quality constituents: nitrate + nitrite (NOx), ammonia (NH_3), orthophosphate (PO_4), and organic matter.
- Revised the upland simulation to simulate PO_4 and organic matter as sediment-associated constituents.
- Added additional instream water quality calibration and validation locations for a total of 50 stations at 33 unique locations.
- Developed atmospheric deposition loadings of wet and dry NOx and NH_3 for explicit representation in the model.

The major modifications and changes made to the EFDC estuary model were as follows:

- Converted the model from a proprietary version of EFDC to a public version of EFDC.
- Added cells to the model grid to represent the tidally influenced streams/reaches in impaired waterbodies.
- Revised the model grid to better represent the topographical and hydrographical characteristics of the Caloosahatchee River Estuary.
- Updated the bathymetry.
- Updated the open, freshwater, north, and south model boundaries using the latest data.
- Processed weather data for precipitation, relative humidity, atmospheric temperature, cloud cover, solar radiation, atmospheric pressure, and wind speed and direction for use in the model.
- Updated the biological and chemical kinetic rates of the water quality model based on model calibration to observed datasets of nutrients, phytoplankton biomass, and DO.

After making the above modifications, Tetra Tech calibrated and validated each model to available hydrologic and water quality existing conditions. The HSPF model was calibrated and validated to watershed flows, temperature, dissolved oxygen (DO), nitrogen, phosphorus, chlorophyll-*a*, and total suspended solids (TSS), while the EFDC model was calibrated and validated to water surface elevation, flows, salinity, temperature, DO, nitrogen, phosphorus, chlorophyll-*a*, TSS, and light penetration. The results from the HSPF model were used to provide water quality loads to the EFDC model.

Based on the calibration results, the updated HSPF model did an acceptable job of simulating hydrology and water quality in the Caloosahatchee River Watershed. The HSPF model predicted flows very well in watersheds where flows were not predominantly inhibited by weirs or structures, although model performance was lower in areas where weirs and structures inhibited the natural flow. Mean and median upland loading rates of TSS, TN, and total phosphorus (TP) compared favorably with target land use loading rates from Harper 1994 and SWET 2008. In addition, the HSPF model was able to represent the

overall magnitudes and trends of instream concentrations for all water quality parameters. When model outputs were compared to measured instream monitoring data, the model did exhibit some bias at several stations, both high and low for various constituents. These biases were likely due to localized conditions (i.e. internal cycling and/or benthic releases of nutrients) that could not be represented realistically in a one-dimensional large-scale watershed model. However, simulated output was generally in range with instream observations and compared very favorably to the measured data, especially when taking into account the hydraulic and land use complexities of the Caloosahatchee River Watershed.

The updated EFDC model also successfully captured the trends and ranges of the hydrodynamics and water quality in the Caloosahatchee River and Estuary. The model was able to reproduce the phase and amplitude of tidal variations within the estuary, as well as the levels of salinity intrusion and stratification in the estuary. The model performed very well in capturing the variability in DO, TN, and TP during the calibration period, as well as the timing and magnitude of important changes in concentrations. The EFDC model was also generally able to capture the magnitudes and range of variability of light extinction observed in the system. The comparison between the model predictions and observations of light extinction indicated that the model was able to simulate the average levels of light extinction in the system and was also able to capture the trends and variability of the observations.

In addition to model calibration for the existing conditions, the models were evaluated for natural background conditions to determine the watershed nutrient loading and estuary conditions in a background scenario. The HSPF model was modified to create a background land use plus Lake Okeechobee at its TMDL (Background Plus) model. In the Background Plus Model, it was assumed that Lake Okeechobee achieved its TMDL for TP, with associated reductions to TN and total organic carbon (TOC). In addition, all anthropogenic land uses were converted to natural land uses, NPDES point source and reuse facilities were removed, septic systems were removed, and agricultural irrigation was removed. When comparing the natural background scenario to the existing condition, concentrations delivered to the estuary from streams were reduced for the background scenario compared to the existing for many of the water quality constituents. However, for organic nitrogen and organic phosphorus, concentrations were typically greater in the background scenario. The natural land uses have a greater amount of organic matter compared to the anthropogenic land uses, which caused these loads to be greater in the background scenario.

In the natural background scenario compared to the existing condition, there was no systematic decrease or increase trend for DO concentration delivered to the estuary from streams. Some streams had an increase in DO concentrations, while others had a decrease in DO concentrations. In streams where concentrations increased, less DO was consumed via processes such as biochemical oxygen demand (BOD) decay and nitrification of ammonia. In reaches that had a decrease in DO, reductions in benthic algae likely reduced the amount of photosynthesis and DO production that occurred.

For the EFDC model, the load in the background scenario caused DO to increase slightly relative to the existing conditions. In particular, the 5th percentile, mean, and 95th percentile DO concentrations increased in average by 10%, 5%, and 1% respectively. The background scenario did result in important nutrient reductions throughout the system. The concentrations of TN and TP systematically decreased from the current levels in all the evaluated stations. For nitrogen, the 5th percentile, mean, and 95th percentile concentrations of TN decreased in average by 8%, 22%, and 32%, respectively. For phosphorus, the 5th percentile, mean, and 95th percentile concentrations of TP decreased in average by 13%, 46%, and 65%, respectively. The background simulation results indicated that the reductions in nutrient loads from the

watershed resulted in small reductions of the phytoplankton concentrations in all the stations evaluated within the estuary.

The purpose of this modeling effort was to revise the calibration of both the HSPF and EFDC models and to provide results for the natural background scenario. The Caloosahatchee River and Estuary, as well as the surrounding watershed, is a complex system to model. There were several uncertainties impacting the models' performance, such as uncertainties in boundary and forcing conditions, calibrated parameters, and calibration and validation measured data. Comparison figures, grades, and statistics are provided in this report to help identify the strengths and limitations of the models. This information will be used by the department to make informed decisions based on the model simulations, and to determine what types of additional model scenarios are needed to evaluate the conditions in the watershed and estuary. These additional evaluations will occur as part of a separate effort. The results presented in this report, as well as the additional results from the department's evaluations, will be used to determine whether the current estuary TMDL should be revised and to set TMDLs for other impaired waterbodies within the watershed.

Section 1.0 INTRODUCTION

The Caloosahatchee River Watershed encompasses approximately 1,339 square miles and covers significant portions of four counties. The 75-mile-long Caloosahatchee River originates as the C-43 Canal at the southwest corner of Lake Okeechobee at the structure S-77, and then flows predominantly east to west, eventually discharging into the Gulf of Mexico at San Carlos Bay **(Figure 1**). Water flow is controlled by the U.S. Army Corps of Engineers (USACE) through three control structures: (1) the Moore Haven Lock (flow from Lake Okeechobee over S-77 into the C-43/Caloosahatchee River), (2) the Ortona Lock (S-78), and (3) the Franklin Lock (S-79) **(Figure 1**). The Franklin Lock separates the freshwater portion of the Caloosahatchee Canal on the east, from the 33.2-mile-long tidal estuarine portion of the Caloosahatchee River on the west (Florida Department of Environmental Protection 2009).

The Caloosahatchee Estuary extends from the Franklin Lock (S-79) to Shell Point, adjacent to San Carlos Bay, with Pine Island Sound to the northwest and Estero Bay to the southeast. The Caloosahatchee River receives flow from Lake Okeechobee, several streams and canals between S-77 and S-78, 14 tributaries between S-78 and S-79, and 23 waterbodies that discharge directly to the estuary below S-79. Approximately half of the volume of water that reaches S-79 is water that has passed through S-77 from Lake Okeechobee (Florida Department of Environmental Protection 2009).

The Florida Department of Environmental Protection (department) identified the tidal Caloosahatchee River and Estuary as impaired for nutrients and dissolved oxygen (DO). This evaluation was made to meet Section 303(d) of the Clean Water Act, which requires states to submit a list of impaired waters that do not meet applicable water quality standards to the U.S. Environmental Protection Agency (USEPA). To address these impairments, the department adopted a total maximum daily load (TMDL) in 2009, which limits the amount of total nitrogen (TN) that the tidal portion of the river and the estuary can receive and still meet water quality standards. The department worked with local stakeholders to develop a basin management action plan (BMAP) to implement projects to start working towards meeting the TMDL. The BMAP was adopted in 2012.

During BMAP development, the stakeholders raised concerns about the existing TMDL and the models used to develop the TMDL. To address these concerns and to update the Hydrologic Simulation Program – FORTRAN (HSPF) watershed model and Environmental Fluid Dynamics Code (EFDC) estuary model for use in additional TMDL development, the department contracted with Tetra Tech, Inc. and Amec Foster Wheeler, Inc. The overall goals of this project were to update the models so that the department had the necessary tools to refine the existing TMDL and to develop TMDLs for other impaired waterbodies in the watershed.

The impaired waterbodies, or waterbody identification (WBID) numbers, that Tetra Tech was focused on during model development were those on the 2010 impaired waters list. These waterbodies are summarized in **Table 1**. In 2016, the department updated list of impaired waterbodies, and the currently listed impaired tributaries are shown in **Table 2**.

TABLE 1: LIST OF 2010 IMPAIRED WATERBODIES

WBID	WBID Name	TMDL Need
3246	C-21 Canal	Development
3235D	Jacks Branch	Development
3235G	Cypress Branch	Development
3235L	Townsend Canal	Development
3235B	Caloosahatchee River between S-79 and S-78	Development
3237B	Long Hammock Creek	Development
3237C	Lake Hicpochee	Development
3237D	Ninemile Canal	Development
3240A	Caloosahatchee (Tidal Segment 1)	Refinement
3240A2	Cape Coral	Development
3240A4	Deep Lagoon Canal	Development
3240B	Caloosahatchee (Tidal Segment 2)	Refinement
3240C	Caloosahatchee (Tidal Segment 3)	Refinement
3240J	Billy Creek	Development
3240Q	Popash Creek	Development

TABLE 2: LIST OF 2016 IMPAIRED TRIBUTARIES

WBID	WBID Name
3246	C-21 Canal
3235L	Townsend Canal
3235M	Goodno Canal
3237B	Long Hammock Creek
3237C	Lake Hicpochee
3237D	Ninemile Canal
3237E	C-19 Canal
3240A2	Cape Coral

This report summarizes the revisions made and calibration results for the HSPF watershed model (**Section 2.0**), and revisions made and calibration results for the EFDC river and estuary model (**Section 3.0**).

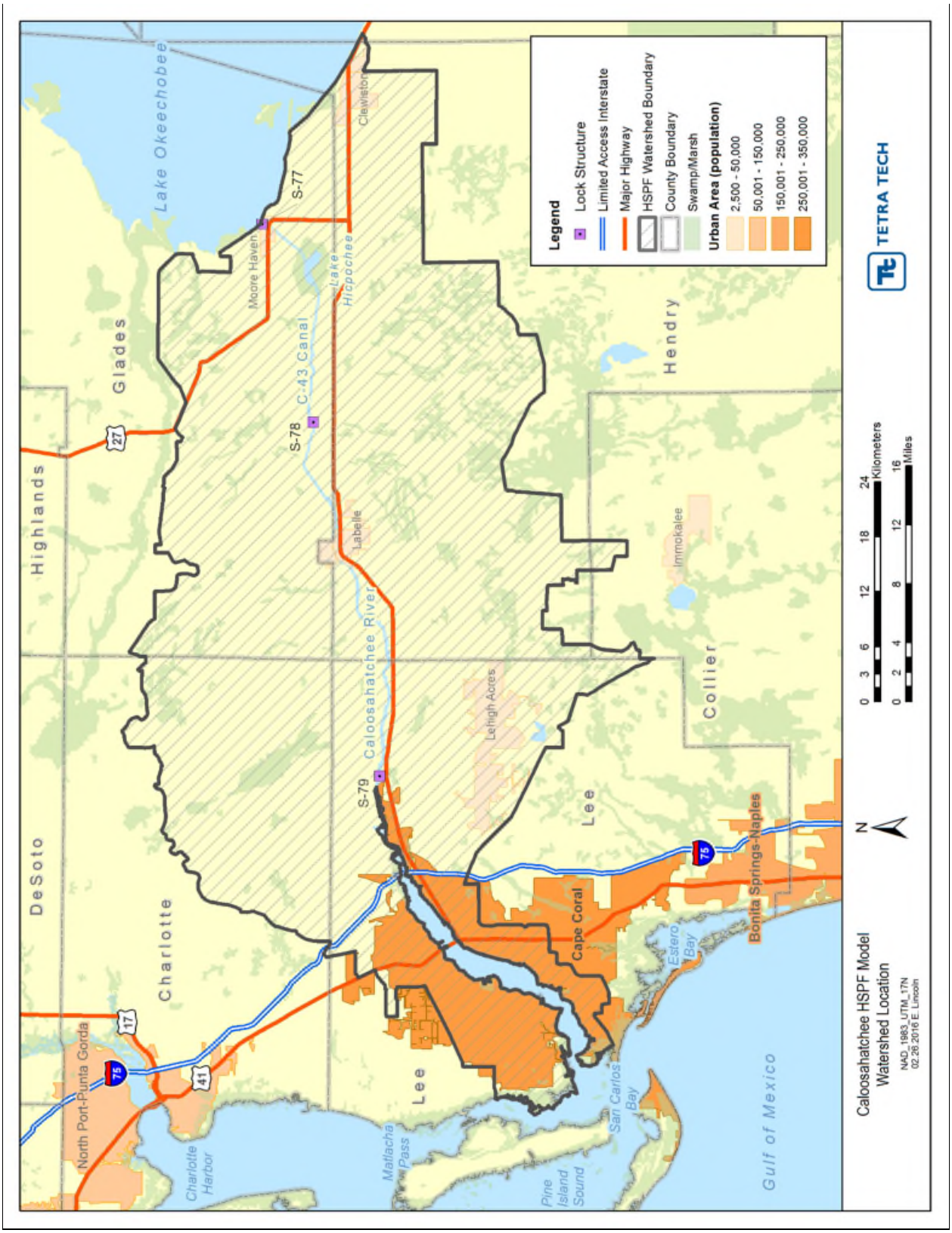

FIGURE 1: CALOOSAHATCHEE BASIN LOCATION MAP

1.1 MODEL BACKGROUND

1.1.1 HSPF Watershed Model

The HSPF model was used to model the hydrology and water quality in the Caloosahatchee River Watershed. It is capable of simulating the hydrologic and associated water quality processes on pervious and impervious land surfaces and in streams and well-mixed impoundments, and it can simulate one or many pervious or impervious unit areas discharging to one or many river reaches (U.S. Geological Survey [USGS] 2016). The HSPF model uses continuous rainfall and other meteorological records to simulate land surface processes, and the runoff and associated water quality is then integrated with in-stream hydraulic and sediment-chemical interactions. The model was initially developed in the 1960s as the Stanford Watershed Model (Crawford and Lindsley 1966). With support from USEPA, the code was ported to FORTRAN in the 1970s and several additional water quality algorithms were added (Crawford and Donigian, 1973, Hydrocomp, 1976, Donigian and Crawford, 1976 a, b). Today, the model is supported and maintained by both the USEPA and USGS.

The HSPF model consists of a set of modules arranged in a hierarchical structure, which permit the continuous simulation of a comprehensive range of hydrologic and water quality processes. It uses three application modules to simulate the flow and water quality interactions in a watershed: (1) PERLND, which simulates runoff and water quality constituents from a pervious land area; (2) IMPLND, which simulates runoff and water quality constituents from an impervious land area; and (3) RCHRES, which simulates the movement of runoff water and chemical processes that occur to its associated water quality constituents instream. Each application module is composed of subset module sections, which are described in **Table 3**. Detailed descriptions of these processes can be found in the HSPF User's Manual (Bicknell et al. 2014).

In order to drive the modules and simulate watershed hydrology, erosion, water quality, and instream transport processes, the HSPF model draws inputs from time series storage files. These storage files contain information on rainfall, climate conditions, point source and reuse loadings, agricultural irrigation, and streamflow and constituent concentrations.

To model the hydrologic runoff, the HSPF model simulates processes that impact the volume and timing of surface flow, interflow, and base flow including interception, infiltration, percolation, soil moisture storage, evapotranspiration (ET), ground water recharge, and instream flow transport. The HSPF model can simulate a variety of water quality constituents, including DO, biochemical oxygen demand (BOD), temperature, sediment, ammonia (NH_3), nitrite-nitrate (NOx), organic nitrogen (OrgN), orthophosphate (PO_4), organic phosphorus (OrgP), and phytoplankton. The HSPF model uses a variety of processes to simulate both the land contribution of water quality constituents and the instream chemical transformations. For example, the HSPF model simulates the accumulation and removal of nutrient constituents via overland flow, along with interflow and ground water concentration contributions. Instream processes are then simulated through adsorption, uptake, settling, benthal release, decay, and transformation processes. To model sediment, the HSPF model simulates sediment detachment and transport, sediment routing by particle size, and channel routing. Detailed descriptions of these processes can be found in the HSPF User's Manual (Bicknell et al. 2014).

TABLE 3: HSPF CONCEPTUAL STRUCTURE

Module	Module Section	Module Section Description
Land modules (PERLND/IMPLND)	PWATER/IWATER	Simulates water budget for a pervious/impervious land segment
Land modules (PERLND/IMPLND)	SEDMNT/SOLIDS	Simulates production and removal of sediment for a pervious/impervious land segment
Land modules (PERLND/IMPLND)	PSTEMP	Simulates soil layer temperatures
Land modules (PERLND/IMPLND)	PWTGAS/IWTGAS	Estimates water temperature and dissolved gas concentrations in the outflows from pervious/impervious land segments
Land modules (PERLND/IMPLND)	PQUAL/IQUAL	Simulates water quality in the outflows from pervious/impervious land segments
Receiving water modules (RCHRES)	HYDR	Simulates instream hydraulic behavior
Receiving water modules (RCHRES)	ADCALC	Simulates instream advection of dissolved or entrained constituents
Receiving water modules (RCHRES)	HTRCH	Simulates instream heat exchange
Receiving water modules (RCHRES)	SEDTRN	Simulates instream behavior of inorganic sediment
Receiving water modules (RCHRES)	GQUAL	Simulates instream behavior of a generalized quality constituent
Receiving water modules (RCHRES)	RQUAL	Simulates instream behavior constituents involved in biochemical transformations

1.1.2 EFDC Hydrodynamic Model

The three-dimensional hydrodynamics of the Caloosahatchee River and Estuary were modeled using the EFDC model. The EFDC model is a hydrodynamic and water quality modeling package for simulating one-dimensional, two-dimensional, and three-dimensional flow and transport in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf scale coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications and is considered public domain software (Hamrick 1992).

The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity, and temperature are also solved. The two turbulence parameter transport equations implement the Mellor-Yamada level 2.5 turbulence closure scheme (Mellor and Yamada 1982; Galperin et al. 1988).

The EFDC model uses Cartesian or curvilinear, orthogonal horizontal coordinates. The numerical scheme employed in the EFDC model to solve the equations of motion uses second order accurate spatial finite differencing on a staggered grid. The model's time integration employs a second order accurate three-time level, finite difference scheme with an internal-external mode splitting procedure to separate the internal shear, or baroclinic mode, from the external free surface gravity wave, or barotropic mode.

The original development of the EFDC Water Quality Module was led by Dr. Keyong Park at the Virginia Institute of Marine Science in 1995 (Park et al. 1995). Dr. Park, working in collaboration with Dr. Carl Cerco of the USACE Research and Development Center, adopted the CE-QUAL-ICM eutrophication

kinetic formulation and sediment flux model into the EFDC model code (Cerco and Cole 1995, Di Toro and Fitzpatrick 1993). Subsequent extensions and enhancements to Dr. Park's work have been made at Tetra Tech over the past 10 years, primarily by Mr. Michael Morton and Dr. John Hamrick.

The central issues in the EFDC water quality module are primary production of carbon by algae and DO concentration. To predict primary production and DO, a large suite of model state variables is necessary. The nitrate (NO_3) state variable in the model represents the sum of nitrate and nitrite nitrogen. Three variables (salinity, water temperature, and total suspended solids [TSS]) are needed for computation of the 21 state variables are provided by the EFDC hydrodynamic model. The interaction among the state variables is illustrated in **Figure 2**. The kinetic processes included in the EFDC water quality model are mostly from the Chesapeake Bay three-dimensional water quality model, CE-QUAL-ICM (Cerco and Cole 1994). The kinetic processes include the exchange of fluxes at the sediment-water interface, including sediment oxygen demand (Park et al. 1995).

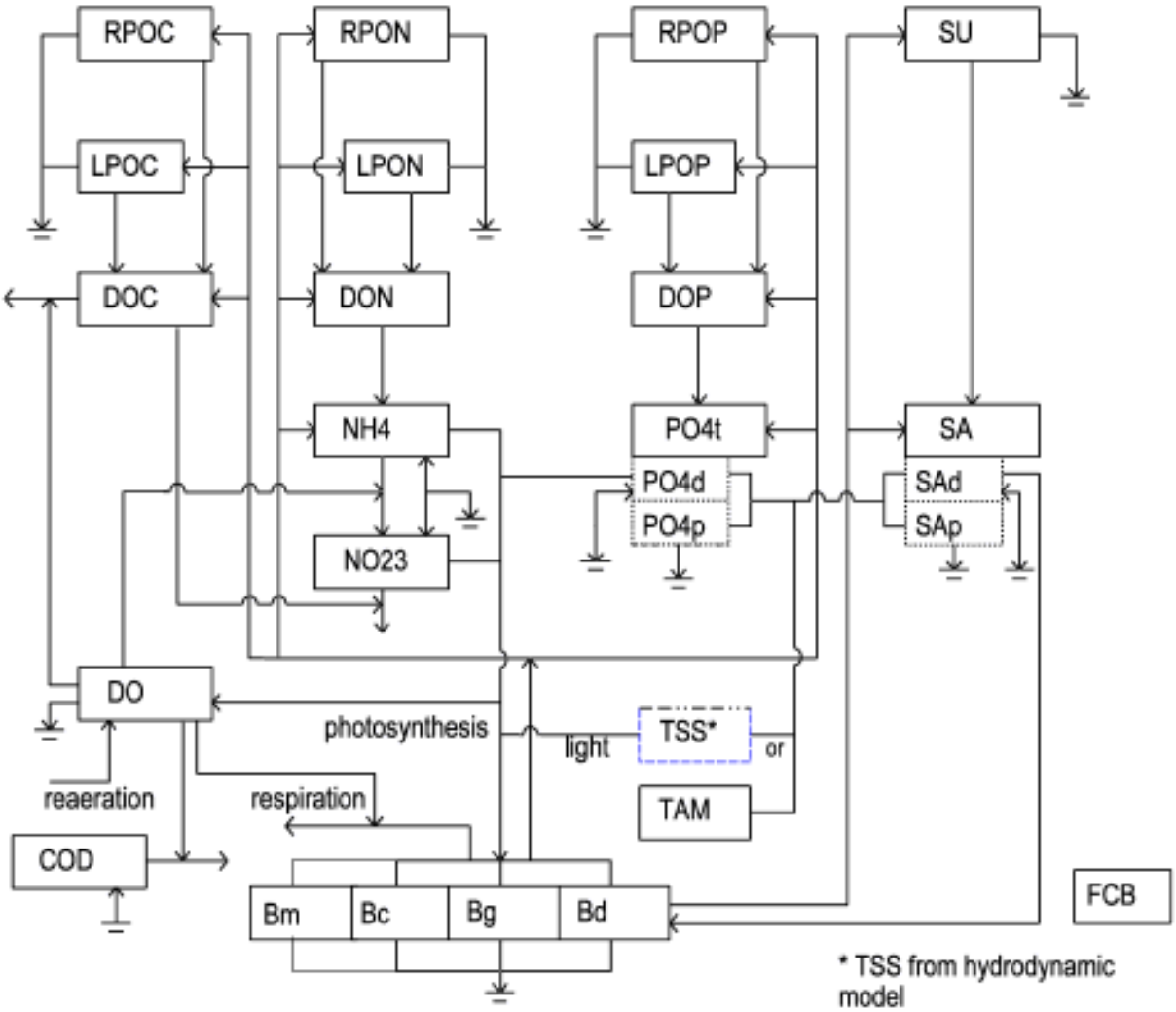

FIGURE 2: SCHEMATIC DIAGRAM FOR THE EFDC WATER QUALITY MODULE

1.1.3 HSPF-EFDC Model Linkage

The HSPF model was used to develop a watershed model to represent the hydrological and water quality conditions in the Caloosahatchee River Watershed and to address the nutrient loadings to the Caloosahatchee River and Estuary. The EFDC model was used to simulate the hydrodynamics and water quality within the Caloosahatchee River and Estuary, as well as the tidally influenced tributaries of the river. The two models were used together to represent the watershed loading and the resulting conditions in the Caloosahatchee River and Estuary. The HSPF model was linked to the EFDC model by providing flows and water quality concentrations from tributaries and local drainage areas (**Figure 3**). A linkage file was used to link the two models.

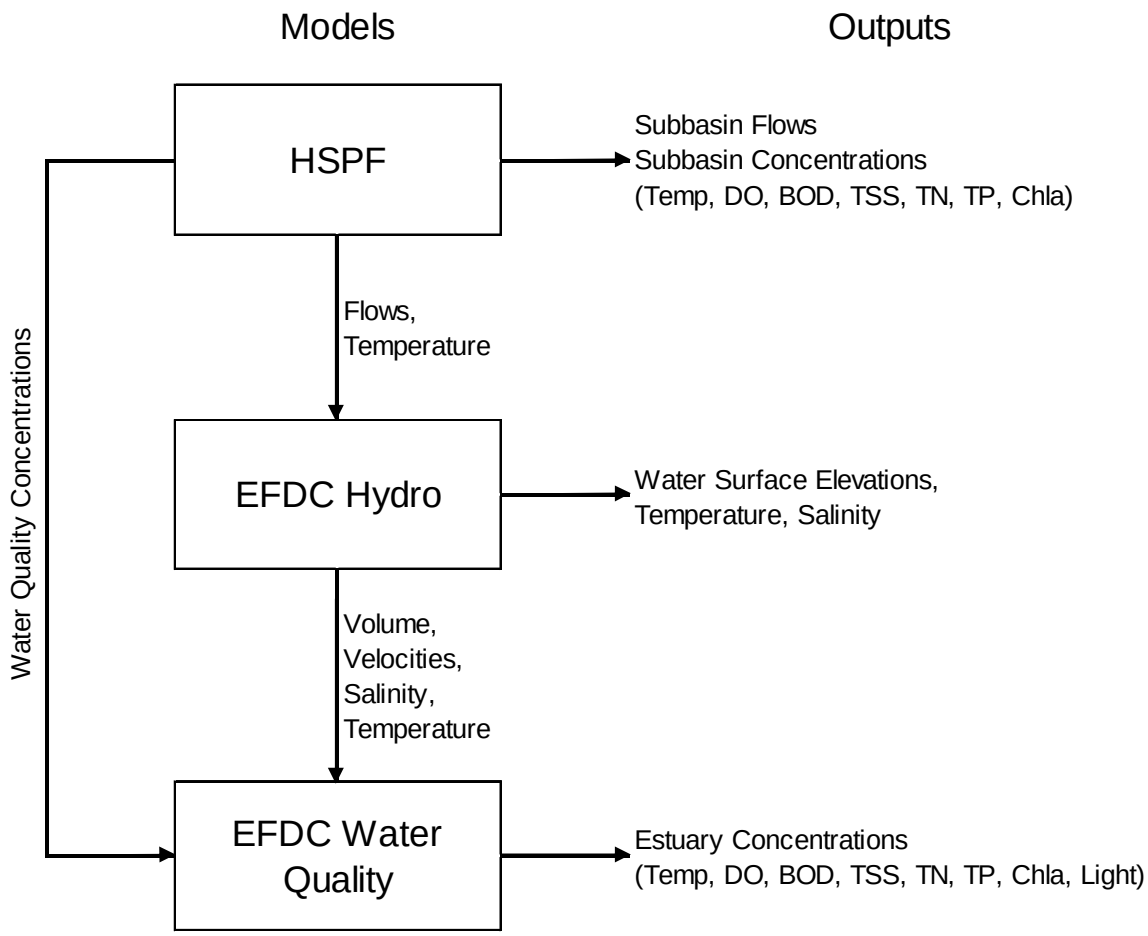

FIGURE 3: LINKAGE BETWEEN HSPF AND EFDC MODELS IN THE CALOOSAHATCHEE RIVER WATERSHED

1.1.4 Caloosahatchee River Watershed Model History

1.1.4.1 2009 Model

The original HSPF and EFDC models for the Caloosahatchee River Watershed were developed by Dynamic Solutions and CDM Smith (Dynamic Solutions and CDM 2009). These models were completed in 2009 and utilized by the department to develop the nutrient TMDL for the Caloosahatchee Estuary, which was adopted in September 2009. The models simulated conditions in the watershed and estuary from January 1, 1997 through December 31, 2005. Throughout this report, the Dynamic Solutions/CDM Smith models are referred to as the "2009 Model."

1.1.4.2 2014 Model

During development of the Caloosahatchee Estuary BMAP to implement the adopted TMDL, the stakeholders expressed concerns about the 2009 Model and the lack of data in certain areas to calibrate the model. To begin addressing these concerns, the department made modifications to both the HSPF and EFDC models, including extending the model simulation time period and adjusting the delineation boundaries. The models simulated conditions in the watershed and estuary from January 1, 1997 through December 31, 2011. Throughout this report, the department's updated version of the models are referred to as the "2014 Model."

1.1.4.3 2017 Model

To complete the model revisions to address stakeholder concerns and to update the models for use in refining the Caloosahatchee Estuary TMDL and developing TMDLs for impaired freshwater bodies within the basin, the department contracted with Tetra Tech and Amec Foster Wheeler. The updates made to the HSPF and EFDC models by Tetra Tech are discussed in this report, and the updated calibration results are provided. Throughout the report, the new model is referred to as the "2017 Model," which is reflective of the project completion date.

Updates to the models, described in detail in **Section 2.1** and **Section 3.1** of this report, included extending the model's simulation period through December 31, 2014, processing new data and time series input files, adding septic systems and reuse facilities, revising agricultural irrigation and point source representation, adding additional land use classifications, modifying the EFDC model grid, and updating the hydrology and water quality calibration. These updates ensured that the 2017 Models provide a good representation of recent conditions in the Caloosahatchee River and Estuary and associated watershed. The additional calibration and validation to recent continuous hydrodynamic and water quality data confirmed that the 2017 Models represent loading in the watershed under a variety of seasonal and flow conditions, and represent nutrient cycling and transport within the river and estuary.

1.2 MODEL PERFORMANCE CRITERIA

For this project, the department requested that Tetra Tech evaluate the goodness-of-fit of the model simulations by comparing the central tendency, time series, and data distribution simulated by the model against the available measured data. These comparisons are made through the graphs provided throughout this report and the appendices. In addition to the graphical analyses, several statistics of goodness-of-fit were calculated to evaluate the performance of the model to reproduce different aspects of the hydrologic, hydrodynamic, and water quality observations such as the means, trends, and level of dispersion. Qualitative grades describing the achieved model performance were assigned to the statistic results based on recommended and expected levels of performance from a calibrated model available in the literature. Given the complexity involved in the development of water quality models and the different uncertainties impacting the models' performance, such as uncertainties in boundary and forcing conditions, calibrated parameters, and calibration and validation measure data, the grades and the statistics should be used as complementary information to assess the model performance. The grades and statistics should not be used as a unique criteria to accept or reject the model. The fundamental purpose of the comparison figures, grades, and statistics is to identify the strengths and limitations of the models to help the department make informed decisions based on the model simulations.

The performance criteria proposed by Donigian (2002) and McCutcheon et al. (1990) (**Table 4** to **Table 6**) were implemented in this project. **Table 4** and **Table 5** list the grades of model performance for the predictions of flow based on the percent difference (**Table 4)** and R^2 statistics (**Table 5)** computed between the simulated and observed values. **Table 6** lists the grades of model performance for the predictions of water quality variables based on the percent difference between the simulated and observed values. While extremely important, a limitation of the performance criteria listed from **Table 4** to **Table 6** is that they only apply for the percent difference and R^2 statistics. More importantly, for water quality analyses, the performance criteria are limited to the evaluation of the percent difference statistic without considering any measure of global fit commonly used in water quality studies such as the Nash-Sutcliffe (NS) coefficient or the Index of Agreement (IA) (a detailed description of these statistics is presented in **Section 2.3.2** and **Section 3.4.2**, respectively).

In order to include a measure of global fit in the performance criteria evaluation for water quality variables, Tetra Tech considered the criteria proposed by Mayer and Butler (1993), Allen et al. (2007a,b), Kolovoyiannis and Tsirtsis (2013), Moriasi, et al. (2015) and Camacho et. al. (2015) for NS and IA (**Table 7**). In a comprehensive study of metrics of model performance, Moriasi et al. (2015) synthesized and performed a meta-analysis of the metrics reported in hundreds of watershed modeling studies based on the models Soil and Water Assessment Tool, HSPF, and Watershed Analysis Risk Management Framework. This study recommended the following grades for the monthly NS: Excellent >0.65, Very Good 0.65-0.5, Good 0.5-0.35, and Poor <0.35. For receiving waterbodies and NS statistics computed at higher temporal resolution (daily, weekly), Allen et al. (2007a, b) and Kolovoyiannis and Tsirtsis (2013) proposed the following grades: Excellent >0.65, Very Good 0.65-0.5, Good 0.5-0.2, and Poor <0.2. The acceptable statistical ranges for grades proposed by Mayer and Butler (1993) were more lenient for Good and Poor.

Although widely used, one of the limitations of the NS criterion is that it is only upper bounded and can take unbounded negative values ($-\infty < NS \leq 1$). Allen et al. (2007b) reported NS values between -0.19 and 0.78 for simulations of phytoplankton biomass, between -2.7 and 0.9 for simulations of phosphorus, and between 0.01 and 0.69 for simulations of nitrogen. Kolovoyiannis and Tsirtsis (2013) reported NS values

between -19 and 0.5 for phytoplankton biomass and between -18.6 and -1.2 for phosphorus. Negative values of NS are difficult to interpret and compare and indicate that the mean of the observations for each study is a better predictor than the model. The IA metric has both an upper and lower bound, which can make it easier to use to measure model performance. Camacho et. al. (2015) adapted the following grading criteria for the IA and for water quality variables: Excellent >0.6, Very Good 0.6-0.5, Good 0.5-0.4, and Poor <0.4. Taking into account that, in general, the IA yields higher values than the NS criteria, the grades used by Camacho et al. were slightly revised for this project. The final performance grades and statistical ranges used for the Caloosahatchee River and Estuary are summarized in **Table 7**.

TABLE 4: MODEL PERFORMANCE CRITERIA FOR FLOW BASED ON THE PERCENT DIFFERENCE BETWEEN MODELED AND OBSERVED VALUES (FROM DONIGIAN 2002)

Category	Range
Very Good	<10%
Good	10% - 15%
Fair	15% - 25%
Poor	>25%

TABLE 5: MODEL PERFORMANCE CRITERIA FOR PREDICTIONS OF DAILY FLOWS BASED ON THE R^2 (FROM DONIGIAN 2002)

Category	Range
Very Good	>0.8
Good	0.7 - 0.8
Fair	0.6 - 0.7
Poor	<0.6

TABLE 6: MODEL PERFORMANCE CRITERIA FOR WATER QUALITY VARIABLES BASED ON THE PERCENT DIFFERENCE BETWEEN MODELED AND OBSERVED VALUES (ADAPTED FROM DONIGIAN 2002 AND MCCUTCHEON ET AL. 1990)

Category	Salinity	Water Temperature	Water Quality/DO	Nutrients/Chlorophyll-*a*
Very Good	<15%	<7%	<15%	<30%
Good	15%-25%	7%-12%	15%-25%	30%-45%
Fair	25%-40%	12%-18%	25%-35%	45%-60%
Poor	>40%	>18%	>35%	>60%

TABLE 7: MODEL PERFORMANCE CRITERIA FOR WATER QUALITY VARIABLES BASED ON THE NS CRITERION AND IA (ADAPTED FROM ALLEN ET AL. 2007A, B; KOLOVOYIANNIS AND TSIRTSIS 2013; AND CAMACHO ET. AL. 2015)

Category	NS	IA
Very Good	>0.65	>0.75
Good	0.5-0.65	0.65-0.75
Fair	0.2-0.5	0.35-0.65
Poor	<0.2	<0.35

Section 2.0 HSPF WATERSHED MODEL

2.1 HSPF MODEL ISSUES AND RECOMMENDATIONS

Tetra Tech reviewed the 2014 HSPF Model to identify data inputs and calibration parameters that could be revised to improve model representation of the Caloosahatchee River Watershed. The 2017 HSPF Model revisions focused on addressing major department and stakeholder comments, as well as issues that Tetra Tech identified with the original model that would limit the model's ability to provide the information needed for the TMDL and BMAP. To update the HSPF model, Tetra Tech processed all new data input files for the full model simulation period (January 1, 1996 – December 31, 2014). The department was unable to provide Tetra Tech with the original data processing sheets and information about processing methodologies; therefore, all files had to be reprocessed to ensure that a consistent method was used for the full model simulation period. The major modifications and changes made by Tetra Tech to the HSPF model are as follows:

- Extended the model simulation period through December 31, 2014 (the 2014 HSPF Model ended on December 31, 2011).
- Updated the model subbasin delineations by delineating to USGS and department flow stations, and delineating to major pumping structures and some major weirs. Delineation to these features allowed for hydrology calibration to USGS and department gages, and assisted with representation of agricultural pumping and water transport in the watershed.
- Adjusted reach function tables (F-TABLES) to represent ponding that occurs behind weirs in the watershed.
- Processed the Next-Generation Radar (NEXRAD) rainfall data for use in the model, and processed South Florida Water Management District (SFWMD), Page Field Airport in Fort Myers, and Surface Airways (SA) weather station air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation data for use in the model.
- Mapped the 2009 HSPF Model NEXRAD and land use water quality parameterization to the new 2017 HSPF Model NEXRAD and land use water quality parameterization and use this as a baseline for further refinement.
- Updated the model land use to the 2008-2009 SFWMD and Southwest Florida Water Management District (SWFWMD) coverages to better represent the model time period and to address stakeholder comments about using a more recent land use coverage in the model.
- Added additional land use classifications to better represent the land uses in the watershed, including adding new agricultural classifications to meet requests by the Florida Department of Agriculture and Consumer Services (FDACS). Also added a separate Florida Department of Transportation (FDOT) right-of-way classification.
- Updated effective impervious land use representation using the 2011 National Land Cover Database (NLCD) coverage and Sutherland 1995 methodology.
- Mapped the 2014 HSPF Model NEXRAD and land use hydrology parameterization to the new 2017 HSPF Model NEXRAD and land use hydrology parameterization.
- Adjusted model parameterization during the hydrology calibration process to ensure parameters were within suggested literature ranges and to improve model calibration.
- Developed new agricultural irrigation demand time series for five different crop classifications to address stakeholder comments. Changed irrigation water sources to surface water and ground water to better represent irrigation sources.

- Revised the representation of National Pollutant Discharge Elimination System (NPDES) facilities in the watershed and developed new assumptions to address incomplete discharge water quality data records. Incorrect facilities were included in the previous models.
- Processed reuse facilities for explicit inclusion in the 2017 HSPF Model to more accurately simulate the flows and loads from these sources. Reuse facilities were not included in the previous models.
- Processed septic systems for explicit inclusion in the 2017 HSPF Model and to reflect the septic system loadings in the watershed. Septic systems were implicitly included in the previous models.
- Reduced the upland simulation to four QUALS (upland quality constituents) from five QUALS. The previous models simulated NOx, NH_3, OrgN, PO_4, and carbonaceous biochemical oxygen demand (CBOD). The 2017 HSPF Model has been revised to simulate NOx, NH_3, PO_4, and organic matter. Organic matter is distributed to OrgN, OrgP, organic carbon (OrgC), and CBOD in the reaches.
- Revised the upland simulation to simulate PO_4 and organic matter as sediment-associated constituents.
- Added additional instream water quality calibration and validation locations for a total of 50 stations at 33 unique locations.
- Developed atmospheric deposition loadings of wet and dry NOx and NH_3 for explicit representation in the model.

2.2 HSPF Model Revisions and Setup

2.2.1 Model Delineation

The Caloosahatchee River Watershed was divided into 102 subbasins in the 2009 and 2014 HSPF Model setups. The subbasin boundaries were delineated using the department's WBID boundaries, topographic data, and the USGS high resolution National Hydrography Dataset (NHD) (DSLLC and CDM 2009). Tetra Tech made several revisions to the 2014 HSPF Model subbasin delineations. These revisions included creating a new subbasin for the Ninemile Canal, extending the Deep Lagoon Canal subbasin further south based on Lee County recommendations, and delineating to the following four flow stations that were not located near an HSPF subbasin outlet (**Figure 4**):

- USGS Station 264514080550700 (Industrial Canal at Clewiston)
- USGS Station 02293055 (Orange River near Buckingham)
- USGS Station 264006081534400 (Hancock Creek at Pondella Road)
- DEP Station Yellow Fever Creek (Yellow Fever Creek)

Pumping for agricultural irrigation, and its subsequent bidirectional flow, was known to occur in the southeast area of the Caloosahatchee River Watershed. Pumping was also known to occur at S-77 for flood protection, causing bidirectional flow to occur between S-77 and S-78 structures (**Figure 5**). In order to identify locations where the agricultural irrigation pumping structures and weirs are located, Tetra Tech conducted a desktop analysis of the agricultural areas of the Caloosahatchee River Watershed. In the southeastern agricultural areas, 18 major pumping structures were identified, along with 59 weir structures, some of which had minor pumping structures. The major pumping structures in the agricultural region were located on reaches that had been identified as having bidirectional flow including:

- Townsend Canal
- C-3
- Hilliard Canal
- Flaghole Canal
- Disston Canal
- Industrial Canal

In order to represent the ponding that occurred behind the pumping structures and major weirs for agricultural irrigation, the model was redelineated to the pumping structures located on the Townsend Canal, C-3, Hilliard Canal, Flaghole Canal, and Industrial Canal. Tetra Tech also bisected four other long, narrow subbasins located in the southeastern region to provide additional detail and flexibility when representing the water storage that occurs in the region due to agricultural irrigation.

The revised 2017 HSPF Model consisted of 121 discrete subbasins. The revised Caloosahatchee River Watershed HSPF delineation and structure locations are provided in **Figure 5**, the revised subbasin numbering schematic is provided in **Figure 6,** and the names of major canals and reaches are shown in **Figure 7**.

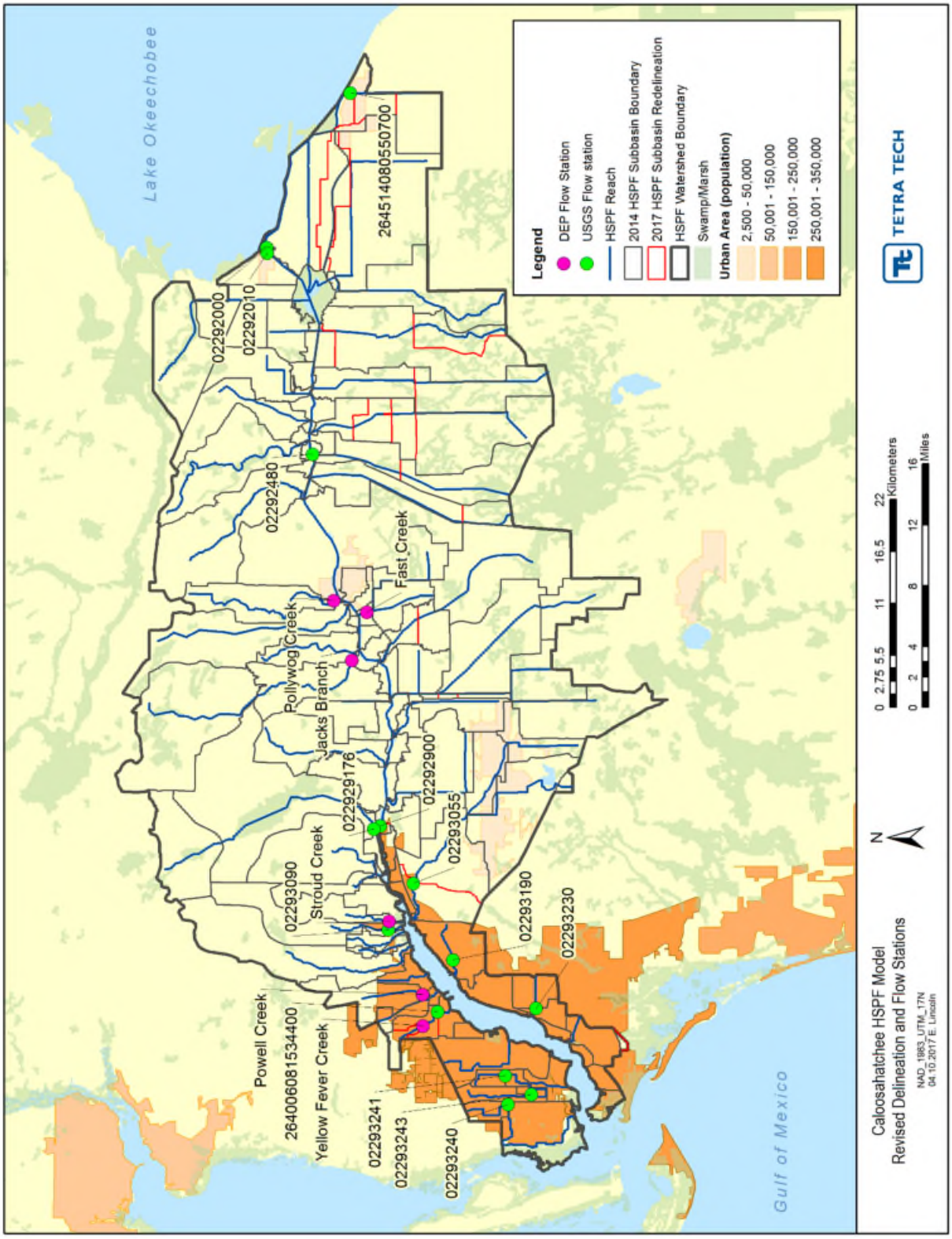

FIGURE 4: FLOW STATIONS IN THE CALOOSAHATCHEE RIVER WATERSHED

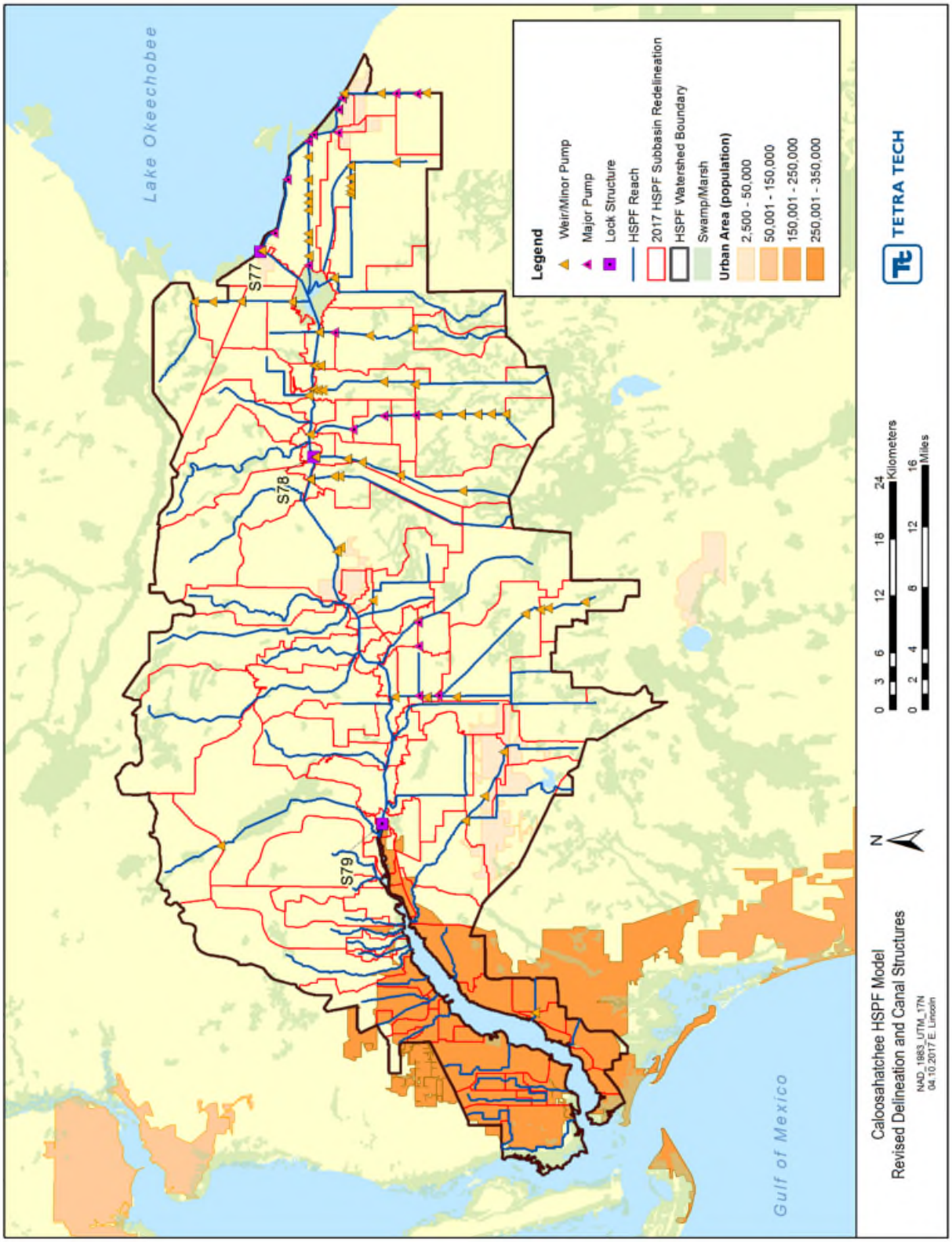

FIGURE 5: REVISED SUBBASIN DELINEATION FOR THE 2017 HSPF MODEL

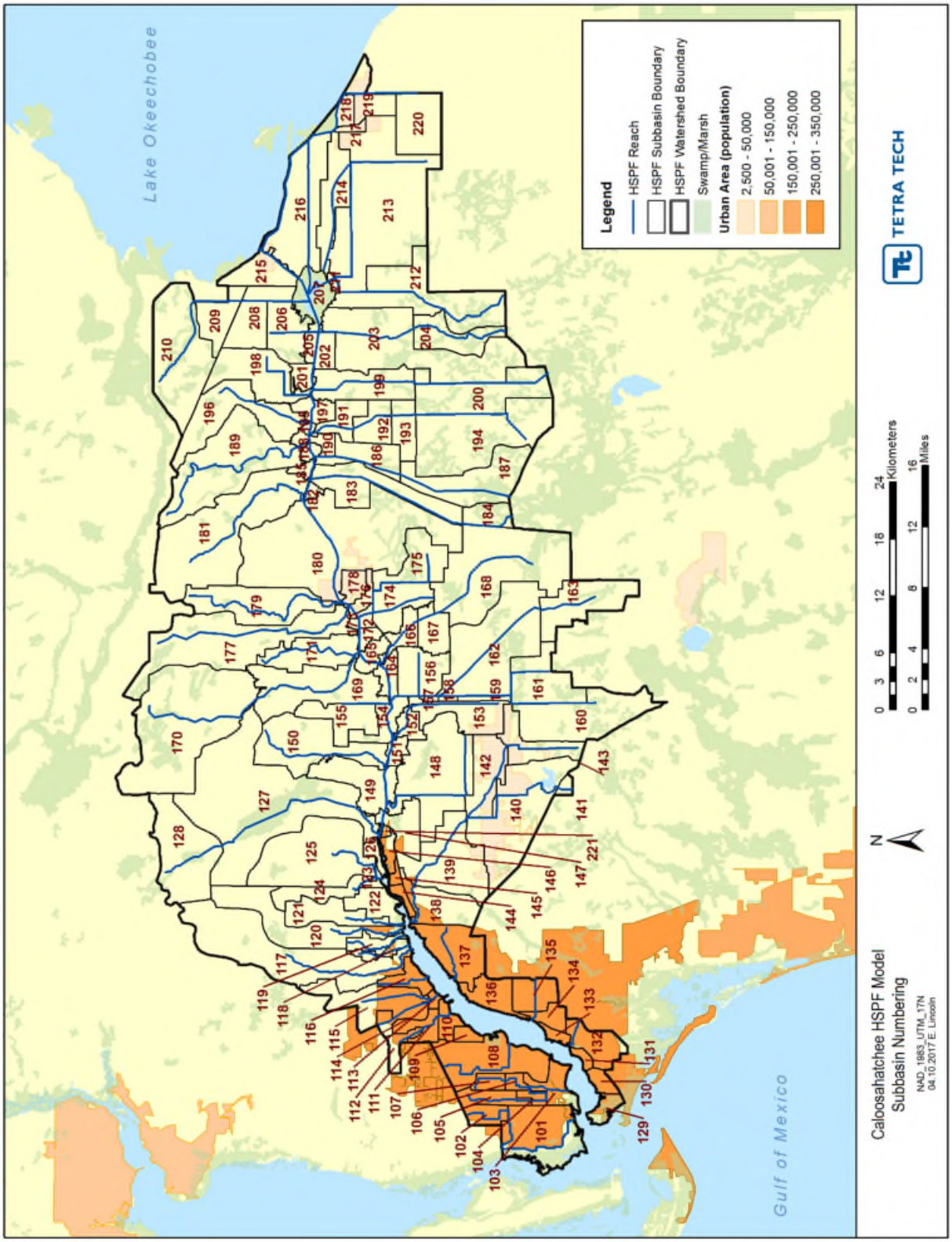

FIGURE 6: 2017 HSPF MODEL SUBBASIN NUMBERING

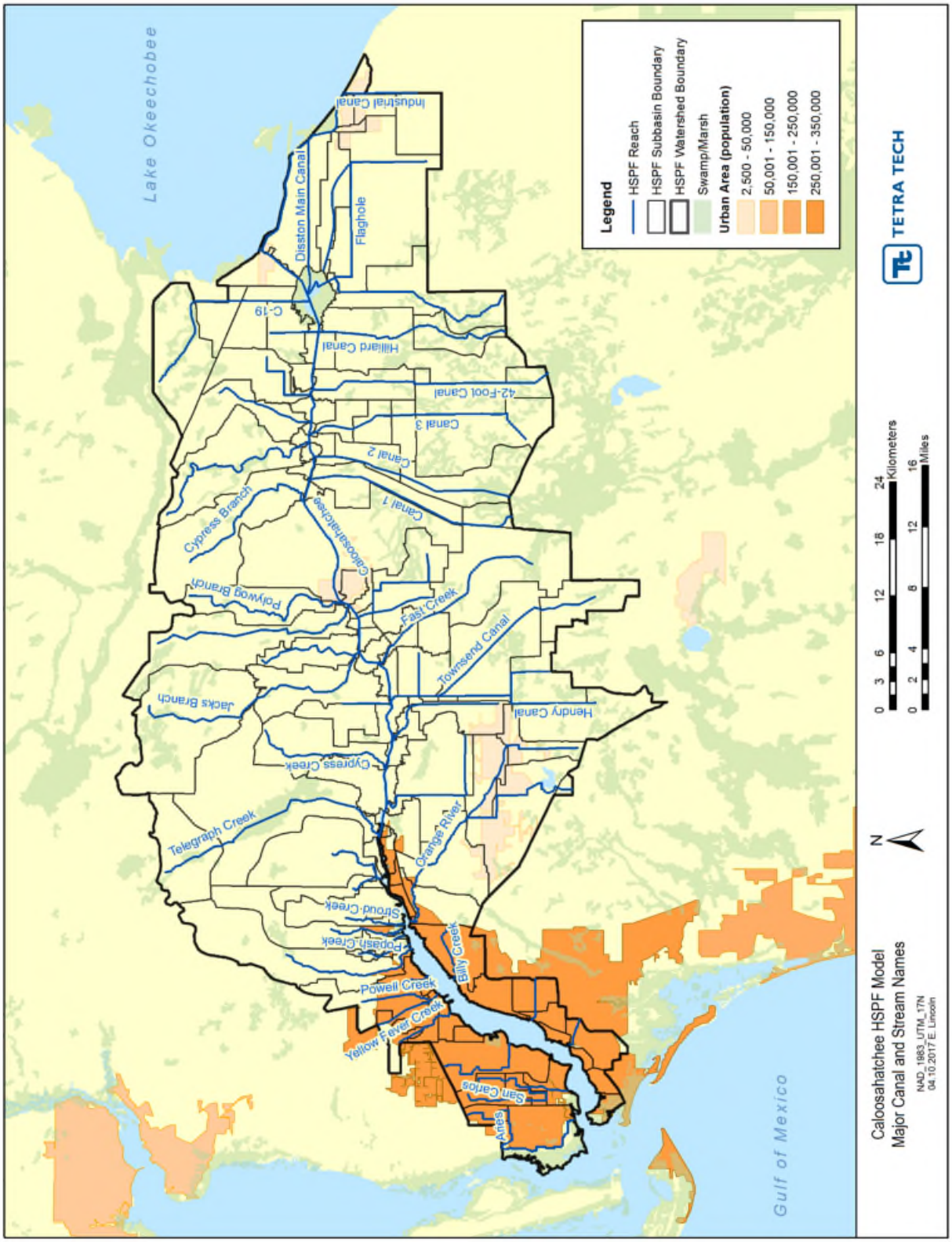

FIGURE 7: 2017 HSPF MODEL MAJOR CANAL AND STREAM NAMES

2.2.2 Reaches and F-TABLES

Of the 121 subbasins in the 2017 HSPF Model, 109 drain to a representative reach. The representative reaches were given a number identical to their subbasin number (**Figure 6).** There are 12 subbasins that do not have reaches, and these subbasins drain directly to the Caloosahatchee Estuary. In addition, there are 10 transport reaches that do not have a contributing area that connect other reaches in the model, and these transport reaches typically represent drainage canals. Each reach has an F-TABLE that describes the hydrology of the segment by defining the functional relationship between water depth, surface area, water volume, and outflow in the segment.

The 2009 HSPF Model calculated F-TABLES using cross-section data provided by SFWMD, as well as topographic data. SFWMD compiled the cross-section data for the Caloosahatchee River, Jacks Branch, County Line Ditch, Canal 1, Canal 2, C-19, 42-foot canal, and Hilliard Canal, which came from various unnamed sources. These data were used for the development of the MIKE-SHE model of the Caloosahatchee River (DSLLC and CDM 2009). The cross-sections for the remaining reach segments were estimated using topographic data.

The revised subbasin delineation used for 2017 HSPF Model required that some model reaches be split. The F-TABLES for these reaches were generated using reach length ratios. Additionally, the existing F-TABLES did not represent the ponding that occurred behind weirs in many of the canal systems. In order to maintain water storage in low-flow conditions, Tetra Tech updated the F-TABLES to represent the effect of the weir structures on the following reaches:

- 42-foot canal (reaches 200 and 199)
- Able Canal (reach 142)
- Big Island Canal (reach 128)
- C-19 (reaches 210, 209, and 208)
- Canal 1 (reach 183)
- Canal 2(reaches 187 and 186)
- Canal 3 (reaches 194, 193, 192 ,and 191)
- Disston Main Canal (reach 216)
- Duda Canal (reaches 159 and 158)
- Flaghole Canal (reach 213)
- Hilliard Canal (reaches 204, 203, and 202)
- Industrial Canal (reach 220)
- Left HH Canal (reach 212)
- LPDD Header Canal (reach 156)
- Fast Creek (Roberts Canal) (reaches 167 and 166)
- SR-229 Ditch (reach 175)
- Townsend Canal (reaches 163, 162, and 157)
- Meanderline Ditch (reach 198)
- WC L-Canal (reach 135)

In addition, several reaches were identified has having significant ponding due to large wetlands or ponds along the reach caused by natural or manmade obstructions. The F-TABLES were modified in the reaches as well to maintain water storage in low-flow conditions:

- Powel Creek (reach 115)
- Popash Creek (reach 120)
- Stroud Creek (reach 121)
- Deep Lagoon Canal (reach 132)
- Billy Creek (reach 137)
- Cypress Branch (reach 181)
- Yellow Fever (reach 112)

For each reach F-TABLE adjusted to maintain ponding during low-flow conditions, Tetra Tech used the top of bank elevation and bottom elevation data that were used in the previously developed MIKE-SHE model to calculate the maximum depth for each reach. It was assumed that each weir maintained a minimum depth equal to one-half the maximum reach depth. Below this depth, the outflow in each F-TABLE was set to 0. Above this depth, Tetra Tech recalculated outflow based on the Cipoletti Weir Equation (Equation 1).

$$Q = 3.367Lh^{3/2} \qquad \text{(Eq. 1)}$$

where Q is discharge (cfs), L is weir length (ft), and h is head (ft).

The length of each weir was estimated using a Google Earth Pro desktop survey. The Cipoletti Weir Equation assumes that each weir is trapezoidal with 4:1 vertical to horizontal side slopes.

2.2.3 Bidirectional Flows

Many of the reaches located downstream of S-79 have bidirectional flow caused by tidal propagation. Reaches downstream of S-79 that are not tidally influenced, such as Whiskey Creek, have channel features or structures located near their confluence with the Caloosahatchee River that prevent the tide from moving upstream into the HSPF model reach and subbasin.

In order to represent the bidirectional flow in the tidal reaches, the Caloosahatchee EFDC model grid was extended into priority reaches downstream of S-79. These reaches were defined as either having measured flow data for calibration, or were located in a 2010 verified impaired WBID. The following priority reaches were identified as having bidirectional flow caused by tidal propagation, and the EFDC model grid was extended to include the tidal portions of the reaches:

- Cape Coral Canals (2010 verified impaired)
- Deep Lagoon Canal (2010 verified impaired)
- Yellow Fever Creek (USGS data)
- Billy Creek (2010 verified impaired)
- Orange River (USGS data)
- Popash Creek (2010 verified impaired)
- Telegraph Creek (USGS data)

The HSPF model provided the watershed flows and water quality loadings to the EFDC model. The EFDC model simulated hydrodynamics and instream water quality of the tidal reaches, including the influence of the Caloosahatchee River on the reach water quality.

2.2.4 Upstream Boundary Condition

2.2.4.1 S-77 Lock

The Caloosahatchee River receives flows and loads from Lake Okeechobee. Water from Lake Okeechobee is discharged into the Caloosahatchee River at the S-77 lock, which is controlled by USACE. Water in the Caloosahatchee River is also pumped back into Lake Okeechobee, and this occurred 6% of the time during the model simulation period (January 1, 1996 through December 31, 2014). During pumping, the flow of water in the Caloosahatchee River reverses and moves towards Lake Okeechobee.

USACE maintains a record of the daily average flow at S-77; positive flow indicates movement from Lake Okeechobee to the Caloosahatchee River and negative flow indicates movement from the Caloosahatchee River to Lake Okeechobee. Positive flows were input into the HSPF model at the uppermost reach, Reach 215. Measured water quality data from station 21FLSFWMS77, located immediately upstream of S-77, were used to construct the water quality time series associated with positive flows. A daily concentration time series for the simulated constituents were created by (1) using observed data on days when observations were available, (2) using the monthly average by year to fill in gaps between daily observations, and (3) using the long-term monthly average (monthly average for entire model simulation period) in months where data were not collected. Input loads were tabulated for days with positive flows by using the positive flow volume and concentration for that day from the time series. The measured negative flows were distributed via volume weighting and withdrawn from all reaches between S-78 and S-77 to represent the bidirectional flow caused by the pumping. The commensurate water quality loads were also withdrawn and removed from the system with the flows that were withdrawn.

2.2.4.2 S-310 Lock and LD-1 Seepage

Flow from Lake Okeechobee enters the S-4 basin at the S-310 lock into the Industrial Canal and at from seepage under the levee into the L-D1 Canal (additional details are provided in **Section 2.2.11.1**). USACE controls the flow from Lake Okeechobee into the Industrial Canal at the S-310 lock. Water in the Industrial Canal is also pumped back into Lake Okeechobee when the S-4 pump is on, which was represented in the model similar to the S-77 negative flow boundary. During pumping, the flow of water in the Industrial Canal reverses and moves towards Lake Okeechobee. USACE maintains a record of the daily average flow at USGS 264514080550700; positive flow indicates movement from Lake Okeechobee to the Industrial Canal and negative flow indicates movement from the Industrial Canal to Lake Okeechobee. Positive boundary flows were input into the HSPF model at Reach 219. In order to represent water quality loads entering the Industrial Canal via the S-310 lock, water quality concentrations were provided for the positive boundary flows. The nearest best available data were located at station 21FLSFWM77, which was used to develop the S-77 water quality concentration boundary. Therefore, the S-77 water quality concentration was assigned to the S-310 lock boundary conditions.

LD-1 seepage is also represented in the hydraulic setup in the 2017 HSPF Model. Measured water quality data for the seepage were sought but could not be located. Therefore, the LD-1 seepage was assigned the water quality concentration time series developed for the S-77 boundary conditions.

2.2.5 Meteorological

The 2017 HSPF Model used NEXRAD data provided by SFWMD for the model simulation period (January 1, 1996 – December 31, 2014). NEXRAD data estimate the amount of precipitation in an area

based on radar measurements. The data provide estimates of the spatial and temporal distribution of rainfall, while ground surface rainfall gages provide estimates of rainfall at a specific location. NEXRAD data were used in the 2009 and 2014 HSPF Models. Ground surface rainfall gages were located throughout the Caloosahatchee River Watershed, and data were collected at these stations by the National Climatic Data Center (NCDC) and Lee County. The NEXRAD data were processed and then compared to the NCDC and Lee County data to determine if the NEXRAD data, which provided the best spatial and temporal resolution, were similar to the NCDC and Lee County data and could be used in the 2017 HSPF Model.

2.2.5.1 NEXRAD Data Processing

SFWMD provided the NEXRAD precipitation data at hourly time steps for 2,152 cells, sized 2 km by 2 km, which covered the Caloosahatchee River Watershed. The hourly data were averaged into 15 NEXRAD precipitation zones (**Figure 8**). The NEXRAD zones corresponded to the subbasin delineation boundaries, and were similar in size, with the average NEXRAD area being 58,700 acres. The NEXRAD zones used in the 2017 HSPF Model setup were identical to the 2009 and 2014 HSPF Models.

The SFWMD NEXRAD precipitation data used the raw reflectivity data produced the National Weather Service radars located at Tampa, Melbourne, Jacksonville, Miami, Tallahassee, and Key West. The raw radar data were adjusted by SFWMD using mean field and local bias corrections to agree with rain gage observation using a six-hour moving window. During radar data adjustment, the rain gage data were reviewed to identify gaps in data and potential errors, and periods where the gages had identified gaps and/or errors were not used for radar data adjustment. After initial processing, monthly radar precipitation totals were compared to the rain gage observation to identify any potential radar data inconsistencies that needed to be addressed and corrected to improve the radar precipitation representation (Vieux & Associates 2013).

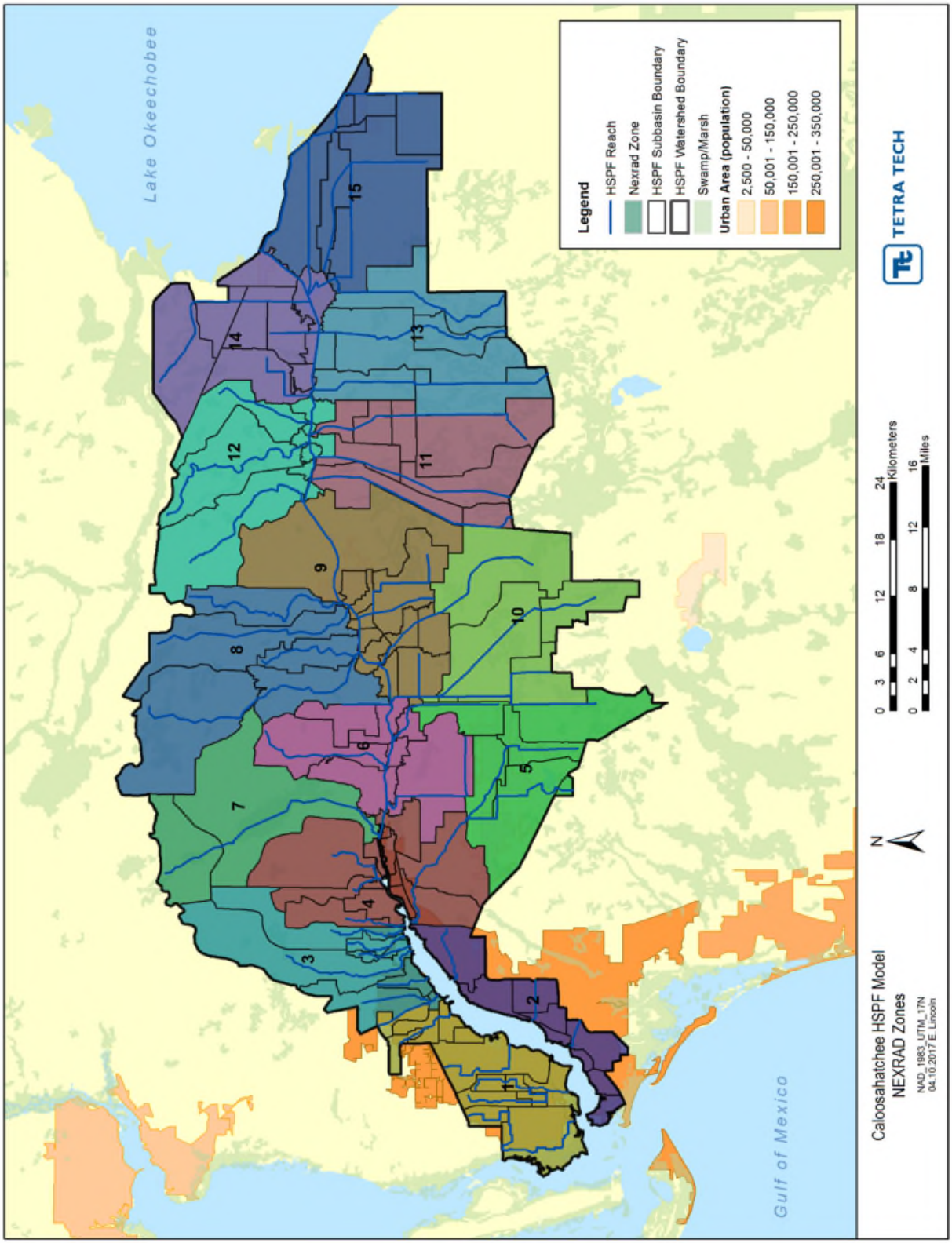

FIGURE 8: CALOOSAHATCHEE RIVER WATERSHED NEXRAD ZONES

2.2.5.2 Comparison to NCDC Summary of the Day (SOD) Data

The NCDC SOD precipitation data were compiled and processed for comparison to the NEXRAD data. NEXRAD data were summarized by zone as an average of the associated grid cell values for linkage to the HSPF model (**Figure 9**), which includes the locations of the local NCDC SOD stations. NCDC station descriptions are listed in **Table 8**.

TABLE 8: NCDC SOD PRECIPITATION MONITORING STATION INFORMATION

Station ID	Station Name	Elevation (ft)	County	Latitude	Longitude
081651	Clewiston No. 2	18	Hendry	26.736111	-81.049167
081654	Clewiston	20	Hendry	26.742222	-80.940000
082298	Devils Garden	20	Hendry	26.603333	-81.129167
083186	Fort Myers FAA/AP	15	Lee	26.586389	-81.863611
084662	LaBelle	16	Hendry	26.743333	-81.432222
085895	Moore Haven Lock 1	35	Glades	26.840000	-81.087222
086657	Ortona Lock 2	20	Glades	26.789722	-81.304444
087397	Punta Gorda 4 ESE	20	Charlotte	26.916389	-81.998333

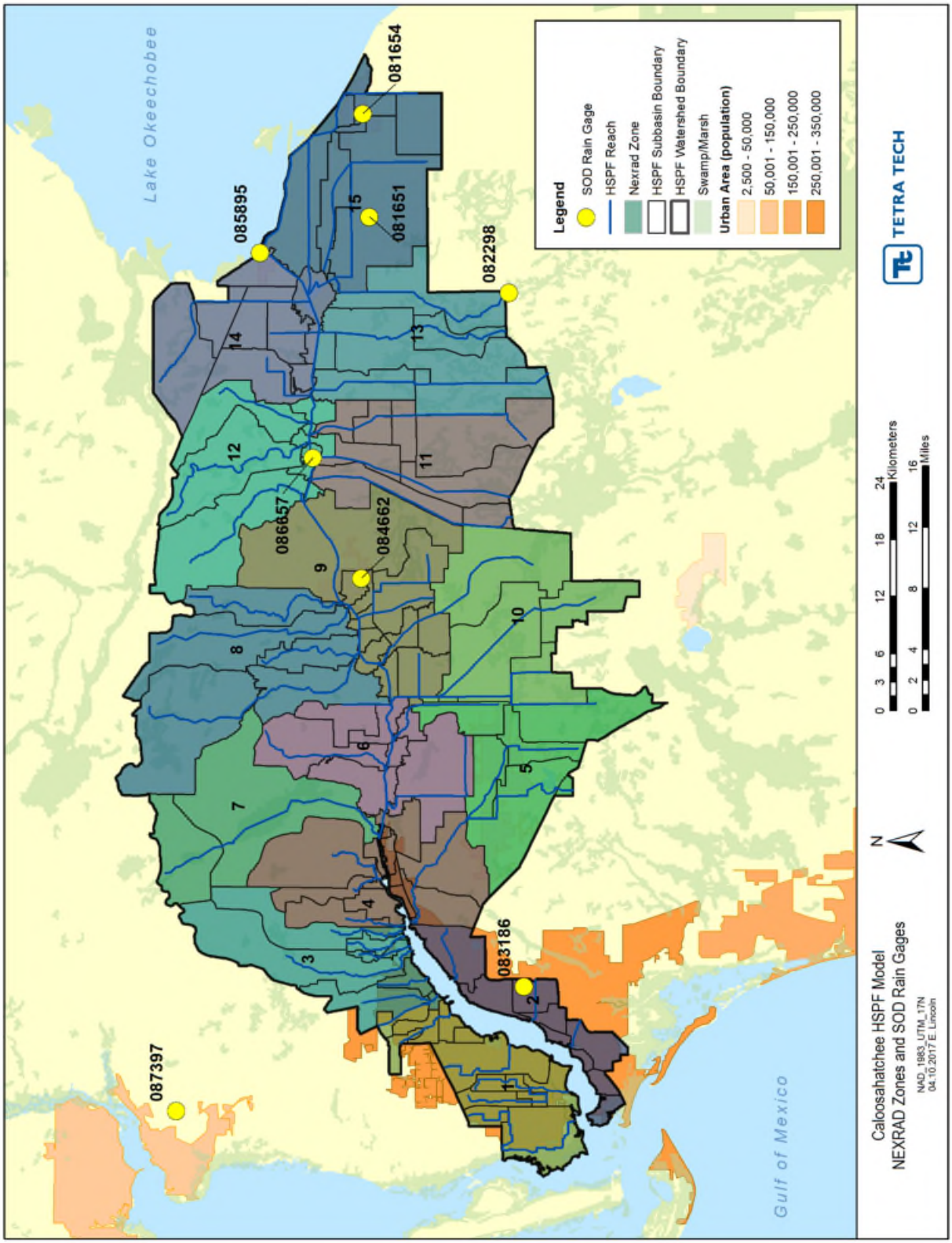

FIGURE 9: CALOOSAHATCHEE RIVER WATERSHED NEXRAD ZONES AND NCDC SOD PRECIPITATION MONITORING STATIONS

As part of the precipitation data processing procedure, the data time series were assessed using a gap analysis that flagged missing time intervals, where a missing interval was defined as 28 consecutive days without a recorded rainfall event. The identification of missing intervals allows for a quick assessment of the monitoring data quality, where a smaller number of missing intervals indicates monitoring data of higher quality. The percent completeness for NCDC SOD and NEXRAD zone data are presented in **Table 9** and **Table 10**, respectively.

TABLE 9: SOD PRECIPITATION MONITORING STATION ANNUAL PERCENT COMPLETENESS

Year	081651	081654	082298	083186	084662	085895	086657	087397
1996	0%***	90%*	93%*	0%***	87%**	83%**	0%***	94%*
1997	0%***	91%*	88%**	0%***	94%*	97%*	0%***	97%*
1998	0%***	84%**	88%**	84%**	86%**	89%**	0%***	92%*
1999	0%***	61%**	89%**	91%*	64%**	91%*	0%***	91%*
2000	0%***	8%	89%**	82%**	55%**	100%	0%***	90%*
2001	0%***	52%**	80%**	73%**	25%***	64%**	0%***	72%**
2002	33%***	74%**	90%*	100%	30%***	92%*	71%**	100%
2003	79%**	38%	96%*	100%	85%**	100%	88%**	99%*
2004	100%	0%	87%**	100%	86%**	100%	93%*	98%*
2005	98%*	0%	100%	83%**	63%**	100%	100%	88%**
2006	78%**	0%	84%**	91%*	3%***	84%**	92%*	82%**
2007	80%**	0%	92%*	100%	0%***	100%	99%*	100%
2008	91%*	0%	91%*	96%*	86%**	88%**	100%	81%**
2009	79%**	0%	87%**	84%**	85%**	88%**	88%**	90%*
2010	91%*	0%	82%**	100%	97%*	99%*	100%	86%**
2011	92%*	0%	96%*	100%	98%*	100%	100%	94%*
2012	79%**	0%	79%**	84%**	79%***	88%**	83%**	74%**
2013	90%*	0%	72%**	100%	100%	100%	100%	93%*
2014	100%	0%	92%*	98%*	100%	100%	100%	89%**
2015	100%	0%	99%*	100%	100%	100%	100%	100%
Avg	**60%**	**25%**	**89%**	**83%**	**71%**	**93%**	**66%**	**91%**

* 90% - 100% complete.
** 50% - 90% complete.
*** Less than 50% complete.

TABLE 10: NEXRAD PRECIPITATION MONITORING PERCENT COMPLETENESS BY ZONE

Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15
1996	98%*	98%*	100%	100%	98%*	100%	100%	100%	100%	98%*	100%	100%	100%	100%	100%
1997	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1998	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1999	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2001	91%*	91%*	83%**	83%**	92%*	100%	92%*	100%	100%	100%	100%	100%	100%	100%	100%
2002	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2003	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2004	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2005	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2006	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2007	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2008	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2009	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2010	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2011	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2012	92%*	92%*	100%	100%	100%	92%*	100%	100%	100%	100%	100%	92%*	92%*	92%*	100%
2013	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%	100%	100%	100%	99%*	99%*	100%	100%	100%	100%	100%
Avg	**99%**	**99%**	**99%**	**99%**	**99%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

* 90% - 100% complete.
** 50% - 90% complete.

These tables indicate that the NEXRAD data had a significantly greater precipitation record completeness than the raw data available at the NCDC SOD stations. The zonal NEXRAD data were mostly complete with the average annual percent completeness at 99% or greater. In comparison, the best percent completeness observed at an SOD station was 93% (SOD station 085895), and four of the eight stations were less than 80% complete. Due to the gaps in data at the SOD stations, significant rainfall patching would need to be done to develop a complete rainfall record for the model simulation period. To further illustrate the differences in monitoring quality and results between the NEXRAD and SOD stations, the SOD stations were assigned to the closest NEXRAD zone for rainfall volume comparisons. Station assignments are shown in **Figure 10** and **Table 11**, along with a comparison of the average annual rainfall totals.

The NEXRAD zones showed, on average, a much greater volume of annual precipitation than the SOD stations, with the exception of SOD stations 082298 and 085895. This phenomenon was caused by the incomplete rainfall records available at most SOD stations. SOD stations 082298 and 085895 had a nearly complete rainfall record throughout the modeling time period, and the average annual precipitation measured at these stations was similar to that average annual precipitation measured in the closest NEXRAD zones. The percent difference between the two data types was 6% at SOD station 082298 and 0% at SOD station 085895.

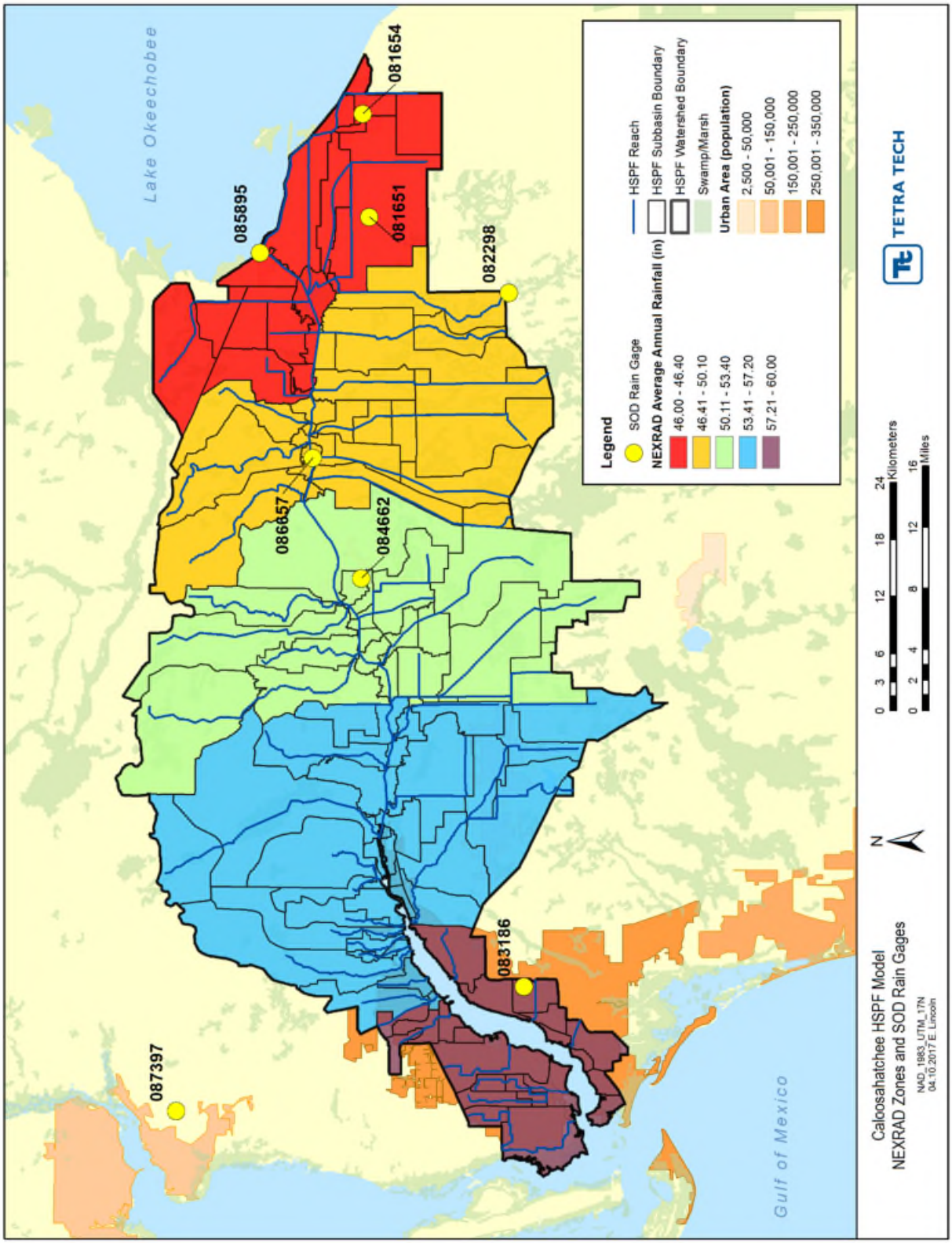

FIGURE 10: CALOOSAHATCHEE RIVER WATERSHED NEXRAD ZONE AVERAGE ANNUAL RAINFALL AND NCDC SOD PRECIPITATION MONITORING STATIONS

TABLE 11: NCDC SOD STATION NEXRAD ZONE STATION ASSIGNMENTS AND AVERAGE ANNUAL RAINFALL TOTALS

NEXRAD Zone	NEXRAD Annual Pre. (in)	Station 081651 (in))	Station 081654 (in)	Station 082298 (in)	Station 083186 (in)	Station 084662 (in)	Station 085895 (in)	Station 086657 (in)	Station 087397 (in)
Zone 1	60.03	-	-	-	-	-	-	-	51.63
Zone 2	59.11	-	-	-	49.64	-	-	-	-
Zone 9	52.91	-	-	-	-	40.30	-	-	-
Zone 12	49.49	-	-	-	-	-	-	39.48	-
Zone 13	48.73	-	-	52.03	-	-	-	-	-
Zone 14	46.02	-	-	-	-	-	46.17	-	-
Zone 15	46.40	30.28	15.21	-	-	-	-	-	-
Data Percent Completeness	99-100%	60%	25%	89%	83%	71%	93%	66%	91%

- = No data

2.2.5.3 Comparison to Lee County Data

As an additional check on the NEXRAD data, daily rainfall data collected by Lee County were downloaded and summarized by NEXRAD zone to compare average annual totals. The locations of the Lee County rainfall monitoring gages are shown in **Figure 11** and listed in **Table 12**. Lee County currently maintains a network of 23 rain gages, 22 of which had data during the modeling period. Data were available at eight of the stations for the entire 20 year analysis period (1996 through 2014), and at seven stations for 15 years during that same period. All other stations had between 4 and 11 years of data. Lee County stations were located in 8 of the 15 HSPF model NEXRAD zones.

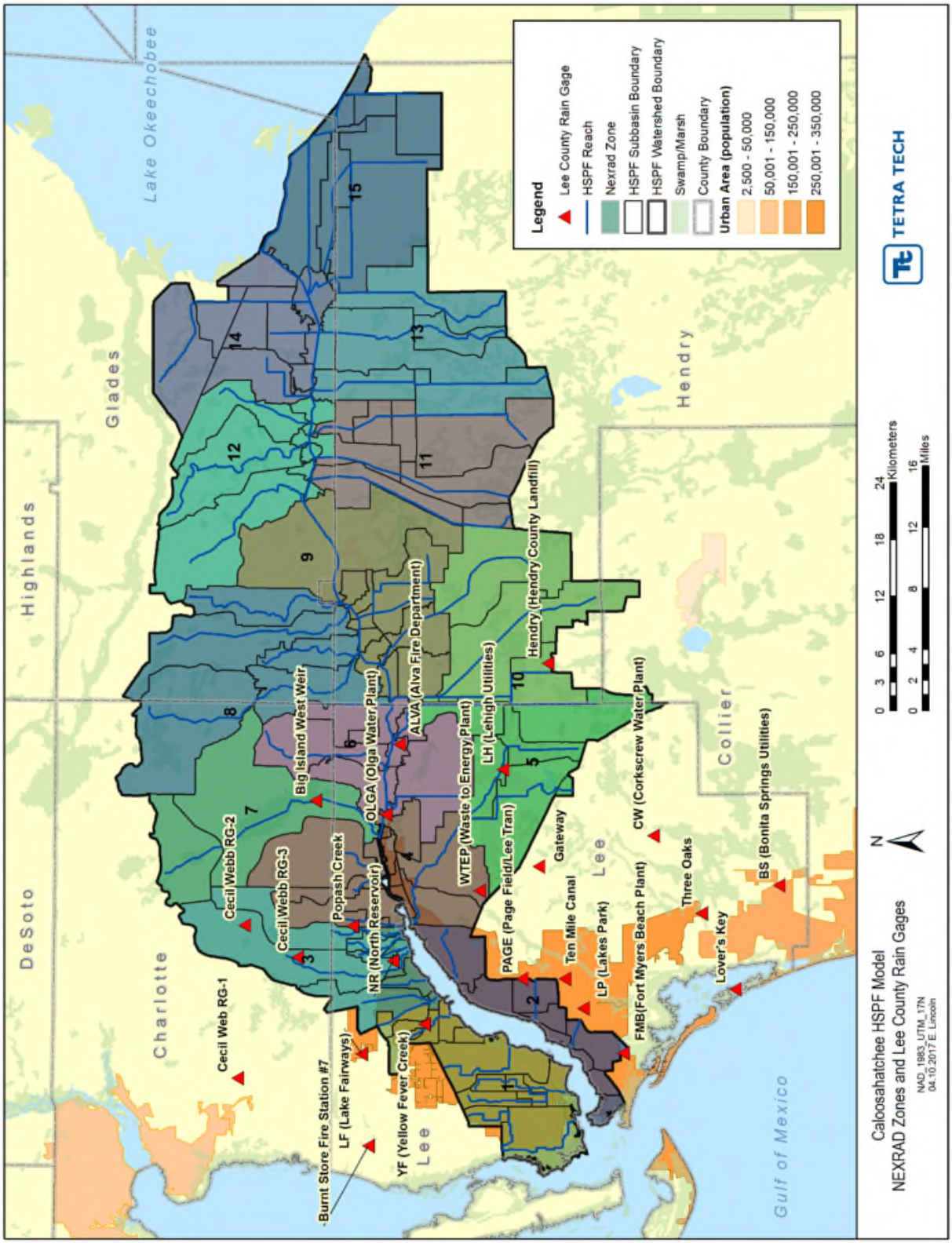

FIGURE 11: LEE COUNTY RAINFALL MONITORING LOCATIONS

TABLE 12: LEE COUNTY RAINFALL MONITORING LOCATION DESCRIPTIONS

Rain Gauge Name	Latitude	Longitude	Location
Ten Mile Canal	26.5474	-81.8552	North side of Daniels between Metro and 41.
ALVA (Alva Fire Department)	26.7064	-81.6083	SR 78 To Styles Rd, Alva Fire Department.
BS (Bonita Springs Utilities)	26.3443	-81.7549	E. Terry St, Bonita Spring Utilities.
CW (Corkscrew Water Plant)	26.4642	-81.7034	Alico Rd, Corkscrew Water Plant.
LF (Lake Fairways)	26.7406	-81.9362	US 41 N, Lake Fairways maintenance building.
LH (Lehigh Utilities)	26.6078	-81.6340	Lee Rd. to Coolidge Ave, Lehigh Utilities.
LP (Lakes Park)	26.5298	-81.8867	Summerlin Rd., Lakes Park.
NR (North Reservoir)	26.7115	-81.8378	Bayshore & Samville Rd, Lee County North Res.
OLGA (Olga Water Plant)	26.7189	-81.6826	SR 78 to Werner Dr., Olga Water Plant.
PAGE (Page Field/Lee Tran)	26.5882	-81.8557	Metro Pkwy to Idlewild, Lee Tran.
WTEP (Waste to Energy Plant)	26.6294	-81.7624	Buckingham Rd, Waste to Energy Plant.
YF (Yellow Fever Creek)	26.6810	-81.9044	Herron Rd. & Pine Island Rd, North Ft. Myers.
FMB (Fort Myers Beach Plant)	26.4913	-81.9335	Fort Myers Beach Plant, Pine Rd. Between Summerlin and San Carlos Blvd.
Cecil Web RG-1	26.8586	-81.9628	Cecil Webb Wildlife MGMT, West side of lane to rangers house.
Gateway	26.5732	-81.7366	Gateway Service District East of Commerce Dr.
Hendry (Hendry County Landfill)	26.5654	-81.5214	Hendry County Landfill @ pump station on hill.
Lover's Key	26.3853	-81.8650	Lover's Key State Recreation Area
Burnt Store Fire Station #7	26.7334	-82.0339	Fire Station #7 on Burnt Store Rd.
Cecil Webb RG-2	26.8528	-81.8010	East on Tuckers Grade Blvd in Cecil Webb Wildlife, along berm, North of Road.
Cecil Webb RG-3	26.8023	-81.8344	Cecil Webb Wildlife, East side along the Power line road.
Big Island West Weir	26.7859	-81.6680	West side of Big Island water control structure in Babcock Ranch.
Popash Creek	26.7502	-81.8011	Popash Creek at Nalle Grade Rd.
Three Oaks	26.4179	-81.7853	Three Oaks Pkwy and Williams Rd.

The comparison of annual rainfall totals at the Lee County locations to the NEXRAD data are presented in **Table 13**. Only stations located within the Caloosahatchee River Watershed that had more than 15 years of data were used for the comparison, with the exception of Big Isla West Weir, as it was the only station located in NEXRAD Zone 2. In five of the NEXRAD zones, the percent difference in annual average precipitation was less than 5%. The percent difference in annual average precipitation in Zone 3 was approximately 8%, in Zone 7 approximately 15%, and in Zone 1 approximately 19%. In two other zones, the difference was approximately 20%. Overall, the NEXRAD annual rainfall totals were greater than the Lee County annual rainfall total, and the percent difference in total volume between individual years typically ranged between -15% and 15%. In zones where the average annual rainfall difference was higher, such as Zone 1, the NEXRAD data reported rainfall that was consistently higher than the Lee County gage. This may be due to more rainfall being recorded near the coastal area of Zone 1 than at the inland Yellow Fever Creek gage.

TABLE 13: LEE COUNTY AVERAGE ANNUAL RAINFALL SUMMARIZED BY NEXRAD ZONE

NEXRAD Zone	Lee County Stations	Years Analyzed	Lee County Avg Annual Rainfall (in)	NEXRAD Avg Annual Rainfall (in)	% Difference
1	Yellow Fever Creek	1999 – 2014	49.29	58.46	-18.61%
2	Lakes Park; Page Field/Lee Tran	1996 – 2014	59.86	59.86	1.47%
3	North Reservoir	1996 – 2014	61.06	56.16	8.03%
4	Waste to Energy Plant	1998 – 2014	56.61	56.48	0.23%
5	Lehigh Utilities; Gateway	1996 – 2014	59.78	57.19	4.33%
6	Alva Fire Department; Olga Water Plant	1996 – 2014	56.12	57.85	-3.08%
7	Big Isla West Weir	2011 – 2014	47.07	53.92	-14.56%
10	Hendry County Landfill	1998 - 2014	56.26	54.2	3.72%

2.2.5.4 Storm Event Comparison

A selection of storm events was examined to compare the measured rainfall totals from the three data sources. The storm events selected occurred in 2008, 2012, and 2013 as shown in **Table 14**, **Table 15**, and

Table 16, respectively. For the storm events occurring in 2008 and 2012, the NEXRAD data showed larger rainfall totals than for the other data sources, while for the 2012 events greater rainfall totals were recorded at the Lee County and SOD stations for Tropical Strom Debby. Slight variation across data sources is to be expected, however, and the rainfall totals for the selected storm events are generally within 25% of the average across the three data sources.

TABLE 14: CO-LOCATED RAINFALL TOTALS FOR THE THREE DATA SOURCES DURING SELECT RAINFALL EVENTS FOR 8/30/2008–9/2/2008

Date	Event	NEXRAD Zone 2 (in)	SOD 12835 (in)	Lee County - Page Field/Lee Tran (in)
8/30/2008	N/A	0.42	0.21	0.22
8/31/2008	Hurricane Gustav	0.84	0.94	0.89
9/1/2008	Hurricane Gustav	0.00	0.00	0.00
9/2/2008	Tropical Storm Hanna	0.00	0.00	0.00
Total	**Total**	**1.25**	**1.15**	**1.11**

TABLE 15: CO-LOCATED RAINFALL TOTALS FOR THE THREE DATA SOURCES DURING SELECT RAINFALL EVENTS FOR 5/18/2012–6/27/2012

Date	Event	NEXRAD Zone 2 (in)	SOD 12835 (in)	Lee County - Page Field/Lee Tran (in)
5/18/2012	Tropical Storm Alberto	0.02	0.01	0.02
5/28/2012	Tropical Storm Beryl	0.00	0.00	0.00
5/29/2012	Tropical Storm Beryl	0.09	0.06	0.01
5/30/2012	Tropical Storm Beryl	0.01	0.00	0.00

Date	Event	NEXRAD Zone 2 (in)	SOD 12835 (in)	Lee County - Page Field/Lee Tran (in)
6/19/2012	Hurricane Chris	0.00	0.00	0.00
6/20/2012	Hurricane Chris	0.06	0.1	0.11
6/21/2012	Hurricane Chris	0.15	0.03	0.02
6/22/2012	Hurricane Chris	0.28	0.31	0.40
6/23/2012	Tropical Storm Debby	0.97	1.68	1.55
6/24/2012	Tropical Storm Debby	1.65	2.72	2.52
6/25/2012	Tropical Storm Debby	0.43	0.28	0.25
6/26/2012	Tropical Storm Debby	0.30	0.32	0.32
6/27/2012	Tropical Storm Debby	0.39	0.15	0.26
Total	**Total**	**4.35**	**5.66**	**5.46**

TABLE 16: CO-LOCATED RAINFALL TOTALS FOR THE THREE DATA SOURCES DURING SELECT RAINFALL EVENTS FOR 6/5/2013–6/7/2013

Date	Event	NEXRAD Zone 2 (in)	SOD 12835 (in)	Lee County - Page Field/Lee Tran (in)
6/5/2013	Tropical Storm Andrea	0.68	0.31	0.23
6/6/2013	Tropical Storm Andrea	2.25	1.78	1.81
6/7/2013	Tropical Storm Andrea	0.00	0.00	0.00
Total	**Total**	**2.93**	**2.09**	**2.04**

Based on the analysis of available rainfall data, and a comparison of the NEXRAD data to SOD and Lee County data, Tetra Tech determined that the NEXRAD data should be used in the Caloosahatchee River Watershed HSPF model. The NEXRAD data are the most complete, both spatially and temporally, and are similar in average annual rainfall totals to both the SOD and Lee County data. In addition, the Lee County rainfall data were not available for the eastern portion of the watershed, and rainfall data source inputs should be consistent throughout the entire watershed.

2.2.5.5 Climate Data Processing

The 2017 HSPF Model used climate data from the SA station Weather-Bureau-Army-Navy (WBAN) 12835 (Page Field Airport), located in Fort Myers (**Figure 12**). Climate data for WBAN 12835 were obtained from two sources: a web subscription from NCDC, and Integrated Surface Database (ISD) maintained by National Oceanic and Atmospheric Administration (NOAA). In the HSPF model, data from WBAN 12835 were used to develop time series for all climate variables (air temperature, dew point temperature, wind speed, cloud cover, and solar radiation), with the exception of ET. The ET data used in the model were from the Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS) model (Brown 2013). Climate data at WBAN 12835 were available at an hourly time step for all variables.

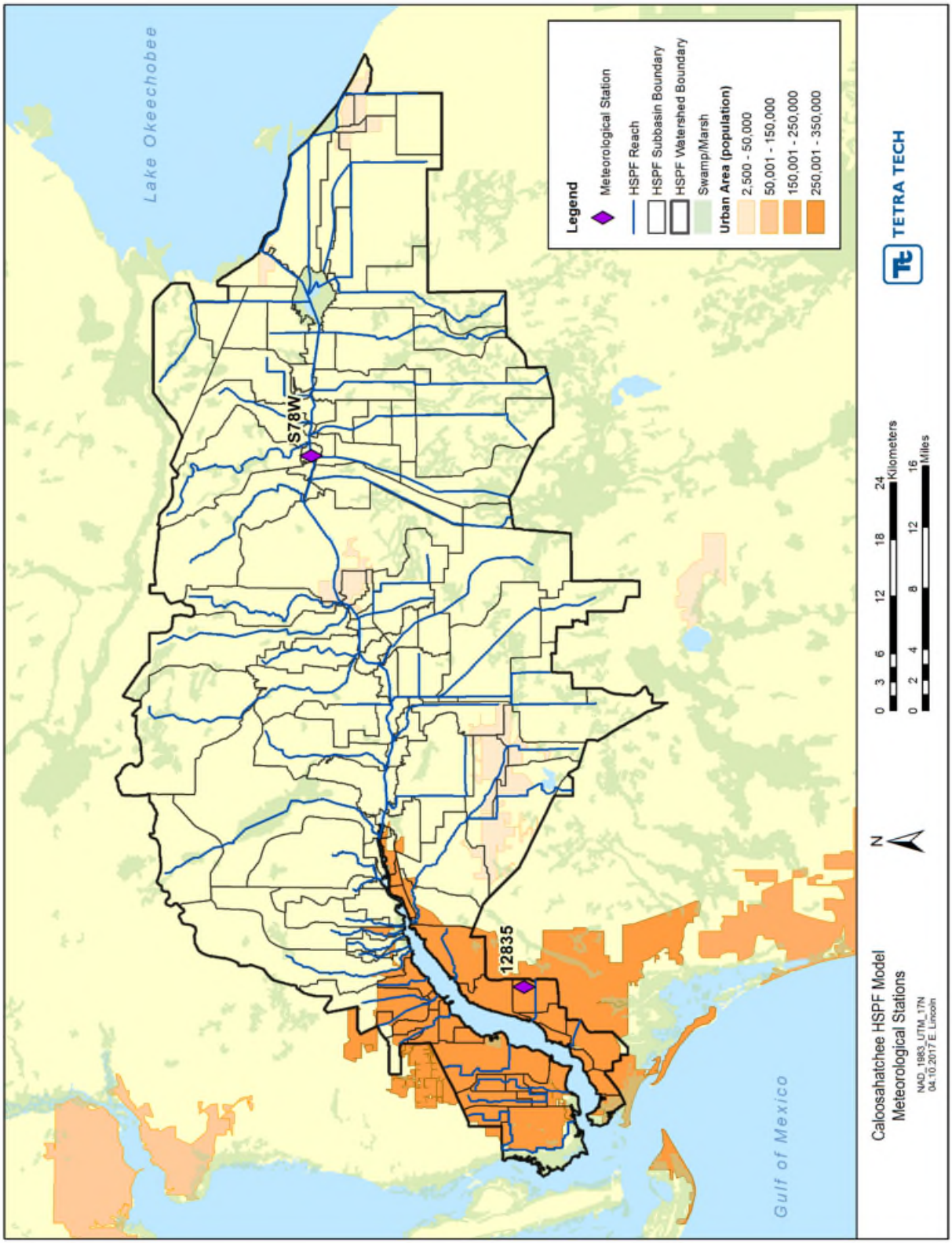

FIGURE 12: METEOROLOGICAL STATIONS USED FOR HSPF MODEL CLIMATE DATA PROCESSING

The SFWMD also provided climate data collected at station S78W at the Ortona Lock. These datasets were provided at a daily time step, and data comparisons from the two sources were performed to identify the differences between data at daily and hourly time steps (see **Figure 13** and **Figure 14**). The hourly data from WBAN 12835 captured the variability in the climate variables and provided a finer data resolution. Therefore, data from WBAN 12835 were used for all climate variables, with the exception of ET.

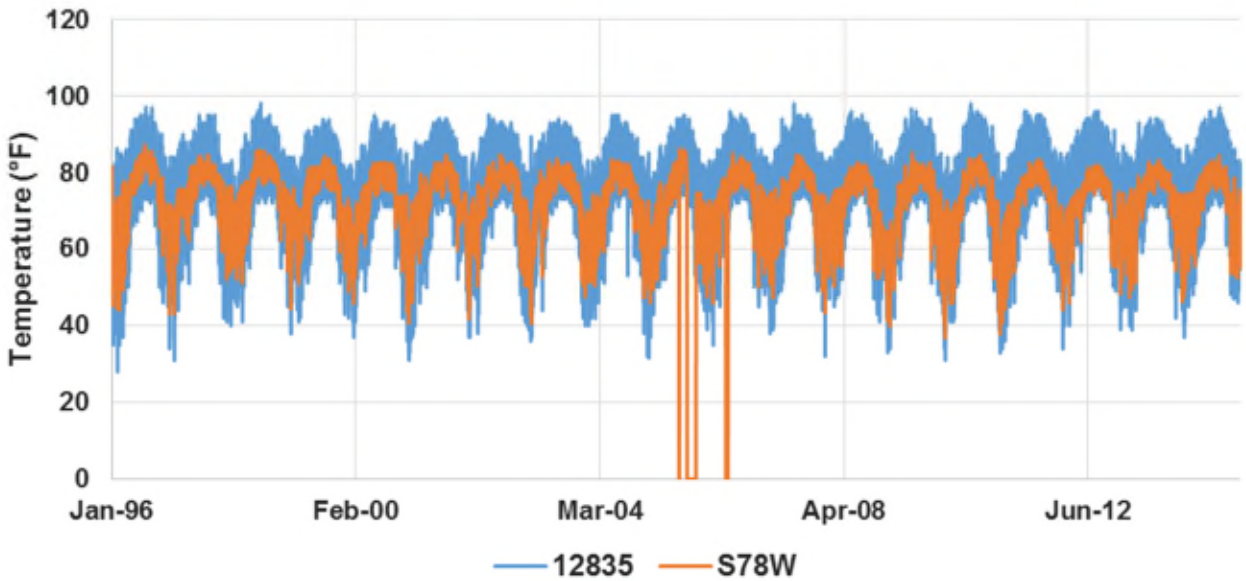

FIGURE 13: AIR TEMPERATURE COMPARISON BETWEEN HOURLY WBAN 12835 DATA AND DAILY S78W DATA FROM 1996 – 2014

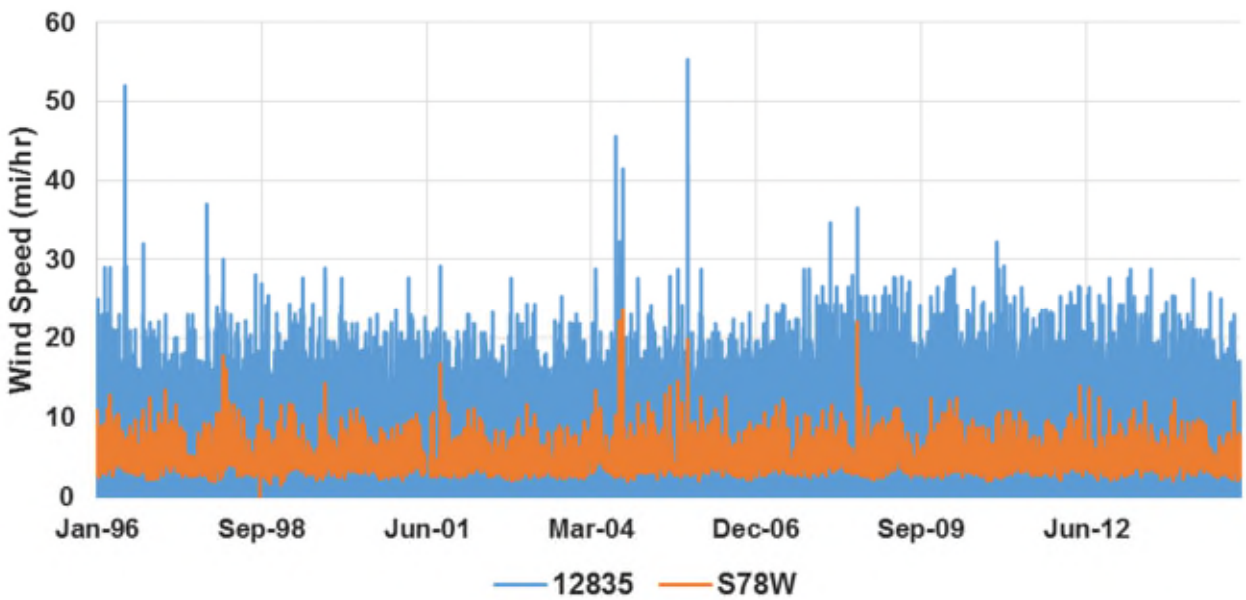

FIGURE 14: WIND SPEED COMPARISON BETWEEN HOURLY WBAN 12835 DATA AND DAILY S78W DATA FROM 1996 – 2014

When processing the data using the WBAN 12835 climate datasets, if the data gaps were less than three hours, the gaps were filled by averaging the available data before and after the gaps. If the data gaps were longer than three hours, data from the neighboring SA station WBAN 12842 (Tampa International Airport) was used. The data record at WBAN 12835 was almost fully complete, and less than 0.2% of the air temperature data and wind speed data, 3% of cloud cover data, and 5% of the relative humidity data required patching. Patching was only required between 1996 and 1998.

Cloud cover data at WBAN 12835 were provided in terms of sky cover, a verbal description of the cloud cover. Based on the information provided in the User's Manual of Meteorological Data Analysis and Preparation Tool (MetADAPT 2007), the following MetADAPT numerical assignments for cloud cover estimates from the sky conditions parameters was applied:

- CLR (clear) : 0
- POB (partial obscuration): 1.25
- SCT (scattered): 4.38
- BKN (broken): 7.5
- OVC & OBS (overcast and obscured): 10

Solar radiation was computed using cloud cover and latitude of the station. The CE-QUAL-W2 method in MetADAPT was used to compute the solar radiation using sun angle relationships and shading from the cloud cover (Cole 2003).

Quality assurance was performed on monthly total rainfall, maximum hourly rainfall, air temperature, relative humidity, solar radiation, atmospheric pressure, and wind speed and direction to ensure that values were within expected ranges for each month and season. Water Resources Database (WRDB) Graph was used to analyze the time series for all the weather parameters.

In order to account for variability in potential ET (PET) across the Caloosahatchee River Watershed, the 2017 HSPF Model used reference ET data predicted from the AFSIRS model (Brown 2013). The daily reference ET was determined by averaging the daily reference ET value from the centroid of each AFSIRS grid cell contained within each NEXRAD zone.

Reference ET data were also available by county from SFWMD, and at S78W (**Figure 12)**. The SFWMD county reference ET and the S78W data were compared to the AFSIRS data. The percent difference ranged between 0% and 12%, and the percent difference over the entire model period ranged from 3% to 5% (**Table 17**). The ET data available at WBAN 12835 were Penman–Monteith. In order to calculate reference ET, a crop coefficient needed to be applied to the dataset. The AFSIRS data were used because they provided reference ET, were available at the finest spatial resolution, and were similar to the SFWMD reference ET data.

TABLE 17: AFSIRS AND SFWMD ANNUAL REFERENCE ET (INCHES) COMPARISON

Year	AFSIRS annual reference ET in Lee County (in)	SFWMD annual reference ET in Lee County (in)	% Difference for Lee County ET data	AFSIRS annual reference ET in Charlotte County (in)	SFWMD annual reference ET in Charlotte County (in)	% Difference for Charlotte County ET data	AFSIRS annual reference ET in Glades County (in)	SFWMD annual reference in Glades County ET (in)	% Difference for Glades County ET data	AFSIRS annual reference ET in Hendry County (in)	SFWMD annual reference in Hendry County ET (in)	% Difference for Hendry County ET data
1996	55.0	52.7	-4.5%	54.9	54.7	-0.2%	55.2	54.7	-0.9%	55.2	53.6	-3.0%
1997	53.4	50.1	-6.6%	53.2	51.9	-2.4%	53.6	51.9	-3.1%	53.6	51.1	-4.8%
1998	56.9	51.0	-11.4%	57.0	52.8	-7.9%	57.7	52.8	-9.2%	57.7	52.7	-9.5%
1999	56.8	52.6	-7.9%	56.6	53.2	-6.4%	57.1	53.2	-7.2%	57.1	52.2	-9.4%
2000	58.7	54.9	-7.0%	58.9	55.0	-7.0%	59.9	55.0	-8.9%	59.9	53.4	-12.2%
2001	55.6	52.6	-5.8%	55.8	53.0	-5.4%	56.8	53.0	-7.2%	56.8	51.4	-10.5%
2002	53.5	53.3	-0.5%	53.6	54.2	1.2%	54.2	54.2	0.0%	54.2	53.0	-2.2%
2003	55.6	50.9	-9.2%	55.6	52.3	-6.3%	55.9	52.3	-6.9%	55.9	52.4	-6.6%
2004	57.5	54.6	-5.2%	57.7	53.9	-7.1%	58.4	53.9	-8.3%	58.3	54.9	-6.3%
2005	56.1	55.5	-1.1%	56.5	55.0	-2.7%	56.9	55.0	-3.5%	56.8	55.5	-2.4%
2006	59.5	59.5	-0.1%	59.9	59.1	-1.3%	60.4	59.1	-2.2%	60.4	59.0	-2.2%
2007	58.8	60.0	2.0%	59.1	59.4	0.4%	59.8	59.4	-0.8%	59.8	59.9	0.1%
2008	56.8	58.8	3.4%	57.1	57.8	1.3%	57.9	57.8	-0.1%	57.8	58.1	0.5%
2009	59.4	59.6	0.4%	60.3	59.2	-1.9%	62.3	59.2	-5.3%	62.3	59.2	-5.1%
2010	55.7	56.1	0.7%	56.4	56.1	-0.6%	57.8	56.1	-3.0%	57.7	56.9	-1.4%
2011	58.7	57.6	-2.0%	59.6	57.2	-4.0%	61.3	57.2	-7.1%	61.2	58.4	-4.8%
2012	57.1	56.0	-2.0%	57.8	56.4	-2.5%	59.5	57.0	-4.4%	59.5	58.0	-2.6%
2013	55.8	55.3	-0.9%	56.4	54.4	-3.7%	57.9	54.4	-6.4%	57.9	54.3	-6.5%
2014	56.6	53.2	-6.5%	57.2	54.3	-5.4%	58.7	54.3	-8.2%	58.6	54.5	-7.6%
Average	56.7	55.0	-3.2%	57.0	55.3	-3.2%	58.0	55.3	-4.8%	57.9	55.2	-5.0%

2.2.6 Land Use

The 2017 HSPF Model used a combination of the 2008-2009 SFWMD land use coverage and 2008 SWFWMD coverage to encompass the entire Caloosahatchee River Watershed. These coverages were selected to represent land uses because the time period in the coverages occurs near the middle of the modeling time period (1996 through 2014). The 2011 NLCD impervious coverage was also used in the model. A 2008-2009 NLCD impervious coverage was not available and the 2011 coverage was the closest time period to the land use coverages. Additional information regarding the selection of these coverages, along with processing, is provided in the sections that follow.

2.2.6.1.1 Impervious Land Use Coverage Comparison

In order to evaluate change in imperviousness in the Caloosahatchee River Watershed during the model simulation period, Tetra Tech downloaded the 2006 and 2011 NLCD Percent Developed Imperviousness shapefiles and compared the change in imperviousness. The comparison was done prior to model redelineation and used the 2014 HSPF subbasin delineation (**Figure 15**). The NLCD impervious shapefiles provide the estimated percent area classified as impervious within discrete 30-meter by 30-meter grid cells. The change in percent impervious area was minimal between the two coverages (**Table 18**). There was a slight decrease in areas with low percentages of impervious areas (0-4% imperviousness) between 2006 and 2011, with 0.36% of the total area in this classification block reclassified as having a higher percentage of imperviousness. There was a 0.05% or less change in all other percent impervious areas classification blocks.

The areas with the largest changes in percent imperviousness classifications occurred in Subbasins 4, 18, and 92 (**Table 19**). Subbasin 4 is located in North Fort Myers and includes the I-75 corridor, Subbasin 18 is located in Olga, and Subbasin 92 is located in the Cypress Lakes neighborhood. However, most subbasins had minimal changes in percent imperviousness classifications.

TABLE 18: PERCENT IMPERVIOUS AREA IN THE CALOOSAHATCHEE RIVER WATERSHED IN THE 2006 AND 2011 NLCD COVERAGES

% Impervious Classification	2006 % of Area	2011 % of Area	Change in % Area
0-4	85.77%	85.41%	-0.36%
5-9	2.38%	2.35%	-0.02%
10-14	1.77%	1.75%	-0.02%
15-19	1.61%	1.60%	-0.01%
20-24	1.51%	1.51%	0.00%
25-29	1.39%	1.39%	0.00%
30-34	1.21%	1.21%	0.00%
35-39	0.99%	1.00%	0.01%
40-44	0.78%	0.80%	0.02%
45-49	0.58%	0.63%	0.04%
50-54	0.42%	0.46%	0.05%
55-59	0.31%	0.36%	0.05%
60-64	0.25%	0.30%	0.05%
65-69	0.22%	0.27%	0.05%
70-74	0.19%	0.23%	0.04%
75-79	0.16%	0.20%	0.03%
80-84	0.13%	0.16%	0.03%
85-89	0.12%	0.14%	0.02%

% Impervious Classification	2006 % of Area	2011 % of Area	Change in % Area
90-94	0.11%	0.12%	0.01%
95-100	0.09%	0.10%	0.01%
Total	100.00%	100.00%	0.00%

TABLE 19: PERCENT CHANGE IN IMPERVIOUS AREA BETWEEN 2006 AND 2011 IN THE CALOOSAHATCHEE RIVER WATERSHED BY SUBBASIN USING THE 2014 HSPF DELINEATION

SWS	0-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
1	-0.40%	-0.17%	-0.12%	-0.10%	0.10%	0.18%	0.20%	0.14%	0.10%	0.07%
2	-2.49%*	-0.59%	-0.22%	-0.03%	0.61%	0.81%	0.93%	0.69%	0.26%	0.05%
3	-1.01%*	-0.47%	-0.21%	-0.12%	0.41%	0.71%	0.47%	0.12%	0.09%	0.00%
4	-5.04%**	-0.21%	-0.09%	0.18%	0.88%	1.06%*	1.28%*	1.03%*	0.67%	0.23%
5	-1.96%*	-0.69%	-0.46%	-0.13%	0.38%	1.30%*	0.84%	0.43%	0.23%	0.05%
6	-1.39%*	-0.66%	-0.65%	-0.51%	-0.01%	0.61%	0.59%	1.08%*	0.70%	0.25%
7	-0.87%	-1.22%*	-1.02%*	-0.47%	-0.11%	0.37%	0.94%	0.90%	0.79%	0.70%
8	-0.61%	-0.40%	-0.39%	-0.33%	-0.06%	0.27%	0.42%	0.47%	0.42%	0.22%
9	-1.71%*	-0.33%	-0.26%	-0.09%	0.19%	0.33%	0.58%	0.57%	0.35%	0.38%
10	-2.51%*	0.29%	0.35%	0.34%	0.48%	0.36%	0.29%	0.18%	0.11%	0.10%
11	-1.14%*	-0.18%	-0.06%	-0.05%	0.26%	0.38%	0.28%	0.21%	0.20%	0.10%
12	-0.38%	-0.03%	-0.03%	-0.03%	0.16%	0.19%	0.03%	0.06%	0.03%	0.00%
13	-0.95%	0.14%	0.13%	0.04%	0.10%	0.12%	0.10%	0.14%	0.08%	0.10%
14	-1.02%*	0.33%	0.12%	0.06%	0.21%	0.18%	0.07%	0.03%	0.02%	0.00%
15	-0.39%	-0.10%	-0.10%	-0.21%	0.10%	0.13%	0.08%	0.26%	0.18%	0.05%
16	-4.22%*	-0.40%	0.08%	0.64%	1.55%*	1.36%*	0.76%	0.20%	0.04%	0.00%
17	-2.34%*	-0.04%	0.11%	0.31%	0.71%	0.58%	0.45%	0.22%	0.00%	0.00%
18	-10.91%***	2.85%*	2.61%*	1.76%*	1.45%*	1.08%*	0.63%	0.33%	0.13%	0.06%
19	-0.16%	-0.05%	0.01%	0.01%	0.06%	0.06%	0.06%	0.01%	0.00%	0.00%
20	-0.02%	-0.01%	-0.01%	0.00%	0.01%	0.01%	0.02%	0.01%	0.00%	0.00%
21	-0.11%	-0.02%	-0.06%	-0.05%	0.02%	0.06%	0.06%	0.05%	0.05%	0.00%
22	-0.02%	0.00%	-0.01%	0.00%	0.00%	0.01%	0.02%	0.00%	0.00%	0.00%
23	-0.36%	0.00%	0.05%	0.10%	0.06%	0.08%	0.06%	0.00%	0.00%	0.00%
24	-0.05%	-0.01%	-0.01%	0.00%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
25	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
26	-0.47%	-0.22%	-0.07%	-0.03%	0.19%	0.31%	0.17%	0.10%	0.02%	0.00%
27	-0.30%	-0.11%	-0.02%	-0.01%	0.13%	0.10%	0.07%	0.04%	0.05%	0.03%
28	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
29	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
30	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
31	-0.08%	-0.04%	-0.01%	0.00%	0.05%	0.05%	0.02%	0.01%	0.00%	0.00%
32	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
33	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
34	-0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%
35	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
36	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
37	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
38	0.00%	-0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%
39	-0.32%	0.03%	0.05%	-0.02%	0.05%	0.05%	0.10%	0.05%	0.00%	0.00%
40	-1.56%*	-0.55%	-0.39%	-0.14%	0.16%	0.36%	0.68%	0.68%	0.45%	0.29%
41	-0.14%	-0.02%	-0.01%	0.00%	0.03%	0.05%	0.05%	0.03%	0.01%	0.01%
42	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
43	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
44	-0.11%	0.00%	0.00%	0.00%	0.03%	0.03%	0.06%	0.00%	0.00%	0.00%
45	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
46	-1.21%*	-0.25%	-0.06%	0.00%	0.17%	0.31%	0.17%	0.20%	0.14%	0.53%
47	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
48	-0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
49	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
50	-0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%

SWS	0-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%
51	-0.02%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%
52	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
53	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
54	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
55	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
56	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
57	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
58	-0.12%	0.00%	0.01%	0.01%	0.02%	0.02%	0.03%	0.02%	0.01%	0.00%
59	-0.04%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
60	-1.15%*	0.23%	0.16%	0.15%	0.13%	0.13%	0.11%	0.08%	0.08%	0.09%
61	-0.70%	0.09%	0.00%	0.04%	0.12%	0.13%	0.12%	0.07%	0.09%	0.03%
62	-0.17%	0.04%	0.03%	0.02%	0.01%	0.03%	0.01%	0.01%	0.02%	0.01%
63	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
64	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
65	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
66	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
67	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
68	-0.02%	-0.01%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%
69	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
70	-0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
71	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
72	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
73	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
74	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
75	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
76	-0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
77	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
78	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
79	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
80	-2.26%*	0.45%	0.37%	0.33%	0.37%	0.37%	0.29%	0.08%	0.00%	0.00%
81	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
82	0.00%	-0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
83	-0.72%	-0.10%	-0.06%	0.03%	0.29%	0.24%	0.18%	0.10%	0.04%	0.01%
84	-0.01%	-0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%
85	-0.03%	-0.02%	0.00%	0.00%	0.01%	0.02%	0.01%	0.01%	0.01%	0.00%
86	-1.14%*	-0.10%	0.00%	-0.03%	0.17%	0.11%	0.26%	0.37%	0.16%	0.20%
87	-0.59%	0.03%	0.07%	0.05%	0.11%	0.13%	0.02%	0.10%	0.08%	0.00%
88	-0.10%	-0.01%	-0.01%	0.00%	0.03%	0.03%	0.03%	0.03%	0.00%	0.00%
89	-1.22%*	-0.22%	-0.13%	0.00%	0.27%	0.28%	0.38%	0.33%	0.17%	0.14%
90	-0.66%	-0.22%	-0.22%	-0.04%	0.22%	0.26%	0.22%	0.31%	0.04%	0.09%
91	-0.16%	-0.07%	-0.03%	-0.03%	0.03%	0.08%	0.09%	0.06%	0.03%	0.01%
92	-11.38%***	0.41%	0.66%	0.77%	1.04%*	2.45%*	3.72%*	1.67%*	0.50%	0.16%
93	-3.89%*	0.04%	0.19%	0.17%	0.62%	0.78%	0.95%	0.61%	0.31%	0.22%
94	-0.80%	-0.57%	-0.27%	-0.04%	0.23%	0.47%	0.57%	0.25%	0.08%	0.08%
95	-1.18%*	-0.83%	-0.41%	-0.22%	0.11%	0.59%	0.67%	0.61%	0.50%	0.18%
96	-0.66%	-0.96%	-0.36%	-0.18%	0.19%	0.73%	0.61%	0.37%	0.23%	0.02%
97	-0.79%	-0.69%	-0.69%	-0.32%	0.09%	0.53%	0.72%	0.39%	0.46%	0.30%
98	-0.48%	-1.05%*	-0.46%	-0.43%	-0.09%	0.49%	0.76%	0.57%	0.52%	0.17%
99	-1.00%*	-0.86%	-0.60%	-0.24%	0.12%	0.74%	0.96%	0.53%	0.33%	0.02%
100	-1.69%*	-1.03%*	-0.98%	-0.55%	0.32%	0.68%	1.02%*	1.38%*	0.69%	0.16%
101	-0.81%	-0.37%	-0.27%	-0.08%	0.15%	0.42%	0.40%	0.29%	0.20%	0.06%
102	-1.44%*	-0.91%	-0.49%	-0.07%	0.27%	0.62%	0.66%	0.68%	0.45%	0.22%
Total	**-0.38%**	**-0.02%**	**0.00%**	**0.01%**	**0.06%**	**0.09%**	**0.10%**	**0.07%**	**0.05%**	**0.03%**

* 1% - 5% change from 2006 to 2011.
** 5% - 10% change from 2006 to 2011.
*** Greater than 10% change from 2006 to 2011.

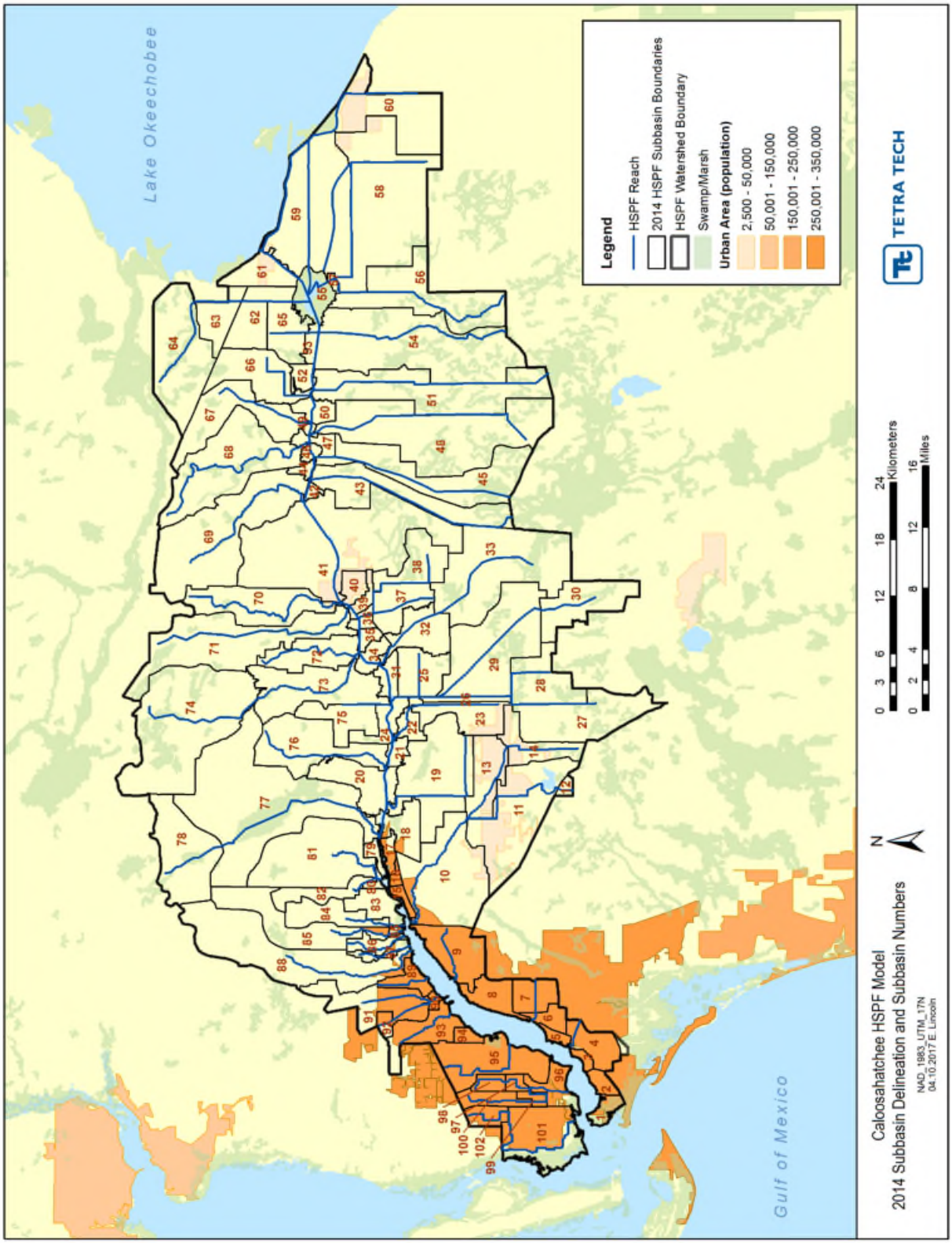

FIGURE 15: 2014 HSPF MODEL SUBBASIN DELINEATION AND SUBBASIN NUMBERS

2.2.6.2 Pervious Land Use Coverage Comparison

In order to evaluate change in pervious land uses in the Caloosahatchee River Watershed during the model simulation period, Tetra Tech compared land use changes between three SFWMD land use/land cover (LULC) shapefiles. The comparison was done prior to model redelineation and used the 2014 HSPF subbasin delineation. Tetra Tech downloaded and used the SFWMD LULC 2004, 2008-2009, and 2012 geographic information system (GIS) coverages for the comparison. For the analysis, Tetra Tech reduced the total number of land use classifications provided by SFWMD by grouping similar land uses (i.e. all 1100 level land use classifications were group together as Low Density Residential). The reduced land use classifications was used to assign runoff and nutrient loads in the Caloosahatchee River Watershed HSPF model. A total of 16 separate pervious land uses are now used in the HSPF model. One of the pervious land uses, FDOT Right-of-Way, was not included in the SFWMD LULC shapefiles. FDOT provided a shapefile of their road right-of-ways, which Tetra Tech clipped into the SFWMD LULC during land use processing for the updated HSPF model.

Overall, there was very little change in land use between the 2004, 2008-2009, and 2012 SFWMD LULC coverage (**Figure 16**). Between the 2004 and 2008-2009 SFWMD LULC coverages, Low Density Residential area increased by approximately 24,000 acres, while the Developed Open Space/Disturbed area decreased by approximately 26,000 acres. This change occurred because land classified as inactive land in the 2004 coverage was reclassified as rural residential in the 2008-2009 coverage. This change in classification was likely not due to an increase in development, but due to a change in how SFWMD classified land use between 2004 and 2008-2009. Between the 2008-2009 and 2012 SFWMD LULC coverages, Citrus Grove acreage decreased by 21,000 acres while Improved and Unimproved Pastures increased by 20,000 acres. This change occurred because land classified as citrus or other groves in 2008-2009 coverage was classified as improved pasture, abandoned groves, or fallow cropland in the 2012 coverage. Approximately 9,500 acres of Citrus Grove that were reclassified as Unimproved Pasture were located in the future Caloosahatchee River (C-43) West Basin Storage Reservoir Project. The citrus groves in this area were removed as part of the project. The project will store excess water from the Caloosahatchee River from large releases from Lake Okeechobee. The area will likely be reclassified as water in future land use classifications. The remaining change in Citrus Grove land use is located throughout the watershed and may be due to loss of citrus groves from greening, as well as how SFWMD classified the agricultural areas.

Tetra Tech compared the change in land use by subbasin. **Table 20** shows the percent change in land use between the 2008-2009 and 2012 SFWMD coverages. Very little change occurred between the two coverages, with the exception of some of the agricultural classes, which was mentioned previously. The change in each land use classification was less than 1% for most subbasins.

Due to the similarities between the two NLCD impervious coverages and three SFWMD LULC coverages, Tetra Tech used one NLCD impervious coverage and one SFWMD LULC coverage in the Caloosahatchee River Watershed HSPF model. The 2008-2009 SFWMD LULC coverage was used to represent land uses because the time period in that coverage occurs near the middle of the modeling time period (1996 through 2014). A NLCD coverage is not available for 2008-2009; therefore, the 2011 NLCD impervious coverage was used in the model.

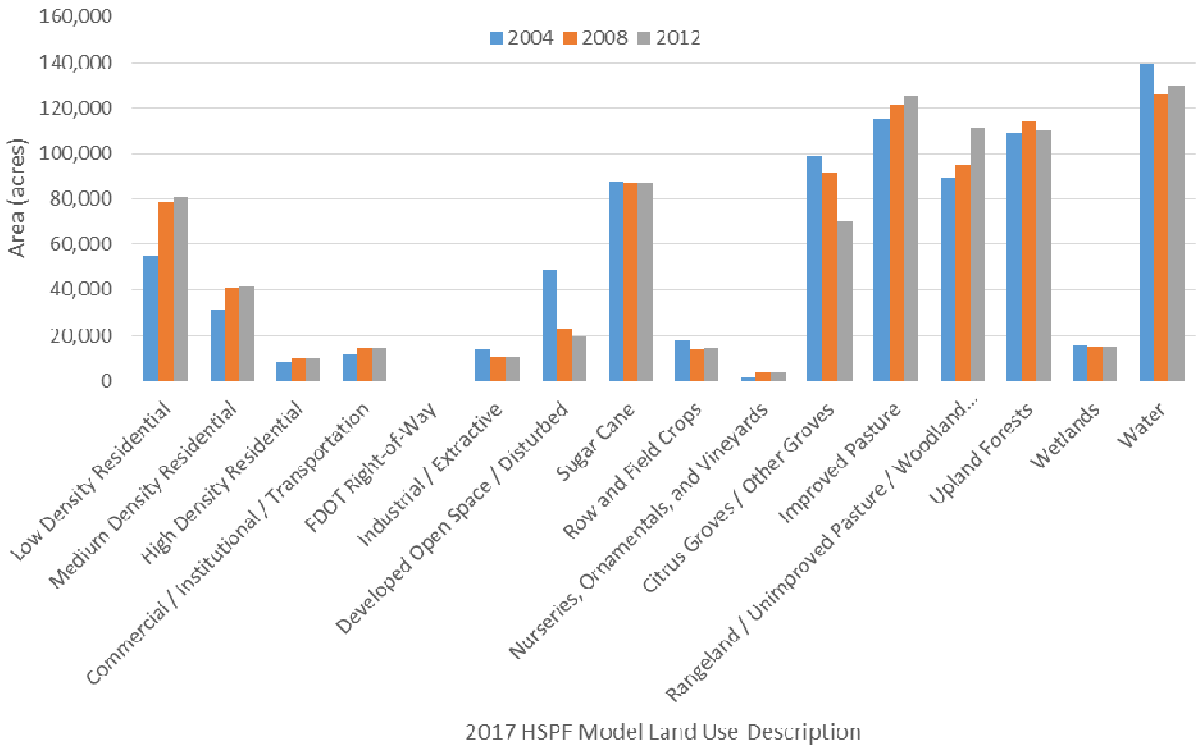

FIGURE 16: DIFFERENCE IN HSPF RECLASSIFICATION MODEL LAND USE BETWEEN THE 2004, 2008-2009, AND 2012 SFWMD COVERAGES

TABLE 20: PERCENT CHANGE IN LAND USE CLASSIFICATIONS BETWEEN THE 2008-2009 AND 2012 SFWMD COVERAGES IN THE CALOOSAHATCHEE RIVER WATERSHED BY SUBBASIN USING THE 2014 HSPF DELINEATION

SWS	Code 1	Code 2	Code 3	Code 4	Code 6	Code 7	Code 8	Code 9	Code 10	Code 11	Code 12	Code 13	Code 14	Code 15	Code 16
1	0.00%	0.67%	0.00%	0.00%	0.00%	-0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.14%	0.05%	-0.06%
2	0.01%	0.41%	0.06%	0.18%	0.00%	1.05%*	0.00%	0.00%	-0.72%	0.00%	0.00%	0.11%	-0.34%	-0.01%	-0.75%
3	0.00%	0.35%	0.13%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.18%	-0.25%	-0.06%
4	-0.20%	0.00%	0.04%	0.34%	0.00%	-2.37%*	0.00%	0.00%	0.00%	0.00%	0.00%	2.93%*	-0.54%	-0.22%	0.01%
5	0.00%	0.00%	0.10%	-0.08%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.22%	0.00%
6	0.00%	0.08%	0.00%	1.17%*	-0.40%	-0.46%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.23%	0.01%	-0.16%
7	0.00%	5.13%	-5.01%**	0.17%	0.00%	-0.13%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.20%	0.05%
8	-0.13%	0.00%	0.04%	0.04%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.12%	0.05%
9	-0.20%	-0.07%	-0.06%	0.51%	-0.01%	-2.39%*	0.00%	0.00%	0.05%	0.00%	0.78%	1.66%*	-0.17%	-0.08%	-0.01%
10	0.69%	0.33%	-0.32%	0.61%	0.07%	-1.80%*	0.00%	0.05%	-0.02%	-0.15%	-0.55%	1.00%*	0.19%	0.07%	-0.16%
11	0.19%	0.08%	0.21%	0.13%	0.00%	-0.43%	0.00%	0.00%	0.00%	0.00%	-0.14%	-0.35%	0.48%	-0.04%	-0.12%
12	0.91%	0.13%	0.00%	0.00%	0.00%	-2.49%*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	1.40%*
13	-0.64%	-0.06%	0.00%	0.21%	0.00%	-0.38%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.76%	-0.04%	0.14%
14	1.33%*	1.20%*	0.00%	0.35%	0.00%	-2.49%*	0.00%	0.00%	0.00%	0.00%	-0.35%	0.00%	0.00%	-0.02%	-0.01%
15	0.00%	0.00%	0.00%	0.54%	0.00%	-0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	-0.54%	0.00%	0.00%
16	0.00%	0.13%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	-0.40%
17	1.51%*	-1.47%*	0.00%	0.04%	0.00%	-0.29%	0.00%	0.00%	0.00%	-0.47%	0.68%	-0.15%	0.23%	-0.08%	0.00%
18	0.08%	0.20%	0.00%	0.00%	0.00%	-9.39%**	0.00%	-0.10%	0.00%	0.00%	0.35%	8.84%**	-0.05%	-0.02%	0.08%
19	1.89%*	0.01%	0.00%	0.00%	0.00%	-0.66%	0.00%	-0.08%	0.00%	-0.12%	0.37%	0.24%	-1.28%*	0.06%	-0.41%
20	0.53%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.24%	2.76%*	-2.46%*	-0.53%	0.03%	-0.10%
21	1.15%*	-1.05%*	0.00%	0.00%	0.00%	-0.32%	0.00%	-0.60%	0.06%	-0.74%	2.94%*	-0.39%	-0.89%	-0.06%	-0.11%
22	1.08%*	0.00%	0.00%	0.00%	0.00%	0.49%	0.00%	0.00%	0.00%	-3.42%*	-3.50%*	-1.43%*	6.78%**	0.00%	0.00%
23	0.58%	0.00%	0.00%	0.05%	-0.45%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.71%	0.01%	0.00%	-0.95%
24	1.63%*	0.00%	0.00%	0.00%	0.00%	-0.89%	0.00%	0.00%	0.23%	-0.33%	1.28%*	-1.46%*	-0.38%	-0.03%	-0.06%
25	-0.05%	0.00%	0.00%	0.00%	0.00%	-0.07%	0.00%	0.00%	0.00%	-70.40%^	0.00%	70.58%^	-0.05%	0.02%	-0.03%
26	-2.45%*	0.00%	0.00%	1.45%*	-1.03%*	3.22%*	0.00%	1.64%*	1.86%*	-4.78%*	0.00%	0.10%	0.00%	0.00%	0.00%
27	2.16%*	0.00%	0.05%	0.00%	0.24%	-3.26%*	0.00%	0.00%	0.00%	0.00%	0.24%	-1.05%*	0.67%	0.98%	-0.02%
28	-0.01%	0.00%	0.00%	0.00%	0.10%	-0.01%	0.00%	0.00%	0.00%	-0.01%	0.00%	-0.33%	0.01%	0.34%	-0.08%
29	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.20%	0.00%	-12.45%^	1.27%*	3.36%*	0.75%	0.01%	-0.14%
30	-0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-3.61%*	-0.14%	-2.76%*	2.80%*	4.05%*	-0.26%	0.00%	0.12%
31	-0.27%	3.87%*	0.00%	-3.87%*	0.00%	-0.77%	0.00%	0.49%	0.00%	-1.27%*	2.54%*	-2.02%*	1.37%*	0.00%	-0.06%
32	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-79.04%^	0.00%	79.36%^	-0.30%	-0.04%	0.01%
33	0.05%	0.00%	0.00%	0.04%	0.00%	0.10%	-0.98%	0.92%	0.00%	-0.01%	-0.26%	1.12%*	-1.01%*	0.02%	0.01%
34	-0.15%	0.00%	0.00%	0.00%	-1.07%*	0.82%	0.00%	-1.59%*	0.00%	-7.29%^	2.93%*	15.28%^	-7.26%**	-0.03%	-1.64%*
35	0.07%	0.00%	0.00%	0.00%	0.00%	-0.11%	0.00%	0.00%	0.00%	-3.17%*	2.51%*	0.70%	0.14%	-0.02%	-0.11%
36	1.08%*	0.00%	0.00%	0.00%	0.00%	-2.82%*	0.00%	0.00%	0.00%	-1.19%*	1.21%*	2.79%*	-1.08%*	0.00%	0.00%
37	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.34%	0.00%	-10.18%^	0.00%	9.56%**	0.00%	-0.03%	0.32%
38	-0.19%	0.25%	0.01%	0.06%	-0.16%	0.02%	0.00%	-0.18%	0.00%	-2.29%*	2.19%*	-0.91%	1.95%*	-0.01%	-0.74%
39	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.91%	0.00%	0.00%	0.91%	-0.13%	0.12%	0.32%	-0.31%
40	0.00%	0.00%	0.53%	-0.44%	0.09%	-4.88%*	0.00%	0.00%	0.00%	0.00%	0.50%	5.24%**	-0.95%	0.00%	-0.09%
41	0.65%	0.01%	0.08%	0.02%	0.20%	-1.61%*	0.00%	0.23%	0.00%	-0.05%	-0.06%	0.77%	0.11%	-0.01%	-0.35%
42	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.50%	0.50%	0.00%	0.00%	0.00%	0.00%

SWS	Code 1	Code 2	Code 3	Code 4	Code 6	Code 7	Code 8	Code 9	Code 10	Code 11	Code 12	Code 13	Code 14	Code 15	Code 16
43	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.57%	0.00%	-2.36%*	0.03%	1.90%*	-0.12%	0.00%	-0.06%
44	0.00%	0.00%	0.00%	0.00%	0.00%	-0.91%	0.00%	0.00%	-1.08%*	-5.44%	5.90%**	1.25%*	0.00%	0.28%	0.00%
45	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	0.00%	1.25%*	0.00%	-3.08%*	-0.89%	2.70%*	-0.05%	0.01%	0.00%
46	0.72%	0.00%	0.00%	0.00%	0.00%	-1.56%*	0.00%	0.00%	0.00%	0.00%	-0.21%	1.05%*	0.00%	0.00%	0.00%
47	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-17.11%^	0.06%	16.88%^	0.00%	0.00%	0.18%
48	0.00%	0.00%	0.00%	0.00%	-0.07%	0.02%	0.96%	-2.91%*	0.00%	-2.37%*	-0.09%	4.54%*	-0.03%	-0.01%	-0.04%
49	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
50	-0.35%	0.00%	0.00%	0.00%	1.11%*	-1.11%*	0.00%	0.00%	0.40%	0.00%	0.02%	0.00%	0.00%	0.00%	-0.08%
51	0.44%	0.00%	0.00%	0.00%	0.00%	-0.09%	0.00%	0.00%	-0.09%	-0.58%	-0.17%	0.61%	0.23%	0.05%	-0.39%
52	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.46%	0.00%	0.00%	0.00%	-0.46%
53	0.00%	0.00%	0.00%	0.00%	4.91%*	0.00%	-4.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
54	0.33%	0.00%	0.00%	0.00%	0.00%	-0.01%	0.66%	1.38%*	0.00%	-4.73%*	0.78%	1.55%*	-0.17%	-0.01%	0.22%
55	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	0.00%	0.00%	0.34%	-0.32%
56	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-1.66%*	0.05%	1.57%*	-0.17%	0.01%	0.09%
57	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
58	-0.06%	0.06%	0.03%	-0.06%	0.07%	0.03%	0.25%	0.55%	0.20%	-8.32%**	-0.99%	8.10%**	-0.11%	-0.12%	0.38%
59	0.14%	0.14%	0.00%	-0.22%	0.08%	0.00%	-1.72%	0.11%	0.19%	-0.08%	0.41%	0.87%	0.00%	-0.08%	0.15%
60	0.11%	-0.05%	0.00%	0.03%	-1.52%*	-0.66%	-0.03%	0.00%	-0.10%	0.00%	0.03%	0.95%	-0.06%	0.11%	1.19%*
61	-0.24%	0.24%	0.00%	0.00%	0.17%	-2.28%*	-0.22%	-0.19%	-0.16%	0.00%	0.19%	2.52%*	-0.07%	-0.16%	0.21%
62	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.07%	0.00%	0.00%	0.00%	-0.18%	0.11%	0.00%	0.25%	-0.31%
63	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
64	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
65	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	-0.03%	0.00%	0.00%	0.00%	1.89%	-2.02%*	0.00%	0.00%	-0.02%
66	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	-0.20%	0.00%	0.17%	-0.18%
67	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.43%	-0.08%	0.09%	0.04%	0.37%
68	-0.03%	0.00%	0.00%	0.04%	0.00%	-0.01%	0.00%	-0.34%	0.00%	0.00%	3.52%*	-3.21%*	0.09%	-0.02%	-0.04%
69	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.44%	-0.71%	1.85%*	-0.90%	0.13%	0.01%	0.06%
70	-0.08%	0.00%	0.00%	0.00%	0.00%	-0.22%	0.00%	-0.69%	0.00%	-0.41%	4.88%*	-0.08%	-3.34%*	0.00%	-0.06%
71	-0.05%	0.00%	0.00%	0.05%	0.00%	-0.05%	0.00%	0.00%	-0.02%	-0.71%	0.92%	-0.36%	0.23%	0.03%	-0.06%
72	0.94%	0.00%	0.00%	0.00%	0.00%	-0.15%	0.00%	-0.11%	0.00%	-0.96%	0.89%	1.28%*	-1.54%*	-0.02%	-0.32%
73	1.11%*	0.00%	0.00%	0.00%	0.00%	-0.01%	0.00%	1.12%*	0.00%	-1.10%*	-0.41%	-1.97%*	1.56%*	0.04%	-0.34%
74	0.14%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.27%	0.00%	-0.21%	2.37%*	-3.77%*	1.60%*	-0.09%	-0.33%
75	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-5.40%	0.00%	-0.03%	0.08%	5.07%	0.01%	0.02%	0.07%
76	0.85%	0.00%	0.00%	0.00%	0.09%	0.00%	0.00%	-2.73%*	0.00%	0.06%	1.46%*	-0.27%	0.49%	0.08%	-0.03%
77	-0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.29%	0.00%	0.00%	0.30%	-0.75%	-1.13%*	0.01%	1.96%*
78	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-1.90%*	0.00%	0.00%	1.19%*	0.46%	0.37%	0.00%	-0.18%
79	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.84%*	-10.28%^	5.45%**	0.00%	0.00%
80	2.09%*	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	3.76%*	0.00%	-5.69%**	-1.95%	1.77%*	0.12%	-0.12%
81	0.07%	0.00%	0.00%	0.00%	0.38%	-0.10%	0.00%	0.24%	0.00%	0.00%	-0.09%	-0.43%	-16.65%^	0.02%	16.55%^
82	0.13%	0.00%	0.00%	0.00%	0.57%	0.00%	0.00%	0.00%	0.00%	-0.41%	1.98%*	-2.00%*	-0.66%	0.00%	0.39%
83	0.60%	0.07%	0.60%	-0.53%	0.00%	-0.41%	0.00%	-0.35%	-0.07%	0.00%	1.07%*	0.19%	-1.12%*	0.02%	-0.07%
84	0.31%	0.00%	0.00%	0.07%	0.06%	-0.59%	0.00%	-0.19%	-0.09%	-0.08%	1.57%*	-1.01%*	0.37%	-0.05%	-0.37%
85	-0.17%	0.18%	0.07%	0.00%	0.00%	-0.12%	0.00%	0.00%	0.00%	0.00%	0.25%	-1.40%*	-2.48%*	-0.03%	3.70%*
86	0.75%	0.00%	0.00%	0.00%	0.00%	-2.96%*	0.00%	0.00%	0.00%	0.00%	10.12%^	-8.51%**	0.65%	-0.05%	0.00%
87	0.18%	0.00%	0.07%	0.00%	0.00%	-0.94%	0.00%	0.00%	0.00%	0.00%	2.54%*	-1.59%*	-0.06%	-0.07%	-0.14%

SWS	Code 1	Code 2	Code 3	Code 4	Code 6	Code 7	Code 8	Code 9	Code 10	Code 11	Code 12	Code 13	Code 14	Code 15	Code 16
88	3.49%*	0.00%	0.10%	-0.04%	0.00%	-0.32%	0.00%	0.00%	-0.04%	0.00%	-3.14%*	-0.44%	-0.41%	-0.08%	0.88%
89	-0.49%	0.49%	0.00%	0.44%	0.00%	0.49%	0.00%	0.00%	0.00%	0.00%	-0.50%	-0.26%	-0.30%	0.12%	0.00%
90	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
91	-0.09%	-4.18%*	0.13%	0.15%	0.03%	3.92%*	0.00%	-0.12%	0.00%	0.00%	-0.03%	0.54%	-0.22%	0.20%	-0.34%
92	0.00%	-0.42%	-0.09%	2.25%*	0.22%	-3.27%*	0.00%	0.00%	0.00%	0.00%	0.00%	3.32%*	-1.42%*	-0.15%	-0.44%
93	0.99%	-1.74%*	-0.20%	0.60%	0.10%	-0.75%	0.00%	0.00%	0.00%	0.00%	0.00%	1.63%*	-0.77%	0.02%	0.14%
94	0.00%	0.00%	0.00%	-0.64%	0.64%	0.14%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.16%	0.07%	-0.06%
95	-0.18%	0.19%	0.00%	0.01%	0.00%	-0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.06%	-0.01%	0.00%
96	0.00%	0.05%	0.02%	0.32%	0.00%	-0.39%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.10%	0.10%
97	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
98	-0.22%	0.12%	0.00%	0.20%	-1.04%*	0.95%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	0.00%
99	0.00%	0.09%	0.25%	0.00%	0.00%	-0.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
100	-7.80%**	9.14%**	0.00%	0.00%	0.00%	-1.31%*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.03%	0.00%
101	-0.29%	-0.02%	0.35%	0.10%	0.00%	-0.13%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.03%	0.03%
102	2.13%*	0.58%	0.00%	0.00%	0.00%	-2.70%*	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	-0.02%	0.00%
Total	0.26%	0.04%	-0.01%	0.03%	0.01%	-0.36%	-0.01%	0.07%	0.00%	-2.49%*	0.48%	1.92%*	-0.43%	0.02%	0.47%

* 1% - 5% change from 2008-2009 to 2012.

** 5% - 10% change from 2008-2009 to 2012.

^ Greater than 10% change from 2008-2009 to 2012

2.2.6.3 Land Use Processing

The land use processing was completed using the 2008-2009 SFWMD GIS coverage. Approximately 1,575 acres of the Caloosahatchee River Watershed, located in Charlotte County, were missing from the 2008-2009 SFWMD GIS coverage. Land use data from the 2008 SWFWMD GIS coverage were merged with the 2008-2009 SFWMD GIS coverage to fill in the missing area. The SFWMD and SWFWMD land use polygon for the Caloosahatchee River Watershed was intersected with the FDOT Right-of-Way coverage to create a composite land use representation for the watershed. The processed land use coverage is shown in **Figure 17**.

The final 2017 HSPF Model land use coverage was intersected with the 2011 NLCD impervious coverage to determine the total impervious area in each subbasin. The impervious areas were classified into seven separate impervious land use classifications, and impervious areas associated with similar land uses were grouped together. Impervious areas associated with Low Density Residential and Developed Open Space/Disturbed land uses were combined into the Low Density Residential (Impervious) classification. Impervious areas associated with Sugar Cane, Row and Field Crops, Nurseries / Ornamentals / Vineyards, Citrus Groves / Other Groves, Improved Pasture, and Rangeland / Unimproved Pasture / Woodland Pasture / Shrub land uses were combined into the Agricultural (Impervious) classification. Impervious areas associated with Upland Forests, Wetlands, and Water land uses were combined into the Other (Impervious) classification.

In low and medium density development areas, the effective impervious area (EIA) was the percentage of the mapped impervious coverage (MIA). In low and medium density areas, rooftops and other impervious areas associated with the single family residential areas are not always connected to the storm sewer or piped directly to the street curb, and runoff from roads is typically directed to grass swales (Sutherland 1995). In high density areas, most areas within a basin are directly connected to the storm sewer system. The MIA was converted to the EIA through the following equations (Sutherland 1995):

- High Density Residential (Impervious) areas are totally connected basins where 100% of the urban area is storm-sewered with all impervious surfaces appearing to be directly connected to the system.

  Equation: $EIA = MIA$

- Medium Density Residential (Impervious) are highly connected basins where the local drainage collector systems for the urban areas are predominately storm sewered with curb and gutters, no dry wells or other drainage infiltration areas are known to exist, and the rooftops are predominately connected to the streets or storm sewer system.

  Equation: $EIA = 0.4(MIA)^{1.2}$

- All other land uses are average basins where the local drainage collector systems for the urban areas are predominately storm sewered with curb and gutters, no dry wells or other drainage infiltration areas are known to exist, and the rooftops in the single family residential areas are not connected to the storm sewer or piped directly to the street curb.

  Equation: $EIA = 0.1(MIA)^{1.5}$

The total pervious and impervious land use acreages used in the 2017 HSPF Model are provided in **Table 21**.

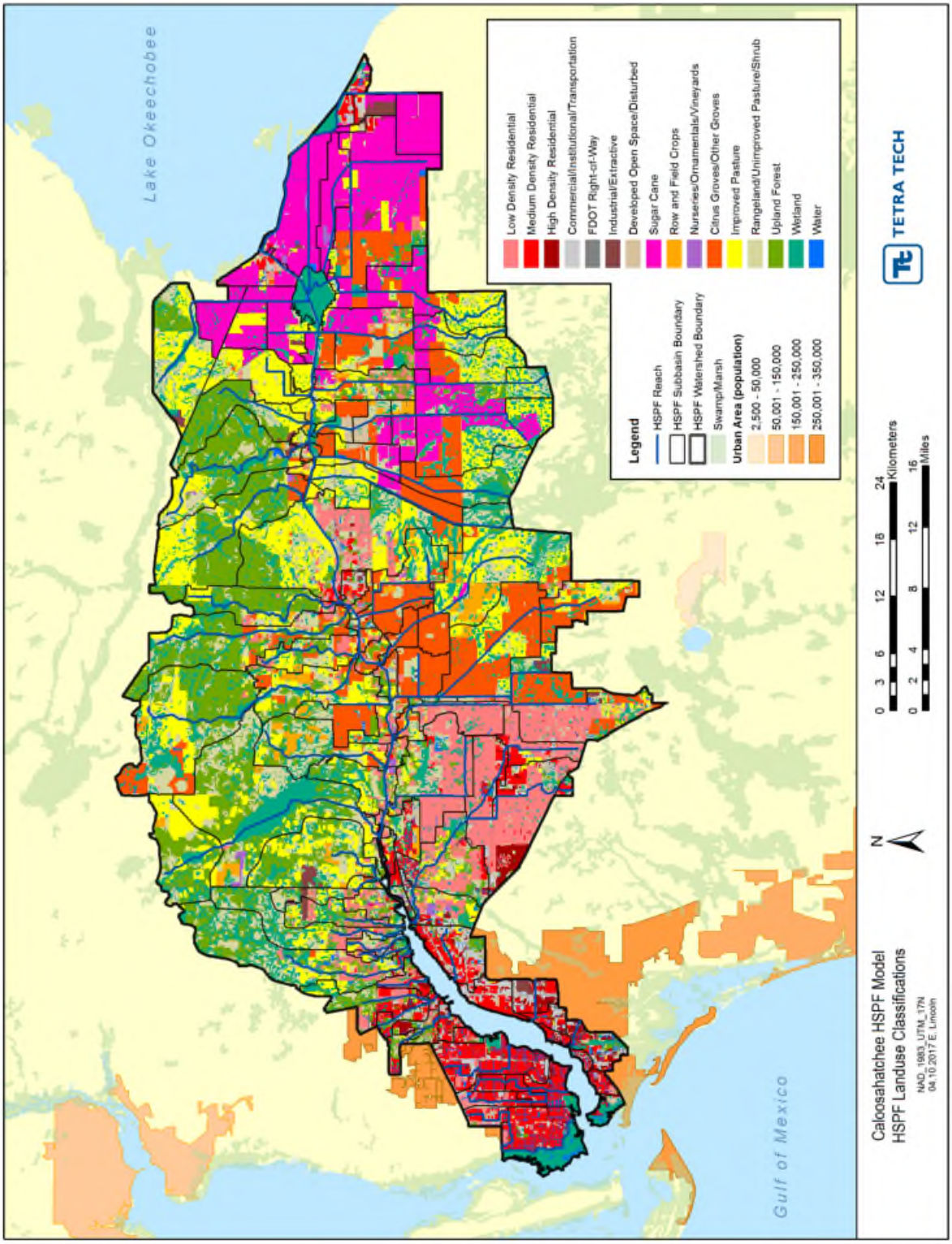

FIGURE 17: HSPF MODEL PROCESSED LAND USE CLASSIFICATIONS

TABLE 21: CALOOSAHATCHEE RIVER WATERSHED HSPF MODEL PERVIOUS LAND USE AND IMPERVIOUS LAND USE CLASSIFICATION CODES AND AREAS FOR THE 2017 HSPF MODEL

HSPF Land Use Code	Land Use Description	Land Segment	Total Acreage	% of Area
01	Low Density Residential (Pervious)	PERLND	74,606	8.5%
02	Developed Open Space / Disturbed (Pervious)	PERLND	21,587	2.5%
03	Medium Density Residential (Pervious)	PERLND	31,118	3.5%
04	High Density Residential (Pervious)	PERLND	6,162	0.7%
05	Commercial / Institutional / Transportation (Pervious)	PERLND	8,234	0.9%
06	Industrial / Extractive (Pervious)	PERLND	7,408	0.8%
07	FDOT Right-of-Way (Pervious)	PERLND	4,300	0.5%
08	Sugar Cane	PERLND	90,632	10.3%
09	Row and Field Crops	PERLND	13,753	1.6%
10	Nurseries / Ornamentals / Vineyards	PERLND	3,670	0.4%
11	Citrus Groves / Other Groves	PERLND	91,032	10.3%
12	Improved Pasture	PERLND	128,792	14.6%
13	Rangeland / Unimproved Pasture / Woodland Pasture / Shrub	PERLND	102,272	11.6%
14	Upland Forests	PERLND	121,115	13.8%
15	Wetlands	PERLND	133,590	15.2%
16	Water	PERLND	13,963	1.6%
01	Low Density Residential (Impervious)	IMPLND	4,691	0.5%
02	Medium Density Residential (Impervious)	IMPLND	9,924	1.1%
03	High Density Residential (Impervious)	IMPLND	3,760	0.4%
04	Commercial / Institutional / Transportation / Industrial / Extractive (Impervious)	IMPLND	7,017	0.8%
05	FDOT Right-of-Way (Impervious)	IMPLND	844	0.1%
06	Agriculture (Impervious)	IMPLND	699	0.1%
07	Other (Impervious)	IMPLND	1,242	0.1%
N/A	Total	TOTAL	880,408	100.0%

2.2.7 Septic Systems

Septic systems are designed to collect and treat wastewater that is eventually discharged into the surrounding soil, and this loading from septic systems can increase nutrient loads in waterbodies. Properly functioning septic systems do not fully remove nutrients from the wastewater supply and these nutrients leach into the local surface and subsurface waters. Conventional septic systems, for example, have an average nitrogen removal efficiency of 20% (Swann 2001) and failing septic systems can be even less efficient. Septic systems were not explicitly included in the 2009 or 2014 HSPF Models, but were represented implicitly through either event mean concentrations (EMCs) or in the buildup and wash off components during calibration. Tetra Tech developed estimated septic flows and loads for each subbasin in the 2017 HSPF Model, and these loads were input into the model as an explicit representation of the non-failing septic systems in the Caloosahatchee River Watershed. Failing septic systems were still represented implicitly in the buildup and washoff component parameterization.

In order to determine the number and location of septic systems in the Caloosahatchee River Watershed, the department provided Tetra Tech with a GIS coverage from Lee County with the septic systems in the unincorporated county, as well as the 2016 GIS coverages from the Florida Department of Health (FDOH) with the septic system locations for the entire Caloosahatchee River Watershed. Tetra Tech used the 2016 FDOH coverages for the four counties within the Caloosahatchee River Watershed (Lee, Charlotte, Glades, and Hillsborough) for consistency throughout the watershed. These coverages included information on the parcels with the "known septic" and "likely septic" throughout the watershed. In addition, Tetra Tech used the 2013 FDOH coverage in Lee County to represent the septic systems within the City of Cape Coral. The city has been actively phasing out septic systems in recent years, and due to the removal of the systems, they were not included in the 2016 FDOH GIS coverage. Therefore, the 2013 FDOH coverage was used to represent septic systems in the City of Cape Coral during the modeling time period. However, the 2013 FDOH coverage included septic systems in Cape Coral south of Pine Island Road that the city removed between 2002 and 2008. These septic systems were removed from the HSPF model to better represent conditions in Cape Coral as recommended by the City of Cape Coral.

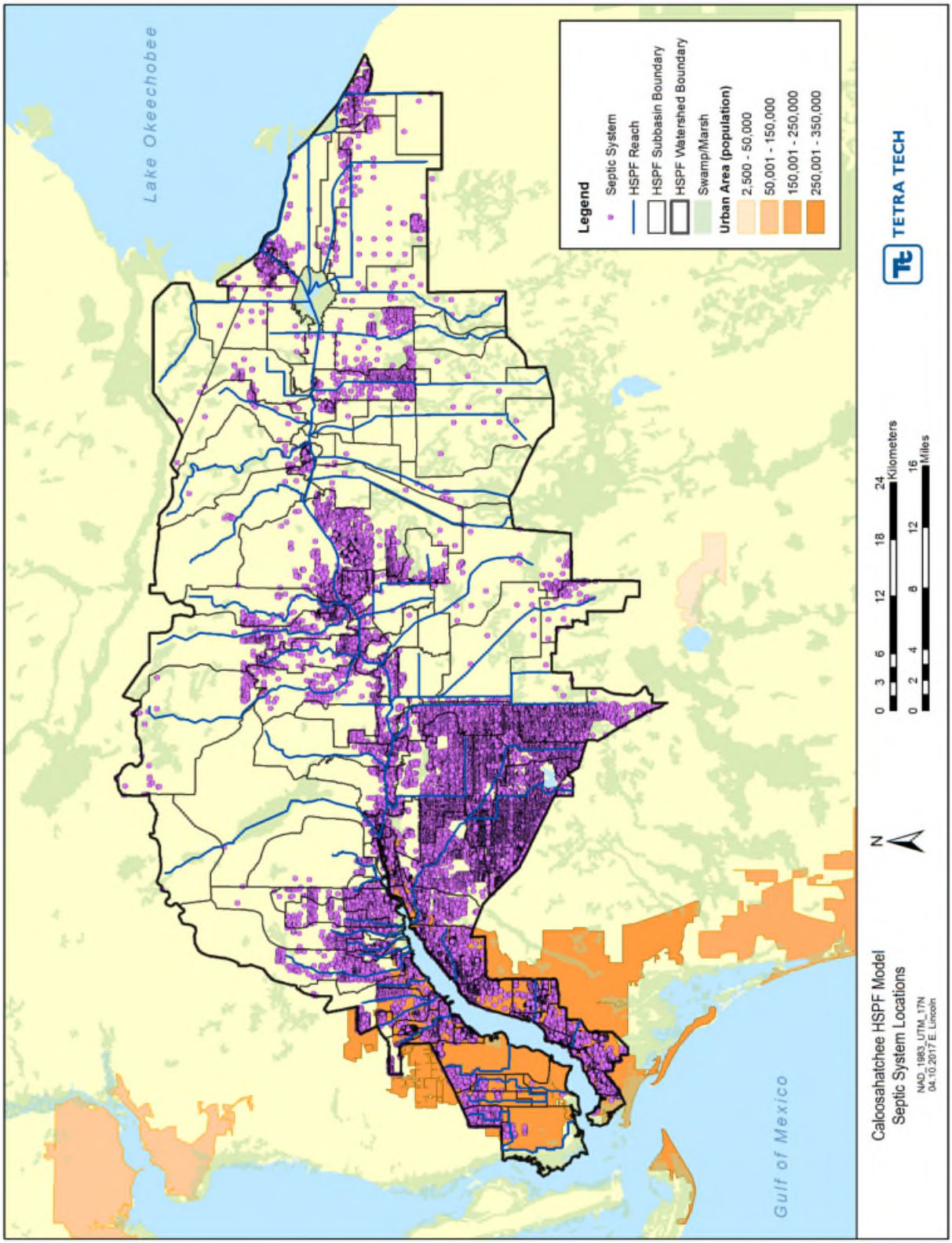

FIGURE 18: SEPTIC SYSTEM LOCATIONS AND PROXIMITY TO WATERBODIES

The percolate concentrations and decay rates from USEPA 2002 were used as the starting point in the Caloosahatchee River Watershed HSPF model. FDOH reviewed the initial proposed percolate concentrations and decay rates and provided the typical ranges of septic percolate concentrations entering the water table in the Caloosahatchee River Watershed. The department suggested that a decay rate for NOx of 0.02/day would be more reflective of conditions in the Caloosahatchee River Watershed. In addition, FDOH recommended revisions to the proposed OrgP and PO_4 effluent concentrations to reflect more recent data on phosphorus concentrations. The septic system effluent concentrations and decay rates that were used in the model are shown in **Table 22**.

TABLE 22: SEPTIC SYSTEM EFFLUENT CONCENTRATIONS AND DECAY RATES

Parameter	Percolate Concentration (mg/L)	Percolate Concentration Data Source	Decay Rate (1/day)	Decay Rate Data Source
BOD_5	2.5	FDOH	0.16	USEPA (2002)
OrgN	4.55	FDOH	0.1	USEPA (2002)
NH_3	0.2	FDOH	0.1	USEPA (2002)
NOx	21.1	FDOH	0.02	Department
OrgP	1.75	FDOH	0.014	USEPA (2002)
PO_4	0.75	FDOH	0.014	USEPA (2002)
TSS	0	USEPA (2002)	0	USEPA (2002)

The department provided the travel times based on the distance from the septic system to a waterbody shown in **Table 23**. The information in this table is based on an interpretation of the results from a recent study in the City of Port St. Lucie, Florida, by Sayemuzzaman and Ye 2015.

TABLE 23: TRAVEL TIME BASED ON DISTANCE FROM SEPTIC SYSTEM TO WATERBODY

Buffer Zone	Travel Distance (m)	Average Velocity (m/day)	Average Travel Time (days)
1	<50	0.182	137.6
2	51-200	0.126	1385.7
3	>200	0.060	9641.0

The concentration of each parameter for each buffer zone was calculated using the effluent concentration and decay rates in **Table 22** and the travel times in **Table 23**. The concentrations used in the model are provided in **Table 24**.

TABLE 24: PARAMETER CONCENTRATIONS IN EACH BUFFER ZONE

Parameter	Buffer Zone 1 Concentration (mg/L)	Buffer Zone 2 Concentration (mg/L)	Buffer Zone 3 Concentration (mg/L)
BOD_5	0.000	0.000	0.000
OrgN	0.000	0.000	0.000
NH_3	0.000	0.000	0.000
NOx	1.346	0.000	0.000
OrgP	0.255	0.000	0.000
PO_4	0.109	0.000	0.000
TSS	0.000	0.000	0.000

A watershed-wide septic system failure rate of 6.5% was determined based on the number of repair permits in the FDOH GIS coverage from 2013. Failure rate information was not included in the 2016 FDOH GIS

coverage. The number of septic systems and percentage of failing tanks by county and for the entire watershed are shown in **Table 25**.

TABLE 25: SEPTIC SYSTEM FAILURE RATE BASED ON FDOH COVERAGE

Area	# of Septic Systems	# Failing Systems	% Failing Systems
Charlotte County	80	5	6.3%
Glades County	308	97	31.5%
Hendry County	1,897	391	20.6%
Lee County*	54,140	3,163	5.8%
Entire Watershed	***56,425***	***3,656***	***6.5%***

* The number of septic systems is based on Lee County's coverage for the unincorporated portion of the county.

A watershed-wide average of 2.76 people per household was determined using the county specific information from the U.S. Census Bureau website (USCB 2015). The number of people per household by county and the watershed average are shown in **Table 26**. It was assumed that each individual used an average of 70 gallons of water per day, and that the flow loss rate was 15% (USEPA 2002). It was therefore assumed that each septic system had a percolate flow rate of 164 gallons per day (percolate flow rate x average people per household).

TABLE 26: PEOPLE PER HOUSEHOLD BY COUNTY AND WATERSHED-WIDE

Area	People per Household
Charlotte County	2.24
Glades County	3.05
Hendry County	3.15
Lee County	2.59
Watershed Average	***2.76***

The distance of each septic to a reach or canal in the NHD reach coverage was used to identify the buffer zone (**Table 27**). The processed septic system flows and water quality loads were aggregated to the subbasin level and incorporated into the HSPF model. Static subbasin loads were represented in the model using the HSPF GENER module. Septic system inputs are loaded directly to the simulated reach or, for the subbasins with no reaches, directly to the Caloosahatchee River Estuary.

TABLE 27: NUMBER OF SEPTIC SYSTEMS IN EACH BUFFER ZONE

Zone	Number
1 (<50m)	5,336
2 (51-200m)	18,005
3 (>200m)	40,394

Failing septic systems were simulated implicitly in the HSPF model upland buildup/washoff algorithms. The unit area export coefficients established by Harper (1994) and Soil and Water Engineering Technology (SWET) (2004) indicate that the Residential Low Density land use assumes failing septic systems are present. Therefore, calibration of the Low Density Residential land use to those target loads implicitly implies failing septic systems are represented.

2.2.8 Agricultural Withdrawals

The 2009 and 2014 HSPF Models represented agricultural irrigation as a point source that discharged directly to the HSPF model reaches. In the 2017 HSPF Model, agricultural irrigation was applied directly to the land surface. Agricultural irrigation time series were developed using crop water demand, growth coefficients, and evapotranspiration data.

2.2.8.1 Agricultural Irrigation Water Demand

Crops requiring irrigation in the Caloosahatchee River Watershed were classified into the following four crop categories: (1) sugar cane, (2) nurseries/ornamentals/vineyards, (3) citrus groves/other groves, and (4) all other crops (including blueberries, melons, peppers, small vegetables, and tomatoes). These categories correspond to the 2017 HSPF Model agricultural land use classifications and to crop classifications in the 2010 Florida Statewide Agricultural Irrigation Demand (FSAID) report and geodatabase. Based on local information provided by FDACS, the pasture areas shown as irrigated in the FSAID report were not included in the model.

Using the 2010 FSAID geodatabase, the irrigated acreage of each crop category was determined by subbasin (**Figure 19**). For each crop category, a general growing season and monthly crop evapotranspiration coefficient were determined. The general growing season information was based on the south zone crop planting and harvesting assumptions information found in Table E-1c of the 2010 FSAID report. **Table 28** summarizes the irrigated area by major crop category and growing season for the Caloosahatchee River Watershed.

TABLE 28: ACREAGE AND GROWING SEASON FOR THE MAJOR CROP CATEGORIES

Crop Category	Growing Season	Area (acres)
Sugar Cane	Perennial	84,470
Nurseries/Ornamentals/Vineyards	Perennial	4,281
Citrus Groves/Other Groves	Perennial	57,121
All Other Crops	September – March	10,375
Total	Total	156,247

For each major crop category, an associated monthly crop evapotranspiration coefficient was determined using information from sources provided by FDACS. FDACS provided the modified Blaney-Criddle model for Excel, which SFWMD uses to determine irrigation needs. **Table 29** through **Table 31** show the monthly growth coefficients for perennial crops and the coefficients for annual crops from the modified Blaney-Criddle model. The monthly coefficients for perennial crops are based on the water needs of the plant based on the growth stage throughout the year (such as bloom, fruit set, fruit development, and fruit maturation) (**Table 29)**. The coefficients for the annual crops are based on the water demand of the plant at different stages in the three- or four-month growing cycle (such as planting, initiation of flowering, maturity, and harvest) (**Table 30** and **Table 31**).

TABLE 29: MONTHLY GROWTH COEFFICIENTS FOR PERENNIAL CROPS

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Citrus	0.63	0.66	0.68	0.70	0.71	0.71	0.71	0.71	0.70	0.68	0.67	0.64
Sugarcane	0.39	0.30	0.53	0.61	0.70	0.79	0.79	0.84	0.73	0.88	0.72	0.69

TABLE 30: MONTHLY GROWTH COEFFICIENTS FOR ANNUAL CROPS – THREE-MONTH GROWING SEASON

Crop	Month 1 of Growing Season	Month 2 of Growing Season	Month 3 of Growing Season
Melons	0.56	0.79	0.72
Tomato	0.50	0.93	0.84
Small vegetables	0.54	0.81	0.62

TABLE 31: MONTHLY COEFFICIENTS FOR ANNUAL CROPS – FOUR-MONTH GROWING SEASON

Crop	Month 1 of Growing Season	Month 2 of Growing Season	Month 3 of Growing Season	Month 4 of Growing Season
Melons	0.52	0.75	0.79	0.71
Tomato	0.47	0.76	1.00	0.80
Small vegetables	0.48	0.77	0.81	0.57

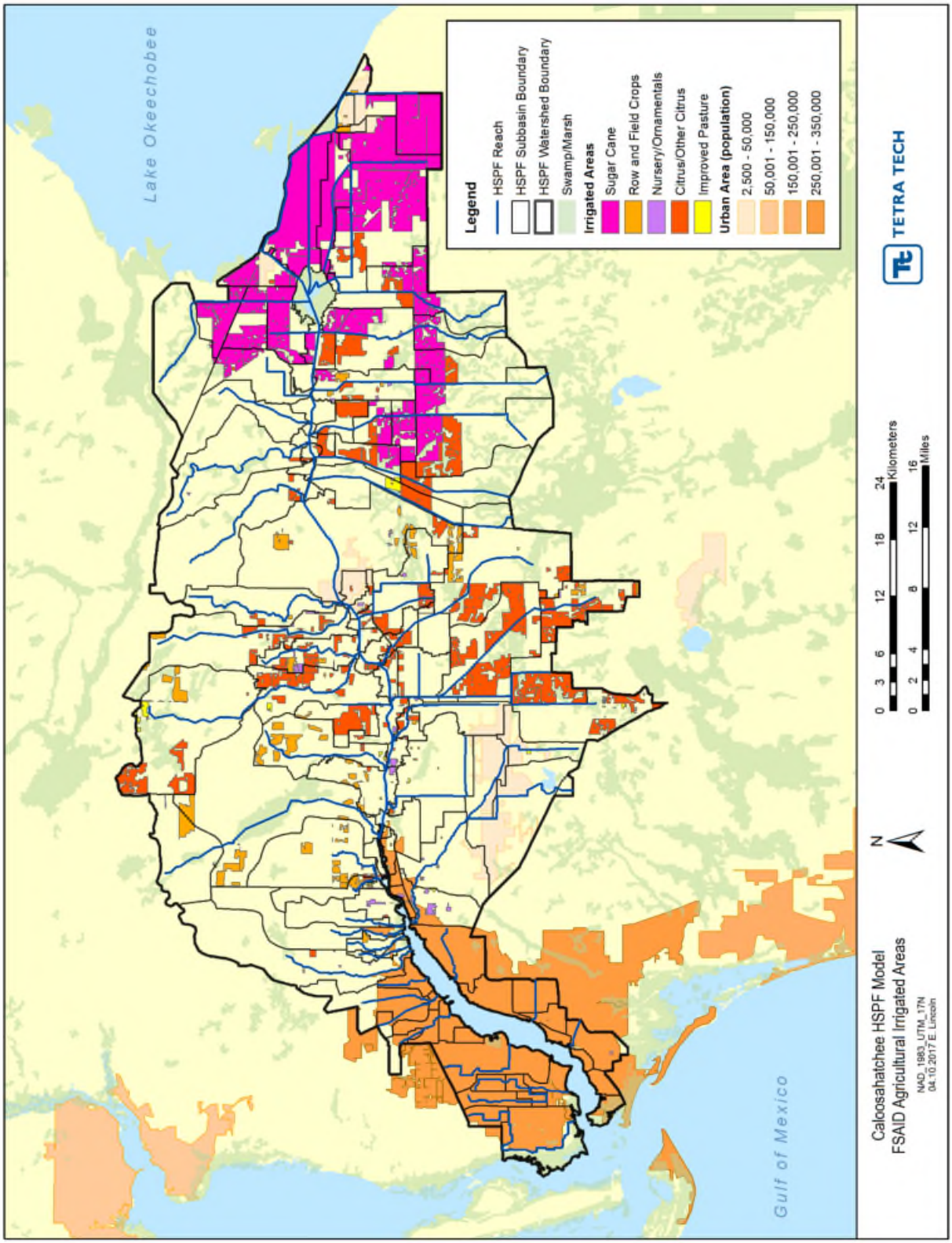

FIGURE 19: FSAID AGRICULTURAL IRRIGATED AREAS BY CROP TYPE

SFWMD also used the AFSIRS model to determine agricultural irrigation demand. The model included a GIS coverage with the reference evapotranspiration (RETo) value for each date (provided 1/1/1996 through 12/31/2014 to match the Caloosahatchee model period) at the center of each of the model grid cells. The AFSIRS model provided information on the irrigated and total root depths by crops, crop water use coefficients, and allowable water use depletions for perennial and annual crops. These factors are shown in **Table 32** and **Table 33** for perennial and annual crops, respectively.

TABLE 32: PERENNIAL CROPS WATER USE COEFFICIENT (KC) DATA BY MONTH

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Citrus	0.9	0.9	0.9	0.9	0.95	1	1	1	1	1	1	1
Container nursery	1	1	1	1	1	1	1	1	1	1	1	1
Field nursery	1	1	1	1	1	1	1	1	1	1	1	1
Sugarcane	0.8	0.6	0.55	0.8	0.95	1	1.05	1.05	1.05	1	0.95	0.9

Notes: Ratio of RET for a specific crop to the reference value of potential ET.

TABLE 33: ANNUAL CROPS: ROOT ZONE AND WATER USE COEFFICIENT DATA

Crop	Depth (in)[1]	Depth (in)[1]	KC[2]	KC[2]
Melons	8	18	0.95	0.65
Peppers, green	8	12	0.95	0.8
Small vegetables	8	12	1	0.85
Tomato	9	12	1.05	0.75

Notes:
[1]Depth = first column is the minimum annual crop irrigated root zone depth (depth that would be irrigated at the beginning of the growing season). Second column is the maximum irrigated crop root zone depth (maximum root zone depth that would be obtained during peak growth stages, which would be expected to be maintained for the remainder of the crop growing season).
[2]KC = crop water use coefficient; ratio of RET for a specific crop to the reference value of potential ET. The first KC value correlates to the root depth at the beginning of the growing season and the second value is associated with the root depth at the peak growth stages.

Tetra Tech also found a University of Florida – Institute of Food and Agricultural Science report (Kisekka et al. 2013) that provides information on crop coefficients for perennial and annual crops that are commonly grown in Florida. **Table 34** shows the coefficients for perennial crops and **Table 35** shows the coefficients for annual crops.

TABLE 34: TYPICAL CROP COEFFICIENTS (KC) FOR PERENNIAL CROPS COMMONLY GROWN IN FLORIDA

Month	Citrus
January	0.79
February	0.86
March	0.93
April	0.97
May	1.03
June	1.05
July	1.05
August	1.03
September	1.00
October	0.95
November	0.87
December	0.79

TABLE 35: TYPICAL CROP COEFFICIENTS (KC) AT VARIOUS GROWTH STAGES FOR ANNUAL CROPS COMMONLY GROWN IN FLORIDA

Crop	Initial Stage	Mid-stage	Late-stage
Tomatoes	0.4	0.9	0.75
Green pepper	-	1.05	0.9
Strawberries	0.2–0.4	0.5	0.6

For sugar cane, the monthly crop ET coefficients were determined using a monthly average of the data presented in **Table 29** and **Table 32**. For nurseries/ornamentals/vineyards, the monthly crop ET coefficients were determined from the data in **Table 32**, as it was the only reference that included data for nurseries. For citrus groves/other groves, the monthly ET coefficients were determined using a monthly average of the data in **Table 29**, **Table 32**, and **Table 34**. For all other crops, the monthly crop ET coefficients were determined using a weighted average of the various crop coefficients (blueberries, melons, peppers, small vegetables, specialty farms, and tomatoes) found in **Table 30**, **Table 31**, **Table 33**, and **Table 34**. Since this category includes crops with different growing seasons, only the crops growing in any specific month were used for weighting in that month. **Table 36** summarizes the monthly crop ET rates by major crop category.

TABLE 36: MONTHLY CROP ET RATES BY MAJOR CROP CATEGORY (IN/DAY)

Month	Sugar Cane	Nurseries/ Ornamentals/ Vineyards	Citrus Groves/ Other Groves	All Other Crops
January	0.60	1.00	0.77	0.54
February	0.45	1.00	0.81	0.77
March	0.54	1.00	0.84	0.75
April	0.71	1.00	0.86	0.00
May	0.83	1.00	0.90	0.00
June	0.90	1.00	0.92	0.00
July	0.92	1.00	0.92	0.00
August	0.95	1.00	0.91	0.00
September	0.89	1.00	0.90	0.49
October	0.94	1.00	0.88	0.82
November	0.84	1.00	0.85	0.84
December	0.80	1.00	0.81	0.57

The 2010 FSAID geodatabase provided information on the areas within the Caloosahatchee River Watershed that are irrigated including the type of crop, type of irrigation, acres that are irrigated, and an estimate of water needed for irrigation based on the FSAID model. Tetra Tech determined an area-weighted average irrigation efficiency based on the efficiencies of different irrigation methods in the 2010 FSAID Report. **Table 37** shows the area-weighted irrigation efficiency for each major crop category.

TABLE 37: IRRIGATION EFFICIENCY FOR EACH MAJOR CROP CATEGORY

Crop Category	Irrigation Efficiency
Sugar Cane	0.700
Nurseries/Ornamentals/Vineyards	0.627
Citrus Groves/Other Groves	0.858
All Other Crops	0.711

The RETo was determined using the predictions from the AFSIRS model (Brown 2013). Daily average RETo was determined for each NEXRAD zone. The daily values were disaggregated to an hourly time step for input into the HSPF model. The disaggregation routine was based on the length of each day.

The irrigation application volume for each subbasin was determined using crop acreages, crop evapotranspiration time series, and the subbasin assigned NEXRAD zone precipitation data. Irrigation application was calculated as the difference between PET (in) and effective precipitation (P_e). P_e was calculated using equation 1 and equation 2 (USDA 1993).

$$P_e = SF * (0.70917\ P_t^{0.82416}) - 0.11556) * (10^{0.02426ETc}) \qquad \text{Equation 1}$$

$$SF = (0.531747 + 0.295164\ D - 0.057697\ D^2 + 0.003804\ D^3) \qquad \text{Equation 2}$$

where P_t is the monthly total precipitation (in.), D is equal to 50 percent of the available water capacity of the soil (in.), and ET_c is the monthly crop evapotranspiration demand

A P_e of 0.2 inches was defined as the critical amount of rainfall that results in no irrigation on that day or the succeeding day. Available water capacity of the soil (in/in) was determined on a subbasin basis using Soil Survey Geographic Database (SSURGO) coverage for the Caloosahatchee River Watershed. In order to convert the volumetric available water capacity to a unit available water capacity, the volumetric available water capacity was multiplied by the crop root depth (**Table 38**).

TABLE 38: TOTAL CROP ROOT DEPTH (IN)

Crop Category	Root Depth (in)
Sugar Cane	36
Nurseries/Ornamentals/Vineyards	8
Citrus Groves/Other Groves	60
All Other Crops	12

2.2.8.2 Agricultural Irrigation Water Supply Sources

Agricultural irrigation water demands were established for the Caloosahatchee River Watershed HSPF model based on the methods described above. Irrigation water demand time series were developed for each cropland type and NEXRAD precipitation zone represented in the model (e.g. sugar cane fields in NEXRAD Zone 2), and these time series were input into the model at a daily time step.

In order to establish irrigation sources in the 2017 HSPF Model, permitted wells (**Figure 20**) and agricultural irrigation sources (**Figure 21**) in the Caloosahatchee River Watershed were reviewed. The agricultural irrigation shapefile, provided by SFWMD, displays the dominant source of irrigation water in each region. Information was not available that provided the daily, monthly, or yearly distribution of irrigation water for each subbasin or region.

In the HSPF model, water needed to satisfy the irrigation demands can be obtained from external sources (i.e. deep ground water or neighboring watershed), model simulated shallow ground water, or model stream reaches. However, the HSPF model has a limitation where the irrigation module that allows for water to be withdrawn only from one reach in each NEXRAD zone. In addition, although water withdrawn from internal sources for irrigation removes the associated water quality loads, it does not return the associated water quality loads to the land when the irrigated water is applied.

In regions where ground water was the dominant source of water, the permitted well shapefile coverage was used to determine the percentage and location of ground water used for irrigation purposes. Permitted wells that withdraw ground water from the water table aquifer or from the surficial aquifer were identified as using shallow ground water resources. Deep ground water wells were established as those that withdrawal from the Lower Tamiami, Floridan, Sandstone, Hawthorn or other aquifer. The fraction of ground water pumping from shallow and deep aquifers in each subbasin was determined based on the pump capacity provided in the permitted wells shapefiles. The pump capacities for shallow and deep wells in subbasin 125, for example, were 695 and 7,500 cfs. Shallow and deep ground water irrigation sources were then established as 8% and 92%, respectively. In regions that did not contain permitted wells but were classified as using ground water for agricultural irrigation, surface water was used to supply irrigation.

In regions where the Caloosahatchee River or Lake Okeechobee was identified as the dominant source of irrigation water, it was assumed that water from local reaches and canals was withdrawn for irrigation purposes. In each NEXRAD zone, the reach with the largest volume of storage water was selected to be used for surface water withdrawals. For agricultural irrigation in subbasins where the source was unclassified, water sources were established as either shallow ground water or external based on the presence of wells in the subbasin. Fractions of irrigation water from these sources were applied to cropland segments within each subbasin. Some subbasin overlaid more than one dominant source region. In these subbasins, water was withdrawn from various sources based on the fraction of irrigated agricultural land located in each dominant source region.

The assigned fractions of irrigation water from the three sources used in the 2017 HSPF Model are shown in **Table 39**. Irrigation water applied to cropland is routed to interception storage, the soil surface, upper soil zone, lower soil zone, and active ground water storage following the distribution shown in **Table 40**.

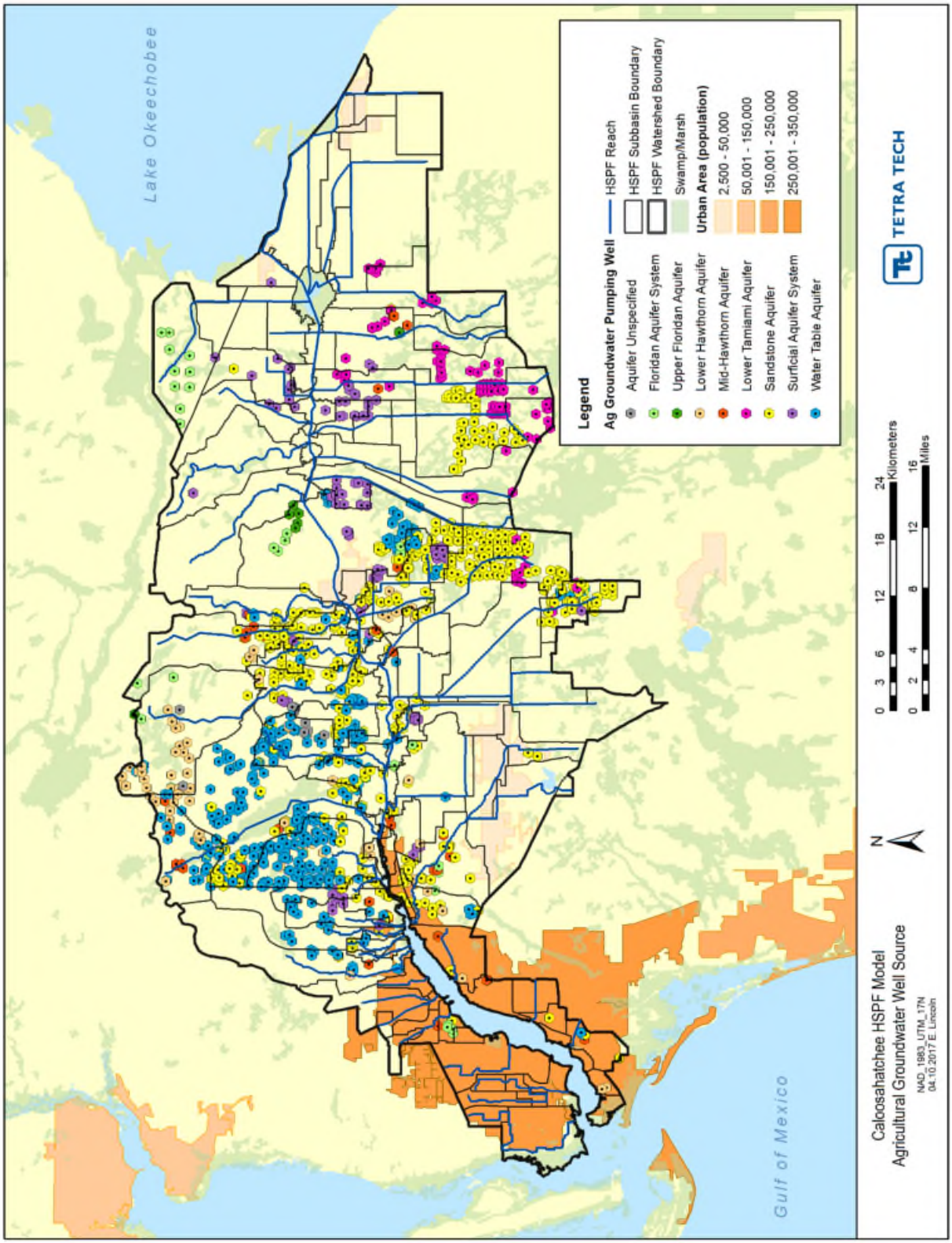

FIGURE 20: PERMITTED WELLS IN THE CALOOSAHATCHEE RIVER WATERSHED

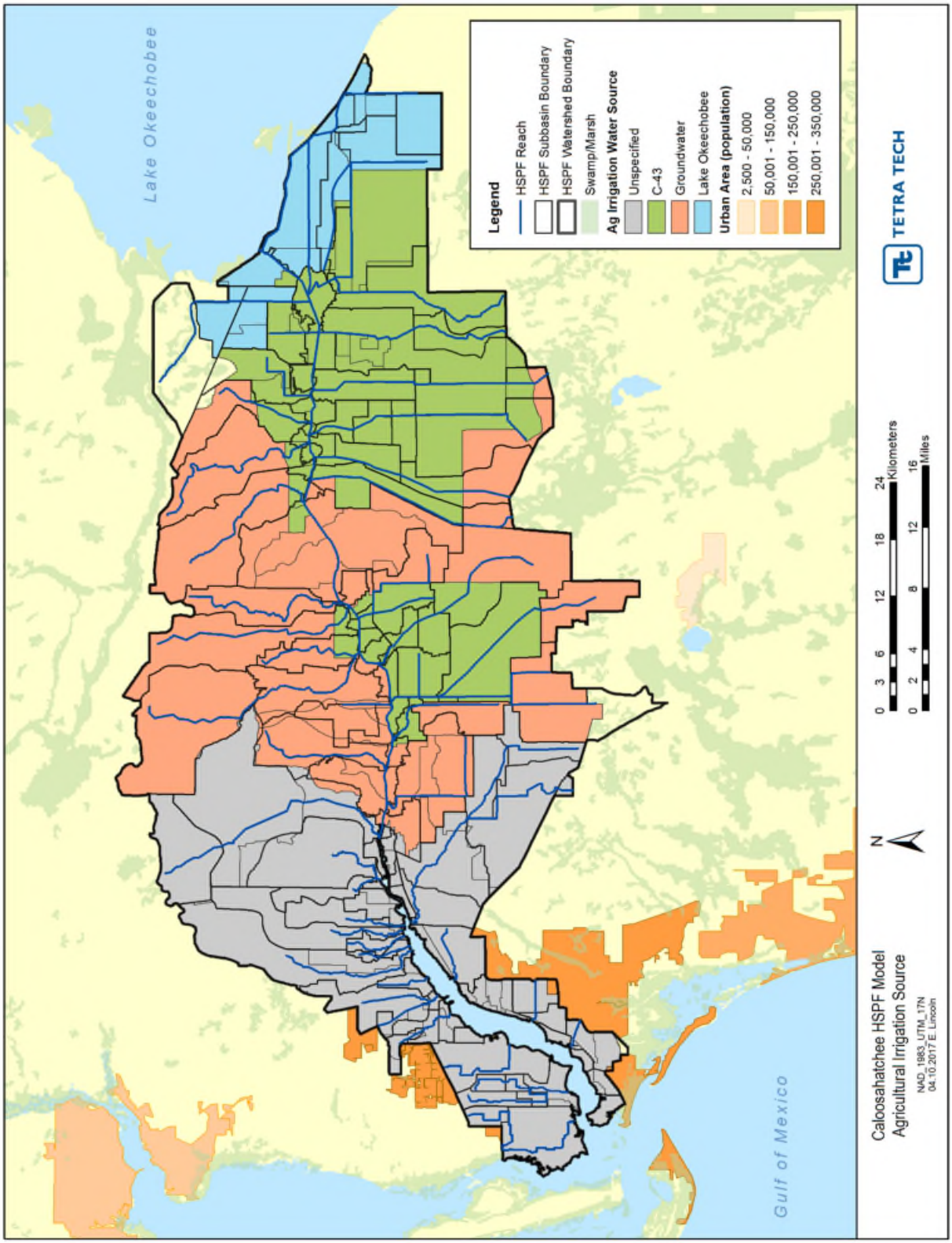

FIGURE 21: WATER SOURCES FOR AGRICULTURAL IRRIGATION IN THE CALOOSAHATCHEE RIVER WATERSHED

TABLE 39: AGRICULTURAL IRRIGATION SOURCES FOR SUBBASINS IN THE CALOOSAHATCHEE RIVER WATERSHED HSPF MODEL

Subbasin	Surface Water	Shallow Ground Water	External Sources
101	0%	0%	100%
102	0%	0%	100%
103	0%	0%	100%
104	0%	0%	100%
105	0%	0%	100%
106	0%	0%	100%
107	0%	0%	100%
108	0%	0%	100%
109	0%	0%	100%
110	0%	0%	100%
111	0%	0%	100%
112	0%	0%	100%
113	0%	0%	100%
114	0%	0%	100%
115	0%	0%	100%
116	0%	0%	100%
117	0%	100%	0%
118	0%	0%	100%
119	0%	100%	0%
120	0%	100%	0%
121	0%	100%	0%
122	0%	100%	0%
123	0%	0%	100%
124	0%	100%	0%
125	0%	100%	0%
126	0%	0%	100%
127	0%	99%	1%
128	0%	100%	0%
129	0%	0%	100%
130	0%	0%	100%
131	0%	0%	100%
132	0%	100%	0%
133	0%	0%	100%
134	0%	0%	100%
135	0%	0%	100%
136	0%	100%	0%
137	0%	0%	100%
138	0%	100%	0%
139	0%	0%	100%
140	0%	0%	100%
141	0%	0%	100%
142	0%	0%	100%
143	0%	0%	100%
144	0%	0%	100%
145	0%	0%	100%
146	0%	0%	100%
147	0%	82%	18%
148	0%	4%	96%
149	0%	51%	49%
150	0%	66%	34%
151	22%	31%	47%
152	100%	0%	0%
153	0%	0%	100%
154	36%	29%	35%

Subbasin	Surface Water	Shallow Ground Water	External Sources
155	0%	49%	51%
156	100%	0%	0%
157	100%	0%	0%
158	100%	0%	0%
159	100%	0%	0%
160	100%	0%	0%
161	100%	0%	0%
162	100%	0%	0%
163	0%	9%	91%
164	61%	5%	34%
165	65%	0%	35%
166	100%	0%	0%
167	100%	0%	0%
168	27%	1%	72%
169	0%	22%	78%
170	0%	15%	85%
171	22%	7%	71%
172	100%	0%	0%
173	100%	0%	0%
174	100%	0%	0%
175	0%	75%	25%
176	63%	11%	26%
177	6%	8%	86%
178	2%	33%	66%
179	0%	25%	75%
180	3%	47%	50%
181	5%	0%	95%
182	100%	0%	0%
183	93%	6%	1%
184	100%	0%	0%
185	100%	0%	0%
186	100%	0%	0%
187	36%	0%	64%
188	100%	0%	0%
189	5%	95%	0%
190	100%	0%	0%
191	100%	0%	0%
192	100%	0%	0%
193	100%	0%	0%
194	67%	0%	33%
195	100%	0%	0%
196	35%	65%	0%
197	100%	0%	0%
198	100%	0%	0%
199	100%	0%	0%
200	87%	0%	13%
201	100%	0%	0%
202	100%	0%	0%
203	100%	0%	0%
204	100%	0%	0%
205	100%	0%	0%
206	100%	0%	0%
207	100%	0%	0%
208	100%	0%	0%
209	100%	0%	0%
210	0%	0%	100%
211	100%	0%	0%

Subbasin	Surface Water	Shallow Ground Water	External Sources
212	100%	0%	0%
213	100%	0%	0%
214	100%	0%	0%
215	100%	0%	0%
216	100%	0%	0%
217	100%	0%	0%
218	100%	0%	0%
219	100%	0%	0%
220	100%	0%	0%
221	0%	0%	100%

Notes: Surface water and shallow ground water supplies for irrigation are withdrawn from the model reaches and active ground water storage, respectively. Sources of water that are external to the HSPF model domain (e.g. ground water pumped from deep aquifers) that are used to satisfy agricultural irrigation demands are also applied to cropland in the model.

TABLE 40: IRRIGATION APPLICATION TARGET FRACTIONS

Target	Fraction
Interception storage	0.4
Soil surface	0.2
Upper soil zone	0.2
Lower soil zone	0.1
Active ground water storage	0.1

2.2.8.3 Agricultural Irrigation Pumping

The reaches with bidirectional flow caused by agricultural pumping and flood protection pumping are located south of the Caloosahatchee River where the land use is predominately agriculture. The bidirectional flow occurs when large pumps transport water upstream over man-made levees and dikes located in the canals. Farmers use the water in the canals for agricultural irrigation, and remove the water from the main canals to a network of smaller ditches and canals that can transport water across their property and, in some areas, transport water across the HSPF model subbasin delineation boundaries. Water not used by the farmers for irrigation is returned towards the Caloosahatchee River via gravity flow. The following reaches were identified as having bidirectional flow caused by agricultural pumping and irrigation (**Figure 22**):

- Caloosahatchee River (between S-77 and S-78)
- Townsend Canal
- C-3
- Hilliard Canal
- Flaghole Canal
- Disston Canal
- Industrial Canal

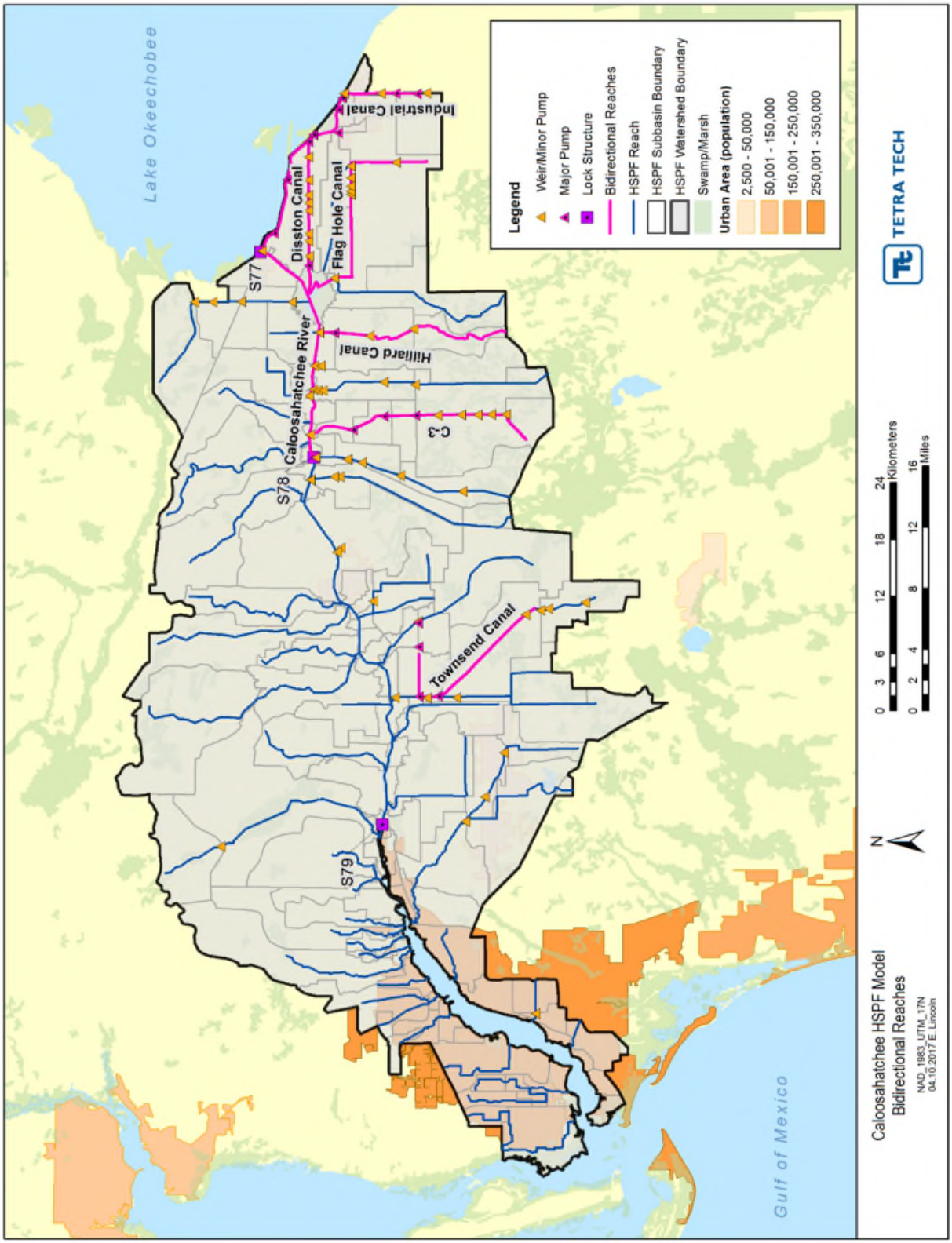

FIGURE 22: REACHES WITH BIDIRECTIONAL FLOW DUE TO AGRICULTURAL AND FLOOD PROTECTION PUMPING

The HSPF model does not have the ability to represent bidirectional flow. In order to represent bidirectional flow in the agricultural time series, Tetra Tech evaluated a methodology to withdraw water from downstream reaches and input that water into upstream reaches to represent the pumping. Pumping records are not available to provide information as to the timing and volume of water moved through the canal systems. It was assumed that pumping occurred when precipitation was not sufficient to satisfy crop requirements and farmers need supplementary water supplies. Furthermore, it was assumed that the volume of water pumped upstream in each canal was directly related to crop irrigation demands. Farmers likely pump excess water supplies from the main stem of the river to ensure that crop irrigation demands can be fully satisfied. Water supplies not used by the farmers are returned to the downstream reaches and Caloosahatchee River via gravity flow.

The timing and volume of water pumped to irrigate cropland likely varies according to irrigation demands in the region. Irrigation demand time series were developed for citrus, nursery/ornamentals, sugar cane, and row and field crops by NEXRAD weather zone. The volume of water routed through a canal each day to satisfy the local irrigation requirement was computed as follows:

$$P_{ci} = I_{ci} A_c S_c f$$

where P_{ci} is the flow of water pumped for irrigation of crop c on day i [cfs]; I_{ci} is the irrigation demand for crop c on day i [in/d]; A_c is the irrigated field area of crop c [ft^2]; S_c is the fraction of the irrigation demand satisfied with surface water resources; and f is a unit conversion factor. Relevant information about the irrigated cropland in the Caloosahatchee River Watershed model is provided in **Table 41**. Excess water, computed as a fraction of the daily irrigation demand, is pumped through the canals, retained in model reaches, and then returned to the Caloosahatchee River. It was assumed that the water retained in canal reaches decreased as supplies are pumped further from the main stem.

TABLE 41: MODELED CROPLAND IRRIGATED WITH PUMPED WATER SUPPLIES

Canal	Crop Irrigated with Pumped Water	Irrigated Area (acres)	Fraction of Irrigation Demand Supplied by Surface Water	Mean Daily Depth of Water Applied for Irrigation (in/d)
Townsend Canal	Citrus	23,748	0.78	0.014
Townsend Canal to LPDD Header Canal 1	Citrus	18,742	0.90	0.013
C-3 Canal	Sugar cane	9,870	0.83	0.012
C-3 Canal	Citrus	13,138	0.72	0.013
Hilliard Canal	Sugar cane	18,167	0.96	0.013
Hilliard Canal	Citrus	10,487	1.00	0.014
Disston Canal	Sugar cane	45,920	1.00	0.012

The HSPF model has a limitation where the irrigation module only allows for water to be withdrawn from one reach in each NEXRAD zone. To satisfy agricultural irrigation demand, water was withdrawn from the major reaches in each NEXRAD zone, which typically corresponded to the most downstream reach in each area where bidirectional pumping occurred. Since water was being withdrawn to satisfy irrigation demand, insufficient quantities of water were available to meet the pumping demand. When insufficient

quantities were available, the HSPF model would augment the withdrawn flow with water from an external source, causing an overall increase in baseflows in the model.

The agricultural irrigation pumping and bidirectional flow that occurs throughout the Caloosahatchee River Watershed agricultural area was therefore assumed to be implicitly represented through the agricultural irrigation module. As stated previously, this setup removes water from one reach in each NEXRAD zone and distributes water throughout the zone, including upstream subbasins. However, bidirectional flow was represented through modification to the HSPF model hydraulic representation in the S-4 basin, which includes both the Disston Canal and Industrial Canal. **Section 2.2.11.1** has additional information on the hydraulic setup and representation in the S-4 basin.

2.2.9 NPDES and Reuse Facilities

The department provided Tetra Tech with the permit and discharge monitoring report (DMR) data for the three domestic wastewater (DW) and industrial wastewater (IW) treatment facilities with surface water discharges that were added in the HSPF model (**Table 42** and **Figure 23**). The department also provided the data for the 11 reuse facilities in the watershed with permitted discharges greater than 0.09 million gallons per day (MGD) that were added in the HSPF model (see **Table 43** and **Figure 24**). Additionally, the department provided the DMR data for five DW and one IW NPDES facilities discharging directly to the EFDC model (**Table 44**).

TABLE 42: NPDES FACILITIES TO INCLUDE IN THE 2017 HSPF MODEL

NPDES ID	Facility Name	Type	Design Capability (MGD)
FL0037541	E R Jahna Ind - Ortona Mine	IW	4.0
FL0040088	Cape Coral, City of - RO WTP	IW	1.2
FL0040665	Clewiston, City of - WWTF	DW	1.5

TABLE 43: REUSE FACILITIES TO INCLUDE IN THE 2017 HSPF MODEL

Facility ID	Facility Name	Facility Type	Usage(s)	Permitted Capacity (MGD)
FL0021261	Fort Myers Central AWWTF	DW	Irrigation and commercial uses	6.000
FL0030007	Cape Coral, City of - Everest WRF	DW	Irrigation	29.400
FL0039829	Fiesta Village Advance Wastewater Treatment Plant	DW	Stormwater lake storage	2.976
FL0040665	Clewiston, City of - WWTF	DW	Land application system (LAS) and irrigation	2.020
FLA014283	LaBelle, City of	DW	LAS	0.750
FLA014290	Port LaBelle	DW	Percolation pond	0.499
FLA014548	Del Prado WWTF (formerly North Fort Myers Utility)	DW	Irrigation	5.251
FLA014565	Lehigh Acres WWTP	DW	Percolation ponds and irrigation	4.040
FLA014676	River Trails Mobile Home Park	DW	Percolation pond	0.097
FLA016891	Glades County Correctional	DW	LAS and wetland application site	0.315
FLA144215	Fort Myers Beach STP	DW	Irrigation, commercial uses, and ponds	5.540

TABLE 44: NPDES FACILITIES IN THE EFDC MODEL

NPDES ID	Facility Name	Type	Design Capacity (MGD)	EFDC Model Cell I	EFDC Model Cell J
FL0021261	Fort Myers Central AWWTF	DW	11.0	71	31
FL0021270	South AWWT Facility	DW	12.0	61	31
FL0030007	Cape Coral, City of - Everest WRF	DW	15.1	62	32
FL0030325	Waterway Estates	DW	5.0	65	36
FL0039829	Fiesta Village Advanced WWTF	DW	1.5	55	30
FL0001490	Florida Power and Light Fort Myers	IW	590.6	79	15

The observed average flow and water quality results for each of the facilities are shown in **Table 45**. The number of end of pipe flow and water quality parameter observations reported by each facility are shown in **Table 46**. For most parameters, results were reported monthly. The period of record for the available data is shown in **Table 47**. The available measured data for these facilities were used in the HSPF model to determine the total loading from each facility. The data were used to fill short- and long-term gaps in the data records. For example, if a facility has TN data for ten years of the modeling period, the monthly long-term average of the measured data was used to represent the expected TN concentration for the remaining portion of the simulation period, where data were unavailable. When at least one measured data point was available for nutrients, a species percentage was used to determine the water quality concentrations for nitrogen and phosphorus. For example, if measured total phosphorus (TP) at a facility averaged 0.08 mg/L, then it was assumed that PO_4 was 90% of the TP concentration and OrgP was 10% of the TP concentration. If no TP data were available, then the default TP, PO_4, and OrgP concentrations were used.

Observed BOD is reported as CBOD 5-day (CBOD5). For the 2017 HSPF model water quality setup, Tetra Tech has assumed that CBOD5 is equal to CBOD, which is simulated by the HSPF model. The HSPF model only has a single CBOD class, and it can be utilized as either CBOD5 or CBOD-ultimate (CBODU) depending in part on the residence time in the model. CBOD5 decay is typically much faster than CBODU and more representative of conditions in smaller to medium sized watersheds, such as the Caloosahatchee River Watershed, and most instream data are CBOD5. CBODU is typically more representative of large, long-residence river systems, such as the Mississippi River. All other organics were classified as refractory OrgC in the model.

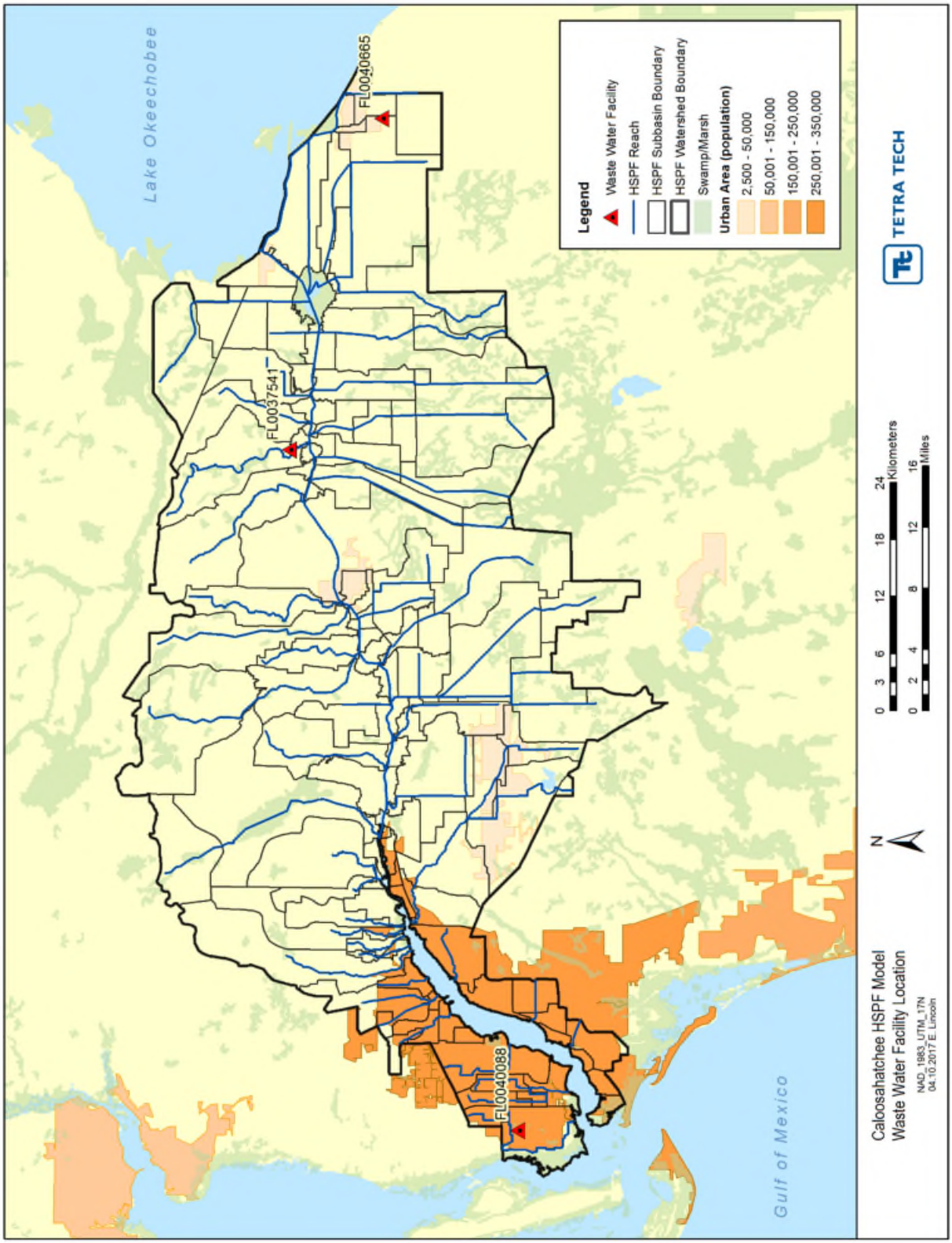

FIGURE 23: WASTEWATER FACILITIES INCLUDED IN THE HSPF MODEL

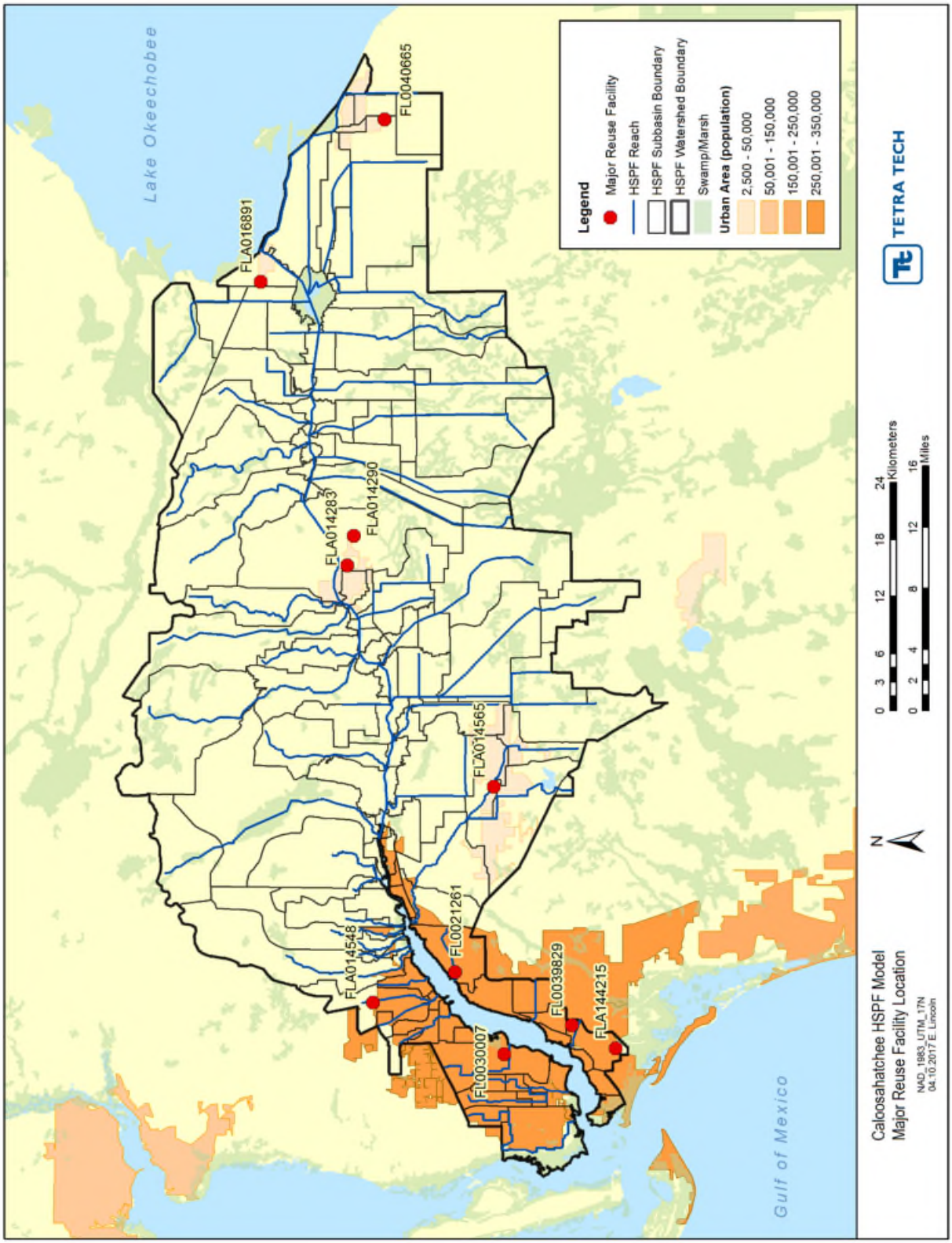

FIGURE 24: MAJOR AND MINOR REUSE FACILITIES LOCATED IN THE CALOOSAHATCHEE RIVER WATERSHED

TABLE 45: OBSERVED AVERAGE VALUE FOR AVAILABLE FLOW AND WATER QUALITY DATA FOR NPDES AND REUSE FACILITIES

Facility Type	Permit	Flow (cfs)	NH_3 (mg/L)	NOx (mg/L)	OrgN (mg/L)	TN (mg/L)	PO_4 (mg/L)	OrgP (mg/L)	TP (mg/L)	CBOD5 (mg/L)	TSS (mg/L)	DO (mg/L)	WTEM (Deg C)
NPDES (HSPF)	FL0037541	9.49	0.021*	>0.1*	-	0.29*	-	-	>0.1*	>2.0*	3.6*	-	-
NPDES (HSPF)	FL0040088	3.15	-	-	-	1.81	-	-	0.23	-	-	7.56	-
NPDES (HSPF)	FL0040665	2.36	0.38	0.23	1.77**	2.28	-	-	0.25	3.43	4.19	5.06	26.73
NPDES (EFDC)	FL0021261	4.88	-	-	-	1.65	-	-	0.15	2.41	4.50	5.52	-
NPDES (EFDC)	FL0021270	12.81	-	-	-	2.04	-	-	0.19	1.98	3.45	5.76	-
NPDES (EFDC)	FL0030007	7.36	-	-	-	1.04	-	-	0.13	2.20	1.38	5.89	-
NPDES (EFDC)	FL0030325	1.32	-	-	-	1.20	-	-	0.08	1.64	0.94	7.07	-
NPDES (EFDC)	FL0039829	2.90	0.07	0.08	0.63**	0.93	-	-	0.10	1.47	0.59	5.98	-
Reuse	FL0021261	2.55	-	-	-	-	-	-	-	2.00	3.78	-	-
Reuse	FL0030007	10.74	-	-	-	-	-	-	-	2.13	2.00	-	-
Reuse	FL0039829	2.30	0.06	0.53	-	-	-	-	-	0.93	1.23	-	-
Reuse	FL0040665	1.86	-	-	-	12.34	-	-	1.94	4.74	4.89	-	-
Reuse	FLA014283	0.75	-	4.02	-	-	-	-	-	3.03	5.73	-	-
Reuse	FLA014290	0.37	-	3.13	-	-	-	-	-	6.13	5.01	-	-
Reuse	FLA014548	1.68	-	7.25	-	-	-	-	-	1.36	1.19	-	-
Reuse	FLA014565	2.87	-	6.62	-	13.21	-	-	-	2.04	0.79	-	-
Reuse	FLA014676	0.09	-	0.63	-	-	-	-	-	4.43	6.88	-	-
Reuse	FLA016891	0.34	-	-	-	-	-	-	-	4.22	4.01	-	-
Reuse	FLA144215	3.59	-	8.44	-	11.24	-	-	3.87	1.53	1.71	-	-

Note: Most flow and water quality values are reported as monthly averages.
* Denotes single sample reported in permit application.
** Calculated.
- = No data.

TABLE 46: NUMBER OF OBSERVATIONS FOR AVAILABLE FLOW AND WATER QUALITY DATA FOR NPDES AND REUSE FACILITIES

Facility Type	Permit	Flow (cfs)	NH_3 (mg/L)	NOx (mg/L)	OrgN (mg/L)	TN (mg/L)	PO_4 (mg/L)	OrgP (mg/L)	TP (mg/L)	CBOD5 (mg/L)	TSS (mg/L)	DO (mg/L)	WTEM (Deg C)
NPDES (HSPF)	FL0037541	111	1	1	-	1	-	-	1	1	1	-	-
NPDES (HSPF)	FL0040088	113	-	-	-	10	-	-	6	-	-	153	-
NPDES (HSPF)	FL0040665	159	33	33	12	-	-	-	160	155	158	158	33
NPDES (EFDC)	FL0021261	103	-	-	-	175	-	-	174	175	174	168	-
NPDES (EFDC)	FL0021270	154	-	-	-	152	-	-	154	155	155	145	-
NPDES (EFDC)	FL0030007	111	-	-	-	58	-	-	59	59	60	59	-
NPDES (EFDC)	FL0030325	124	-	-	-	126	-	-	126	124	122	78	-
NPDES (EFDC)	FL0039829	159	34	33	34	147	-	-	157	157	157	158	-
Reuse	FL0021261	142	-	-	-	-	-	-	-	110	110	-	-
Reuse	FL0030007	36	-	-	-	-	-	-	-	111	111	-	-
Reuse	FL0039829	99	2	2	-	-	-	-	-	79	80	-	-
Reuse	FL0040665	76	-	-	-	142	-	-	142	179	152	-	-
Reuse	FLA014283	36	-	36	-	-	-	-	-	36	36	-	-
Reuse	FLA014290	47	-	108	-	-	-	-	-	109	107	-	-
Reuse	FLA014548	27	-	13	-	-	-	-	-	25	25	-	-
Reuse	FLA014565	30	-	30	-	25	-	-	-	29	28	-	-
Reuse	FLA014676	41	-	30	-	-	-	-	-	30	30	-	-
Reuse	FLA016891	16	-	-	-	-	-	-	-	22	29	-	-
Reuse	FLA144215	9	-	4	-	9	-	-	9	9	9	-	-

- = No data.

TABLE 47: PERIOD OF RECORD FOR AVAILABLE FLOW AND WATER QUALITY DATA FOR NPDES AND REUSE FACILITIES

Facility Type	Permit	Flow (cfs)	NH_3 (mg/L)	NOx (mg/L)	OrgN (mg/L)	TN (mg/L)	PO_4 (mg/L)	OrgP (mg/L)	TP (mg/L)	CBOD5 (mg/L)	TSS (mg/L)	DO (mg/L)	WTEM (Deg C)
NPDES (HSPF)	FL0037541	10/1/2002 - 12/1/2014	11/1/2011	11/1/2011	-	11/1/2011	-	-	11/1/2011	11/1/2011	11/1/2011	-	-
NPDES (HSPF)	FL0040088	1/1/1999 - 6/1/2010	1/1/1999 - 6/1/2010	-	-	6/1/2008 - 12/1/2011	-	-	6/1/2008 - 12/1/2011	-	-	1/1/1999 - 1/1/2012	-
NPDES (HSPF)	FL0040665	4/1/1999 - 12/1/2014	4/1/1999 - 12/1/2014	4/1/2012 - 12/1/2014	4/1/2012 - 12/1/2014	-	-	-	4/1/1999 - 12/1/2014	4/1/1999 - 12/1/2014	4/1/1999 - 12/1/2014	4/1/1999 - 12/1/2014	4/1/2012 - 12/1/2014
NPDES (EFDC)	FL0021261	4/1/2006 - 12/1/2014	-	-	-	5/1/2000 - 12/1/2014	-	-	5/1/2000 - 12/1/2014	5/1/2000 - 12/1/2014	5/1/2000 - 12/1/2014	1/1/2001 - 12/1/2014	-
NPDES (EFDC)	FL0021270	12/1/1999 - 12/1/2014	-	-	-	2/1/2000 - 11/1/2014	-	-	2/1/2000 - 12/1/2014	12/1/1999 - 12/1/2014	12/1/1999 - 12/1/2014	12/1/1999 - 12/1/2014	-
NPDES (EFDC)	FL0030007	6/1/2000 - 10/1/2014	-	-	-	6/1/2000 - 9/1/2008	-	-	6/1/2000 - 9/1/2008	6/1/2000 - 9/1/2008	6/1/2000 - 9/1/2008	6/1/2000 - 9/1/2008	-
NPDES (EFDC)	FL0030325	1/1/2000 - 10/1/2012	-	-	-	1/1/2000 - 10/1/2012	-	-	1/1/2000 - 10/1/2012	1/1/2000 - 10/1/2012	1/1/2000 - 10/1/2012	1/1/2000 - 4/1/2010	-
NPDES (EFDC)	FL0039829	6/1/2000 - 12/1/2014	2/1/2010 - 1/1/2014	2/1/2010 - 1/1/2014	2/1/2010 - 1/1/2014	6/1/2000 - 1/1/2014	-	-	6/1/2000 - 12/1/2014	6/1/2000 - 12/1/2014	6/1/2000 - 12/1/2014	6/1/2000 - 12/1/2014	-
Reuse	FL0021261	9/1/2000 - 2/1/2013	-	-	-	-	-	-	-	10/1/2005 - 12/1/2014	10/1/2005 - 12/1/2014	-	-
Reuse	FL0030007	11/1/2011 - 12/1/2014	-	-	-	-	-	-	-	9/1/2005 - 12/1/2014	9/1/2005 - 12/1/2014	-	-
Reuse	FL0039829	9/1/2003 - 12/1/2014	2/1/2009 - 5/1/2009	2/1/2009 - 5/1/2009	-	-	-	-	-	9/1/2003 - 11/1/2014	9/1/2003 - 1/1/2014	-	-
Reuse	FL0040665	4/1/1998 - 8/1/2005	-	-	-	4/1/1998 - 4/1/2011	-	-	4/1/1998 - 4/1/2011	4/1/1998 - 12/1/2014	4/1/1998 - 12/1/2014	-	-
Reuse	FLA014283	6/1/2011 - 5/1/2014	-	6/1/2011 - 5/1/2014	-	-	-	-	-	6/1/2011 - 5/1/2014	6/1/2011 - 5/1/2014	-	-
Reuse	FLA014290	2/1/2011 - 12/1/2014	-	8/1/2005 - 12/1/2014	-	-	-	-	-	8/1/2005 - 12/1/2014	8/1/2005 - 12/1/2014	-	-
Reuse	FLA014548	1/1/2012 - 3/1/2014	-	3/1/2013 - 3/1/2014	-	-	-	-	-	1/1/2012 - 3/1/2014	1/1/2012 - 3/1/2014	-	-
Reuse	FLA014565	1/1/2012 - 12/1/2014	-	1/1/2012 - 12/1/2014	-	1/1/2012 - 3/1/2014	-	-	-	1/1/2012 - 12/1/2014	1/1/2012 - 12/1/2014	-	-
Reuse	FLA014676	2/1/2010 - 12/1/2014	-	1/1/2012 - 12/1/2014	-	-	-	-	-	1/1/2012 - 12/1/2014	1/1/2012 - 12/1/2014	-	-
Reuse	FLA016891	12/1/2012 - 6/1/2014	-	-	-	-	-	-	-	1/1/2011 - 6/1/2014	1/1/2011 - 6/1/2014	-	-
Reuse	FLA144215	1/1/2015 - 10/1/2015	-	6/1/2015 - 10/1/2015	-	1/1/2015 - 10/1/2015	-	-	1/1/2015 - 10/1/2015	1/1/2015 - 10/1/2015	1/1/2015 - 10/1/2015	-	-

- = No data.

2.2.9.1 Missing Data Assumptions

When available, measured water quality data were used to represent the NPDES and reuse facilities discharge flows and concentrations and to fill gaps in the data record. The available data at each facility were used to fill short- and long-term gaps in the data records. For example, if a facility had TN data for ten years of the modeling period, the long-term average of the measured data was used to represent the expected TN concentration for the remaining portion of the simulation period, where data were unavailable.

However, as shown in **Section 2.2.9**, measured data were not available for all parameters, specifically for the reuse facilities. In order to provide parameter concentrations for the facilities, Tetra Tech identified default assumptions that were used for the NPDES facilities (**Table 49**) and reuse facilities (**Table 50**). These assumptions were based on available data from all facilities in the watershed, and information obtained from reclaimed and reuse studies conducted in south Florida.

The primary difference between reuse water that has received secondary or advanced treatment processes is the amount of nutrients that remain in the water. Tertiary treatment generally removes 75% of the nitrogen and phosphorus contained in water subjected to only secondary treatment. The nutrient content of reclaimed water will vary greatly depending on the facility-specific treatment processes used (Tchobanoglous et al., 2003; Asano et al., 2007). Four of the NPDES facilities also had corresponding reuse permits (FL0021261, FL0030007, FL0039829, and FL0040665). One facility, FL0040665, had measured nutrient data for both the surface water discharge (NPDES) and reuse system discharge. The average observed TN concentration for the NPDES discharge was 7.11 mg/L while the average observed concentration for the reuse discharge was 12.34 mg/L. The average observed TP concentration for the NPDES discharge was 0.25 mg/L while the average observed reuse concentration was 1.94 mg/L. It is believed that these observed differences in nutrient concentrations likely arise from different advanced treatment processes between the surface water discharges and reuse system discharges. Because of the differences in average observed nutrient concentration between the NPDES surface water discharge and the reuse system discharge, Tetra Tech determined that data from the source of the reuse water (NPDES facility) could not be used as an assumption of the reuse water quality.

Tetra Tech found four references that described expected water quality concentrations for NPDES and reuse facilities in the south Florida area. The Manatee County Utilities Department reported the average seasonal TN and TP concentrations contained in the county's reclaimed water. These concentrations were determined using weekly analytical data from each of the county's three water reclamation facilities as shown in **Table 48**. The Everglade City Florida Case Study (Rony Joel, P.E., DEE, AEC Water) provided the department's annual average treatment standards of BOD_5 = 20 mg/L, TSS = 5 mg/L, TN = no limit, and TP = no limit. Chapter 62-610, Florida Administrative Code, states that "nitrate concentration in applied reclaim water shall not exceed 12 mg/L," and that "reclaimed water shall not contain more than 10 mg/L TSS unless the system is designed to provide reliability in operation and maintenance." Finally, The U.S. Environmental Protection Guidelines for Water Reuse provided the following information:

- NH_3 limit of 0.5 mg/L in Miami-Dade County.
- Florida Urban Reuse Guidelines (Table 4-7): BOD_5 = 30 mg/L (monthly average), TSS = 5 mg/L (max).
- Florida Agricultural Reuse Guidelines (Table 4-9): BOD_5 = 30 mg/L (monthly average), TSS = 5 mg/L (max).

TABLE 48: MANATEE COUNTY AVERAGE SEASONAL RECLAIMED WATER CONCENTRATIONS

Nutrient	Dry Season (Oct – May) Avg. Conc. (mg/L)	Dry Season (Oct – May) Range (mg/L)	Wet Season (Jun – Sep) Avg. Conc. (mg/L)	Wet Season (Jun – Sep) Range (mg/L)
TN	14	4 – 33	12	5 – 30
TP	7	0.1 – 25	2	0.6 – 5

TABLE 49: RECOMMENDED DEFAULT ASSUMPTIONS FOR MISSING FLOW AND WATER QUALITY DATA FOR NPDES FACILITIES

Constituent	Parameter ID	Minor (<1.0 MGD)	Major (>1.0 MGD)	Rationale
Total Phosphorus	TP	0.15 mg/L	0.15 mg/L	Average of available data = 0.15 mg/L; range of 0.08 - 0.25 mg/L
Orthophosphate	PO4	0.135 mg/L (90% of TP)	0.105 mg/L (70% of TP)	Professional recommendation
Organic Phosphorus	OrgP	0.015 mg/L (10% TP)	0.045 mg/L (30% of TP)	Professional recommendation
Total Nitrogen	TN	1.50 mg/L (sum of species)	1.50 mg/L (sum of species)	Average of available data = 1.38 mg/L; range of 0.29 - 2.28 mg/L
Ammonia	NH3	0.15 mg/L (10% of TN)	0.15 mg/L (10% of TN)	Average of available data = 0.15 mg/L; range of 0.021 - 0.38 mg/L
Nitrate + Nitrite	NOx	0.15 mg/L (10% of TN)	0.15 mg/L (10% of TN)	Average of available data = 0.16 mg/L; range of 0.08 - 0.23 mg/L
Organic Nitrogen	OrgN	1.20 mg/L (80% of TN)	1.20 mg/L (80% of TN)	Average of available data = 1.09 mg/L; range of 0.63 - 1.77 mg/L
Carbonaceous BOD5	CBOD5	2.0 mg/L	2.0 mg/L	Average of available data = 2.16 mg/L; range of 0.63 - 6.50 mg/L
Dissolved Oxygen	DO	6.0 mg/L	6.0 mg/L	Average of available data = 6.12 mg/L; range of 5.06 - 7.56 mg/L
Total Suspended Solids	TSS	3.5 mg/L	3.5 mg/L	Average of available data = 3.25 mg/L; range of 0.59 - 7.36 mg/L
Water Temperature	WTEM	20.0 °C October through March 30.0 °C April through September	20.0 °C October through March 30.0 °C April through September	Professional recommendation

TABLE 50: RECOMMENDED DEFAULT ASSUMPTIONS FOR MISSING FLOW AND WATER QUALITY DATA FOR REUSE FACILITIES

Constituent	Parameter ID	Minor (<1.0 MGD)	Major (>1.0 MGD)	Rationale
Total Phosphorus	TP	3.0 mg/L	3.0 mg/L	Average of available data = 2.91 mg/L; range of 0.078 - 3.98 mg/L
Orthophosphate	PO4	2.7 mg/L (90% of TP)	2.1 mg/L (70% of TP)	Professional recommendation
Organic Phosphorus	OrgP	0.3 mg/L (10% TP)	0.9 mg/L (30% of TP)	Professional recommendation
Total Nitrogen	TN	12.0 mg/L (sum of species)	12.0 mg/L (sum of species)	Average of available data = 12.27 mg/L; range of 0.0 - 25.5 mg/L
Ammonia	NH3	0.6 mg/L (5% of TN)	0.6 mg/L (5% of TN)	Average percent of TN
Nitrate + Nitrite	NOx	6.0 mg/L (50% of TN)	6.0 mg/L (50% of TN)	Average percent of TN
Organic Nitrogen	OrgN	5.4 mg/L (45% of TN)	5.4 mg/L (45% of TN)	Difference between TN and (NOx + NH3)
Carbonaceous BOD5	CBOD5	3.0 mg/L	3.0 mg/L	Average of available data = 2.96 mg/L
Dissolved Oxygen	DO	6.0 mg/L	6.0 mg/L	Professional recommendation

Constituent	Parameter ID	Minor (<1.0 MGD)	Major (>1.0 MGD)	Rationale
Total Suspended Solids	TSS	3.5 mg/L	3.5 mg/L	Average of available data = 3.38 mg/L
Water Temperature	WTEM	20.0 °C October through March 30.0 °C April through September	20.0 °C October through March 30.0 °C April through September	Professional recommendation

The NPDES facilities listed in **Section 2.2.9** were setup as direct input time series to the HSPF model reaches. The daily average time series values were input it into the model at an hourly time step. **Table 51** identifies the mapping established between the NPDES facility time series and the HSPF model simulation.

TABLE 51: NPDES FACILITY CONSTITUENT MAPPING AND RATIO ASSUMPTION

NPDES Constituent	Parameter ID	HSPF Constituent	Ratio
Flow	Flow	Flow	1
Orthophosphate	PO4	Orthophosphate	1
Organic Phosphorus	OrgP	Organic Phosphorus	1
Ammonia	NH3	Total Ammonia	1
Nitrate + Nitrite	NOx	Nitrate Nitrite	90% 10%
Organic Nitrogen	OrgN	Organic Nitrogen	1
Carbonaceous BOD5	CBOD5	Carbonaceous BOD Organic Carbon	1 3
Dissolved Oxygen	DO	Dissolved Oxygen	1
Total Suspended Solids	TSS	Sand Silt Clay	10% 50% 40%
Water Temperature	WTEM	Water Temperature	1

The reuse facilities listed in **Section 2.2.9** were setup as lateral input time series to specific pervious land uses. Unique land uses for each reuse facility's application area were not established during the land use processing. Therefore, it was assumed that the Low Density Residential (Pervious) NEXRAD and land use zones containing the reuse facility received the facilities application. **Table 52** identifies the land use (i.e. Low Density Residential [Pervious]) and NEXRAD zone combination (PERLND ID) that received the reuse application effluent in the model, as well as the area of that application. For a lateral input time series, the HSPF model requires the units of inches for flow and pounds/acre for pollutant mass. To transform the input data into the proper units, the PERLND ID area along with each facility's flow and constituent load were used to calculate the rate of flow and loading for each pollutant mass (**Table 53)**. This ensures that each facility's flow volume and constituent load are appropriately represented even though the application area in the model is different from the application area of the facility.

TABLE 52: REUSE FACILITY MODEL IMPLEMENTATION

Permit	PERLND ID	PERLND Area
FL0021261	41	639.47
FL0030007	21	2,549.61
FL0039829	41	639.47
FL0040665	301	937.15
FLA14283	181	7,947.28
FLA14290	181	7,947.28
FLA144215	41	639.47
FLA14548	61	5,968.77
FLA14565	101	27,335.39
FLA14676	61	5,968.77
FLA16891	281	585.97

TABLE 53: REUSE FACILITY CONSTITUENT MAPPING

NPDES Constituent	Parameter ID	HSPF Constituent
Flow	Flow	Lateral inflow
Orthophosphate	PO4	Lateral orthophosphate
Organic Phosphorus	OrgP	Lateral organic matter
Ammonia	NH3	Lateral total ammonia
Nitrate + Nitrite	NOx	Lateral nitrate-nitrite
Organic Nitrogen	OrgN	Lateral organic matter
Carbonaceous BOD5	CBOD5	Lateral organic matter
Total Suspended Solids	TSS	Lateral sediment

2.2.10 Atmospheric Deposition

Atmospheric deposition is an important source of loading of nitrogen to waterbodies and watersheds. The HSPF model specifies wet deposition of pollutants as concentrations, which are applied to precipitation falling on the land and streams/waterbodies. Dry deposition is also incorporated in the HSPF model, and is represented as a mass flux to both land surfaces and directly to streams/waterbodies. Time series data were available for quantifying nitrogen deposition, but time series data were not available for phosphorus deposition. Atmospheric deposition of nitrogen was explicitly represented in the model as a time series input, while atmospheric deposition of phosphorus was implicitly represented in the model through setup and parameterization as a sediment-sorbed constituent.

2.2.10.1 Wet Deposition of Nitrogen

Wet deposition of nitrogen occurs primarily as ammonium (NH_4) and NO_3 and has been monitored throughout the country by the National Trends Network (NTN) of the National Atmospheric Deposition Program (NADP). The active NTN sites closest to the Caloosahatchee River Watershed are FL41 (Verna Well Field in Sarasota County, Florida) and FL11 (Everglades National Park Research Center in Dade County, Florida). Data from NADP are provided as monthly precipitation-weighted average concentrations.

Monitoring at the NTN stations (NADP 2016) showed that the wet atmospheric deposition concentration of NH_4 typically ranged between 0.01 – 0.40 mg/L during the HSPF model simulation period, with no clear trend over time (**Figure 25**). NO_3 concentrations decreased slightly throughout the model simulation

period (**Figure 26**), and typically varied between 0.05 – 0.40 mg/L. The decreasing trend in NO_3 was not statistically significant.

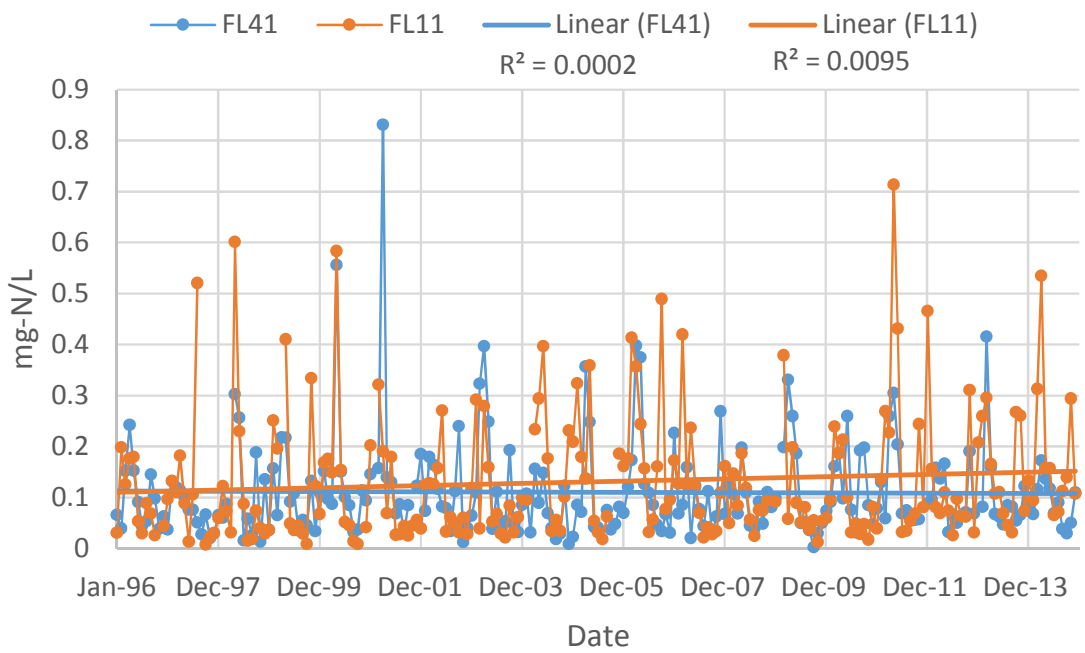

FIGURE 25: NADP NTN PRECIPITATION-WEIGHTED CONCENTRATION OF NH_4

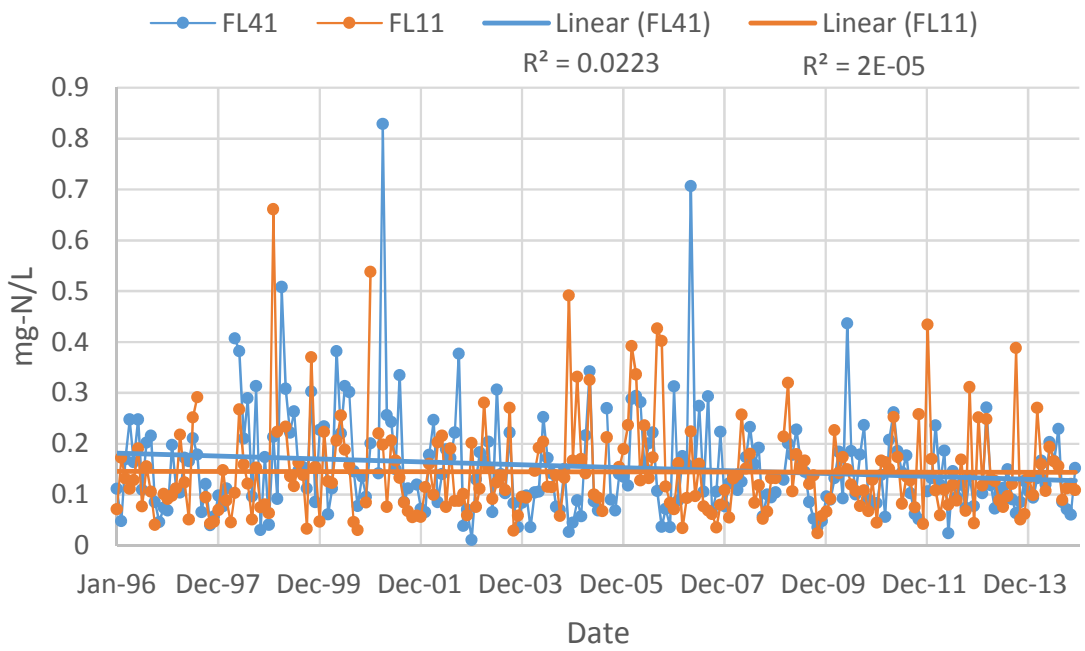

FIGURE 26: NADP NTN PRECIPITATION-WEIGHTED CONCENTRATION OF NO_3

2.2.10.2 Dry Deposition of Nitrogen

Dry deposition of nitrogen is subject to much greater uncertainty than wet deposition because it is difficult to directly measure. USEPA's Clean Air Status and Trends Network (CASTNET) monitors air concentrations of NH_4, HNO_3, and NO_3, and calculates net dry deposition fluxes using the Multi-Layer Model. The closest active CASTNET sites to the Caloosahatchee River Watershed are the Indian River Lagoon in Indian River County, Florida (IRL141) and Everglades National Park in Dade County, Florida FL (EVE419). Data from CASTNET are provided as seasonal three-month totals.

Monitoring at the CASTNET stations (CASTNET 2016) showed that the dry atmospheric deposition loads of HNO_3 typically ranged between 0.05 – 0.15 kg/ha/3-months during the HSPF model simulation period, with a decreasing trend over time (**Figure 27**). Loads of NO_3 decreased over time (**Figure 28**) and typically varied between 0.2 – 0.4 kg/ha/3-months. Loads of NH_4 also decreased over time (**Figure 28**) and typically varied between 0.2 – 0.5 kg/ha/3-months. The decreasing trends in HNO_3, NO_3, and NH_4 were all statistically significant.

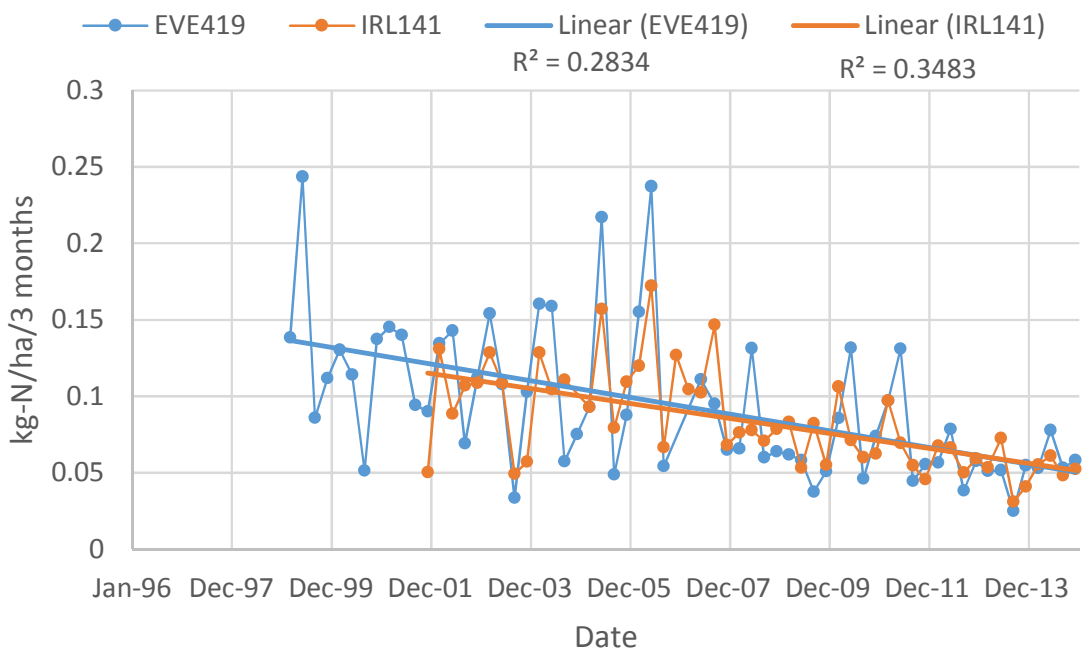

FIGURE 27: CASTNET THREE-MONTH TOTAL MASS OF NITRATE AS N FROM HNO_3 ION

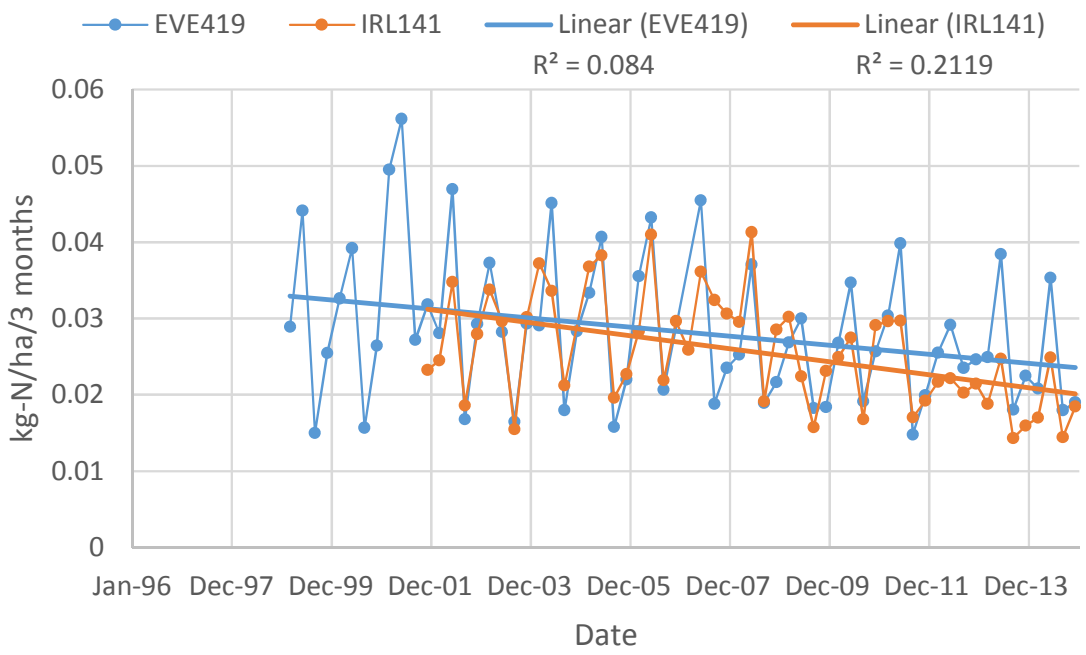

FIGURE 28: CASTNET THREE-MONTH TOTAL MASS OF NITRATE AS N FROM NO_3 ION

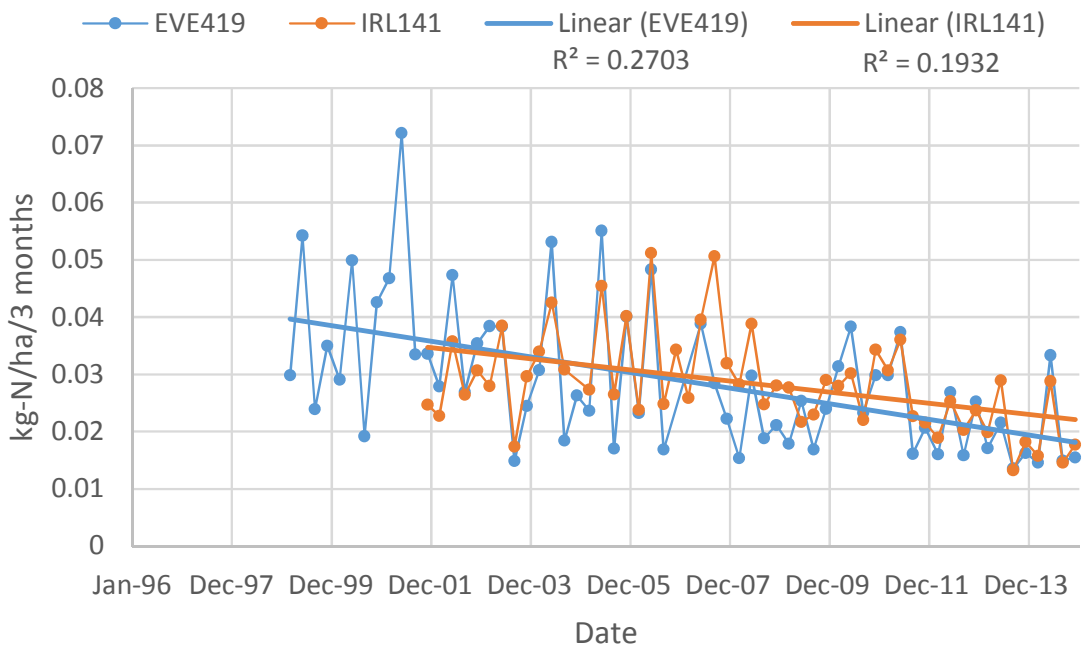

FIGURE 29: CASTNET THREE-MONTH TOTAL MASS OF AMMONIUM AS N FROM NH_4 ION

2.2.10.3 Model Implementation

To account for seasonal and yearly variability in atmospheric deposition as shown in **Figure 25** through **Figure 29**, Tetra Tech represented wet and dry atmospheric deposition as time series input into the 2017 HSPF Model.

Wet and dry deposition data were input into the .WDM as seasonal three-month totals (winter = January through March, spring = April through June, summer = July through September, and fall = October through December) and the DIV transformation function was used to generate the model input.

For wet deposition, both NTN stations had partially incomplete records for monthly average concentration for the simulation period. Generation of the wet deposition time series was a two-step process. First, monthly concentrations were averaged to determine a three-month seasonal average for each station. Second, both stations' three-month seasonal average concentrations were averaged with an equal weight applied to each location for model input.

Tabulation of the dry deposition input time series was a five-step process. First, ionic masses were converted to N masses based on molecular weights. Second, both locations were averaged together with an equal weight applied to each location. Third, the years with missing data (1996, 1997, and 1998) were assigned the long-term monthly average of the location averages. Fourth, HNO_3 and NO_3 were combined to represent the nitrate input. Fifth, kg/ha/season values were converted to lbs/acre/season for model input.

2.2.11 Specialized Hydrologic and Hydraulic Representations

2.2.11.1 S-4 Basin and Industrial Canal

The reach referred to as the Industrial Canal in the 2017 HSPF Model is comprised of five connected canals and is located in the S-4 basin (**Figure 30**). Flows between Lake Okeechobee and the canals, and the Caloosahatchee River and the canals, are regulated by the SFWMD through the operation of five structures that include a lock, culverts, and major pumping structure:

- S-310 lock connects Lake Okeechobee to the C-21 canal.
- The LD-1 culverts include C1, C1A, and C2 that connect the canal network to Lake Okeechobee via culverts through the dike/levee.
- S-235 connects the LD-3 canal to the Caloosahatchee River.
- S-169 connects the Industrial Canal via C-21 and S-4 to Lake Okeechobee.
- S-4 pump connects the entire canal network to Lake Okeechobee.

Table 54 describes the operation of each structure in relation to the other structures.

TABLE 54: S-4 BASIN STRUCTURES OPERATIONS

Lake Okeechobee Stage	S-310 Gate Status	LD-1 Culverts Gate Status	S-235 Gate Status	S-169 Gate Status	Normal Range S-4 High Water
Over 15.5	Closed	Closed	Full Open	Auto	11-14
14-15.5	Full Open	Closed	Full Open	Closed	11-14
13-14	Full Open	Closed	Full Open	Closed	11-14
Below 13	Full Open	Full Open	Closed	Full Open	Below 13

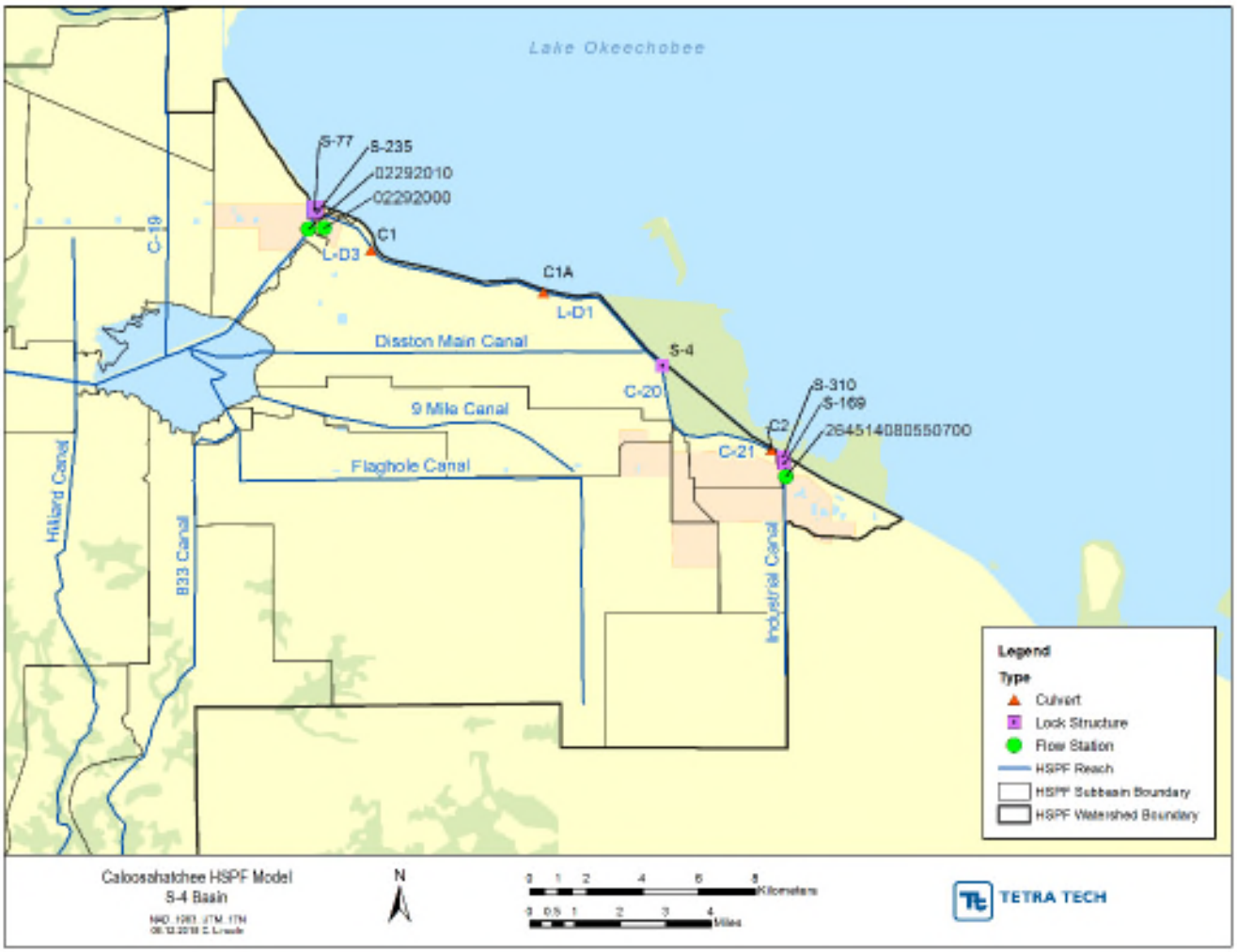

FIGURE 30: S-4 BASIN CANALS, LOCK STRUCTURES, AND CULVERTS

Operation of the locks, culverts, and pumps is dependent on Lake Okeechobee stage, although operations may differ on occasions from the prescribed operations. The operation schedule is summarized below:

- During major storm events/flooding periods:
  - Water is pumped from C-20, C-21, L-D1, and the Industrial Canal into Lake Okeechobee via the S-4 pump.
  - The S-235 culvert is open, and excess flows from the L-D3 and L-D1 are discharged into the Caloosahatchee River (design flow of 200 cfs).
- When Lake Okeechobee stage is between 13 feet and 15.5 feet:
  - Water is flowing from Lake Okeechobee into the Industrial Canal via the S-310 lock.
  - Water in the Industrial Canal flows south and exits the model domain, draining towards agricultural areas and the Everglades.
  - Water is likely entering the L-D1 via seepage, and excess water is flowing toward the Caloosahatchee River. (0.9 cfs per mile per foot of head gradient).
  - The S-235 culvert is open, and excess flows from the L-D3 and L-D1 are discharged into the Caloosahatchee River (design flow of 200 cfs).

- When Lake Okeechobee stage is below 13 feet:
  - Water is pumped from C-20, C-21, L-D1, and the Industrial Canal into Lake Okeechobee via S-4 pump.

When S-4 is not in operation, water flows out of Lake Okeechobee in a southerly direction through the Industrial Canal at Clewiston. Water is then routed toward the agricultural interior of the model domain, ultimately discharging into the Caloosahatchee River near Lake Hicpochee. When flow in the Industrial Canal is in that direction, measured flows at USGS 264514080550700 are positive. When the S-4 pump is on and removing water from C-20, C-21, L-D1, and the Industrial Canal, measured flows at USGS 264514080550700 are negative. However, even when S-4 pumps are not operational, flows in the S-4 basin are still bidirectional (see **Table 55**). This may be due to wind, waves, or operation of structures differently than described in the manuals.

TABLE 55: FLOWS FROM THE S-4 BASIN

Date	Flow (cfs)
11/2/1998	90
11/3/1998	134
11/4/1998	-28
11/5/1998	-99
11/6/1998	86
11/7/1998	-108
11/8/1998	-87
11/9/1998	89
11/10/1998	-77
11/11/1998	-12
11/12/1998	66
11/13/1998	-103
11/14/1998	-56
11/15/1998	45

When the Lake Okeechobee elevation is between 13 feet and 15.5 feet, waters flows from Lake Okeechobee into the Industrial Canal via the S-310 lock. There are no flow rates for the volume of water that enters the Industrial Canal during this period.

The S-235 culvert is open when the Lake Okeechobee stage is greater than 13 feet. However, there is no discharge information or studies summarizing actual or potential flow from L-D1 and L-D3 into the Caloosahatchee River. The main source of water moving towards the Caloosahatchee River through L-D1 and L-D3 is likely seepage under the L-D1 levee.

In addition, there is no information on pumping rates from C-20, C-21, L-D1, and the Industrial Canal into the neighboring subbasins (i.e. subbasin 216) for agricultural usage, nor is their pumping information from the neighboring subbasins into the canals during flooding periods.

In order to estimate the flow entering the Industrial Canal from the Lake Okeechobee rim canal via the S-310 lock, Tetra Tech used the flow information at USGS 264514080550700 to develop a positive time series of flow entering the Industrial Canal at HSPF model Reach 219. Measured flow in the canal reversed daily at times, potentially due to wind, waves, or structure operation, and during these periods, measured flow at USGS 264514080550700 averaged near 0 cfs. Therefore, in order to represent the overall directional movement of water in the Industrial Canal and total volume, Tetra Tech used a 7-day moving

average of the USGS flows to develop the S-310 input time series. Positive values from the 7-day moving average were input into the model into Reach 219 as a point source time series.

Water in the Industrial Canal is used for agricultural irrigation in the S-4 basin, and water in the Industrial Canal also appears to exit the canal through the S-4 basin interior. The Industrial Canal is connected to the S-4 basin interior canals through a system of culverts and pumps. To represent movement of water through the S-4 basin interior, the Reach 219 F-TABLE in the model was setup to hold water in the reach to a depth of 10.0 feet before outflow occurs. When outflow occurs from Reach 219, half of the flows input into Reach 219 are routed downstream into Reach 220, and the remaining half are routed to the S-4 interior into Reach 213. The flows routed to Reach 220 are then routed to the S-4 interior into Reach 213 when depth in Reach 220 exceeds 10.0 feet.

To represent the negative flows in the Industrial Canal and the operation of the S-4 pump, water was pumped from reaches 213, 214, 216, 218, 219, 220, and 999 into the Lake Okeechobee rim canal (outside the HSPF model domain). To be consistent with the development of the positive inflow time series through the S-310 lock, a 7-day moving average was also applied to the S-4 pump withdrawal time series. The fraction of the total withdrawal volume from each reach was determined by reach volume weighting.

Approximately once per year, the total withdrawal volume required for the S-4 pump could not be satisfied without causing one of more model reaches to go dry. During these periods, the S-4 pump time series was reduced by 10% so that the total withdrawal volume could be satisfied without causing reaches to go dry. The model reaches most likely go dry because a portion of the S-4 withdrawal is coming from the area just east of the Industrial Canal, which is outside the HSPF model domain. By reducing the S-4 withdrawal time series, Tetra Tech is accounting for this area.

In addition, a point source time series was added to represent seepage flow under the levee into the LD-1 canal. The daily under seepage time series was applied as a constant rate of 0.9 cfs per mile per foot of head gradient between the lake and the canal (USGS 1969). The levee was approximately 8.75 miles in length. The head difference was calculated using the daily Lake Okeechobee stage recorded at USGS 02276400 and a constant-head value of 13 feet for the LD-1 canal. In order to maintain a constant head in the LD-1 canal, the F-TABLE was modified to represent a weir with no outflow below a pool depth of 13 ft.

2.2.11.2 Jacks Branch

The 2017 HSPF Model under simulated storm flows at the Jacks Branch gage, which measured discharge from October 1, 2009 through January 3, 2011. The model was able to represent measured storm flows and total flow volumes at USGS 022929176, located in the neighboring watershed, Telegraph Creek. Predictive errors in storm flow and total volume flow was less than 5% at USGS 022929176. Telegraph Creek and Jacks Branch have similar areas and land uses, which indicates that the under representation of storm flows in Jacks Branch was either due to an external or unaccounted for source of flow contributing to the Jacks Branch storm flow or potential errors in high flow measurements at Jacks Branch.

For the 2017 HSPF Model, it was assumed that the error in high flow was due to an external source of flow contributing to Jacks Branch during storms following large precipitation events. The under prediction occurred during the wet period of March through September. An area of land located immediately north of the Jacks Branch watershed appeared to be connected to the watershed via canals and drainage ditches, and was identified as the likely external source of additional storm flow volumes. This assumption was

verified with Ben Paswater of the department who confirmed that canals connected this area to the Jacks Branch watershed during high flows.

To represent this external source of water, Tetra Tech attempted to determine the relationship between rainfall and total storm flow, as well as rainfall and the modeled storm flow deficit from October 1, 2009 through January 3, 2011. The storm flow deficit was calculated as the observed flow minus the simulated flow. A relationship was needed to estimate contributing flow from the external source during the remaining modeling period when measured flow data were not available at Jacks Branch. The total storm flow volume was plotted again daily rainfall, and the storm flow volume deficit was plotted against daily precipitation. There was no relationship between the storm flows and all rainfall events, likely due to (1) seasonal differences, (2) antecedent moisture conditions, (3) rising and falling limb response, and (4) uncertainty and/or error in measured high flow volume.

There was a relationship between rainfall events greater than 1 inch and storm flows (R^2=0.35 for total storm flow volume and R^2=0.41 for deficit storm flow volume), as shown in **Figure 31** for the deficit storm flow volume. However, only 12 data points were used for these relationships. When this regression equation was used to estimate the storm flow deficit, it underestimated peak flow, because peak flow typically occurred several days following the storm event.

Tetra Tech was able to identify a weak relationship between precipitation and total storm flow volume and deficit storm flow volume when total rainfall was greater than 1 inch using the 7-day moving rainfall total during the wet months (R^2=0.16) (**Figure 32**). The 7-day moving rainfall total accounted for some of the lag time in hydrograph response and antecedent moisture conditions. The deficit flow volume regression formula was applied to the wet months, March through September, for the entire modeling period (January 1, 1996 through December 31, 2014) (**Figure 33**).

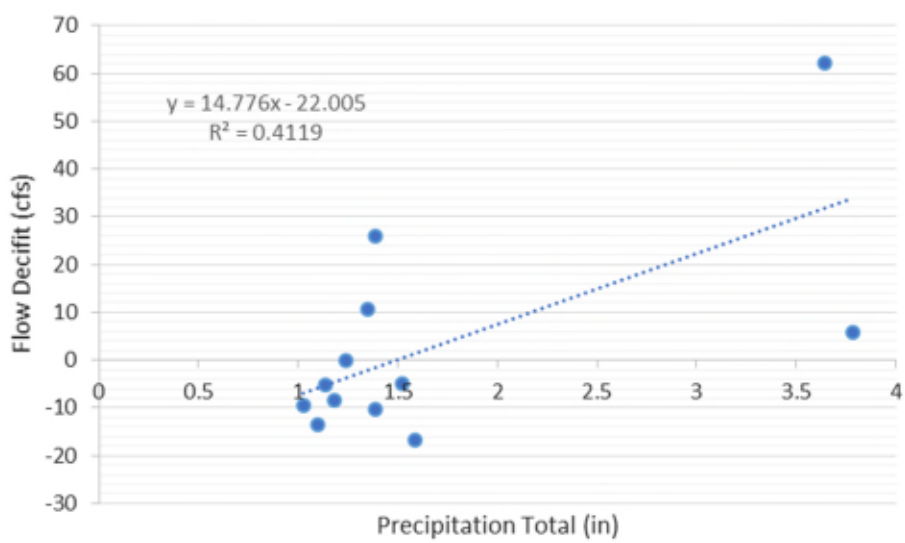

FIGURE 31: DAILY PRECIPITATION TOTAL GREATER THAN 1 INCH VS. STORM FLOW DEFICIT AT JACKS BRANCH DEP GAGE

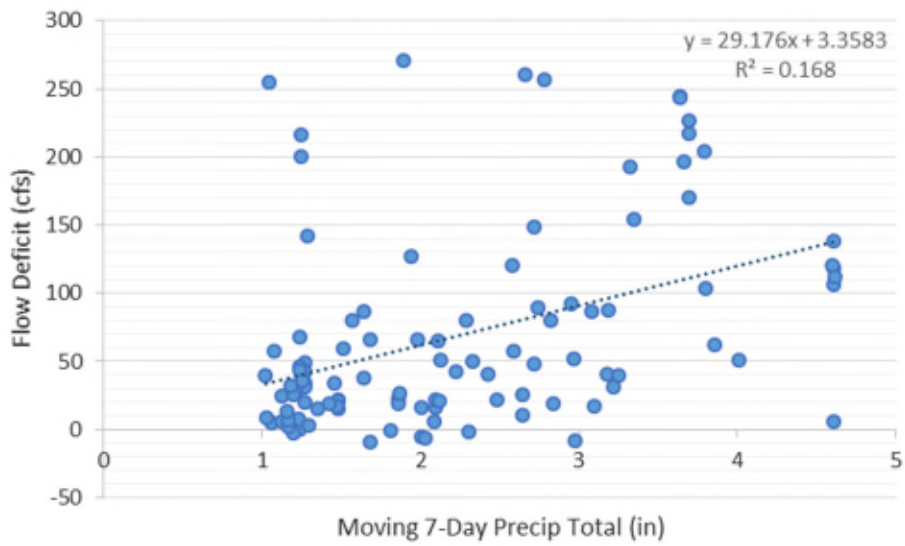

FIGURE 32: MOVING 7-DAY PRECIPITATION TOTALS GREATER THAN 1 INCH FROM MARCH THROUGH SEPTEMBER VS. STORM FLOW DEFICIT AT JACKS BRANCH DEP GAGE

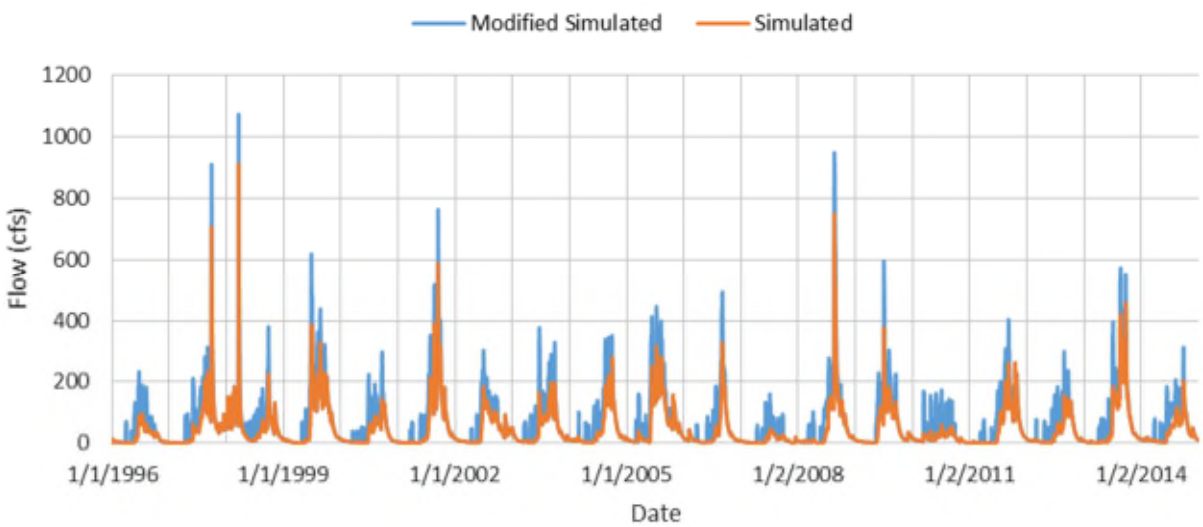

FIGURE 33: SIMULATED TIME SERIES VS. MODIFIED SIMULATED TIME SERIES THAT INCLUDES CALCULATED EXTERNAL SOURCE AT JACKS BRANCH DEP GAGE (01/01/1996 – 12/31/2014)

Tetra Tech established a time series of corrective flow for when the area of land was connected to Jacks Branch during the hydrology calibration. Loads for water quality constituents when the area of land was connected to Jacks Branch were then established during the water quality calibration. All water quality monitoring stations in Jacks Branch were used to develop a daily concentration time series for the simulated constituents by (1) using observed data on days when observations were available, (2) using the monthly average by year to fill in gaps between daily observations, and (3) using the long-term monthly average (monthly average for entire model simulation period) in months where data were not collected. Input loads were tabulated for days with positive flows by using the positive flow volume and

concentration for that day from the time series. **Table 56** identifies the water quality monitoring stations used in the development of the daily concentration time series.

TABLE 56: JACK'S BRANCH WATER QUALITY STATIONS

Station ID	Station Name
112WRD 264510081313100	JACKS BRANCH @ NORRIS RD TELSWAMP SE
112WRD 264939081330000	JACKS BR @ SR-720 TELEGRAPH SWSE
21FLA 28020238	JACK'S BRANCH ABOVE KIRBY-THOMPSON RD
21FLBABRJACKS_BR_INFLOW	Jacks_Branch_Inflow_location_WB3235D
21FLBABRJACKS_BR_INFLW2	Jacks_Br_Inflow_at_property_line_WB3235D
21FLBABRJACKS_BR_OUT	Jacks_Branch_Outflow_location_WB3235D
21FLFTM CALUSA0047FTM	Jacks Branch at Kirby Thompson Rd.
21FLFTM CALUSA0048FTM	Jacks Branch at Jacks Branch Rd.
21FLFTM CALUSA0049FTM	Jacks Branch at CR 720
21FLFTM 28020238	JACK'S BRANCH ABOVE KIRBY-THOMPSON RD
21FLFTM 28020238	JACK'S BRANCH ABOVE KIRBY-THOMPSON RD
21FLFTM 28020301FTM	BEE BRANCH SITE 4
21FLGW 10145	SFD-HS-1014 JACK'S BRANCH
21FLGW 10146	SFD-HS-1019 JACK'S BRANCH
21FLSFWMCR-30.3T	JACK'S BRANCH AT NORRIS RD OFF S.R.78
21FLWQSPHEN640GS	Jack's Branch upstream of Kirby-Thompson Rd (WBID 3235D)

2.2.11.3 Fast Creek

The 2017 HSPF Model under simulated storm flows at the Fast Creek gage, which measured discharge from April 4, 2010 through December 8, 2010. According to stakeholder information provided during the site visit, Fast Creek is connected to neighboring subbasins during storm events, and flow from the neighboring watershed is routed to Fast Creek through canals.

To represent the movement of water from the neighboring subbasins, Tetra Tech attempted to determine the relationship between rainfall and total storm flow, as well as rainfall and the modeled storm flow deficit from April 4, 2010 through December 8, 2010. A relationship was needed to estimate contributing flow from the external source during the remaining modeling period when measured flow data were not available at Fast Creek. Similar to Jacks Branch, when the total storm flow volume and the storm flow volume deficit volume were plotted against daily precipitation, there was no relationship between the storm flows and all rainfall events. This was likely due to (1) seasonal differences, (2) antecedent moisture conditions, (3) rising and falling limb response, and (4) uncertainty and/or error in measured high flow volume.

Tetra Tech was able to identify a relationship between precipitation and deficit storm flow volume when total rainfall was greater than 1 inch using 7-day moving rainfall total during the wet months (R^2=0.63) (**Figure 34**). The 7-day moving rainfall total accounted for some of the lag time in hydrograph response and antecedent moisture conditions.

The deficit flow volume regression formula was calculated for the entire modeling period (January 1, 1996 through December 31, 2014) (**Figure 35**). However, the flow volume needed to make up the deficit was greater than the total storm flow volumes of the neighboring subbasins. Because of this, storm volume has not been routed from neighboring watersheds to Fast Creek at this time.

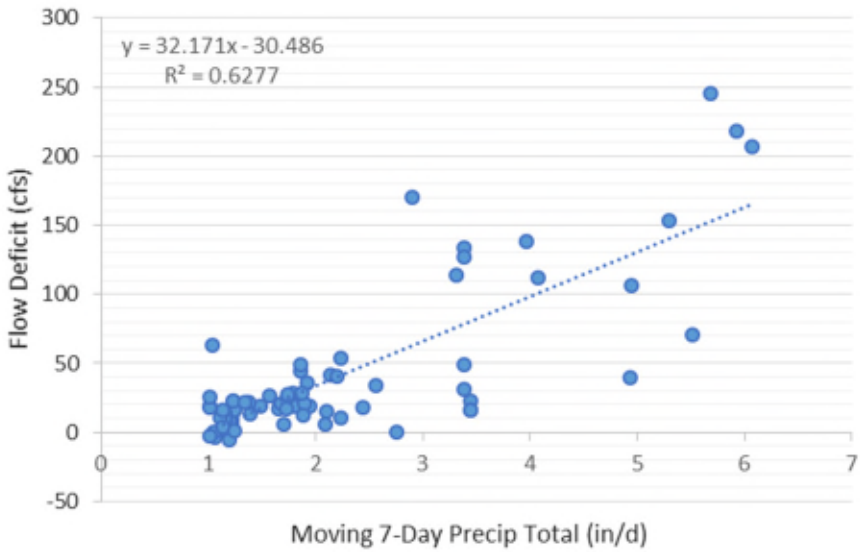

FIGURE 34: MOVING 7-DAY PRECIPITATION TOTALS GREATER THAN 1 INCH FROM MARCH THROUGH SEPTEMBER VS. STORM FLOW DEFICIT AT FAST CREEK DEP GAGE

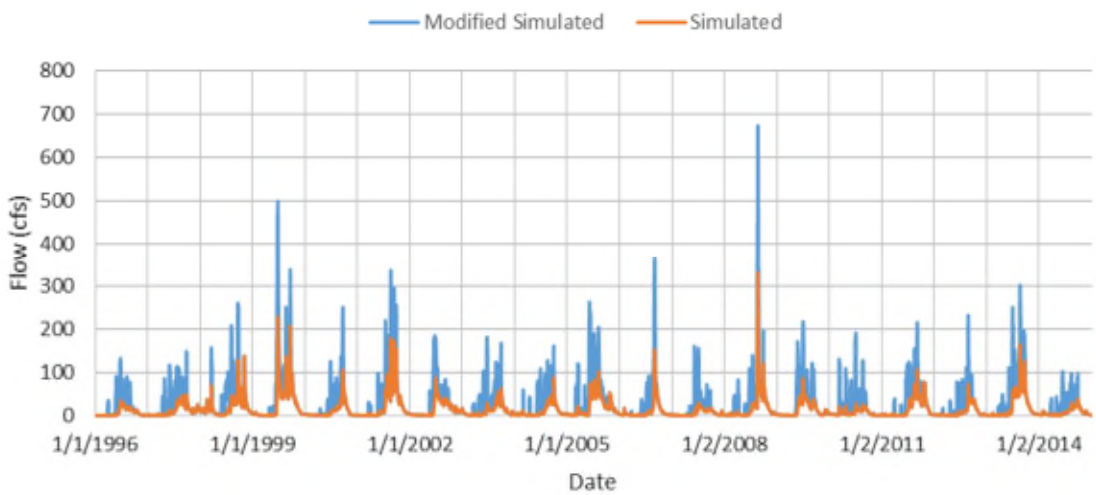

FIGURE 35: SIMULATED TIME SERIES VS. MODIFIED SIMULATED TIME SERIES THAT INCLUDES CALCULATED EXTERNAL SOURCE AT FAST CREEK DEP GAGE (01/01/1996 – 12/31/2014)

2.3 HSPF MODEL HYDROLOGY CALIBRATION

Tetra Tech completed the setup of the 2017 HSPF model and evaluated the hydrology calibration and validation results. Tetra Tech compared modeled hydrology outputs to measured hydrology outputs at 20 USGS and department gages (**Section 2.3.1)**. **Appendix A** includes daily and monthly average temporal comparison plots, frequency distribution curves, regression plots, and relative error and NS model efficiency statistics for the 15 stations with more than one year of continuous data. Regression plots and temporal comparisons were provided for the five stations that had less than one year of data.

Five of the gages are tidally influenced: USGS 022929176 Telegraph Creek, USGS 02293055 Orange River, USGS 02293090 Popash Creek, USGS 02293190 Billy Creek, and USGS 264006081534400 Hancock Creek. USGS used the Godin low-pass filter to remove the tidal frequencies and obtain the tidally filtered flows at the tidal stations. After filtering the data, there were some negative discharges at the stations, indicating a general upstream movement of water on those days. Negative flows were also measured at four other gages with more than one year of data: USGS 02292000 Caloosahatchee Canal at Moore Haven, USGS 02292010 Caloosahatchee Canal at S-77 lock, USGS 26451408150700 Industrial Canal, and DEP Jacks Branch. In **Appendix A**, the negative measurements were removed from the visual comparison and statistical analysis.

2.3.1 Calibration and Validation Stations

The modeled hydrology outputs were compared to measured hydrology outputs at 20 USGS and department gages (**Table 57** and **Figure 36**). Continuous discharge data were available for more than one year at 13 USGS station locations and one department station. Seven of the USGS stations had data available for less than a five-year period. Due the relatively limited data, all of the USGS stations were used for calibration with the exception of Hancock Creek. Hancock Creek and the department stations with less than one year of data were used as validation stations.

TABLE 57: 2017 HSPF MODEL HYDROLOGY CALIBRATION AND VALIDATION STATIONS

Station ID	Station Name	Purpose
USGS 02292000	Caloosahatchee Canal at Moore Haven	Calibration
USGS 02292010	Caloosahatchee Canal DWS of S-77 at Moore Haven	Calibration
USGS 02292480	Caloosahatchee Canal at Ortona Lock near LaBelle S-78	Calibration
USGS 26451408150700	Industrial Canal at Clewiston	Calibration
USGS 02292900	Caloosahatchee River at S-79 near Olga, FL	Calibration
USGS 02293230	Whiskey Creek at Fort Myers	Calibration
USGS 02293240	Aries Canal at Cape Coral	Calibration
USGS 02293241	San Carlos Canal at Cape Coral	Calibration
USGS 022929176	Telegraph Creek at State Highway at Olga	Calibration
USGS 02293055	Orange River near Buckingham	Calibration
USGS 02293090	Popash Creek at Leetana Road near Fort Myers	Calibration
UGS 02293190	Billy Creek at Fort Myers	Calibration
USGS 02293243	Courtney Canal at Cape Coral	Calibration
USGS 264006081534400	Hancock Creek at Pondella Road, North Fort Myers, FL	Validation
DEP Jacks Branch	DEP Jacks Branch at SR 78	Calibration
DEP Fast Creek	DEP Fast Creek at SR 80	Validation
DEP Pollywog Creek	DEP Pollywog Creek at SR 78	Validation
DEP Powell Creek	DEP Powell Creek at SR 78 (13 daily values)	Validation
DEP Stroud Creek	DEP Stroud Creek (13 daily values)	Validation
DEP Yellow Fever Creek	DEP Yellow Fever Creek (13 daily values)	Validation

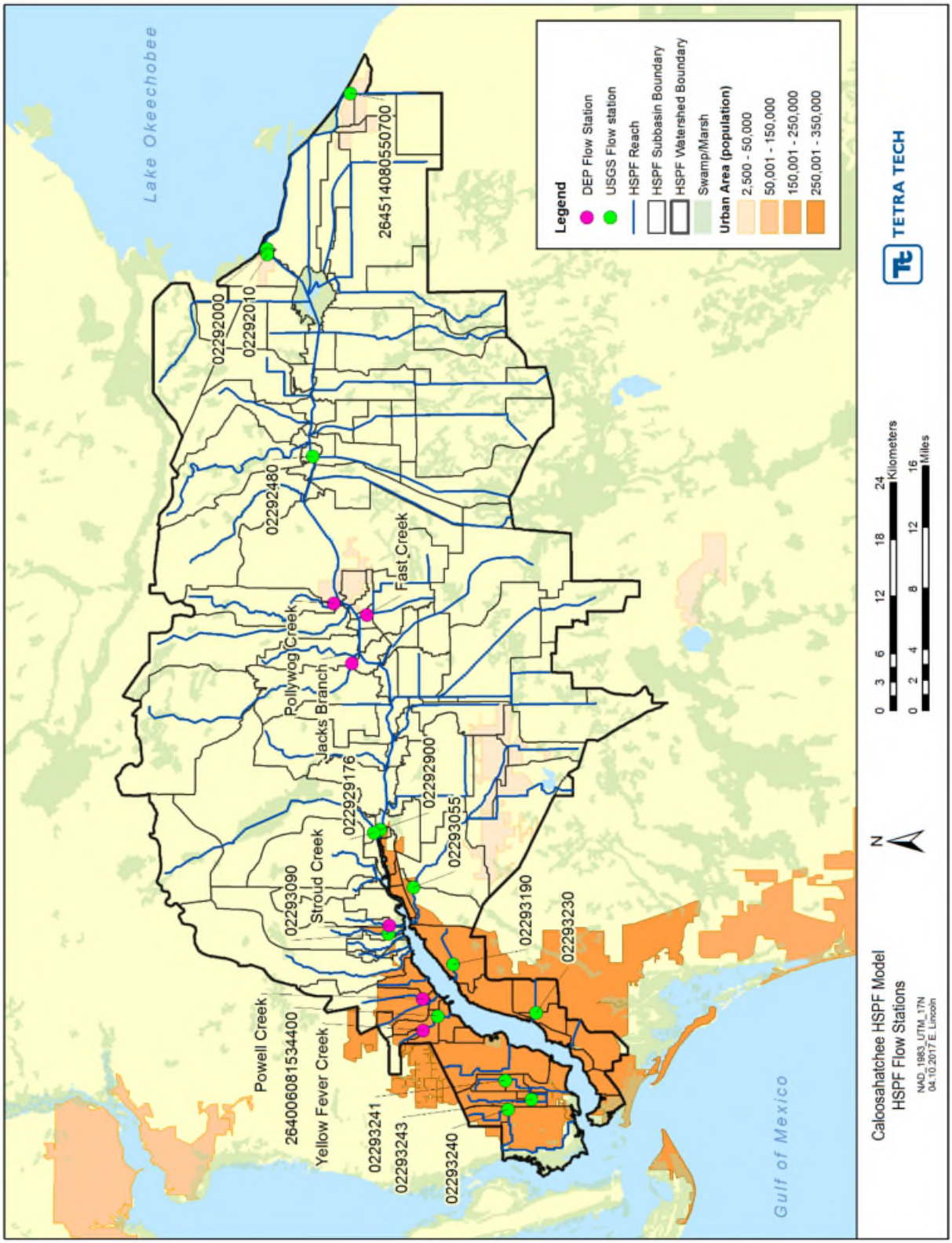

FIGURE 36: 2017 HSPF MODEL HYDROLOGY CALIBRATION AND VALIDATION STATIONS

2.3.2 Calibration Methodology

The calibration of the model was based on graphical and statistical comparisons between the model predictions and the observations. An iterative process was performed to adjust parameters. Initially, parameters were defined for the first model run, typically using values from the 2014 Model. Parameters were adjusted during subsequent runs, and typically one parameter was adjusted at a time to quantify the impact of the change on model calibration. Parameters that controlled the overall water balance, such as infiltration and ground water recession rates, were adjusted and analyzed first. Following parameter adjustments, the model was executed and the results were post-processed for both visual and statistical comparisons. The results were analyzed to determine if there was or was not an improvement in the model calibration, i.e. model appeared to better capture trends and magnitudes of measured data, and/or statistics showed an over prediction or under prediction compared to measured data. If model performance was unsatisfactory, parameters were adjusted again. If model performance was satisfactory or if further parameter adjustment could not improve model calibration, the model was considered calibrated.

The temporal analyses were performed using Microsoft Excel. Plots were created to compare the observed flows to the model predictions for mean monthly flows, mean daily flows, flow exceedance, and monthly flow regression. Excel was also used to generate the following goodness-of-fit statistics where P represents the time series of model predictions and O the time series of observations:

Correlation coefficient: $$R^2 = \frac{\left(n\sum_{i=1}^{n}\left(P_i \times O_i\right)\right) - \left(\sum_{i=1}^{n} O_i \times \sum_{i=1}^{n} P_i\right)}{\sqrt{\left[n\sum_{i=1}^{n}\left(P_i^2\right) - \sum_{i=1}^{n}\left(P_i\right)^2\right]} \times \sqrt{\left[n\sum_{i=1}^{n}\left(O_i^2\right) - \sum_{i=1}^{n}\left(O_i\right)^2\right]}}$$

Nash-Sutcliffe Formula: $NS = 1 - \frac{\sum_{i=1}^{N}(O_i - P_i)^2}{\sum_{i=1}^{N}(O_i - \bar{O})^2}$

Percent Error (PE) Formula: $PE = \frac{\overline{O} - \overline{P}}{\overline{O}}$

The correlation coefficient (R^2) measures the degree of linear correlation between the trends of two time series, in this case the series of observations and model predictions. It can range from –1 to 1, with negative values indicating that the observed and predicted values tend to vary inversely. It should be recognized that even if the correlation is close to 1, the predicted and observed values may not match each other; they only tend to vary similarly (Stow et al. 2003).

The NS coefficient (Nash and Sutcliffe 1970) is defined as one minus the sum of the squared differences between the observed and predicted time series normalized by the variance of the observations. The NS coefficient is a global measure of goodness of fit and provides an estimate of how good the variance of the measurements is explained by the model predictions. The NS ranges from minus infinity to one. A NS equal to one represents a perfect fit while values of NS lower than zero indicate that the mean of the observations is a better prediction of the observations compared to the model predictions. This coefficient

is widely used in hydrological sciences and is considered one of the most important statistics for the evaluation of continuous-hydrograph simulation programs.

PE is a measure of the relative deviation of the simulations from the observations. The smaller the magnitude of PE, the better the agreement between the means of the observations and simulations. Over predictions or under predictions of the simulations relative to the observations are reflected by negative and positive values of PE respectively. PE were calculated for key flow statistics, including total volume, low flows, high flows, and seasonal volume error.

The hydrology parameters for the HSPF PWATER and IWATER modules were mapped from the 2014 HSPF Model to the 2017 HSPF Model by land modules (PERLND/IMPLND). The 2014 HSPF Model hydrology parameters were used for the initial 2017 HSPF model runs. The 2017 HSPF land modules were represented as a three-digit number that identified both the NEXRAD zone and land use. The 2017 HSPF Model included 16 pervious land segments and seven impervious land segments. Both pervious and impervious land segments are included for each of the 15 NEXRAD zones. The parameter mapping from the 2014 HSPF Model to the 2017 HSPF Model is shown below in **Table 58**.

TABLE 58: HYDROLOGY PARAMETER MAPPING FOR HSPF PWATER AND IWATER MODULES

Land Use Description	Land Segment	2014 HSPF Land Segment ID	2017 HSPF Land Segment ID
Low Density Residential (Pervious)	PERLND	8	1
Developed Open Space / Disturbed (Pervious)	PERLND	8	2
Medium Density Residential (Pervious)	PERLND	9	3
High Density Residential (Pervious)	PERLND	7	4
Commercial/Institutional/Transportation (Pervious)	PERLND	6	5
Industrial / Extractive (Pervious)	PERLND	6	6
FDOT Right-of-Way (Pervious)	PERLND	6	7
Sugar Cane	PERLND	1	8
Row and Field Crops	PERLND	1	9
Nurseries, Ornamentals, and Vineyards	PERLND	1	10
Citrus Groves / Other Groves	PERLND	3	11
Improved Pasture	PERLND	2	12
Rangeland / Unimproved Pasture / Woodland Pasture / Shrub	PERLND	2	13
Upland Forests	PERLND	4	14
Wetlands	PERLND	10	15
Water	PERLND	10	16
Low Density Residential (Impervious)	IMPLND	8	1
Medium Density Residential (Impervious)	IMPLND	9	2
High Density Residential (Impervious)	IMPLND	7	3
Commercial / Institutional / Transportation / Industrial / Extractive (Impervious)	IMPLND	6	4
FDOT Right-of-Way (Impervious)	IMPLND	6	5
Agriculture (Impervious)	IMPLND	1	6
Other (Impervious)	IMPLND	6	7

Hydrologic parameters in the 2014 HSPF Model were found to be outside of the recommended ranges presented in USEPA's BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF (USEPA 2000). As part of model calibration, the parameters were revised to be within

recommended ranges. The 2017 HSPF Model parameterization is summarized in **Table 59**, and a discussion of the hydrology parameters and calibration methodology is provided below.

The recommended range for the fraction of evapotranspiration from baseflow (BASETP) is 0 to 0.05 with a maximum possible value of 0.2. The 2014 HSPF Model used a value of 0.99 for all land uses, which is well outside the recommended range. BASETP represents the fraction of PET taken directly from baseflow and is, generally, attributable to riparian vegetation. Land uses with natural vegetated land cover in areas with a dense stream network (e.g. canals) typically have values closer to the recommended maximum of 0.2.

In the HSPF model, surface water can percolate into the active ground water, or the surficial aquifer. Once in the active ground water, water can be lost through evapotranspiration (AGWETP), enter the stream as baseflow (AGWRC), or enter deep ground water (DEEPFR). The recommended range for AGWETP is 0 to 0.05 with a maximum possible value of 0.2. The 2014 HSPF Model used a value of 0.5 for all land uses, well outside the recommended range. AGWETP represents the fraction of PET directly taken from shallow ground water and is typically considered as a function of wetlands extent. Thus, it may be reasonable to have values toward the higher end of the possible range for wetland land cover. Since wetlands are a separate pervious land segment in the 2017 Caloosahatchee HSPF Model, AGWETP was set to 0 for all non-wetland land uses and calibrated for the wetland land use.

The recommended range for interception storage capacity (CEPSC) is 0.03 to 0.2, with a minimum possible value of 0.01. The 2014 HSPF Model used a single set of monthly values for all pervious land uses, and assigned 0 for the months of January and December. In the Caloosahatchee River Watershed, vegetative growth occurs in the winter and interception occurs during the months of January and February. In order to improve the model calibration, CEPSC was varied across land uses (e.g., interception for forested areas should be greater than for urban lawns) and varied seasonally, with CEPSC values greater than 0 used for winter months.

The recommended range for lower zone evapotranspiration (LZETP) is 0.2 to 0.7 with a maximum possible value of 0.9. The 2014 HSPF Model used a range of 0.25 to 1.49, with the highest values assigned to land uses occurring in NEXRAD zones 1 through 5. LZETP represents the fraction of PET taken from the lower zone soil layer and is usually considered in terms of vegetation type and density. The LZETP parameterization was updated in the 2017 Model to be within recommended ranges, and to vary by season and land use.

The ground water recession rate (AGWRC) represents the change in head of active ground water, which determines the volume of water from the active ground water that is discharged to the stream as baseflow. AGWRC was within the recommended range of 0.85 to 0.99 in the 2014 HSPF Model, although it was set to 0.999 for some land uses and areas. The AGWRC parameterization was updated as part of the 2017 Model calibration.

In addition to the parameters discussed above, Tetra Tech adjusted the parameterization of infiltration rate (INFILT), upper zone storage (UZSN), lower zone storage (LZSN), lower zone evapotranspiration (LZETP), and ground water recession (AGWRC) to improve model calibration. In the 2014 HSPF Model, parameterization was similar between land uses. By increasing the number of hydrology calibration stations in the 2017 Caloosahatchee HSPF Model, Tetra Tech was able to adjust these parameters to account for differences between land uses.

TABLE 59: HSPF MODEL PARAMETRIZATION FOR HYDROLOGY PARAMETERS

Land Use	LZSN	INFILT	AGWRC	BASETP	AGWETP	CEPSC[1]	UZSN	NSUR	INTFW	IRC	LZETP[1]
Low Density Residential (Pervious)	6	0.21	0.9	0.1	0	0.05	0.7	0.23	3	0.75	0.54
Developed Open Space / Disturbed (Pervious)	4	0.21	0.9	0.1	0	0.02	0.39	0.23	3	0.75	0.26
Medium Density Residential (Pervious)	5	0.21	0.9	0.1	0	0.03	0.39	0.21	3	0.75	0.26
High Density Residential (Pervious)	5	0.21	0.9	0.1	0	0.03	0.39	0.14	3	0.75	0.26
Commercial/Institutional/Transportation (Pervious)	5	0.21	0.93	0.05	0	0.03	0.39	0.12	3	0.75	0.26
Industrial / Extractive (Pervious)	5	0.21	0.93	0.05	0	0.03	0.39	0.12	3	0.75	0.32
FDOT Right-of-Way (Pervious)	5	0.21	0.93	0.05	0	0.03	0.39	0.12	3	0.75	0.26
Sugar Cane	6	0.21	0.92	0.05	0	0.10	0.49	0.25	3	0.75	0.87
Row and Field Crops	6	0.21	0.92	0.05	0	0.10	0.49	0.25	3	0.75	0.87
Nurseries, Ornamentals, and Vineyards	6	0.21	0.92	0.05	0	0.10	0.49	0.25	3	0.75	0.87
Citrus Groves / Other Groves	6	0.21	0.96	0.05	0	0.14	0.49	0.25	3	0.75	1.10
Improved Pasture	6	0.21	0.93	0.025	0	0.02	1	0.25	3	0.75	0.85
Rangeland / Unimproved Pasture / Woodland Pasture / Shrub	6	0.21	0.93	0.025	0	0.02	1	0.25	3	0.75	0.85
Upland Forests	6	0.21	0.96	0.025	0	0.14	1	0.27	3	0.75	1.10
Wetlands	6.5	0.05	0.99	0.05	0.7	0.20	1.5	0.01	3	0.75	1.10
Water	6.5	0.05	0.99	0.05	0	0.00	2	0.01	3	0.75	1.10

[1] Varies by month (average value supplied).

2.3.3 Calibration Performance

The 2017 HSPF Model was calibrated to reproduce observed records of freshwater flows at 13 USGS stations, and validated to freshwater flows at one USGS stations and six department stations. In general, the model was able to represent the range and magnitude of flows observed throughout the watershed. The ability of the 2017 HSPF Model to accurately predicts flows improved compared to the 2014 HSPF Model, and the across the watershed flow predictions were not biased high or low. Statistical metrics at each stations were compared to Donigian (2002) performance metrics and given a qualitative rating of Very Good (VG), Good (G), Fair (F), or Poor (P) (refer to **Section 1.2** for the details on the metrics). The statistical summary of calibration results for the 2017 HSPF model are provided in **Table 60**.

The 2017 HSPF model was used to verify the upstream boundary condition from Lake Okeechobee at USGS 02292000 Caloosahatchee Canal at Moore Haven, FL and USGS 02292010 Caloosahatchee Canal downstream of S-77. Both stations were located at the S-77 lock, but collected data for different time periods. Both stations had R^2 coefficients greater than 0.99 and NS coefficients greater than 0.97, indicating that the boundary condition was correctly developed. The slight differences between the observed data and modeled predictions were likely due to the fact that the model was not delineated to the gages, and flow exchange from the S-4 basin at S-235 was included in the model predications, but not in the observed data. In addition, uncertainty in the flow measurement/estimates collected by USACE and USGS may have contributed to the slight disparities in the observed and modeled flows.

The 2017 HSPF Model was not developed to represent USACE lock operations at S-78 and S-79 because this would require disconnecting the reach linkages at both locations and developing a flow boundary

condition time series that would be input into the model similar to a point source boundary condition. Instead, fixed weirs were included in the 2017 HSPF Model to improve representation of storage that occurred behind each lock during low-flow periods. However, low flows were still slightly over simulated at both USGS 02292480 Caloosahatchee Canal at S-78 and USGS 02292900 Caloosahatchee River at S-79 due to USACE operational procedures. The 2017 HSPF Model was able to predict the total flow volume at both stations, and the R^2 coefficients and NS coefficients rated as Very Good and Good, respectively.

The 2017 HSPF Model predicted flows very well in watersheds where flows were not predominantly inhibited by weirs or structures, such as at USGS 0229176 Telegraph Creek, USGS 02293055 Orange River, and USGS 02293190 Billy Creek. In all of these stations, the total error in flow was less than 10% (Very Good) and the R^2 and monthly NS coefficients were rated as Very Good or Good.

Model performance was lower in areas where weirs and structures inhibited the natural flow, such as USGS 02293230 Whiskey Creek and the three stations located in Cape Coral (USGS 02293240 Aries Canal, USGS 02293241 San Carlos Canal, and USGS 02293243 Courtney Canal). USGS 02293230 was located in between two structures in a small pond and was tidally influenced during high flows. Although the 2017 HSPF Model was able to represent the overall volume in Whiskey Creek, it could not represent the correct low flow-high flow distribution due to ponding behind the weirs and influences from tides. At both USGS 02293241 and USGS 02293243, the total error in flow was less than 10% (Very Good). Low flows at both stations were typically less than 0.1 cfs, and the model typically predicted flows near 1 cfs. Visually, the low flow calibration was within range, but statistically the differences were very large. At all three Cape Coral stations, the high flows were under predicted, which may have been due to influences from tides (e.g. ponding of water in the canal system during in coming tides), or additional storm flow from neighboring areas being routed to the canals via unidentified storm conveyances.

Calibration performance was poor at USGS 26451408150700 Industrial Canal due to the representation of the Industrial Canal in the 2017 HSPF Model. The model was constructed to represent the overall hydrodynamics of the S-4 basin and general water transfer between the interior of the basin and the Industrial Canal. Due to this representation and model limitations on locations where flow can be routed, flow was routed from the Industrial Canal to the interior of the basin upstream of USGS 26451408150700, whereas in reality the flow is routed through numerous smaller canals to the interior of basin downstream of USGS 26451408150700. Therefore, the overall water balance of the S-4 basin was maintained, but due to the routing, the model appears to under simulate high flows at USGS 26451408150700.

Model performance was good at some department stations, such as Jacks Branch and Stroud Creek, but was poor at other stations. This may be due to the limited amount of data collected at some stations, and to potential data collection errors.

TABLE 60: STATISTICAL SUMMARY OF 2017 HSPF MODEL HYDROLOGICAL CALIBRATION RESULTS (NEGATIVE FLOWS REMOVED)

Station ID	Station Name	R^2 (monthly)	R^2 Rating	NS (daily)	NS Rating (daily)	NS (monthly)	NS (monthly) Rating	Total Volume % Error	Total Volume % Error Rating
USGS 02292000	Caloosahatchee Canal at Moore Haven	0.99	VG	0.98	VG	0.99	VG	6.1	VG
USGS 02292010	Caloosahatchee Canal DWS of S-77 at Moore Haven	0.99	VG	0.97	VG	0.99	VG	-6.5	VG
USGS 02292480	Caloosahatchee Canal at Ortona Lock near LaBelle S-78	0.92	VG	0.84	VG	0.92	VG	-3.5	VG
USGS 26451408150700	Industrial Canal at Clewiston	0.97	VG	0.29	P	0.50	P	-56.4	P
USGS 02292900	Caloosahatchee River at S-79 near Olga, FL	0.90	VG	0.78	G	0.85	VG	-16.8	F
USGS 02293230	Whiskey Creek at Fort Myers	0.76	G	-0.15	P	0.39	P	38.2	P
USGS 02293240	Aries Canal at Cape Coral	0.69	F	0.26	P	0.24	P	-55.8	P
USGS 02293241	San Carlos Canal at Cape Coral	0.65	F	0.47	P	0.61	F	-10.0	VG
USGS 022929176	Telegraph Creek at State Highway at Olga	0.87	VG	0.79	G	0.84	VG	0.8	VG
USGS 02293055	Orange River near Buckingham	0.80	G	0.47	P	0.73	G	8.8	VG
USGS 02293090	Popash Creek at Leetana Road near Fort Myers	0.83	VG	0.68	F	0.79	G	28.9	P
UGS 02293190	Billy Creek at Fort Myers	0.86	VG	0.35	P	0.85	VG	6.1	VG
USGS 02293243	Courtney Canal at Cape Coral	0.65	F	0.44	P	0.58	P	-6.7	VG
USGS 264006081534400	Hancock Creek at Pondella Road, North Fort Myers, FL	0.80	G	0.27	P	0.58	P	-40.3	P
DEP Jacks Branch	DEP Jacks Branch at SR 78	0.85	VG	0.62	F	0.80	G	-10.2	G
DEP Fast Creek	DEP Fast Creek at SR 80	0.30	P	NC	NC	NC	NC	NC	NC
DEP Pollywog Creek	DEP Pollywog Creek at SR 78	0.15	P	NC	NC	NC	NC	NC	NC
DEP Powell Creek	DEP Powell Creek at SR 78 (13 daily values)	0.46	P	NC	NC	NC	NC	NC	NC
DEP Stroud Creek	DEP Stroud Creek (13 daily values)	0.82	VG	NC	NC	NC	NC	NC	NC
DEP Yellow Fever Creek	DEP Yellow Fever Creek (13 daily values)	0.39	P	NC	NC	NC	NC	NC	NC

NC = Not calculated

2.3.4 Hydrology Parameter Sensitivity Analysis

A parameter sensitivity analysis was conducted using five of the primary hydrology parameters: ground water recession rate (AGWRC), infiltration rate (INFILT), upper zone storage (UZSN), lower zone storage (LZSN), and lower zone evapotranspiration (LZETP). Results of the sensitivity analysis were compared at two major tributaries in the Caloosahatchee River Watershed: Orange River (USGS 02293055) and Telegraph Creek (USGS 022929176). These two drainage areas have different land use compositions. Orange River is predominantly urban whereas Telegraph Creek is primarily composed of agricultural and natural (i.e. wetland and forest) land use types.

A draft 2017 HSPF Model version date stamped June 14, 2016, was used as the baseline model. Ten sensitivity scenarios were developed by varying parameters in the baseline model, and the scenarios setups are summarized in **Table 61**. The monthly average percent flow difference for each sensitivity analysis for the Orange River and Telegraph Creek compared to the baseline model are summarized in **Table 62** and **Table 63**, respectively. **Table 64** and **Table 65** summarize the total cumulative volume percent difference and flow duration differences at six points along the flow duration curve for the Orange River and Telegraph Creek, respectively, compared to the baseline model. Percent different statistical comparisons were calculated as (Scenario-Baseline)/Baseline. A positive value indicates an increase in flow/volume and a negative value indicates a decrease in flow/volume. The bold numbers highlight the month and points on the flow duration curve where the largest changes in flow/volume occurred due to changes in the parameterization.

Decreasing INFILT by 50% caused model instability, and the HSPF model terminated on July 4, 2008. Therefore, to evaluate INFILT sensitivity, the model results from January 1, 1996 through July 4, 2008 were used (Baseline-2008). For all other parameter sensitivities, the full model simulation period from January 1, 1996 through December 31, 2014 was used (Baseline-2014).

Modifying AGWRC had the most impact on average monthly flows during the late fall and winter months. For Orange River, decreasing AGWRC by 0.01 decreased the monthly average flows by more than 16% in the month of January, whereas an increase of AGWRC by 0.01 increased monthly average flows in January by over 29% (**Table 62**). At Telegraph Creek, decreasing AGWRC by 0.01 decreased the monthly average flows by more than 30% in the month of January, whereas an increase of AGWRC by 0.01 increased monthly average flows in January by over 58% (**Table 63**). Modifying AGWRC had the most impact on the 5th and 50th percentile flows, and relatively little influence on total volume and the 95th percentile and maximum flows in Orange River (**Table 64)** and Telegraph Creek (**Table 65**). The response of the model to AGWRC modifications agree with preconceived impacts, as AGWRC controls the ground water recession rate, which would be most noticeable during baseflows. Because AGWRC does not have a large impact on high flows, it does not impact the total cumulative volume. Sensitivity to AGWRC modification was greater in Telegraph Creek, likely because the watershed has less impervious area than the Orange River watershed, and therefore has a greater percentage of area contributing to infiltration and soil storage capacity, which results in more baseflow.

A change in INFILT had the most impact on average monthly flows during the winter months in the Orange River and late spring, early summer, and winter months in Telegraph Creek. These months typically had lower average flows compared to other months due to less precipitation. For Orange River, decreasing INFILT by 50% decreased the monthly average flows by more than 17% in the month of December, whereas an increase to INFILT by 50% increased monthly average flows in December by over

10% (**Table 62**). At Telegraph Creek, decreasing INFILT by 50% increased the monthly average flows by more than 38% in the month of June, whereas increasing INFILT by 50% decreased monthly average flows in January by approximately 4% (**Table 63**). Modifying INFILT had relatively little influence on total volume at Orange River (**Table 64)** and Telegraph Creek (**Table 65**). Decreasing INFILT increased peak flows (95th percentile and maximum flows) and reduced baseflows (5th percentile and minimum flows) for both Orange River and Telegraph Creek, and increasing INFILT had the opposite effect. The response of the model to INFILT modifications agree with preconceived impacts to maximum flow and baseflow. However, the individual monthly results, specifically from November through December, did not necessarily respond as expected. Precipitation is highest in the Caloosahatchee River Watershed during the summer and early fall, typically ranging between 6 and 12 inches a month, and total flow volume increases throughout the summer and is highest in the early fall. Beginning in November, precipitation decreases significantly to less than 1 inch, and total flow volume decreases rapidly to less than 10 cfs during this period. During these months, stormflow is a low percentage of the total flow, and lower INFILT likely prevents replenishment of ground water storage, which causes baseflow derived from ground water storage to be reduced at a greater rate, which results in less streamflow.

Modifying UZSN had the most impact on average monthly flows during the summer months. For Orange River, decreasing UZSN by 50% increased the monthly average flows by 10% in the month of June, whereas increasing UZSN by 50% decreased monthly average flows in July by over 6% (**Table 62**). At Telegraph Creek, decreasing UZSN by 50% increased the monthly average flows by nearly 29% in the month of May, whereas increasing UZSN by 50% decreased monthly average flows in June by over 18% (**Table 63**). Modifying UZSN had the most impact on total volume and the 95th percentile and maximum flows for Orange River (**Table 64**) and Telegraph Creek (**Table 65**). The response of the model to UZSN modifications agree with preconceived impacts. When the upper zone storage capacity is filled, which would occur more quickly and frequently when UZSN is lower, more overland flow would occur, increasing higher flows. During low flow period, less water would be available to supply the stream with baseflow.

Modifying LZSN had the most impact on average monthly flows during the summer months. For Orange River, decreasing LZSN by 50% increased the monthly average flows by 33% in the month of June, whereas increasing LZSN by 50% decreased monthly average flows in July by over 18% (**Table 62**). At Telegraph Creek, decreasing LZSN by 50% increased the monthly average flows by nearly 61% in the month of May, whereas increasing LZSN by 50% decreased monthly average flows in May by nearly 27% (**Table 63**). Modifying LZSN had the greatest impact on total volume, average flows, and the 95th percentile flows for Orange River (**Table 64**), and all flows except the minimum flows in Telegraph Creek (**Table 65**). The response of the model to LZSN modifications is seasonal in nature. During the wet summer periods, a decrease in LZSN causes less water to be available and lost to ET, and more water to runoff as overland flow when the storage is full, thereby increasing overall flow volume. An increase in LZSN allows for an increase in water storage, causing more water to be lost through ET during the summer months.

A change in LZETP had the most impact on average monthly flows during the summer months. For Orange River, decreasing LZETP by 0.2 increased the monthly average flows by nearly 16% in the month of June, whereas increasing LZETP by 0.2 decreased monthly average flows in June by over 19% (**Table 62**). At Telegraph Creek, decreasing LZETP by 0.2 increased the monthly average flows by nearly 41% in the month of May, whereas increasing LZETP by 0.2 decreased monthly average flows in May by over 42% (**Table 63**). Modifying LZETP resulted in a change in volume greater than 10% for minimum, 5th

percentile, and 50th percentile flows in Orange River (**Table 64**) and a change in volume greater than 10% along the entire flow duration curve of Telegraph Creek, with the exception of the minimum and maximum flows (**Table 65**). The response of the model to LZTEP modifications agree with preconceived impacts. A lower LZETP values decreases the amount of water lost to ET, and the volume in the lower zone storage would be greater which can supply the stream with more baseflow, and the opposite is true for higher LZETP values.

TABLE 61: LIST OF SENSITIVITY SCENARIOS

Scenario Description	Parameter	Decrease	Increase
AGWRC Shift	AGWRC	0.01	0.01
INFILT Shift	INFILT	50%	50%
UZSN Shift	UZSN	50%	50%
LZSN Shift	LZSN	50%	50%
LZETP Shift	LZETP	0.2	0.2

TABLE 62: MONTHLY AVERAGE FLOW PERCENT DIFFERENCE AT USGS 02293055

Scenario	Jan (cfs)	Feb (cfs)	Mar (cfs)	Apr (cfs)	May (cfs)	Jun (cfs)	Jul (cfs)	Aug (cfs)	Sep (cfs)	Oct (cfs)	Nov (cfs)	Dec (cfs)
Baseline - 2014	14.97	18.80	22.91	15.17	18.57	85.40	154.14	206.35	229.88	118.51	52.87	27.26
Baseline - 2008*	15.11	21.77	23.14	13.04	16.65	94.82	155.67	198.84	237.76	116.07	57.77	28.57
AGWRC-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.01	***-16.1%***	-5.5%	-2.0%	-3.0%	-1.7%	2.8%	3.6%	2.8%	1.8%	-1.6%	-7.1%	-12.2%
+0.01	***29.2%***	17.5%	9.2%	11.4%	7.7%	-1.8%	-4.1%	-4.1%	-3.7%	-1.8%	3.7%	13.3%
INFILT-Shift*	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**
-50%	-16.2%	4.6%	0.9%	-6.6%	-2.4%	13.2%	5.2%	4.0%	3.2%	-7.6%	-5.5%	***-17.8%***
+50%	9.0%	-2.3%	0.2%	3.9%	1.9%	-4.9%	-2.1%	-1.6%	-1.8%	3.9%	3.8%	***10.3%***
UZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	-3.9%	3.3%	6.2%	3.2%	1.3%	***10.0%***	7.3%	5.2%	4.2%	3.2%	3.5%	-4.6%
+50%	3.8%	-0.9%	-2.9%	-1.1%	-0.6%	***-6.5%***	-5.2%	-3.6%	-2.8%	-2.1%	-1.9%	3.7%
LZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	-9.6%	-2.9%	7.0%	8.1%	10.2%	***33.0%***	31.0%	16.4%	9.4%	3.4%	-4.9%	-10.9%
+50%	5.8%	6.9%	2.9%	0.7%	-0.8%	-13.1%	***-18.5%***	-13.1%	-9.2%	-5.8%	-1.9%	3.2%
LZETP-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.2	10.6%	11.7%	13.8%	13.4%	11.2%	***15.5%***	10.6%	5.2%	2.9%	2.3%	5.5%	10.9%
+0.2	-11.8%	-11.5%	-13.8%	-13.8%	-10.3%	***-19.1%***	-14.2%	-7.9%	-4.7%	-3.8%	-7.5%	-13.0%

* Results based on model run from January 1, 1996 - July 4, 2008

TABLE 63: MONTHLY AVERAGE FLOW PERCENT DIFFERENCE AT USGS 022929176

Scenario	Jan (cfs)	Feb (cfs)	Mar (cfs)	Apr (cfs)	May (cfs)	Jun (cfs)	Jul (cfs)	Aug (cfs)	Sep (cfs)	Oct (cfs)	Nov (cfs)	Dec (cfs)
Baseline - 2014	25.77	18.67	19.79	9.54	5.90	44.18	79.71	144.18	182.17	121.63	81.96	42.97
Baseline - 2008*	28.31	22.38	25.53	8.63	5.05	57.98	83.43	132.56	178.87	118.89	85.57	44.61
AGWRC-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.01	***-30.6%***	-22.9%	-11.5%	-18.8%	-22.1%	8.9%	15.9%	12.4%	9.1%	0.7%	-13.1%	-27.1%
+0.01	58.2%	65.8%	43.7%	73.2%	***100.7%***	0.3%	-16.6%	-17.8%	-17.6%	-14.6%	2.7%	28.6%
INFILT-Shift*	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**
-50%	***-18.3%***	-0.9%	0.4%	-28.4%	-20.8%	38.6%	13.9%	10.3%	7.7%	-13.0%	-9.4%	-23.3%
+50%	***10.7%***	3.4%	-1.6%	16.5%	14.8%	-15.7%	-6.0%	-4.3%	-3.7%	5.8%	4.2%	14.5%
UZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	-0.8%	1.0%	8.2%	12.6%	7.6%	***28.8%***	19.4%	11.4%	8.3%	2.9%	4.8%	-1.9%
+50%	2.1%	0.9%	-3.0%	-8.2%	-3.0%	***-18.1%***	-12.8%	-8.0%	-5.2%	-2.1%	-4.3%	2.1%
LZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	-8.1%	-6.8%	-1.7%	0.0%	16.0%	***63.0%***	55.5%	35.3%	20.8%	8.7%	0.8%	-4.4%
+50%	-0.6%	3.5%	3.5%	8.7%	8.7%	-21.4%	***-26.9%***	-21.8%	-16.1%	-11.0%	-6.9%	-4.2%
LZETP-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.2	10.3%	13.2%	13.0%	29.3%	***40.5%***	30.0%	22.4%	13.1%	7.4%	5.6%	6.9%	9.0%
+0.2	-13.4%	-14.5%	-12.0%	-36.7%	***-42.1%***	-38.0%	-29.4%	-18.7%	-12.2%	-9.9%	-11.7%	-13.1%

* Results based on model run from January 1, 1996 - July 4, 2008

TABLE 64: PERCENT VOLUME DIFFERENCE AT USGS 02293055

Scenario	Total Cumulative Volume (cfs)	Minimum Flow (cfs)	5th Percentile Flow (cfs)	50th Percentile Flow (cfs)	Average Flow (cfs)	95th Percentile Flow (cfs)	Maximum Flow (cfs)
Baseline - 2014	560,026.44	0.76	1.58	27.64	80.70	321.14	3102.90
Baseline - 2008*	364,904.45	0.76	1.47	26.29	79.87	323.37	3102.90
AGWRC-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.01	0.4%	-24%	***-28%***	-10%	0%	3%	0%
+0.01	-0.9%	12%	***100%***	8%	-1%	-4%	0%
INFILT-Shift*	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**
-50%	1.7%	-7%	-9%	-19%	2%	7%	***30%***
+50%	-0.4%	5%	4%	12%	0%	-1%	***-25%***
UZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	4.8%	-1%	-3%	0%	5%	***6%***	3%
+50%	-3.2%	1%	1%	0%	-3%	***-3%***	-4%
LZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	13.8%	-4%	0%	5%	14%	***15%***	7%
+50%	-9.6%	6%	3%	-5%	-10%	***-10%***	-6%
LZETP-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.2	6.9%	11%	***19%***	13%	7%	4%	0%
+0.2	-9.2%	-6%	-16%	***-18%***	-9%	-6%	-1%

* Results based on model run from January 1, 1996 - July 4, 2008

TABLE 65: PERCENT VOLUME DIFFERENCE AT USGS 022929176

Scenario	Total Cumulative Volume (cfs)	Minimum Flow (cfs)	5th Percentile Flow (cfs)	50th Percentile Flow (cfs)	Average Flow (cfs)	95th Percentile Flow (cfs)	Maximum Flow (cfs)
Baseline - 2014	450,340.9298	0.01	0.95	26.27	64.89	242.87	2017.00
Baseline - 2008*	294,651.1929	0.01	0.75	24.19	64.49	240.20	2017.00
AGWRC-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.01	1.6%	2%	***-60%***	-24%	2%	11%	1%
+0.01	-3.4%	-2%	***384%***	38%	-3%	-17%	-2%
INFILT-Shift*	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**	**% Diff from Baseline 2008**
-50%	2.4%	0%	-21%	-18%	2%	14%	***67%***
+50%	-0.5%	0%	9%	11%	-1%	-8%	***-25%***
UZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	9.0%	0%	-4%	4%	***9%***	14%	8%
+50%	-5.8%	0%	3%	-2%	-6%	-10%	***-9%***
LZSN-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-50%	21.6%	0%	19%	18%	***22%***	28%	16%
+50%	-14.2%	0%	7%	-13%	***-14%***	-18%	-13%
LZETP-Shift	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**	**% Diff from Baseline 2014**
-0.2	11.9%	0%	***48%***	27%	12%	10%	3%
+0.2	-16.9%	0%	***-43%***	-33%	-17%	-14%	-4%

* Results based on model run from January 1, 1996 - July 4, 2008

2.4 HSPF MODEL WATER QUALITY CALIBRATION

Tetra Tech completed the 2017 HSPF Model final water quality setup and evaluated the water quality calibration and validation results. For sediment, TN, and TP, Tetra Tech compared the simulated average annual unit area export loads to target unit area export loads. **Figure 37** shows simulated and target loads for sediment. Target loads for sediment were only obtained from Harper 1994, as SWET 2008 does not provide information for sediment export. **Figure 38** shows simulated and target loads for TN. **Figure 39** shows simulated and target loads for TP. Calibration plots showing comparisons between observed and predicted time series of TSS, NH_3, NOx, OrgN, total Kjeldahl nitrogen (TKN), TN, TP, BOD, DO, DO percent saturation, chlorophyll-*a*, and temperature are provided in **Appendix B**. **Appendix B** provides the simulated daily average concentration vs. point in time observed concentration temporal comparison plots; yearly box and whisker plots of simulated and observed concentration; plots of daily paired concentration regressions for TSS, TN, and TP; and monthly, annual, and daily paired statistical summaries for the six calibration and ten validation stations that had more than 98 sampling days of data. In addition, **Appendix B** includes the simulated and observed daily paired load regressions and simulated and observed annual and daily paired load statistics for TSS, TN, and TP. Loads were developed at the six water quality calibration stations and three water quality validation stations that were co-located with USGS flow monitoring gages.

Appendix B, as well as the calibration discussion in **Section 2.4.3**, were structured to present result information based on stream location and upstream land uses. Behavior of the instream water quality, including concentration magnitudes and seasonal trends, was similar among stations with similar dominant contributing land uses. In the results and **Appendix B**, the mainstem Caloosahatchee River stations were grouped together because they receive most of their load from Lake Okeechobee. In addition, stations with predominantly urban contributing land uses were grouped together, stations with predominantly natural contributing land uses were grouped together, and stations with predominantly agricultural contributing land uses were grouped together.

The statistical analysis of monthly, yearly, and daily paired concentrations along with yearly and daily paired loads were compared to Donigian (2002) and McCutcheon et. al. 1990 performance metrics and given a qualitative rating of Very Good (VG), Good (G), Fair (F), and Poor (P) (refer to **Section 1.2** for the details). The summary of the annual comparison of TSS, TN, and TP concentrations at each of the calibration and validation locations are shown in **Table 72**, **Table 73**, and **Table 74**, respectively.

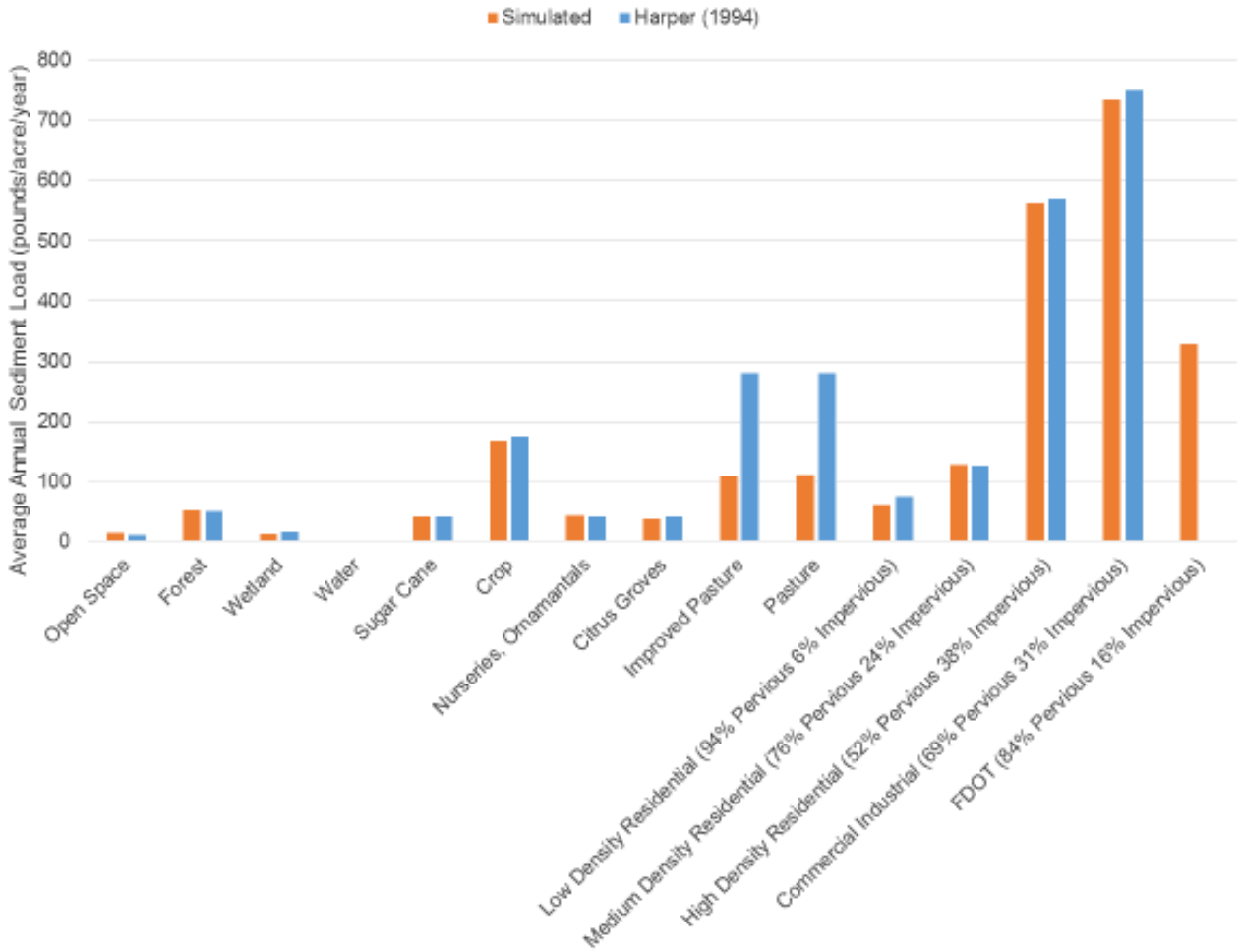

FIGURE 37: COMPARISON OF SIMULATED AND TARGET SEDIMENT AVERAGE ANNUAL SEDIMENT LOADS (HARPER 1994)

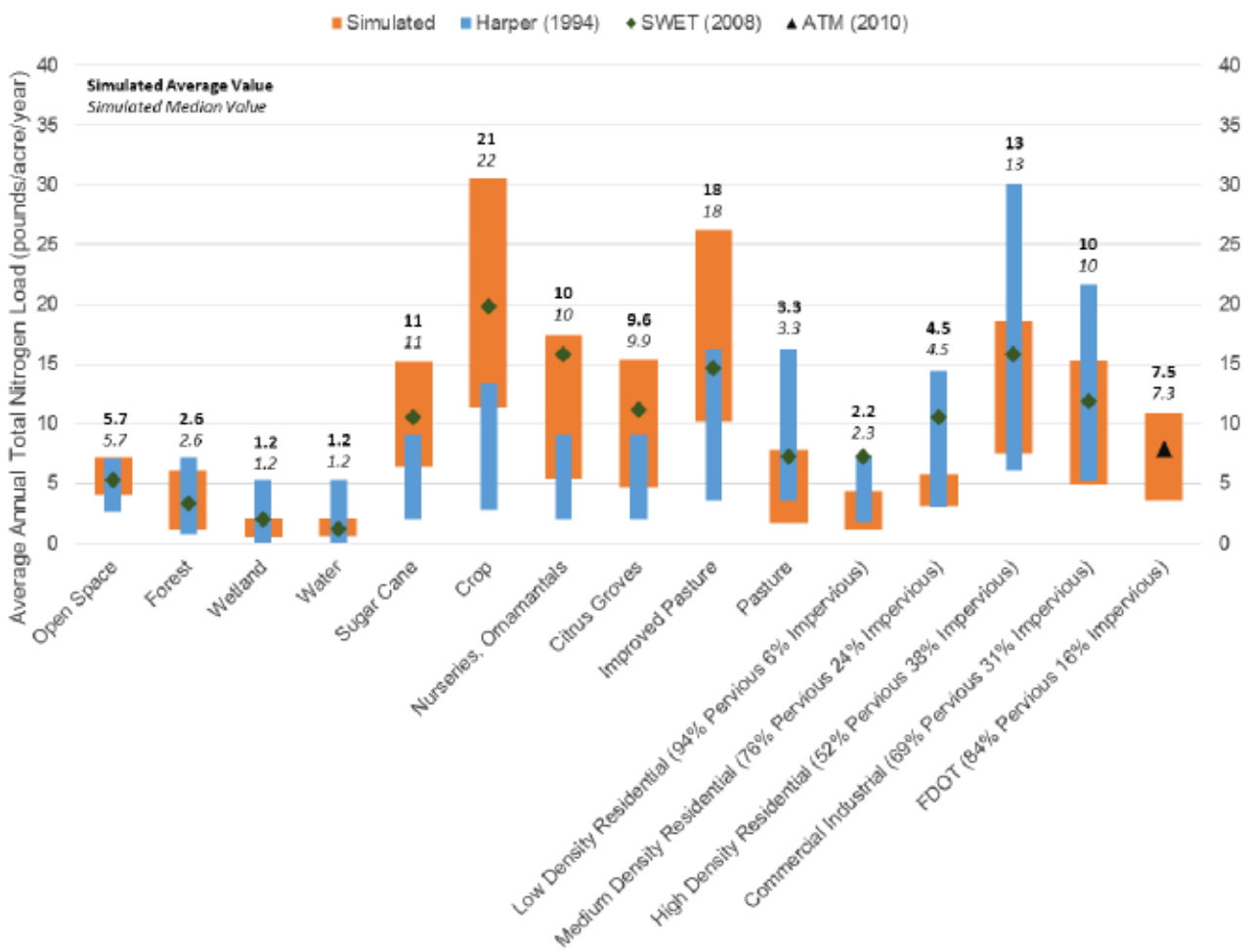

FIGURE 38: COMPARISON OF SIMULATED AND TARGET SEDIMENT AVERAGE ANNUAL TN LOADS (HARPER 1994, SWET 2008, AND ATM 2010)

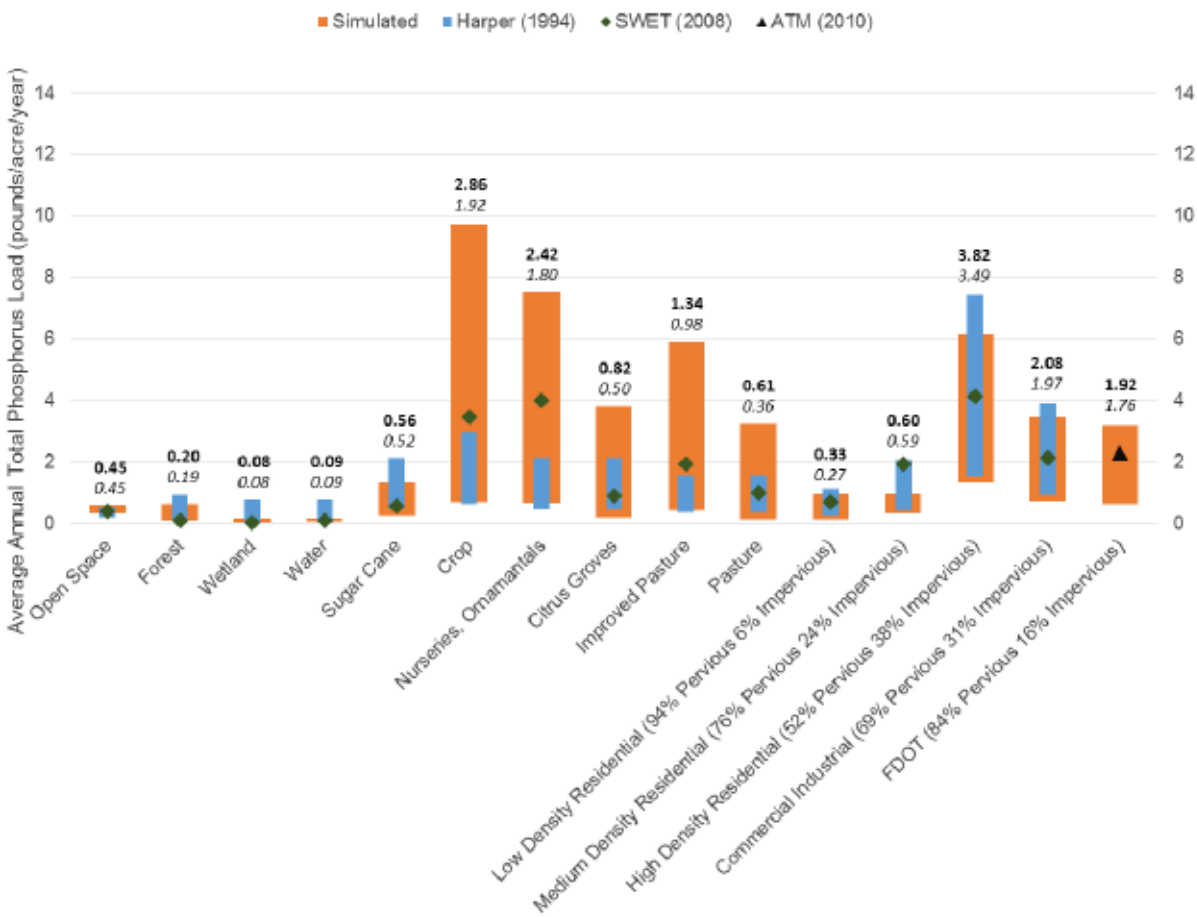

FIGURE 39: COMPARISON OF SIMULATED AND TARGET SEDIMENT AVERAGE ANNUAL TP LOADS (HARPER 1994, SWET 2008, AND ATM 2010)

2.4.1 Water Quality Calibration Methodology

Tetra Tech completed the setup of the 2017 HSPF model and evaluated the water quality calibration and validation results. The water quality model parameterization is summarized in **Table 66**. To calibrate the water quality portion of the model, Tetra Tech used similar methodology as outlined in **Section 2.3.2** for the hydrodynamic portion of the model. Graphical figures were developed to assess the temporal representation of the model to observed data on a daily and annual basis. Plots were created to compare daily observed data to modeled daily data to determine if the model was able to represent the correct seasonal trends and magnitudes of the measured data. Annual concentration box-and-whisker and regression plots were developed to evaluate model representation as well. The graphical analyses was complimented with a series of statistical tables that evaluated percent error on a daily, monthly, and annual basis. These evaluations determine if the model was representing seasonal and annual trends in the observed data.

TABLE 66: HSPF MODEL WATER QUALITY PARAMETRIZATION

Land Use	ACQOP NOx	SQOLIM NOx	WSQOP NOx	IFLW-CONC NOx	GRND-CONC NOx	ACQOP NH3	SQOLIM NH3	WSQOP NH3	IFLW-CONC NH3	GRND-CONC NH3	POTFW OrgM	IFLW-CONC OrgM	GRND-CONC OrgM	POTFW PO4	IFLW-CONC PO4	GRND-CONC PO4
Low Density Residential (Pervious)	0.0016	0.0128	0.9	0.14	0.06	0.0008	0.0024	0.9	0.07	0.03	225	13	1.95	6	0.13	0.013
Developed Open Space / Disturbed (Pervious)	0.0008	0.0064	0.9	0.08	0.04	0.0004	0.0012	0.9	0.04	0.02	450	10	6	3	0.02	0.002
Medium Density Residential (Pervious)	0.004	0.032	0.8	0.18	0.1	0.002	0.006	0.8	0.09	0.05	275	14	2.1	10	0.15	0.015
High Density Residential (Pervious)	0.006	0.048	0.7	0.2	0.089	0.003	0.009	0.7	0.1	0.044	325	15	2.25	15	0.2	0.02
Commercial/Institutional/Transportation (Pervious)	0.006	0.048	0.7	0.2	0.086	0.003	0.009	0.7	0.1	0.043	200	12	1.8	5	0.15	0.015
Industrial / Extractive (Pervious)	0.006	0.048	0.7	0.2	0.086	0.003	0.009	0.7	0.1	0.043	200	12	1.8	5	0.15	0.015
FDOT Right-of-Way (Pervious)	0.0036	0.0288	0.7	0.18	0.08	0.0018	0.0054	0.7	0.09	0.04	300	12	1.8	11	0.15	0.015
Sugar Cane	0.008	0.064	0.9	0.52	0.24	0.004	0.012	0.9	0.26	0.12	140	38	17.1	10	0.1	0.01
Row and Field Crops	0.024	0.192	0.9	1.04	0.48	0.012	0.036	0.9	0.52	0.24	175	69	31.05	25	0.26	0.026
Nurseries, Ornamentals, and Vineyards	0.034	0.272	0.9	1.3	0.6	0.017	0.051	0.9	0.65	0.3	525	22	9.9	75	0.75	0.075
Citrus Groves / Other Groves	0.034	0.272	0.9	1.3	0.6	0.017	0.051	0.9	0.65	0.3	210	44	19.8	30	0.07	0.007
Improved Pasture	0.0006	0.0048	0.9	1.3	0.6	0.0003	0.0009	0.9	0.65	0.3	114	76	34.2	14	0.25	0.025
Rangeland / Unimproved Pasture / Woodland Pasture / Shrub	0.00162	0.01296	0.8	0.18	0.08	0.00081	0.00243	0.8	0.09	0.04	100	12	5.4	8	0.15	0.015
Upland Forests	0.004	0.032	1.2	0.2	0.1	0.002	0.006	1.2	0.1	0.05	150	10	6	1	0.01	0.001
Wetlands	0.000048	0.000384	1.5	0.18	0.09	0.000024	0.000072	1.5	0.09	0.045	25	7.5	7	1	0.01	0.001
Water	0.000024	0.000192	1.5	0.12	0.06	0.000012	0.000036	1.5	0.06	0.03	10	6	5.6	2	0.03	0.003

[1] Varies by month (average value supplied).

The water quality parameters for the HSPF PQUAL, PSTEMP, PWTGAS, IQUAL, IWTGAS, and RQUAL modules were mapped from the 2009 HSPF Model to the 2017 HSPF Model and used for the initial 2017 HSPF Model water quality run, which represented a baseline for model improvement. The 2017 HSPF Model land modules were represented as a three-digit number that identified both the NEXRAD zone and land use. The 2017 HSPF Model included 16 pervious land segments and seven impervious land segments. Both pervious and impervious land segments were included for each of the 15 NEXRAD zones. The parameter mapping from the 2009 HSPF Model to the 2017 HSPF Model is shown below in **Table 58**. Unique parameters were not specified for the individual RCHRES in the 2009 HSPF Model; therefore, all RCHRES were assigned the 2009 HSPF Model parameterization in the initial 2017 HSPF Model.

TABLE 67: HYDROLOGY PARAMETER MAPPING FOR HSPF MODEL WATER QUALITY MODULES

Land Use Description	Land Segment	2009 HSPF Land Segment ID	2017 HSPF Land Segment ID
Low Density Residential (Pervious)	PERLND	8	1
Developed Open Space / Disturbed (Pervious)	PERLND	5	2
Medium Density Residential (Pervious)	PERLND	9	3
High Density Residential (Pervious)	PERLND	7	4
Commercial/Institutional/Transportation (Pervious)	PERLND	6	5
Industrial / Extractive (Pervious)	PERLND	6	6
FDOT Right-of-Way (Pervious)	PERLND	6	7
Sugar Cane	PERLND	1	8
Row and Field Crops	PERLND	1	9
Nurseries, Ornamentals, and Vineyards	PERLND	3	10
Citrus Groves / Other Groves	PERLND	3	11
Improved Pasture	PERLND	1	12
Rangeland / Unimproved Pasture / Woodland Pasture / Shrub	PERLND	2	13
Upland Forests	PERLND	4	14
Wetlands	PERLND	10	15
Water	PERLND	10	16
Low Density Residential (Impervious)	IMPLND	8	1
Medium Density Residential (Impervious)	IMPLND	9	2
High Density Residential (Impervious)	IMPLND	7	3
Commercial / Institutional / Transportation / Industrial / Extractive (Impervious)	IMPLND	6	4
FDOT Right-of-Way (Impervious)	IMPLND	6	5
Agriculture (Impervious)	IMPLND	1	6
Other (Impervious)	IMPLND	6	7

2.4.1.1 Sediment

Sediment can be a difficult water quality constituent to represent accurately in watershed and stream models due to the complex behavior of sediment within a watershed system. Within a watershed, sediment sources and pathways include land surface runoff loading and erosion, delivery of these eroded sediment sources to streams, drains and other pathways, and subsequent instream transport, scour, and deposition processes (USEPA 2006). Sediment calibration requires estimating model parameters and then adjusting parameterization to ensure a reasonable simulation of the sediment sources on the watershed, delivery to the waterbody, and transport behavior within the channel system. Sediment calibration for the 2017 HSPF

Model was undertaken in accordance with guidelines contained in *BASINS Technical Note 8: Sediment Parameters and Calibration Guidance for HSPF* (USEPA 2006).

Tetra Tech compared the 2014 HSPF Model sediment parameters to recommended ranges from USEPA's *BASINS Technical Note 8: Sediment Parameter and Calibration Guidance for HSPF* (USEPA 2006), and most were found to be reasonable and within range. The following parameters were found to be outside the recommended range:

- KRER is the coefficient in the soil detachment equation and is analogous to the soil erodibility factor (K) in the Universal Soil Loss Equation. The recommended range for KRER is 0.15 to 0.45 with a minimum possible value of 0.05. The 2014 HSPF Model used a range of 0.001 to 0.25, with the lowest values assigned to the wetlands/water land use.
- COVER is the fraction of land surface protected from rainfall and a value of 1 equates to effectively no sediment erosion occurring. The recommended range for COVER is 0 to 0.9 with a maximum possible value of 0.98. The 2014 HSPF Model used a range of 0.3 to 1, with the values of 1 assigned to the wetlands/water land use.
- KSER is the coefficient in the sediment wash off equation for pervious lands, where a lower value represents a lower potential for detached sediment to wash off the land. The recommended range for KSER is 0.5 to 5 with a minimum possible value of 0.1. The 2014 HSPF Model used a range of 0.001 to 0.34, with the values of 0.001 assigned to the wetlands/water land use.
- KEIM is the coefficient in the sediment wash off equation for impervious lands, where a lower value represents a lower potential for detached sediment to wash off the land. The recommended range for KEIM is 0.5 to 5 with a minimum possible value of 0.1. The 2014 HSPF Model used a universal value of 0.075 for all land uses.

The 2014 HSPF Model used a consistent set of instream sediment parameter values applied to all model reaches. This approach allows for minimal refinement of the sediment simulation.

Review of the initial 2017 HSPF Model water quality results indicated that sediment transport was not appropriately represented at many stations, and that the fractionation of upland sediment into the RCHRES did not appear to be based on measured data or literature values. To address this issue, Tetra Tech updated TAUCS (critical shear stress for scour) and TAUCD (critical shear stress for deposition) for each individual reach. Upland fractionation of sediment was updated based on upland particle size distribution and weighted to promote the upland transport of fines. Additionally, upland loads of sediment were constrained to within observed unit area loads based on Harper (1994) (**Section 2.4.2**) by adjusting the upland soil erodibility factor (KRER), which is analogous to K in the Universal Soil Loss Equation. The delivery of sediment was further constrained by the upland sediment transport (KSER). The 2017 HSPF Model final water quality calibration was updated using the following methodology:

- KRER set to values based on analysis of SSURGO KKFACT (soil erodibility factor) for each land use and NEXRAD zone. The SSURGO analysis indicated that extremely small values (average 0.05) of KKFACT are found in the Caloosahatchee River Watershed. During upland sediment calibration, KRER was increased by an order of magnitude above the processed KKFACT. This allowed for appropriate sediment generation while keeping KSER near the recommended ranges.
- COVER was adjusted to more appropriately represent the fraction on land shielded from raindrop impact based on land use type. Revised values ranged from 0.3 to 0.8, although 0.098 used for the Water land use.

- KSER was adjusted to calibrate upland sediment yields to target yields after supplying updated KRER values. The revised values ranged from 0.001 to 5. Low values were used for Water and Wetlands, and high values were used for Commercial and Industrial land uses.
- For impervious lands, the parameters JSER, JRER, ACCUM, and REMSDP were modified so that land use export of solids was in range with values used in previous modeling experience for impervious surfaces. The initial 2017 HSPF Model water quality simulation had impervious land generating more than one ton of sediment per year, which was not realistic for the area. The impervious associated sediment load was reduced in the final 2017 HSPF Model.
- Instream transport was updated by analyzing simulated TAU (critical shear stress) and supplying values for TAUCS (critical shear stress for scour) and TAUCD (critical shear stress for deposition) based on the simulated TAU for each individual reach. TAUCS was set at the 95th percentile of TAU for silt and 90th percentile of TAU for clay. TAUCD was set at the 25th percentile of TAU for silt and 20th percentile of TAU for clay. This provided each reach its own unique values for TAUCS and TAUCD based on the simulated TAU of that reach.
- The HSPF model simulates sediment delivery from the land surface in a single class; this is partitioned into sand, silt, and clay at the edge of a reach. SSURGO data from the top soil layer were analyzed and results indicated that the surface sediment is comprised of 92.5% sand, 3.7% silt, and 3.8% clay. Fine particles, however, are more easily transported and enrichment of fines takes place both in the process of pickup of detached soil particles from the land surface and during transport in ephemeral streams. The coarser sand fraction is less likely to be moved in the first place, and is more likely to be deposited out in first-order and ephemeral streams before reaching modeled stream reaches. To account for this, Tetra Tech assumed an enrichment factor of 10 for clay and 5 for silt. This resulted in sediment partitioning at stream edge to 44% sand, 18% silt, and 38% clay.

2.4.1.2 Temperature and DO

A detailed diel simulation of stream water temperature is a complex undertaking. Water quality simulation depends on the simulation of hydrology and sediment transport. For temperature, the timing and magnitude of heat fluxes are controlled by a variety of factors, such as stream orientation and vegetative and topographic shading angles that cannot be fully represented in a watershed-scale HSPF model. The HSPF model approximates all these details through the assignment of a temporally constant "surface exposed" (CFSAEX) factor that represents the average fraction of treetop solar radiation reaching the water surface. In addition to instream temperature influences, the model also approximates the temperature of runoff from the uplands for each individual flow path (surface, interflow, and ground water). These temperatures are calculated by the model by supplying the slope and intercept of an equation that regresses observed soil layer temperature and observed air temperature. The model then uses those coefficients and calculates the soil layers temperature based on the air temperature supplied as an atmospheric forcing.

The DO simulation uses reaeration, the decay of organic matter (CBOD), oxidation of NH_3 and nitrite nitrogen, sediment oxygen demand, algal photosynthesis and respiration, and is also dependent on stream temperature. Therefore, obtaining a precise calibration to DO can be very complex. Both the DO and temperature parameters were adjusted during the 2017 HSPF Model calibration to improve model representation.

Review of the initial 2017 HSPF Model water quality results identified issues with both temperature and BOD/DO concentrations. The simulated temperature was low at many stations. Tetra Tech modified the

stream bed temperature interaction, the correction factor for solar radiation (CFSAEX), and the soil temperature regression equation values to improve calibration. The instream BOD/DO concentrations were not within range of the measured data at most locations. The reaeration and BOD decay instream parameters were revised, and partitioning of organic matter into CBOD was also revised to improve model calibration. The 2017 HSPF Model final water quality calibration was updated using the following methodology:

- CFSAEX was modified for each reach and was determined by tabulating the contributing upland area fraction of forest and citrus groves and subtracting that value from 1. Values near 1 mean little to low solar radiation correction because there is little to no forest and citrus groves to provide shading to waterways.
- Soil temperature regression equations were updated based on regressions created using measured air temperature and soil temperature from eight years of continuous monitoring at Brunswick, Georgia. The regression data supplied the relationship between air temperature and soil temperature, and it was assumed that the relationship observed at Brunswick, Georgia is similar in the Caloosahatchee River Watershed. Ultimately, soil temperature is mostly dependent on the supplied air temperature.
- Stream bed temperatures were modified to obtain a better fit to observed temperature data. In the final 2017 HSPF Model setup, stream bed temperature had a large influence on simulated instream temperature and modifying stream bed temperature was the dominant calibration parameter for temperature.
- BOD was brought into reasonable range with observed data primarily by modifying the partitioning of organic matter into CBOD. The assignment from organic matter to CBOD is based on the labile fraction of OrgC (x 2.7 to obtain O_2 units). The labile fraction of OrgC from nonpoint sources is typically low since there has been time for decay on the land surface and in the flow path to the stream. Therefore, it was assumed that the labile fraction of OrgC was 15%, and when converted to O_2 units, the multiplier from organic matter to CBOD became 0.40 (40%).

DO was brought into reasonable range with observed data by specifying an increased benthic oxygen demand (BENOD) for all non-mainstem RCHRES (50 $mg/m^2/hr$). Higher values of BENOD (100 $mg/m^2/hr$) along with a reduction to DO super saturation from 1.15 to 1.0 were used for Deep Lagoon Canal, Billy Creek, Popash Creek, Powell Creek, Stroud Creek, Orange River, Telegraph Creek, Hickey Creek, Bedman Creek, Pollywog Creek, and Jack's Branch. BENOD for the Industrial Canal and the mainstem Caloosahatchee River were decreased to 25 $mg/m^2/hr$ and 15 $mg/m^2/hr$, respectively, based on the model predictions of DO in comparison to observed DO in those RCHRES. In some reaches, small natural or artificial impoundments along with wetland areas caused ponding of water and slower velocities. In these reaches the F-TABLES were modified to represent small weir structures that slowed velocities and decreased DO (referred to as 'fake ponds' in the UCI file). Additionally, the DO reaeration parameters were forced to only use the O'Connor-Dobbins equation, instead of varying between Owens, Churchill, or O'Connor-Dobbins equations depending on the velocity and depth of water.

2.4.1.3 Nutrients and Phytoplankton

Accumulation and wash off rates play an important role in the determination of nonpoint source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of hydrological characteristics within a watershed. It must also appropriately represent the rate at which nutrient components build-up between rain events and wash off during rain events. Key water quality

parameters include initial storage, wash off and scour potency, accumulation rates, and asymptotic maximum storage amounts. The water supplied to a stream from ground water and through interflow also plays an important role in loading to a water body.

Biochemical instream processes play an important role on nutrient concentrations spatially and temporally. Biochemical processing can also have a large influence on DO and ultimately water quality. The watershed model should appropriately represent the major biochemical processes occurring within the stream, including DO balances, organic and inorganic nutrient balances, and plankton populations. Key processes for nutrients include nitrification, denitrification, sediment adsorption/desorption of NH_3 and PO_4, assimilation, and plankton respiration.

The major nutrients controlling algal growth are phosphorus and nitrogen. Both are simulated in detail in the HSPF model. Plant growth has an important effect on nutrient balances during low flow conditions and serves to convert inorganic nutrients into organic forms; therefore, nitrogen and phosphorus species must be calibrated simultaneously with algae. The scheme does not include a representation of floating or emergent rooted macrophytes. While these can sometimes be successfully approximated with the benthic algae routines, the light availability calculations for benthic algae are not appropriate to these types of macrophytes and the program does not consider that floating/rooted macrophytes can exchange gases with the atmosphere and water column and obtain nutrients from the sediment and water column.

Nutrient concentrations observed instream are the result of both upland and biochemical channel processes, and there are multiple sets of parameters that control results. The general strategy for nutrient calibration consists of the following steps:

- Specify initial upland parameter values based on external information, if known, for TN and TP.
- Adjust upland parameters to approximate nutrient unit loading calibration targets available from other studies.
- Partition upland total nutrients into species at the edge of stream.
- Compare to instream monitoring data and adjust upland and reach parameters to obtain as good a fit as is possible.

Tetra Tech reviewed the 2014 HSPF Model water quality parameters and the following documents major findings of the review:

- For the upland simulation of NOx, NH_3, OrgN, PO_4, and CBOD, the pollutant accumulation rates and limits appeared to have been developed using a manual calibration for both pervious and impervious lands. The values varied across the modeled pervious land uses, but were consistent for the same land use category in different precipitation zones. This was also the case for the monthly interflow and ground water concentrations assigned to pervious land uses.
- A single pollutant accumulation rate and limit was applied to all impervious land uses for each upland pollutant. WSQOP, defined as the rate of surface runoff that removes 90% of the accumulated pollutant, was set at 0.5 inches for all pollutants for impervious land uses. The values assigned to pervious areas varied across land uses, but like the accumulation rates and limits, were consistent across precipitation zones.
- Atmospheric deposition of NOx, NH_3, OrgN, and PO_4 to surface waters was represented on a monthly basis.

- For the instream nutrient simulation using HSPF RQUAL, all parameters were fixed in the 2014 HSPF Model, generally to HSPF model defaults, except PHYSET, which is the phytoplankton settling rate. This parameter was generally assigned a value of 0.015 feet/hour, although smaller values were assigned to some reaches.
- When loads were transferred from the upland simulation to the reach simulation, professional judgement assumptions were likely made for disaggregating upland parameters to instream constituents. The only disaggregation that was referenced, however, was the relation of OrgP to OrgN, which was described as being "based on [station] CES01 data" in the model UCI file notes. For the remainder of the modeled pollutants there was no documentation on how the fractionations were determined. This includes the disaggregation of sediment into sand, silt, and clay; OrgN into OrgC; and NOx into nitrate and nitrite.

Review of the initial 2017 HSPF Model water quality results identified several issues with the nutrient calibration. The TP loading from urban areas was high when compared to the target unit area loads from Harper (1994) and SWET (2008). Loads were reduced to be within range of the literature values. In contrast, the TN loading from natural areas and agricultural areas was low. The upland loading calibration was adjusted to be closer within range of the Harper (1994) unit area loads for the natural areas and the SWET (2008) unit area loads for agricultural areas. In addition, chlorophyll-*a* was high at most station locations. After reducing the TP loads and improving the BOD calibration, chlorophyll-*a* concentrations were reduced and nutrient uptake parameters, optimal temperature ranges for algal growth, and death rates were adjusted to improve the overall chlorophyll-*a* calibration. Additional information describing the methodology used to develop the 2017 HSPF Model final water quality calibration is provided in the paragraphs below.

The number and type of upland simulated pollutants were changed to improve model representation. Additionally, the previous approach of using a single pollutant accumulation rate and limit applied to all impervious land uses for each upland pollutant was changed. The 2017 HSPF Model instead uses a unique pollutant accumulation rate and limit for each type of impervious land. The unique pollutant accumulation rates were established during calibration when tuning the upland simulation to the target unit area loads. The following components were simulated as loadings from the land surface as quality constituents or pollutants in the outflows from a pervious/impervious land segment using simple relationships with water and/or sediment yield (PQUAL/IQUAL): NOx, NH_3, PO_4, and organic matter. Each of these constituents was then partitioned at the point of entry into the stream network (RCHRES):

- NOx upland loads were partitioned into dissolved nitrate and dissolved nitrite. The 2014 HSPF Model included this as a 50/50 split, but it was updated to a 90/10 split in the 2017 HSPF Model, which accounts for the unstable nature of the nitrite form.
- NH_3 upland loads entered the stream as 100% dissolved NH_3. NH_3 was simulated as sediment-associated in the stream and equilibrium partitioning to the sorbed form occurred instantaneously with the local suspended sediment concentration. Therefore, there was no need to assign a fraction to the sorbed form from the uplands.
- PO_4 upland loads entered the stream as 100% dissolved PO_4. PO_4 was simulated as sediment-associated in the stream, and the fraction that became sorbed depended on the local suspended sediment concentration.
- Organic matter (biomass) upland loads were partitioned into labile and refractory OrgC, OrgN, and OrgP components. The stoichiometry of organic matter in the HSPF model is often assumed

to follow the typical composition of plant matter. For instance, the HSPF model defaults assume that carbon is 49% of biomass by weight, while the C:P ratio is 106 and the C:N ratio is 6.62. For terrestrial detritus, however, the ratios may be quite different, with a depletion of N and P relative to carbon. For example, Cross et al. (2003) working at the Coweeta Hydrologic Laboratory in western North Carolina, documented a C:N ratio of 34 and a C:P ratio of 1,015 in fine particulate organic matter in headwater streams. Tetra Tech assumed that the stoichiometric ratios for organic matter wash off from the land were a calibration parameter within these ranges.

The partitioning of upland constituents to instream constituents does not occur for subbasins without reaches within the HSPF domain. Subbasins without reaches were located adjacent to the Caloosahatchee Estuary and were not located upstream of another HSPF model reach. When analyzing and calibrating unit area export loads by land use, the output for the HSPF model was analyzed based on the land use loading export, not the RCHRES output. Upland loads of constituents that partitioning needed to be accounted for were calculated externally. External post-processing was completed in Excel to generate TN and TP export loads by land use, and the calculation to generate that information incorporated the discussed partitioning coefficients. The subbasins without reaches were assumed to have the same partitioning as subbasins with RCHRES.

All four upland components (NOx, NH_3, PO_4, and organic matter) can be loaded into the model reaches through either surface flow or subsurface flow (interflow and ground water discharge). Surface wash off loading was determined by parameterizing land use runoff from pervious and impervious surfaces. The HSPF PQUAL algorithms require the user to specify concentration values, which may vary monthly, for interflow and ground water. Inorganic phosphorus loading from pervious surfaces was simulated as a sediment-associated process because of the strong affinity of PO_4 for soil particles. Surface loading of inorganic phosphorus was thus determined by applying a potency factor to the sediment load. Subsurface flow pathways were assumed to primarily load small amounts of dissolved inorganic phosphorus. Organic matter was also simulated as a sediment-associated load from pervious surfaces, as this primarily represents the erosion of humus, leaf litter, and other detritus. Subsurface flow pathways are assumed to primarily load small amounts of dissolved organic material, which represents organic acids picked up by water moving through the soil profile.

In contrast to phosphorus, inorganic nitrogen is highly soluble, and loading in surface runoff may occur independent of sediment movement, such as in areas where fertilizer is applied. Further, much of the nitrate load in surface runoff represents input from atmospheric deposition. Therefore, inorganic nitrogen loading from pervious surfaces was represented via a buildup-wash off process in which the user specifies a rate of accumulation, an accumulation limit, and a flow rate sufficient to remove 90% of the accumulated material.

All four upland constituents (NOx, NH_3, PO_4, and organic matter) and all three flow paths (surface flow, interflow, and ground water) for each land use were adjusted until an acceptable agreement between simulated average annual upland load and published average annual upland land use load was achieved. The buildup and wash off surface flow parameterization was first adjusted to ensure that upland loads were within range of expected “edge of field” TN and TP loads (Harper 1994 and SWET 2008). For the interflow and ground water concentrations, the 2009 Model interflow and ground water nutrient concentration parameters were refined by refining parameterization to improve the multi-constituent and multi-station instream simulated concentrations versus observed concentrations. Throughout the calibration process, the upland to instream partition coefficient for organic matter to OrgN, OrgP, and

OrgC was evaluated to ensure it was within accepted measured ratios (Redfield Ratio and Cross et. al. 2003).

The parameterization across the different land uses was heterogeneous, but was homogenous across the 15 NEXRAD zones in the model. This ensured that upland land use parameterization were not specifically fit to any one set of data, and that variability of upland loads for each land use were driven by atmospheric forcing (i.e. precipitation). After achieving acceptable upland land use calibration to targets, the instream calibration was reviewed and the upland land use parameterization was modified as necessary to bring acceptable agreement between simulated and observed instream concentration while maintaining acceptable agreement between simulated and target upland land use annual loads.

For calibration, Tetra Tech initially used the same organic matter to refractory OrgN and OrgP partitioning for all land uses in the model. During the course of calibration, it was determined that to achieve acceptable instream calibration for nitrogen and phosphorus, the organic matter to refractory OrgN and OrgP needed to be variable by land use. Therefore, different organic matter to refractory OrgN and OrgP partitioning was supplied for urban land uses, natural land uses, and agricultural land uses. **Table 68** provides the final calibrated organic matter to refractory OrgN and OrgP used for each land use type.

TABLE 68: ORGANIC MATTER TO REFRACTORY ORGN AND ORGP PARTITION COEFFICIENTS BY LAND USE TYPE

Constituent	Urban	Natural	Agricultural
OrgN	10.42%	13.02%	12.62%
OrgP	0.58%	0.98%	0.38%

2.4.2 Upland Land Use Calibration Performance

Literature upland land use nutrient loading rates for TN and TP represent “edge of field” values (Harper 1994 and SWET 2008). For the 2017 HSPF Model, the upland land use nutrient loading rates were assumed to represent “delivered to stream” values for the combination of surface runoff, interflow, and baseflow. **Table 69** presents TN and TP unit area loads provided in Harper 1994 and SWET 2008. Loads from each land use from Harper 1994 and SWET 2008 were assigned to similar 2017 HSPF Model land uses classifications. Harper and SWET values were similar for urban and natural land uses, but were different for agricultural land uses. The department provided guidance that more weight to should be given to Harper 1994 for urban areas and to SWET 2008 for agricultural areas.

TABLE 69: COMPARISON OF HARPER (1994) AND SWET (2008) TN AND TP LOADS PER ACRE

2017 HSPF Land Uses	Land use Classes (Harper 1994)	TN lb/acre/yr (Harper 1994)	TP lb/acre/yr (Harper 1994)	Sediment lb/acre/yr (Harper 1994)	Land Use Classes (SWET 2008)	TN lb/acre/yr (SWET 2008)	TP lb/acre/yr (SWET 2008)
Low Density Residential (Pervious)	Low Density Residential	1.7 - 7.3	0.26-1.11	75	Low Density Residential	7.26	0.68
Low Density Residential (Impervious)	Low Density Residential	1.7 - 7.3	0.26-1.11	75	Low Density Residential	7.26	0.68
Medium Density Residential (Pervious)	Medium Density Residential	3.0 - 14.4	0.43-2.07	125	Medium Density Residential	10.56	1.93
Medium Density Residential (Impervious)	Medium Density Residential	3.0 - 14.4	0.43-2.07	125	Medium Density Residential	10.56	1.93
High Density Residential (Pervious)	High Density Residential	6.1 - 30.1	1.51-7.45	570	High Density Residential	15.84	4.14
High Density Residential (Impervious)	High Density Residential	6.1 - 30.1	1.51-7.45	570	High Density Residential	15.84	4.14
Commercial / Institutional / Transportation (Pervious)	Industrial and Commercial	5.2 - 21.7	0.93-3.89	750	Other Urban	9.24 - 14.52	0.91 - 3.31
Industrial / Extractive (Pervious)	Industrial and Commercial	5.2 - 21.7	0.93-3.89	750	Other Urban	9.24 - 14.52	0.91 - 3.31
Commercial / Institutional / Transportation / Industrial / Extractive (Impervious)	Industrial and Commercial	5.2 - 21.7	0.93-3.89	750	Other Urban	9.24 - 14.52	0.91 - 3.31
Commercial / Institutional / Transportation / Industrial / Extractive (Impervious)	Mining	0.9 - 5.5	0.12-0.77	390	N/A	N/A	N/A
Developed Open Space / Disturbed (Pervious)	Open Land	2.6 - 7.1	0.18-0.51	10	Open Land	5.28	0.39
Rangeland / Unimproved Pasture / Woodland Pasture / Shrub	Pasture	3.6 - 16.3	0.35-1.57	280	Unimproved Pasture	7.26	0.99
Improved Pasture	Pasture	3.6 - 16.3	0.35-1.57	280	Improved Pasture	14.65	1.93
Row and Field Crops	Agriculture General	2.8 - 13.4	0.61-2.96	175	Row crops	19.8	3.45
Agriculture (Impervious)	Agriculture General	2.8 - 13.4	0.61-2.96	175	Row crops	19.8	3.45
Sugar Cane	Agriculture Tree Crop	2.0 - 9.0	0.46-2.12	40	Sugar Cane	10.56	0.55
Nurseries / Ornamentals / Vineyards	Agriculture Tree Crop	2.0 - 9.0	0.46-2.12	40	Ornamentals	15.84	4
Citrus Groves / Other Groves	Agriculture Tree Crop	2.0 - 9.0	0.46-2.12	40	Citrus	11.22	0.9
Rangeland / Unimproved Pasture / Woodland Pasture / Shrub	Rangeland	1.7 - 6.5	0.09-0.33	10	Rangeland	5.41	0.25
Upland Forests	Forest	0.8 - 7.2	0.11-0.92	50	Upland Forest	3.3	0.1
Wetlands	Wetland	0.0 - 5.3	0.00-0.76	15	Wetland	1.98	0.01
Water	Water	0.0 - 5.3	0.00-0.76	0	Water	1.19	0.07
FDOT Right-of-Way (Pervious)	N/A	N/A	N/A	N/A	Transportation	12.14	2.28
FDOT Right-of-Way (Impervious)	N/A	N/A	N/A	N/A	Transportation	12.14	2.28
Other (Impervious)	N/A	N/A	N/A	N/A	N/A	N/A	N/A

FDOT provided a report that included EMC values for the land uses under its jurisdiction (ATM 2010). The HSPF model does not allow for the explicit input of EMC data. Therefore, Tetra Tech processed the FDOT EMC data into unit area loads. The FDOT report provided the percent imperviousness for each drainage area in the study. Tetra Tech averaged the drainage area imperviousness and assigned runoff values from the SWET report. The runoff value, FDOT EMC, and average imperviousness were used to calculate TN and TP loads per acre per year for both FDOT Right-of-Way Pervious and FDOT Right-of-Way Impervious land use classes (**Table 70**).

TABLE 70: TN AND TP LOADS PER ACRE FOR FDOT LAND USES

FDOT Land Use Classes	Average % Impervious	TN mg/L (ATM 2010)	TP mg/L (ATM 2010)	Runoff in/year	TN load lb/acre/year	TP load lb/acre/year
FDOT Right-of-Way (Pervious)	35	1.16	0.157	27.43	7.21	0.26
FDOT Right-of-Way (Impervious)	65	1.16	0.157	49.88	11.30	2.56

For sediment, simulated average annual loads compared favorably with target average annual loads for all land uses except Pasture and Improved Pasture. As previously stated, after supplying appropriate values of KRER for each land use and NEXRAD zone, KSER was used to constrain simulated upland loads to target upland loads. For Pasture and Improved Pasture, matching target upland loads would have resulted in KSER values presumably too high for the recommended ranges (KSER greater than 10). Therefore, KSER for Pasture and Improved Pasture was set to a high level within the bounds of the recommended ranges. However, based on past modeling experience, the pasture land target appeared to be too high. Crop land uses typically produce more sediment than pasture land uses, and the final sediment calibration appropriately represents that assumption while keeping KSER within recommended ranges. FDACS provided feedback that the literature values for sediment loading from pasture lands was too high; therefore, the approach used in the modeling was appropriate.

For TN and TP, simulated average annual loads compared favorably with target average annual loads for all land uses. As previously stated, urban areas were compared to the Harper (1994) values and agricultural areas are compared to the SWET (2008) values. Generally, the target export values in Harper (1994) and SWET (2008) were near the median and average of the simulated range. Occasionally, target export values in Harper (1994) and SWET (2008) fell above or below the median of the simulated range due to balancing the upland load comparison and instream calibration. Occasionally, simulated upland loads for certain land uses were increased or decreased because instream observed concentrations suggested such a changed was needed.

For both sediment and nutrients, upland loading parameters were heterogeneous among the simulated land uses but homogeneous across NEXRAD zones by land use. This ensured that upland parameterization was not fit to any individual set of observed instream water quality data.

2.4.3 Calibration and Validation Stations

Instream model calibration and validation was to 50 water quality stations at 33 unique locations (14 locations for calibration and 19 locations for validation). **Table 71** provides the locations, associated water quality stations assigned to each location, and how each location was employed in the modeling effort. Calibration stations were dispersed throughout the watershed and were typically located in subbasins that

were listed on the 2010 verified impaired list (refer to **Table 1**). **Figure 40** provides the spatial distribution of the calibration and validation locations.

TABLE 71: 2017 HSPF MODEL WATER QUALITY CALIBRATION AND VALIDATION STATIONS

Location	RCHRES	Station Name	Purpose
San Carlos Canal	107	CAPECRD 390	Calibration
Yellow Fever Creek	112	21FLEECO16-18GR	Validation
Yellow Fever Creek	112	21FLFTM 28020337FTM	Validation
Powell Creek	115	21FLEECOPOWLGR20	Validation
Powell Creek	115	21FLFTM POWLGR20	Validation
Popash Creek	120	21FLEECO23-5GR	Calibration
Stroud Creek	121	21FLEECO24-7GR	Validation
Stroud Creek	121	21FLFTM 28020039	Validation
Telegraph Creek	127	21FLEECO29-8GR	Calibration
Telegraph Creek	127	21FLFTM CALUSA0024FTM	Calibration
Deep Lagoon	132	21FLEECODEEPGR10	Validation
Whiskey Creek	135	21FLEECOWHISGR10	Calibration
Billy Creek	137	21FLEECOBILLGR20	Validation
Orange River	139	21FLEECO40-18GR	Calibration
Orange River	139	21FLFTM CALUSA0023FTM	Calibration
Caloosahatchee River (S-79)	147	21FLEECOCES01SUR	Calibration
Hickey Creek	148	21FLEECO38-3GR	Validation
Bedman Creek	152	21FLEECO37-4GR	Validation
Robert's Canal	166	21FLFTM 28020252FTM	Validation
Jack's Branch	169	21FLFTM 28020238	Validation
Jack's Branch	169	21FLFTM CALUSA0047FTM	Validation
Jack's Branch	169	21FLWQSPHEN640GS	Validation
Fast Creek	173	21FLFTM 28020057	Validation
Fast Creek	173	21FLFTM 28020058	Validation
Pollywog Creek	179	21FLFTM 28020268FTM	Validation
Pollywog Creek	179	21FLFTM POLLYCRK	Validation
Caloosahatchee River	180	21FLFTM 28020274FTM	Validation
Cypress Branch	181	21FLFTM 28020239	Calibration
Caloosahatchee River (S-78)	188	21FLFTM CALUSA0026FTM	Validation
Caloosahatchee River (S-78)	188	21FLFTM S78	Validation
Caloosahatchee River (S-78)	188	21FLSFWMS78	Validation
Long Hammock Canal	192	21FLFTM 28020256FTM	Calibration
Lake Hicpochee LH1	197	21FLFTM 28020245FTM	Validation
C-4 Canal	199	21FLFTM 28020257FTM	Calibration
Lake Hicpochee LH2	207	21FLFTM 28020246FTM	Validation
C-19	208	21FLSFWMCR-04.8T	Calibration
Ninemile Canal	214	21FLFTM 28020139	Calibration
Caloosahatchee (S-77)	215	21FLFTM 28020247FTM	Validation
Caloosahatchee (S-77)	215	21FLFTM RECON-MH2-FTM	Validation
Caloosahatchee (S-77)	215	21FLFTM RECON-MH-FTM	Validation
Caloosahatchee (S-77)	215	21FLSFWMMHASRDIS	Validation
Caloosahatchee (S-77)	215	21FLSFWMS77	Validation
Caloosahatchee (S-77)	215	21FLSFWMS77-SW	Validation

Location	RCHRES	Station Name	Purpose
Disston Canal	216	21FLFTM 28020254FTM	Calibration
Industrial Canal	219	21FLSFWMINDUSCAN	Validation
C-19 Canal	990	21FLFTM 28020248FTM	Validation
Whidden	991	21FLFTM 28020269FTM	Calibration
Townsend Canal	996	21FLFTM 28020030	Calibration
Townsend Canal	996	21FLFTM 28020250FTM	Calibration
Jacks Branch	997	21FLFTM 28020044	Validation

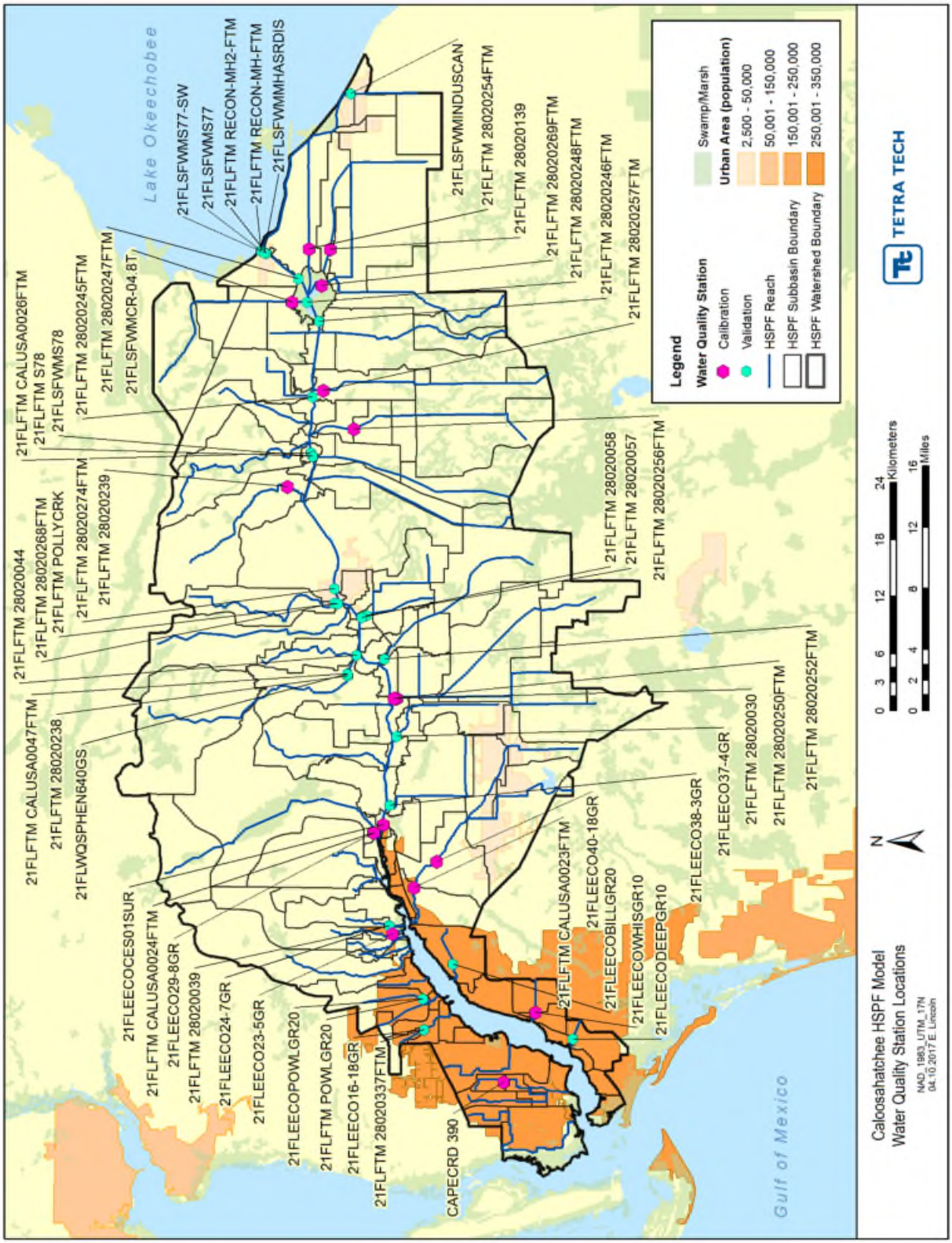

FIGURE 40: LOCATION OF THE WATER QUALITY CALIBRATION AND VALIDATION STATIONS IN THE CALOOSAHATCHEE RIVER WATERSHED

2.4.4 Instream Calibration Performance

Instream model calibration and validation was to 50 water quality stations at 33 unique locations. If observed OrgN concentrations were not provided at the water quality stations, OrgN concentrations were calculated using TKN and NH_3 data, when available. In addition, data listed below the detection limit and with a < flag were included in the analysis. When data were below detection, the goal of the calibration was to achieve concentrations near to or less than the constituent's detection limit. Constituents frequently at detection limits included NH_3, NOx, and CBOD.

A summary of the calibration results are presented below based on stream location and upstream land uses. Behavior of the instream water quality, including concentration magnitudes and seasonal trends, was similar among stations with similar dominant contributing land uses. The mainstem Caloosahatchee River stations were grouped together because they received most of their nutrient loads from Lake Okeechobee. Stations with predominantly urban, natural, or agricultural contributing land uses were also grouped together. In addition, statistical analyses were performed for TSS, TN, and TP at stations that had more than 98 sampling days of data.

2.4.4.1 Caloosahatchee River Mainstem

One calibration station was located in the Caloosahatchee River mainstem at S-79 (21FLEECOCES01SUR). At this location, TSS concentrations were slightly higher than observed data, which indicated that the simulation was slightly biased high. The average observed monthly and yearly TSS concentrations were approximately 3 mg/L, while the simulated concentrations were 12 mg/L and 7 mg/L, respectively. However, the load scatter plots do not indicate there was any bias in the loads. Nitrogen constituents were within range to the measured data and the TN simulation was rated as Very Good. Concentrations were low compared to observed data for NH_3 and OrgN during some periods, typically winter and early spring. However, concentrations were measured at the detection limit for NH3 during these periods, so the modeled was likely within ranges of the actual concentrations. In addition, the model correctly predicted the overall trends and the high magnitudes for both constituents. The model also was able to predict the seasonal trends and magnitudes for NOx. The observed TP concentrations shift during the simulation, showing a slight increasing trend. The model was within ranged during 2009 through 2011, but was slightly high after 2011 and slightly low prior to 2009. Overall, the simulation was unbiased and there was an equal distribution around the 1:1 line, and the statistics for loads generally show acceptable agreement between the simulated and observed loads. The model was typically rated as Very Good for the TP simulation. DO concentrations were in range compared to the observed data, and temperatures were within range and match the observed magnitudes and trends. Chlorophyll-*a* concentrations, which were predicted to be between 0 µg/L and 20 µg/L were within range of the observed data.

2.4.4.2 Urban Drainages

The urban drainages were represented at three calibration stations: (1) RCH107 San Carlos Canal (CAPECRD 390), (2) RCH135 Whiskey Creek (21FLEECOWHISGR10), and (3) RCH139 Orange River (21FLEECO40-18GR, 21FLFTM CALUSA0023FTM). At these stations, TSS concentrations were generally in range with observed data. Concentration and load statistics for TSS showed a wide range of simulated and observed fit when looking at monthly and yearly statistics at Orange River and San Carlos Canal but mainly show a high bias when looking at Whiskey Creek. NH_3 concentrations were generally

in range compared to the observed data. OrgN and TKN concentrations were generally in range compared to the observed data, but were slightly low for Orange River. NOx concentrations were generally in range compared to the observed data at Whiskey Creek, but were high at San Carlos Canal and Orange River. TN concentrations were generally in range with observed data but were slightly low for Orange River. Statistical summaries of TN concentration and loads generally showed a very favorable comparison between simulated and observed results. TP concentrations were generally in range to slightly higher compared to the observed data. Observed TP at Whiskey Creek and Orange River showed a decreasing concentration with time, which cannot be replicated in the HSPF model since parameterization cannot vary through time. Concentration and load statistics for TP also showed a high bias in simulated compared to observed concentrations. CBOD concentrations were generally in range with observed data, but were low for San Carlos Canal. DO concentrations and percent saturations were generally in range with observed data but were biased high for Orange River compared to observed data. The Orange River location was not very responsive to BENOD demand increases or changes to reaeration methods. Chlorophyll-*a* concentrations were generally in range with observed data at Whiskey Creek, but the simulation misses timing and magnitude at Orange River and at San Carlos Canal. In addition, temperatures were in range with observed data at all locations.

2.4.4.3 Natural Drainages

The natural drainages were represented at three calibration stations: (1) RCH120 Popash Creek (21FLEECO23-5GR), (2) RCH127 Telegraph Creek (21FLEECO29-8GR, 21FLFTM CALUSA0024FTM), and (3) RCH181 Cypress Branch (21FLFTM 28020239). TSS concentrations were generally in range with observed data. Concentration statistical analysis showed a wide range of model fit when looking at monthly and yearly comparisons. However, the load analysis shows an unbiased spread of over and under prediction at Telegraph Creek, but indicated that the simulated load was higher than observed at Popash Creek. NH_3 concentrations were generally in range to high compared to the observed data. OrgN and TKN concentrations were generally in range compared to the observed data. NOx concentrations were generally in range compared to the observed data but biased high at Telegraph Creek and Cypress Branch. The high bias at these two locations was likely due to septic system representation which provided relatively large NOx loads to the reaches during low flow periods. TN concentrations were generally in range compared to the observed data. The TN concentration statistical analysis showed a very favorable fit between simulated and observed concentrations. The load analysis showed an unbiased spread of over and under prediction when comparing that simulated and observed loads at Telegraph Creek, but that the simulation was higher than observed at Popash Creek. TP concentrations were generally in range compared to the observed data, but the simulation was biased low at Popash Creek. Concentration statistical analysis showed a wide range of model fit when looking at monthly and yearly comparisons. The load analysis showed an unbiased spread of over and under prediction when comparing the simulated and observed loads at Telegraph Creek, but indicated the simulation was higher than observed at Popash Creek. CBOD concentrations were generally in range to slightly biased high compared to observed data. DO concentrations and percent saturations were generally in range compared to the observed data for Cypress Branch and Popash Creek, but were biased high for Telegraph Creek when compared to observed data. The Telegraph Creek location was not responsive to BENOD increases or changes to reaeration methods. The simulated chlorophyll-*a* concentrations did capture the timing or magnitude at all three locations. Temperatures were in range with observed data at all locations.

2.4.4.4 Agricultural Drainages

None of the stations associated with agricultural drainages had enough sample points for daily paired regression analysis, and they were not associated with USGS flow gages for load analysis. Therefore, the analysis below is based on the time series results compared to the very limited data set at each location. The stations evaluated were RCH192 Long Hammock Canal (21FLFTM 28020256FTM), RCH199 C-4 Canal (21FLFTM 28020257FTM), RCH208 C-19 (21FLSFWMCR-04.8T), RCH214 Ninemile Canal (21FLFTM 28020139), RCH216 Disston Canal (21FLFTM 28020254FTM), RCH991 Whidden (21FLFTM 28020269FTM), and RCH996 Townsend Canal (21FLFTM 28020030, 21FLFTM 28020250FTM). TSS simulated concentrations at C-19 were biased low, and the other six locations had limited measured data so a bias determination could not be determined. NH_3 concentrations were generally in range compared to observed data, but biased low at Disston Canal and C-19 Canal. OrgN and TKN concentrations were generally in range to high compared to observed data. In the S-4 basin, the simulations were generally biased low at Ninemile Canal and Disston Canal and unbiased and in range at Whidden Canal. NOx concentrations were generally biased high when comparing simulated and observed concentrations, but were unbiased and in range at Whidden Canal and Townsend Canal. TN concentrations were generally in range to high compared to observed data but the simulation. In the S-4 basin, the simulation was generally biased low at Ninemile Canal and Disston Canal and unbiased and in range at Whidden Canal. TP concentrations were generally in range compared to observed data but biased high at Long Hammock Canal and Whidden Canal. CBOD concentrations were generally in range with observed data. DO concentrations and percent saturations were generally in range with observed data but biased high at Townsend Canal. Chlorophyll-*a* was rarely measured at these stations, however, the simulation was in range with the observed data when collected. Temperatures were in range at all locations.

TABLE 72: SUMMARY OF ANNUAL TSS CONCENTRATION COMPARISONS

Station ID	Station Name	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating	R^2	R^2 Rating
21FLEECOCES01SUR	Caloosahatchee River (S-79)	132.0	P	105.0	P	0.00	P
CAPECRD 390	San Carlos Canal	-28.4	F	-27.0	F	0.07	P
21FLEECOWHISGR10	Whiskey Creek	502.4	P	994.9	P	0.10	P
21FLEECO40-18GR, 21FLFTM CALUSA0023FTM	Orange River	-18.8	G	37.5	P	0.00	P
21FLEECO23-5GR	Popash Creek	-34.2	F	-12.6	VG	0.01	P
21FLEECO29-8GR, 21FLFTM CALUSA0024FTM	Telegraph Creek	46.5	P	56.1	P	0.14	P
21FLFTM CALUSA0026FTM, 21FLFTM S78, 21FLSFWMS78	Caloosahatchee River (S-78)	88.1	P	121.1	P	0.23	P
21FLFTM 28020247FTM, 21FLFTM RECON-MH2-FTM, 21FLFTM RECON-MH-FTM, 21FLSFWMMHASRDIS, 21FLSFWMS77, 21FLSFWMS77-SW	Caloosahatchee (S-77)	-7.6	VG	3.5	VG	0.87	VG
21FLEECODEEPGR10	Deep Lagoon	234.9	P	377.5	P	0.20	P
21FLEECOBILLGR20	Billy Creek	43.9	P	79.7	P	0.15	P
21FLEECO38-3GR	Hickey Creek	68.2	P	89.4	P	0.07	P
21FLEECO37-4GR	Bedman Creek	72.2	P	132.2	P	0.29	P
21FLEECO16-18GR, 21FLFTM 28020337FTM	Yellow Fever Creek	122.8	P	280.4	P	0.43	P
21FLEECOPOWLGR20, 21FLFTM POWLGR20	Powell Creek	220.6	P	309.7	P	0.04	P
21FLEECO24-7GR, 21FLFTM 28020039	Stroud Creek	-23.0	G	-18.0	G	0.01	P
21FLSFWMINDUSCAN	Industrial Canal	-4.2	VG	-0.5	VG	0.27	P

TABLE 73: SUMMARY OF ANNUAL TN CONCENTRATION COMPARISONS

Station ID	Station Name	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating	R^2	R^2 Rating
21FLEECOCES01SUR	Caloosahatchee River (S-79)	-3.5	VG	-1.2	VG	0.14	P
CAPECRD 390	San Carlos Canal	8.3	VG	5.2	VG	0.09	P
21FLEECOWHISGR10	Whiskey Creek	19.7	VG	30.0	VG	0.04	P
21FLEECO40-18GR, 21FLFTM CALUSA0023FTM	Orange River	-18.9	VG	-17.1	VG	0.01	P
21FLEECO23-5GR	Popash Creek	-9.5	VG	1.6	VG	0.01	P
21FLEECO29-8GR, 21FLFTM CALUSA0024FTM	Telegraph Creek	122.0	P	135.0	P	0.00	P
21FLFTM CALUSA0026FTM, 21FLFTM S78, 21FLSFWMS78	Caloosahatchee River (S-78)	22.2	VG	20.9	VG	0.34	P
21FLFTM 28020247FTM, 21FLFTM RECON-MH2-FTM, 21FLFTM RECON-MH-FTM, 21FLSFWMMHASRDIS, 21FLSFWMS77, 21FLSFWMS77-SW	Caloosahatchee (S-77)	10.4	VG	9.3	VG	0.31	P
21FLEECODEEPGR10	Deep Lagoon	-19.0	VG	-20.0	VG	0.01	P
21FLEECOBILLGR20	Billy Creek	-32.2	G	-30.8	G	0.32	P
21FLEECO38-3GR	Hickey Creek	-24.3	VG	-19.9	VG	0.01	P
21FLEECO37-4GR	Bedman Creek	4.8	VG	16.6	VG	0.07	P
21FLEECO16-18GR, 21FLFTM 28020337FTM	Yellow Fever Creek	4.7	VG	14.3	VG	0.00	P
21FLEECOPOWLGR20, 21FLFTM POWLGR20	Powell Creek	2.0	VG	8.9	VG	0.05	P
21FLEECO24-7GR, 21FLFTM 28020039	Stroud Creek	-5.1	VG	0.4	VG	0.03	P
21FLSFWMINDUSCAN	Industrial Canal	-29.5	VG	-31.2	G	0.02	P

TABLE 74: SUMMARY OF ANNUAL TP CONCENTRATION COMPARISONS

Station ID	Station Name	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating	R^2	R^2 Rating
21FLEECOCES01SUR	Caloosahatchee River (S-79)	-2.1	VG	4.0	VG	0.04	P
21FLEECOWHISGR10	Whiskey Creek	134.6	P	167.7	P	0.22	P
21FLEECO40-18GR, 21FLFTM CALUSA0023FTM	Orange River	36.0	G	32.4	G	0.11	P
21FLEECO23-5GR	Popash Creek	-56.5	F	-57.2	F	0.03	P
21FLEECO29-8GR, 21FLFTM CALUSA0024FTM	Telegraph Creek	51.2	F	58.6	F	0.65	F
21FLFTM CALUSA0026FTM, 21FLFTM S78, 21FLSFWMS78	Caloosahatchee River (S-78)	4.8	VG	11.1	VG	0.00	P
21FLFTM 28020247FTM, 21FLFTM RECON-MH2-FTM, 21FLFTM RECON-MH-FTM, 21FLSFWMMHASRDIS, 21FLSFWMS77, 21FLSFWMS77-SW	Caloosahatchee (S-77)	35.9	G	49.8	F	0.13	P
21FLEECODEEPGR10	Deep Lagoon	59.6	F	45.7	F	0.04	P
21FLEECOBILLGR20	Billy Creek	-17.4	VG	-20.8	VG	0.09	P
21FLEECO38-3GR	Hickey Creek	-2.1	VG	0.9	VG	0.00	P
21FLEECO37-4GR	Bedman Creek	144.7	P	136.3	P	0.00	P
21FLEECO16-18GR, 21FLFTM 28020337FTM	Yellow Fever Creek	-50.0	F	-51.7	F	0.01	P
21FLEECOPOWLGR20, 21FLFTM POWLGR20	Powell Creek	-50.7	F	-48.9	F	0.05	P
21FLEECO24-7GR, 21FLFTM 28020039	Stroud Creek	-32.5	G	-27.8	VG	0.02	P
21FLSFWMINDUSCAN	Industrial Canal	7.0	VG	23.1	VG	0.05	P

2.4.5 Parameter Sensitivity Analysis

A water quality parameter sensitivity analysis was conducted on the primary parameters controlling upland pollutant load generation, which ultimately controls the instream concentrations of TN and TP. A final draft version of the 2017 HSPF Model was used as the baseline model. Sensitivity was conducted on seven of the primary water quality parameters that control pollutant loads from the land: (1) rate of surface runoff that results in 90% wash off in one hour (in/hr) (WSQOP), (2) rate of accumulation on the surface (ACCUM), (3) maximum storage on the surface (SQOLIM), (4) ratio of constituent yield to sediment outflow (POTFW), (5) interflow concentration (IFLW Conc), (6) ground water concentration (GRND Conc), and (7) upland organic matter to instream organic nutrient partitioning (MASS-LINK).

Five sets of scenarios were configured and the water quality parameters were increased and decreased from the baseline model. **Table 75** identifies the scenario name which is based on the parameter(s) modified, upland constituents that were modified, and how much the upland constituent parameter was changed for the decreased and increased condition. ACCUM and SQOLIM were modified together within the same scenario because, within the model algorithms, these two parameters together control the amount of the constituent that is built up and/or stored on the upland surface at any given moment in time. IFLW Conc and GRND Conc were modified together within the same scenario because they are related to each other and control the baseflow conditions in the stream. Additionally, in HSPF models interflow concentrations are typically elevated in comparison to the baseflow concentrations to implicitly represent terrestrial plant uptake and soil biochemical transformations and adsorption that reduces the amount of nutrients that leach from upper soil layers to lower soil layers. In the 2017 HSPF Model, it was assumed that interflow concentrations were elevated above ground water outflow concentrations.

TABLE 75: LIST OF UPLAND POLLUTANT LOAD SENSITIVITY SCENARIOS

Scenario Set	Upland Constituent*	Decreased by	Increased by
WSQOP	NOx and NH_3	50%	50%
ACCUM and SQOLIM	NOx and NH_3	50%	50%
POTFW	PO_4 and organic matter	50%	50%
IFLW Conc and GRND Conc	NOx, NH_3, PO_4, and organic matter	50%	50%
MASS-LINK	Organic matter to instream organics	Lower Bound[1]	Upper Bound[2]

[*] Refer to **Section 2.4.2** for additional details
[1] OrgN = 3.32%, OrgP = 0.25%, OrgC= 96.43% (Cross et. al. 2003)
[2] OrgN = 15.0%, OrgP = 2.0%, OrgC= 83.0% (Redfield Ratio)

Results of the sensitivity analysis were compared at three tributaries in the Caloosahatchee River Watershed: (1) Whiskey Creek (RCHRES 135, station 21FLEECOWHISGR10), (2) Ninemile Canal (RCHRES 214, station 21FLFTM 28020139), and (3) Pollywog Creek (RCHRES 179, stations 21FLFTM 28020268FTM and 21FLFTM POLLYCRK). These three tributaries were selected based on the land use composition of their contributing upstream drainage area. Whiskey Creek is predominantly urban (93%), Ninemile Canal is predominantly agricultural (95%), and Pollywog Creek is predominantly natural (68%).

Results from the sensitivity analysis are provided in **Table 76** through **Table 97**. The tables present instream TN and TP sensitivity scenario results and the percent difference for the scenario results compared to the baseline results at three locations described above. Model sensitivity was analyzed for the average monthly and average yearly concentrations, as well as daily loads.

Increasing and decreasing WSQOP by 50% for NOx and NH_3 had very little impact on the instream TN concentrations when comparing the scenario outputs to the baseline model. **Table 76** and **Table 77** show that TN decreased or increased by less than 1% when WSQOP was varied by +/- 50%. Increasing WSQOP increased the amount of water it takes to remove 90% of the stored constituent, which resulted in less surface load washing off from the land and entering the stream, decreasing instream concentrations. Decreasing WSQOP had the opposite effect, in which more surface load washed off from the land and entered the stream, slightly increasing instream concentrations. The changes to WSQOP only affects the NOx and NH_3 removal from the land, which in the baseline model, and dependent on land use, ranged between 6% and 36% of TN, with OrgN making up the remaining fraction of TN. **Table 78** and **Table 79** show that TP at all three locations was not impacted by increasing and decreasing WSQOP by 50% for NOx and NH_3.

Increasing and decreasing ACCUM and SQOLIM by 50% for NOx and NH_3 had very little impact on the instream TN concentrations when comparing the scenario outputs to the baseline model. **Table 80** and **Table 81** show that TN increased or decreased by less than 1% when ACCUM and SQOLIM were varied by +/- 50%. Increasing ACCUM and SQOLIM increased the amount of mass stored on the land surface at any given time because the accumulation rate and maximum storage were both increased together. When ACCUM and SQOLIM are decreased, the amount of mass stored on the land surface at any given time is decreased. The changes to ACCUM and SQOLIM only affect NOx and NH_3 removal from the land, which as previously discussed are a small fraction of TN; therefore, varying their concentrations did not have a large impact on TN. **Table 82** and **Table 83** show that TP at all three locations is not impacted by increasing and decreasing ACCUM and SQOLIM by 50% for NOx and NH_3.

Increasing and decreasing POTFW by 50% for PO_4 and organic matter resulted in concentration changes between 0% and 20% for both TN and TP (**Table 84**, **Table 85**, **Table 86**, and **Table 87)**. Instream concentrations and loads of both TN and TP increased when POTFW was increased and decreased when POTFW was decreased. In Whiskey Creek, the largest changes occurred in July, August, September, and October, and in the years of 2008, and 2010 through 2014. In addition, the change in loads was greatest during high flow periods with high loads, specifically in 75th percentile and maximum load statistics. In Ninemile Canal, the largest changes occurred in November, and the year of 2008. In addition, the change in loads was greatest during high flow periods with high loads, specifically in 75th percentile and maximum load statistics. In Pollywog Creek, the largest changes occurred in March and July, and the year of 2009. In addition, the change in loads was greatest during high flow periods with high loads, specifically in 75th percentile and maximum load statistics. Generally, the variability in the results across the gages showed the impact of the association of PO_4 and organic matter loading to sediment. Each location analyzed had different land use compositions with different upland loading rates of sediment. Additionally, each land use responded differently to rain events, which leads to varying sediment production. Finally, at all stations, the daily paired loads above the 75th percentile were most affected by adjusting POTFW. The loads above the 75th percentile are likely attributable to times of wet conditions when sediment is moving from the upland areas and into the stream.

Increasing and decreasing IFLW and GRND Conc by 50% for NO_X, NH_3, PO_4, and organic matter resulted in concentration changes between 10% and 30% for both TN and TP (**Table 88**, **Table 89**, **Table 90**, and **Table 91**). Instream concentrations and loads of both TN and TP increased when IFLW and GRND Conc were increased and decreased when IFLW and GRND Conc were decreased. Modifying IFLW and GRND Conc by 50% for PO_4 and organic matter have noticeable impacts on the instream nutrient simulation. At Ninemile Canal and Pollywog Creek, IFLW and GRND Conc noticeably impacted all loads, whereas at

Whiskey Creek the highest loads were not impacted. This difference in results suggested that for agricultural and natural areas, interflow and ground water dominate the upland simulation at all times. However, in urban areas, interflow and ground water dominate the upland simulation during dry times while upland surface flows, which have pollutant loads controlled by WSQOP, ACCUM, SQOLIM, and POTFW, dominate the upland simulation during wet times.

Modifying the MASS-LINK partitioning of upland organic matter into instream organic nutrients resulted in concentration changes between 5% and 30% for both TN and TP (**Table 92**, **Table 93**, **Table 94**, and **Table 95)**. Instream concentrations and loads of both TN and TP increased when the MASS-LINK was set to the literature upper bound, and decreased when the MASS-LINK was set to the literature lower bound (refer to **Table 75**). While all of the parameters modified for the sensitivity analysis control the upland simulation of nutrients, the MASS-LINK modification controls the partitioning of upland organic matter into organic nutrients in the stream. Because of this, the percent change for each month, year, and daily load statistic are similar for each station. The amount of change was variable across the stations largely due to the amount of organic nutrients contributing to the total nutrients at each location. Pollywog Creek had mostly natural land comprising the drainage area to it, whereas Whiskey Creek had the most urban land draining to it. Pollywog Creek had a larger percentage change than Whiskey Creek because natural lands have a higher percentage of organic nutrient comprising the total nutrients in the 2017 HSPF Model.

After completing the upland pollutant load generation sensitivity scenarios and determining that the IFLW and GRND Conc most strongly influence upland pollutant load generation, the sensitivity analysis was expanded to investigate the impact of upland nutrient load changes on instream DO. The change in DO between the baseline and the IFLW and GRND Conc (+50% and -50%) were evaluated at Whiskey Creek, Ninemile Canal, and Pollywog Creek as well. Additionally, BENOD was increased and decreased by 50% from baseline conditions. Results for DO sensitivity are provided in **Table 96** and **Table 97**. At Whiskey Creek, increasing and decreasing upland loads resulted in concentration changes between 0% and 4.7%, whereas increasing and decreasing BENOD resulted in concentration changes between 7.4% and 36%. At Ninemile Canal, increasing and decreasing upland load resulted in concentration changes between 0% and 4.2%, whereas increasing and decreasing BENOD resulted in concentration changes between 27% and 89%. At Pollywog Creek, DO was relatively uninfluenced by either sensitivity scenario with concentration differences less than 0.1%. These results indicate that instream DO is less sensitive to upland loads and instream concentrations of nutrients than it is to BENOD. The results of the sensitivity analysis reveal that DO for Pollywog Creek is insensitive to parameterization, which is likely due to the hydraulics setup. Weirs are present in both Whiskey Creek and Ninemile Canal in the 2017 HSPF Model, which pond water and slow velocities, whereas Pollywog Creek flows normally with no obstructions. This indicates that the instream DO simulation is sensitive to instream hydraulics.

In summary, the model is relatively insensitive to changes in the upland NOx, NH_3, and PO_4 parameters. This is largely due to observed instream nutrients being mostly organic (on average 85% to 95% at the three locations used for sensitivity analysis), and the model being setup to load mostly organic nutrients from the upland. Instream TN and TP concentrations were most sensitive to interflow and ground water concentration specifications (ranging from 5% to 30% change), as well as organic matter to instream organic MASS-LINK partitioning. In addition, upland loading of nutrients and BENOD can impact instream DO, but this is dependent on instream hydraulics.

TABLE 76: MONTHLY AVERAGE AND YEARLY AVERAGE TN CONCENTRATION COMPARISON FOR WSQOP

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.584	0.623	0.734	0.635	0.787	1.016	1.070	0.927	1.192	0.901	0.754	0.658
WSQOP	+50%	mg/l	0.584	0.622	0.734	0.635	0.787	1.016	1.069	0.927	1.191	0.900	0.753	0.658
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.585	0.623	0.734	0.635	0.787	1.017	1.072	0.930	1.195	0.902	0.754	0.658
WSQOP	-50%	% difference	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.3%	0.1%	0.1%	0.0%
Ninemile Canal Baseline	N/A	mg/L	0.640	0.550	0.621	0.723	0.845	1.028	1.469	1.682	1.866	1.686	1.313	0.844
WSQOP	+50%	mg/l	0.640	0.550	0.620	0.723	0.845	1.028	1.468	1.681	1.866	1.685	1.311	0.843
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	-0.1%	-0.1%
WSQOP	-50%	mg/l	0.640	0.550	0.621	0.723	0.845	1.029	1.469	1.682	1.867	1.686	1.313	0.844
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Pollywog Creek Baseline	N/A	mg/L	1.226	1.166	1.163	1.250	1.410	1.776	1.929	1.966	1.874	1.647	1.367	1.290
WSQOP	+50%	mg/l	1.226	1.166	1.163	1.250	1.410	1.776	1.929	1.966	1.874	1.647	1.367	1.290
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	1.226	1.166	1.163	1.250	1.410	1.777	1.930	1.967	1.875	1.648	1.367	1.291
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.821	0.670	0.858	0.725	0.724	0.745	0.671	0.932	0.950	0.752	0.809	0.903
WSQOP	+50%	mg/l	0.820	0.669	0.858	0.724	0.724	0.745	0.671	0.932	0.950	0.751	0.809	0.903
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.0%	-0.1%	0.0%
WSQOP	-50%	mg/l	0.821	0.670	0.859	0.725	0.724	0.746	0.672	0.934	0.951	0.753	0.811	0.904
WSQOP	-50%	% difference	0.09%	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%
Ninemile Canal Baseline	N/A	mg/L	0.758	1.024	1.478	0.957	0.777	1.240	1.349	0.679	1.168	0.860	0.817	0.785
WSQOP	+50%	mg/l	0.758	1.024	1.478	0.956	0.777	1.238	1.349	0.679	1.168	0.860	0.817	0.784
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.758	1.025	1.479	0.957	0.777	1.241	1.349	0.679	1.168	0.860	0.817	0.785
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	mg/L	1.484	1.483	1.513	1.465	1.635	1.588	1.392	1.802	1.435	1.442	1.512	1.399
WSQOP	+50%	mg/l	1.484	1.483	1.512	1.465	1.635	1.588	1.391	1.802	1.435	1.442	1.512	1.399
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	1.484	1.483	1.513	1.465	1.635	1.588	1.392	1.802	1.435	1.443	1.513	1.399
WSQOP	-50%	% difference	0.02%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

TABLE 77: DAILY TN LOAD STATISTICAL COMPARISON FOR WSQOP

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	78,084.810	125.090	5.290	18.980	86.450	20.220
WSQOP	+50%	pounds/day	78,059.900	124.930	5.290	18.980	86.410	20.210
WSQOP	+50%	% difference	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	pounds/day	78,109.070	125.500	5.290	18.990	86.500	20.230
WSQOP	-50%	% difference	0.0%	0.3%	0.0%	0.1%	0.1%	0.0%
Ninemile Canal Baseline	N/A	pounds/day	5,691.550	207.880	33.690	84.390	248.010	91.580
WSQOP	+50%	pounds/day	5,667.010	207.740	33.690	84.370	247.970	91.550
WSQOP	+50%	% difference	-0.4%	-0.1%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	pounds/day	5,706.700	208.000	33.690	84.400	248.050	91.590
WSQOP	-50%	% difference	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	pounds/day	9,621.280	127.840	9.560	39.970	156.280	37.490
WSQOP	+50%	pounds/day	9,596.360	127.800	9.560	39.970	156.270	37.490
WSQOP	+50%	% difference	-0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	pounds/day	9,680.130	127.950	9.560	39.970	156.310	37.500
WSQOP	-50%	% difference	0.6%	0.1%	0.0%	0.0%	0.0%	0.0%

TABLE 78: MONTHLY AVERAGE AND YEARLY AVERAGE TP CONCENTRATION COMPARISON FOR WSQOP

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
WSQOP	+50%	mg/l	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ninemile Canal Baseline	N/A	mg/L	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
WSQOP	+50%	mg/l	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	mg/L	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
WSQOP	+50%	mg/l	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
WSQOP	+50%	mg/l	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
WSQOP	-50%	% difference	0.01%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ninemile Canal Baseline	N/A	mg/L	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
WSQOP	+50%	mg/l	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	mg/L	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
WSQOP	+50%	mg/l	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	mg/l	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
WSQOP	-50%	% difference	0.00%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

TABLE 79: DAILY TP LOAD STATISTICAL COMPARISON FOR WSQOP

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	26,777.800	28.260	0.640	2.280	10.900	2.560
WSQOP	+50%	pounds/day	26,777.800	28.260	0.640	2.280	10.900	2.560
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	pounds/day	26,777.810	28.260	0.640	2.280	10.900	2.560
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ninemile Canal Baseline	N/A	pounds/day	1,378.750	16.200	2.100	5.230	15.200	5.790
WSQOP	+50%	pounds/day	1,378.760	16.200	2.100	5.230	15.200	5.790
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	pounds/day	1,378.740	16.200	2.100	5.230	15.200	5.790
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
WSQOP	+50%	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
WSQOP	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WSQOP	-50%	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
WSQOP	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

TABLE 80: MONTHLY AVERAGE AND YEARLY AVERAGE TN CONCENTRATION COMPARISON FOR ACCUM AND SQOLIM

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.584	0.623	0.734	0.635	0.787	1.016	1.070	0.927	1.192	0.901	0.754	0.658
ACCUM and SQOLIM	+50%	mg/l	0.584	0.623	0.734	0.635	0.787	1.017	1.072	0.928	1.193	0.901	0.754	0.658
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.584	0.622	0.734	0.635	0.787	1.016	1.069	0.926	1.191	0.900	0.753	0.658
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	0.0%
Ninemile Canal Baseline	N/A	mg/L	0.640	0.550	0.621	0.723	0.845	1.028	1.469	1.682	1.866	1.686	1.313	0.844
ACCUM and SQOLIM	+50%	mg/l	0.640	0.550	0.621	0.723	0.845	1.029	1.469	1.682	1.867	1.686	1.313	0.844
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.639	0.550	0.620	0.723	0.845	1.028	1.468	1.680	1.865	1.685	1.310	0.843
ACCUM and SQOLIM	-50%	% difference	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	0.0%	-0.2%	-0.1%
Pollywog Creek Baseline	N/A	mg/L	1.226	1.166	1.163	1.250	1.410	1.776	1.929	1.966	1.874	1.647	1.367	1.290
ACCUM and SQOLIM	+50%	mg/l	1.226	1.166	1.163	1.250	1.410	1.777	1.930	1.967	1.874	1.647	1.367	1.291
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	1.226	1.166	1.163	1.250	1.410	1.776	1.929	1.966	1.874	1.647	1.367	1.290
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.821	0.670	0.858	0.725	0.724	0.745	0.671	0.932	0.950	0.752	0.809	0.903
ACCUM and SQOLIM	+50%	mg/l	0.821	0.670	0.859	0.725	0.724	0.746	0.671	0.933	0.951	0.752	0.810	0.904
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.820	0.669	0.858	0.724	0.724	0.744	0.671	0.931	0.950	0.751	0.808	0.903
ACCUM and SQOLIM	-50%	% difference	-0.05%	0.0%	-0.1%	-0.1%	0.0%	-0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%
Ninemile Canal Baseline	N/A	mg/L	0.758	1.024	1.478	0.957	0.777	1.240	1.349	0.679	1.168	0.860	0.817	0.785
ACCUM and SQOLIM	+50%	mg/l	0.758	1.025	1.479	0.957	0.777	1.241	1.349	0.679	1.168	0.860	0.817	0.785
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.758	1.024	1.478	0.956	0.777	1.237	1.349	0.679	1.168	0.860	0.817	0.784
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	mg/L	1.484	1.483	1.513	1.465	1.635	1.588	1.392	1.802	1.435	1.442	1.512	1.399
ACCUM and SQOLIM	+50%	mg/l	1.484	1.483	1.513	1.465	1.635	1.588	1.392	1.802	1.435	1.442	1.512	1.399
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	1.484	1.483	1.512	1.465	1.635	1.588	1.391	1.802	1.435	1.442	1.512	1.399
ACCUM and SQOLIM	-50%	% difference	-0.01%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

TABLE 81: DAILY TN LOAD STATISTICAL COMPARISON FOR ACCUM AND SQOLIM

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	78,084.810	125.090	5.290	18.980	86.450	20.220
ACCUM and SQOLIM	+50%	pounds/day	78,284.040	125.340	5.290	18.990	86.460	20.220
ACCUM and SQOLIM	+50%	% difference	0.3%	0.2%	0.0%	0.1%	0.0%	0.0%
ACCUM and SQOLIM	-50%	pounds/day	78,036.590	124.850	5.290	18.980	86.320	20.210
ACCUM and SQOLIM	-50%	% difference	-0.1%	-0.2%	0.0%	0.0%	-0.2%	0.0%
Ninemile Canal Baseline	N/A	pounds/day	5,691.550	207.880	33.690	84.390	248.010	91.580
ACCUM and SQOLIM	+50%	pounds/day	5,706.700	208.000	33.690	84.400	248.050	91.590
ACCUM and SQOLIM	+50%	% difference	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	pounds/day	5,641.810	207.640	33.690	84.370	247.970	91.550
ACCUM and SQOLIM	-50%	% difference	-0.9%	-0.1%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	pounds/day	9,621.280	127.840	9.560	39.970	156.280	37.490
ACCUM and SQOLIM	+50%	pounds/day	9,662.840	127.870	9.560	39.970	156.300	37.500
ACCUM and SQOLIM	+50%	% difference	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	pounds/day	9,609.230	127.810	9.560	39.970	156.260	37.490
ACCUM and SQOLIM	-50%	% difference	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%

TABLE 82: MONTHLY AVERAGE AND YEARLY AVERAGE TP CONCENTRATION COMPARISON FOR ACCUM AND SQOLIM

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
ACCUM and SQOLIM	+50%	mg/l	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ninemile Canal Baseline	N/A	mg/L	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
ACCUM and SQOLIM	+50%	mg/l	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	mg/L	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
ACCUM and SQOLIM	+50%	mg/l	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
ACCUM and SQOLIM	+50%	mg/l	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
ACCUM and SQOLIM	-50%	% difference	0.00%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ninemile Canal Baseline	N/A	mg/L	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
ACCUM and SQOLIM	+50%	mg/l	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	mg/L	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
ACCUM and SQOLIM	+50%	mg/l	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	mg/l	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
ACCUM and SQOLIM	-50%	% difference	0.00%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

TABLE 83: DAILY TP LOAD STATISTICAL COMPARISON FOR ACCUM AND SQOLIM

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	26,777.800	28.260	0.640	2.280	10.900	2.560
ACCUM and SQOLIM	+50%	pounds/day	26,777.810	28.260	0.640	2.280	10.900	2.560
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	pounds/day	26,777.800	28.260	0.640	2.280	10.900	2.560
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ninemile Canal Baseline	N/A	pounds/day	1,378.750	16.200	2.100	5.230	15.200	5.790
ACCUM and SQOLIM	+50%	pounds/day	1,378.740	16.200	2.100	5.230	15.200	5.790
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	pounds/day	1,378.770	16.200	2.100	5.230	15.200	5.790
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
ACCUM and SQOLIM	+50%	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
ACCUM and SQOLIM	+50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ACCUM and SQOLIM	-50%	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
ACCUM and SQOLIM	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

TABLE 84: MONTHLY AVERAGE AND YEARLY AVERAGE TN CONCENTRATION COMPARISON FOR POTFW

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.584	0.623	0.734	0.635	0.787	1.016	1.070	0.927	1.192	0.901	0.754	0.658
POTFW	+50%	mg/l	0.585	0.638	0.741	0.637	0.790	1.032	1.170	0.961	1.312	0.937	0.781	0.660
POTFW	+50%	% difference	0.1%	2.5%	0.9%	0.3%	0.3%	1.6%	9.4%	3.7%	10.0%	4.0%	3.6%	0.3%
POTFW	-50%	mg/l	0.584	0.607	0.728	0.633	0.784	1.000	0.970	0.894	1.072	0.864	0.727	0.656
POTFW	-50%	% difference	-0.1%	-2.5%	-0.9%	-0.3%	-0.3%	-1.6%	-9.4%	-3.6%	-10.0%	-4.1%	-3.6%	-0.3%
Ninemile Canal Baseline	N/A	mg/L	0.640	0.550	0.621	0.723	0.845	1.028	1.469	1.682	1.866	1.686	1.313	0.844
POTFW	+50%	mg/l	0.643	0.551	0.621	0.724	0.846	1.029	1.472	1.693	1.871	1.689	1.351	0.851
POTFW	+50%	% difference	0.4%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.7%	0.3%	0.2%	3.0%	0.9%
POTFW	-50%	mg/l	0.637	0.549	0.620	0.722	0.844	1.027	1.466	1.670	1.862	1.682	1.274	0.836
POTFW	-50%	% difference	-0.5%	-0.2%	0.0%	-0.1%	-0.1%	-0.1%	-0.2%	-0.7%	-0.2%	-0.2%	-3.0%	-0.9%
Pollywog Creek Baseline	N/A	mg/L	1.226	1.166	1.163	1.250	1.410	1.776	1.929	1.966	1.874	1.647	1.367	1.290
POTFW	+50%	mg/l	1.227	1.166	1.168	1.251	1.410	1.780	1.936	1.972	1.879	1.648	1.368	1.291
POTFW	+50%	% difference	0.0%	0.0%	0.5%	0.1%	0.0%	0.2%	0.3%	0.3%	0.2%	0.1%	0.0%	0.1%
POTFW	-50%	mg/l	1.226	1.165	1.158	1.249	1.410	1.773	1.923	1.961	1.870	1.646	1.367	1.290
POTFW	-50%	% difference	0.0%	0.0%	-0.5%	-0.1%	0.0%	-0.2%	-0.3%	-0.3%	-0.2%	-0.1%	0.0%	-0.1%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.821	0.670	0.858	0.725	0.724	0.745	0.671	0.932	0.950	0.752	0.809	0.903
POTFW	+50%	mg/l	0.830	0.673	0.865	0.730	0.724	0.764	0.674	0.955	0.995	0.763	0.833	0.929
POTFW	+50%	% difference	1.1%	0.5%	0.8%	0.7%	0.0%	2.5%	0.3%	2.4%	4.8%	1.5%	2.9%	2.8%
POTFW	-50%	mg/l	0.812	0.666	0.851	0.719	0.723	0.727	0.669	0.909	0.905	0.741	0.785	0.878
POTFW	-50%	% difference	-1.10%	-0.5%	-0.8%	-0.7%	0.0%	-2.5%	-0.3%	-2.4%	-4.8%	-1.5%	-2.9%	-2.8%
Ninemile Canal Baseline	N/A	mg/L	0.758	1.024	1.478	0.957	0.777	1.240	1.349	0.679	1.168	0.860	0.817	0.785
POTFW	+50%	mg/l	0.759	1.026	1.482	0.955	0.777	1.259	1.349	0.681	1.168	0.860	0.817	0.785
POTFW	+50%	% difference	0.2%	0.2%	0.3%	-0.1%	0.0%	1.6%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
POTFW	-50%	mg/l	0.757	1.023	1.474	0.958	0.777	1.220	1.350	0.677	1.169	0.860	0.817	0.785
POTFW	-50%	% difference	-0.2%	-0.1%	-0.3%	0.1%	0.0%	-1.6%	0.0%	-0.3%	0.0%	0.0%	0.0%	0.0%
Pollywog Creek Baseline	N/A	mg/L	1.484	1.483	1.513	1.465	1.635	1.588	1.392	1.802	1.435	1.442	1.512	1.399
POTFW	+50%	mg/l	1.485	1.484	1.513	1.466	1.636	1.590	1.400	1.803	1.436	1.443	1.517	1.400
POTFW	+50%	% difference	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.6%	0.1%	0.1%	0.1%	0.3%	0.0%
POTFW	-50%	mg/l	1.484	1.482	1.512	1.465	1.634	1.586	1.384	1.800	1.434	1.441	1.508	1.399
POTFW	-50%	% difference	-0.03%	-0.1%	-0.1%	0.0%	-0.1%	-0.1%	-0.6%	-0.1%	-0.1%	-0.1%	-0.3%	0.0%

TABLE 85: DAILY TN LOAD STATISTICAL COMPARISON FOR POTFW

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	78,084.810	125.090	5.290	18.980	86.450	20.220
POTFW	+50%	pounds/day	116,410.470	150.340	5.290	19.000	87.240	20.380
POTFW	+50%	% difference	49.1%	20.2%	0.0%	0.1%	0.9%	0.8%
POTFW	-50%	pounds/day	39,760.930	99.860	5.290	18.970	85.950	20.010
POTFW	-50%	% difference	-49.1%	-20.2%	0.0%	-0.1%	-0.6%	-1.0%
Ninemile Canal Baseline	N/A	pounds/day	5,691.550	207.880	33.690	84.390	248.010	91.580
POTFW	+50%	pounds/day	6,130.430	210.400	33.690	84.360	248.580	91.740
POTFW	+50%	% difference	7.7%	1.2%	0.0%	0.0%	0.2%	0.2%
POTFW	-50%	pounds/day	5,252.270	205.370	33.700	84.500	247.870	91.400
POTFW	-50%	% difference	-7.7%	-1.2%	0.0%	0.1%	-0.1%	-0.2%
Pollywog Creek Baseline	N/A	pounds/day	9,621.280	127.840	9.560	39.970	156.280	37.490
POTFW	+50%	pounds/day	12,932.380	129.060	9.560	40.000	156.310	37.530
POTFW	+50%	% difference	34.4%	1.0%	0.0%	0.1%	0.0%	0.1%
POTFW	-50%	pounds/day	6,310.190	126.620	9.560	39.970	156.140	37.460
POTFW	-50%	% difference	-34.4%	-1.0%	0.0%	0.0%	-0.1%	-0.1%

TABLE 86: MONTHLY AVERAGE AND YEARLY AVERAGE TP CONCENTRATION COMPARISON FOR POTFW

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
POTFW	+50%	mg/l	0.075	0.092	0.101	0.082	0.103	0.137	0.215	0.144	0.254	0.141	0.119	0.085
POTFW	+50%	% difference	0.5%	6.9%	2.4%	0.9%	1.0%	4.4%	19.7%	9.1%	21.1%	10.6%	9.8%	0.8%
POTFW	-50%	mg/l	0.074	0.080	0.096	0.081	0.101	0.126	0.144	0.120	0.165	0.114	0.097	0.084
POTFW	-50%	% difference	-0.5%	-6.9%	-2.4%	-0.9%	-1.0%	-4.4%	-19.7%	-9.1%	-21.1%	-10.7%	-9.8%	-0.8%
Ninemile Canal Baseline	N/A	mg/L	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
POTFW	+50%	mg/l	0.054	0.050	0.053	0.053	0.071	0.076	0.093	0.116	0.115	0.099	0.148	0.077
POTFW	+50%	% difference	12.8%	10.1%	4.7%	1.7%	1.3%	2.0%	2.6%	7.4%	3.7%	3.0%	20.0%	14.0%
POTFW	-50%	mg/l	0.042	0.041	0.048	0.052	0.069	0.073	0.088	0.100	0.107	0.093	0.099	0.058
POTFW	-50%	% difference	-12.8%	-10.1%	-4.6%	-1.7%	-1.3%	-2.0%	-2.6%	-7.4%	-3.6%	-3.0%	-20.0%	-14.0%
Pollywog Creek Baseline	N/A	mg/L	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
POTFW	+50%	mg/l	0.078	0.077	0.084	0.080	0.086	0.098	0.108	0.110	0.105	0.089	0.077	0.078
POTFW	+50%	% difference	0.1%	0.3%	2.8%	0.5%	0.1%	2.0%	3.9%	2.7%	1.9%	0.6%	0.3%	0.4%
POTFW	-50%	mg/l	0.078	0.077	0.079	0.079	0.085	0.094	0.100	0.104	0.101	0.088	0.077	0.078
POTFW	-50%	% difference	-0.1%	-0.3%	-2.8%	-0.5%	-0.1%	-2.0%	-3.9%	-2.7%	-1.9%	-0.6%	-0.3%	-0.4%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
POTFW	+50%	mg/l	0.109	0.083	0.110	0.093	0.088	0.108	0.087	0.135	0.160	0.107	0.122	0.137
POTFW	+50%	% difference	3.1%	1.4%	2.4%	2.1%	0.1%	6.7%	1.0%	6.5%	11.7%	3.9%	7.6%	8.0%
POTFW	-50%	mg/l	0.102	0.081	0.104	0.089	0.088	0.094	0.085	0.119	0.127	0.099	0.105	0.117
POTFW	-50%	% difference	-3.10%	-1.4%	-2.4%	-2.1%	-0.1%	-6.7%	-1.0%	-6.5%	-11.7%	-3.9%	-7.6%	-8.0%
Ninemile Canal Baseline	N/A	mg/L	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
POTFW	+50%	mg/l	0.040	0.064	0.099	0.051	0.044	0.117	0.089	0.067	0.075	0.057	0.052	0.053
POTFW	+50%	% difference	1.6%	4.8%	3.2%	0.5%	0.1%	13.9%	0.5%	7.4%	0.7%	0.7%	0.1%	0.2%
POTFW	-50%	mg/l	0.039	0.058	0.093	0.050	0.044	0.088	0.089	0.058	0.074	0.056	0.052	0.053
POTFW	-50%	% difference	-1.6%	-4.6%	-3.2%	-0.5%	-0.1%	-13.9%	-0.4%	-7.4%	-0.7%	-0.7%	-0.1%	-0.2%
Pollywog Creek Baseline	N/A	mg/L	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
POTFW	+50%	mg/l	0.084	0.085	0.086	0.085	0.091	0.090	0.098	0.095	0.084	0.085	0.094	0.079
POTFW	+50%	% difference	0.3%	0.5%	0.5%	0.3%	0.6%	1.0%	5.3%	0.8%	0.8%	0.5%	2.0%	0.3%
POTFW	-50%	mg/l	0.083	0.084	0.085	0.085	0.090	0.088	0.088	0.094	0.083	0.084	0.090	0.079
POTFW	-50%	% difference	-0.30%	-0.5%	-0.5%	-0.3%	-0.6%	-1.0%	-5.3%	-0.8%	-0.8%	-0.5%	-2.0%	-0.3%

TABLE 87: DAILY TP LOAD STATISTICAL COMPARISON FOR POTFW

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	26,777.800	28.260	0.640	2.280	10.900	2.560
POTFW	+50%	pounds/day	40,056.120	37.510	0.640	2.280	11.010	2.590
POTFW	+50%	% difference	49.6%	32.7%	0.0%	0.0%	1.0%	1.2%
POTFW	-50%	pounds/day	13,500.140	19.020	0.640	2.270	10.750	2.510
POTFW	-50%	% difference	-49.6%	-32.7%	0.0%	-0.4%	-1.4%	-2.0%
Ninemile Canal Baseline	N/A	pounds/day	1,378.750	16.200	2.100	5.230	15.200	5.790
POTFW	+50%	pounds/day	1,949.140	17.880	2.130	5.310	15.460	5.900
POTFW	+50%	% difference	41.4%	10.4%	1.4%	1.5%	1.7%	1.9%
POTFW	-50%	pounds/day	808.360	14.520	2.050	5.110	14.870	5.650
POTFW	-50%	% difference	-41.4%	-10.4%	-2.4%	-2.3%	-2.2%	-2.4%
Pollywog Creek Baseline	N/A	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
POTFW	+50%	pounds/day	4,610.510	8.750	0.590	2.240	8.180	2.200
POTFW	+50%	% difference	46.8%	7.4%	0.0%	0.0%	0.7%	0.5%
POTFW	-50%	pounds/day	1,671.370	7.550	0.590	2.240	8.070	2.180
POTFW	-50%	% difference	-46.8%	-7.4%	0.0%	0.0%	-0.6%	-0.5%

TABLE 88: MONTHLY AVERAGE AND YEARLY AVERAGE TN CONCENTRATION COMPARISON FOR IFLW AND GRND CONC

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.584	0.623	0.734	0.635	0.787	1.016	1.070	0.927	1.192	0.901	0.754	0.658
IFLW and GRND Conc	+50%	mg/l	0.698	0.756	0.861	0.743	0.873	1.129	1.294	1.176	1.484	1.185	0.940	0.814
IFLW and GRND Conc	+50%	% difference	19.4%	21.3%	17.3%	16.9%	10.9%	11.1%	21.0%	26.8%	24.5%	31.5%	24.7%	23.8%
IFLW and GRND Conc	-50%	mg/l	0.450	0.467	0.581	0.505	0.687	0.889	0.819	0.646	0.833	0.541	0.520	0.472
IFLW and GRND Conc	-50%	% difference	-23.0%	-25.0%	-20.9%	-20.5%	-12.7%	-12.5%	-23.4%	-30.3%	-30.1%	-39.9%	-31.0%	-28.3%
Ninemile Canal Baseline	N/A	mg/L	0.640	0.550	0.621	0.723	0.845	1.028	1.469	1.682	1.866	1.686	1.313	0.844
IFLW and GRND Conc	+50%	mg/l	0.808	0.685	0.750	0.828	0.925	1.235	2.003	2.358	2.631	2.386	1.767	1.105
IFLW and GRND Conc	+50%	% difference	26.2%	24.5%	20.9%	14.5%	9.5%	20.2%	36.3%	40.2%	41.0%	41.6%	34.6%	31.0%
IFLW and GRND Conc	-50%	mg/l	0.452	0.398	0.475	0.605	0.756	0.806	0.888	0.942	1.020	0.914	0.812	0.554
IFLW and GRND Conc	-50%	% difference	-29.4%	-27.6%	-23.5%	-16.3%	-10.5%	-21.6%	-39.6%	-44.0%	-45.3%	-45.8%	-38.1%	-34.4%
Pollywog Creek Baseline	N/A	mg/L	1.226	1.166	1.163	1.250	1.410	1.776	1.929	1.966	1.874	1.647	1.367	1.290
IFLW and GRND Conc	+50%	mg/l	1.799	1.706	1.689	1.818	2.038	2.572	2.823	2.884	2.757	2.422	2.006	1.895
IFLW and GRND Conc	+50%	% difference	46.7%	46.4%	45.2%	45.5%	44.6%	44.8%	46.3%	46.7%	47.1%	47.1%	46.8%	46.8%
IFLW and GRND Conc	-50%	mg/l	0.623	0.596	0.608	0.652	0.749	0.932	0.979	0.994	0.944	0.827	0.688	0.652
IFLW and GRND Conc	-50%	% difference	-49.2%	-48.8%	-47.7%	-47.9%	-46.9%	-47.5%	-49.3%	-49.4%	-49.6%	-49.8%	-49.7%	-49.5%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.821	0.670	0.858	0.725	0.724	0.745	0.671	0.932	0.950	0.752	0.809	0.903
IFLW and GRND Conc	+50%	mg/l	1.005	0.861	1.058	0.875	0.850	0.920	0.793	1.115	1.138	0.905	0.995	1.082
IFLW and GRND Conc	+50%	% difference	22.4%	28.6%	23.3%	20.7%	17.5%	23.4%	18.2%	19.6%	19.7%	20.4%	22.9%	19.8%
IFLW and GRND Conc	-50%	mg/l	0.603	0.437	0.611	0.552	0.580	0.530	0.534	0.708	0.728	0.568	0.585	0.695
IFLW and GRND Conc	-50%	% difference	-26.57%	-34.7%	-28.8%	-23.9%	-19.9%	-28.9%	-20.5%	-24.1%	-23.4%	-24.4%	-27.7%	-23.1%
Ninemile Canal Baseline	N/A	mg/L	0.758	1.024	1.478	0.957	0.777	1.240	1.349	0.679	1.168	0.860	0.817	0.785
IFLW and GRND Conc	+50%	mg/l	1.015	1.360	2.038	1.236	1.044	1.698	1.810	0.924	1.535	1.128	1.106	1.023
IFLW and GRND Conc	+50%	% difference	33.8%	32.8%	37.8%	29.2%	34.4%	37.0%	34.2%	36.1%	31.4%	31.2%	35.4%	30.4%
IFLW and GRND Conc	-50%	mg/l	0.474	0.656	0.848	0.650	0.480	0.732	0.851	0.412	0.763	0.568	0.498	0.531
IFLW and GRND Conc	-50%	% difference	-37.5%	-35.9%	-42.6%	-32.1%	-38.2%	-40.9%	-36.9%	-39.3%	-34.7%	-33.9%	-39.0%	-32.3%
Pollywog Creek Baseline	N/A	mg/L	1.484	1.483	1.513	1.465	1.635	1.588	1.392	1.802	1.435	1.442	1.512	1.399
IFLW and GRND Conc	+50%	mg/l	2.174	2.169	2.219	2.142	2.387	2.322	2.032	2.639	2.081	2.110	2.218	2.046
IFLW and GRND Conc	+50%	% difference	46.5%	46.3%	46.7%	46.2%	46.0%	46.2%	46.0%	46.5%	45.1%	46.3%	46.6%	46.2%
IFLW and GRND Conc	-50%	mg/l	0.754	0.756	0.766	0.750	0.841	0.812	0.715	0.914	0.749	0.735	0.771	0.713
IFLW and GRND Conc	-50%	% difference	-49.22%	-49.0%	-49.3%	-48.8%	-48.6%	-48.9%	-48.6%	-49.3%	-47.8%	-49.1%	-49.0%	-49.0%

TABLE 89: DAILY TN LOAD STATISTICAL COMPARISON FOR IFLW AND GRND CONC

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	78,084.810	125.090	5.290	18.980	86.450	20.220
IFLW and GRND Conc	+50%	pounds/day	78,576.410	143.760	6.450	23.150	109.780	24.940
IFLW and GRND Conc	+50%	% difference	0.6%	14.9%	21.9%	22.0%	27.0%	23.3%
IFLW and GRND Conc	-50%	pounds/day	77,550.930	102.910	3.750	13.470	58.060	14.090
IFLW and GRND Conc	-50%	% difference	-0.7%	-17.7%	-29.1%	-29.0%	-32.8%	-30.3%
Ninemile Canal Baseline	N/A	pounds/day	5,691.550	207.880	33.690	84.390	248.010	91.580
IFLW and GRND Conc	+50%	pounds/day	7,743.020	274.100	40.940	105.750	326.980	116.140
IFLW and GRND Conc	+50%	% difference	36.0%	31.9%	21.5%	25.3%	31.8%	26.8%
IFLW and GRND Conc	-50%	pounds/day	3,449.790	135.150	24.200	57.500	154.660	62.160
IFLW and GRND Conc	-50%	% difference	-39.4%	-35.0%	-28.2%	-31.9%	-37.6%	-32.1%
Pollywog Creek Baseline	N/A	pounds/day	9,621.280	127.840	9.560	39.970	156.280	37.490
IFLW and GRND Conc	+50%	pounds/day	10,957.450	186.920	13.950	58.680	229.370	54.750
IFLW and GRND Conc	+50%	% difference	13.9%	46.2%	45.9%	46.8%	46.8%	46.0%
IFLW and GRND Conc	-50%	pounds/day	8,169.530	65.440	4.970	20.210	78.770	19.220
IFLW and GRND Conc	-50%	% difference	-15.1%	-48.8%	-48.0%	-49.4%	-49.6%	-48.7%

TABLE 90: MONTHLY AVERAGE AND YEARLY AVERAGE TP CONCENTRATION COMPARISON FOR IFLW AND GRND CONC

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
IFLW and GRND Conc	+50%	mg/l	0.087	0.102	0.114	0.094	0.111	0.145	0.208	0.164	0.248	0.164	0.131	0.104
IFLW and GRND Conc	+50%	% difference	17.8%	18.6%	15.9%	15.1%	9.7%	10.1%	15.7%	23.9%	18.2%	28.0%	21.1%	22.7%
IFLW and GRND Conc	-50%	mg/l	0.061	0.070	0.082	0.068	0.092	0.118	0.151	0.100	0.166	0.086	0.082	0.064
IFLW and GRND Conc	-50%	% difference	-18.3%	-19.2%	-17.1%	-16.1%	-9.8%	-10.2%	-15.9%	-24.7%	-20.8%	-33.1%	-24.3%	-24.0%
Ninemile Canal Baseline	N/A	mg/L	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
IFLW and GRND Conc	+50%	mg/l	0.055	0.051	0.055	0.056	0.073	0.084	0.116	0.140	0.147	0.128	0.145	0.079
IFLW and GRND Conc	+50%	% difference	14.5%	12.0%	9.9%	7.6%	4.8%	12.5%	28.3%	29.6%	32.5%	33.7%	16.9%	16.9%
IFLW and GRND Conc	-50%	mg/l	0.043	0.041	0.046	0.049	0.067	0.066	0.064	0.075	0.072	0.063	0.104	0.058
IFLW and GRND Conc	-50%	% difference	-11.4%	-9.4%	-8.1%	-6.3%	-4.0%	-11.7%	-29.0%	-30.5%	-34.5%	-34.5%	-15.9%	-14.4%
Pollywog Creek Baseline	N/A	mg/L	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
IFLW and GRND Conc	+50%	mg/l	0.117	0.114	0.118	0.117	0.125	0.140	0.152	0.158	0.154	0.133	0.115	0.116
IFLW and GRND Conc	+50%	% difference	49.0%	48.4%	44.8%	46.9%	45.9%	46.0%	46.6%	48.0%	49.5%	50.2%	49.8%	49.4%
IFLW and GRND Conc	-50%	mg/l	0.041	0.040	0.046	0.043	0.047	0.052	0.057	0.057	0.054	0.045	0.039	0.040
IFLW and GRND Conc	-50%	% difference	-48.0%	-47.3%	-43.8%	-45.7%	-44.9%	-45.2%	-45.4%	-46.5%	-47.5%	-48.9%	-48.9%	-48.4%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
IFLW and GRND Conc	+50%	mg/l	0.128	0.106	0.131	0.109	0.102	0.122	0.100	0.150	0.167	0.122	0.137	0.149
IFLW and GRND Conc	+50%	% difference	21.6%	28.6%	22.7%	19.8%	16.1%	21.2%	16.7%	17.7%	16.7%	18.1%	20.6%	17.3%
IFLW and GRND Conc	-50%	mg/l	0.081	0.056	0.079	0.073	0.074	0.077	0.072	0.102	0.118	0.083	0.088	0.104
IFLW and GRND Conc	-50%	% difference	-23.16%	-31.9%	-25.9%	-20.5%	-16.2%	-23.9%	-16.4%	-19.9%	-18.0%	-19.7%	-22.6%	-18.3%
Ninemile Canal Baseline	N/A	mg/L	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
IFLW and GRND Conc	+50%	mg/l	0.050	0.076	0.123	0.062	0.054	0.125	0.109	0.072	0.090	0.068	0.063	0.063
IFLW and GRND Conc	+50%	% difference	27.7%	24.6%	27.9%	23.5%	24.8%	21.4%	23.1%	15.6%	21.5%	20.2%	21.9%	19.6%
IFLW and GRND Conc	-50%	mg/l	0.029	0.046	0.067	0.040	0.033	0.081	0.070	0.055	0.058	0.046	0.041	0.044
IFLW and GRND Conc	-50%	% difference	-26.4%	-24.1%	-30.3%	-21.5%	-23.9%	-20.9%	-21.8%	-11.9%	-22.2%	-18.2%	-20.8%	-17.0%
Pollywog Creek Baseline	N/A	mg/L	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
IFLW and GRND Conc	+50%	mg/l	0.125	0.126	0.128	0.127	0.134	0.132	0.134	0.140	0.122	0.125	0.137	0.118
IFLW and GRND Conc	+50%	% difference	49.3%	48.7%	49.7%	48.9%	47.4%	48.1%	44.1%	48.7%	46.2%	48.6%	48.3%	49.0%
IFLW and GRND Conc	-50%	mg/l	0.043	0.044	0.044	0.044	0.049	0.047	0.053	0.049	0.046	0.044	0.049	0.041
IFLW and GRND Conc	-50%	% difference	-48.35%	-47.8%	-48.3%	-47.9%	-46.5%	-46.9%	-43.2%	-47.8%	-45.3%	-47.6%	-46.5%	-48.0%

TABLE 91: DAILY TP LOAD STATISTICAL COMPARISON FOR IFLW AND GRND CONC

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	26,777.800	28.260	0.640	2.280	10.900	2.560
IFLW and GRND Conc	+50%	pounds/day	26,849.240	30.720	0.780	2.760	13.780	3.140
IFLW and GRND Conc	+50%	% difference	0.3%	8.7%	21.9%	21.1%	26.4%	22.7%
IFLW and GRND Conc	-50%	pounds/day	26,706.630	25.580	0.480	1.680	7.400	1.870
IFLW and GRND Conc	-50%	% difference	-0.3%	-9.5%	-25.0%	-26.3%	-32.1%	-27.0%
Ninemile Canal Baseline	N/A	pounds/day	1,378.750	16.200	2.100	5.230	15.200	5.790
IFLW and GRND Conc	+50%	pounds/day	1,405.230	19.400	2.390	6.360	18.620	6.930
IFLW and GRND Conc	+50%	% difference	1.9%	19.8%	13.8%	21.6%	22.5%	19.7%
IFLW and GRND Conc	-50%	pounds/day	1,352.230	12.930	1.800	4.280	10.910	4.610
IFLW and GRND Conc	-50%	% difference	-1.9%	-20.2%	-14.3%	-18.2%	-28.2%	-20.4%
Pollywog Creek Baseline	N/A	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
IFLW and GRND Conc	+50%	pounds/day	3,239.290	11.700	0.870	3.370	12.180	3.250
IFLW and GRND Conc	+50%	% difference	3.1%	43.6%	47.5%	50.4%	50.0%	48.4%
IFLW and GRND Conc	-50%	pounds/day	3,042.800	4.720	0.310	1.140	4.160	1.150
IFLW and GRND Conc	-50%	% difference	-3.1%	-42.1%	-47.5%	-49.1%	-48.8%	-47.5%

TABLE 92: MONTHLY AVERAGE AND YEARLY AVERAGE TN CONCENTRATION COMPARISON FOR MASS-LINK

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.584	0.623	0.734	0.635	0.787	1.016	1.070	0.927	1.192	0.901	0.754	0.658
MASS-LINK	Upper Bound	mg/l	0.717	0.765	0.904	0.769	0.966	1.254	1.354	1.156	1.503	1.094	0.919	0.807
MASS-LINK	Upper Bound	% difference	22.8%	22.9%	23.1%	21.1%	22.8%	23.4%	26.5%	24.7%	26.1%	21.5%	21.9%	22.6%
MASS-LINK	Lower Bound	mg/l	0.363	0.385	0.456	0.414	0.499	0.634	0.605	0.547	0.681	0.573	0.476	0.408
MASS-LINK	Lower Bound	% difference	-37.9%	-38.1%	-37.8%	-34.8%	-36.6%	-37.7%	-43.5%	-41.0%	-42.9%	-36.4%	-36.9%	-37.9%
Ninemile Canal Baseline	N/A	mg/L	0.640	0.550	0.621	0.723	0.845	1.028	1.469	1.682	1.866	1.686	1.313	0.844
MASS-LINK	Upper Bound	mg/l	0.686	0.587	0.659	0.756	0.871	1.094	1.632	1.890	2.098	1.892	1.463	0.918
MASS-LINK	Upper Bound	% difference	7.1%	6.8%	6.3%	4.6%	3.1%	6.3%	11.1%	12.4%	12.4%	12.2%	11.5%	8.8%
MASS-LINK	Lower Bound	mg/l	0.473	0.414	0.480	0.605	0.753	0.787	0.854	0.897	0.989	0.902	0.775	0.572
MASS-LINK	Lower Bound	% difference	-26.0%	-24.7%	-22.7%	-16.2%	-10.8%	-23.5%	-41.8%	-46.6%	-47.0%	-46.5%	-41.0%	-32.2%
Pollywog Creek Baseline	N/A	mg/L	1.226	1.166	1.163	1.250	1.410	1.776	1.929	1.966	1.874	1.647	1.367	1.290
MASS-LINK	Upper Bound	mg/l	1.386	1.320	1.321	1.421	1.600	2.020	2.192	2.232	2.125	1.864	1.543	1.459
MASS-LINK	Upper Bound	% difference	13.1%	13.3%	13.6%	13.6%	13.5%	13.7%	13.6%	13.5%	13.4%	13.2%	12.9%	13.0%
MASS-LINK	Lower Bound	mg/l	0.555	0.534	0.540	0.582	0.664	0.850	0.909	0.916	0.868	0.761	0.632	0.589
MASS-LINK	Lower Bound	% difference	-54.8%	-54.2%	-53.6%	-53.4%	-52.9%	-52.2%	-52.9%	-53.4%	-53.7%	-53.8%	-53.8%	-54.3%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.821	0.670	0.858	0.725	0.724	0.745	0.671	0.932	0.950	0.752	0.809	0.903
MASS-LINK	Upper Bound	mg/l	1.001	0.809	1.044	0.888	0.886	0.916	0.832	1.147	1.180	0.929	1.000	1.113
MASS-LINK	Upper Bound	% difference	22.0%	20.9%	21.6%	22.6%	22.5%	22.9%	24.0%	23.0%	24.2%	23.6%	23.6%	23.2%
MASS-LINK	Lower Bound	mg/l	0.521	0.433	0.548	0.454	0.456	0.460	0.406	0.580	0.574	0.458	0.493	0.559
MASS-LINK	Lower Bound	% difference	-36.54%	-35.4%	-36.2%	-37.4%	-37.0%	-38.3%	-39.5%	-37.8%	-39.6%	-39.0%	-39.1%	-38.1%
Ninemile Canal Baseline	N/A	mg/L	0.758	1.024	1.478	0.957	0.777	1.240	1.349	0.679	1.168	0.860	0.817	0.785
MASS-LINK	Upper Bound	mg/l	0.834	1.124	1.644	1.035	0.855	1.387	1.486	0.756	1.280	0.940	0.904	0.857
MASS-LINK	Upper Bound	% difference	9.9%	9.7%	11.2%	8.2%	10.0%	11.9%	10.2%	11.4%	9.6%	9.3%	10.7%	9.3%
MASS-LINK	Lower Bound	mg/l	0.479	0.651	0.857	0.661	0.485	0.698	0.825	0.403	0.745	0.560	0.489	0.514
MASS-LINK	Lower Bound	% difference	-36.8%	-36.5%	-42.0%	-30.9%	-37.6%	-43.7%	-38.9%	-40.7%	-36.3%	-34.9%	-40.2%	-34.4%
Pollywog Creek Baseline	N/A	mg/L	1.484	1.483	1.513	1.465	1.635	1.588	1.392	1.802	1.435	1.442	1.512	1.399
MASS-LINK	Upper Bound	mg/l	1.681	1.681	1.715	1.658	1.861	1.807	1.573	2.053	1.629	1.635	1.715	1.586
MASS-LINK	Upper Bound	% difference	13.3%	13.3%	13.4%	13.2%	13.8%	13.8%	13.1%	13.9%	13.5%	13.4%	13.4%	13.3%
MASS-LINK	Lower Bound	mg/l	0.686	0.688	0.699	0.676	0.761	0.742	0.634	0.839	0.684	0.668	0.701	0.653
MASS-LINK	Lower Bound	% difference	-53.75%	-53.6%	-53.8%	-53.8%	-53.4%	-53.3%	-54.5%	-53.5%	-52.3%	-53.7%	-53.7%	-53.4%

TABLE 93: DAILY TN LOAD STATISTICAL COMPARISON FOR MASS-LINK

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	78,084.810	125.090	5.290	18.980	86.450	20.220
MASS-LINK	Upper Bound	pounds/day	107,209.430	161.190	6.320	23.110	107.010	24.580
MASS-LINK	Upper Bound	% difference	37.3%	28.9%	19.5%	21.8%	23.8%	21.6%
MASS-LINK	Lower Bound	pounds/day	32,693.680	67.170	3.420	12.140	52.320	12.790
MASS-LINK	Lower Bound	% difference	-58.1%	-46.3%	-35.3%	-36.0%	-39.5%	-36.7%
Ninemile Canal Baseline	N/A	pounds/day	5,691.550	207.880	33.690	84.390	248.010	91.580
MASS-LINK	Upper Bound	pounds/day	6,599.000	229.060	35.970	90.750	272.440	99.000
MASS-LINK	Upper Bound	% difference	15.9%	10.2%	6.8%	7.5%	9.9%	8.1%
MASS-LINK	Lower Bound	pounds/day	2,606.010	129.530	24.490	58.090	152.830	62.230
MASS-LINK	Lower Bound	% difference	-54.2%	-37.7%	-27.3%	-31.2%	-38.4%	-32.0%
Pollywog Creek Baseline	N/A	pounds/day	9,621.280	127.840	9.560	39.970	156.280	37.490
MASS-LINK	Upper Bound	pounds/day	11,309.470	145.140	10.840	45.170	176.650	42.480
MASS-LINK	Upper Bound	% difference	17.5%	13.5%	13.4%	13.0%	13.0%	13.3%
MASS-LINK	Lower Bound	pounds/day	3,804.080	59.060	4.420	18.460	73.450	17.430
MASS-LINK	Lower Bound	% difference	-60.5%	-53.8%	-53.8%	-53.8%	-53.0%	-53.5%

TABLE 94: MONTHLY AVERAGE AND YEARLY AVERAGE TP CONCENTRATION COMPARISON FOR MASS-LINK

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	0.074	0.086	0.098	0.081	0.102	0.131	0.180	0.132	0.210	0.128	0.108	0.085
MASS-LINK	Upper Bound	mg/l	0.116	0.131	0.152	0.124	0.158	0.206	0.269	0.205	0.308	0.190	0.161	0.132
MASS-LINK	Upper Bound	% difference	56.8%	52.5%	54.4%	52.2%	55.3%	56.8%	49.8%	54.7%	46.8%	48.3%	48.7%	55.8%
MASS-LINK	Lower Bound	mg/l	0.063	0.074	0.085	0.070	0.088	0.113	0.157	0.114	0.185	0.111	0.094	0.072
MASS-LINK	Lower Bound	% difference	-14.7%	-13.6%	-13.7%	-13.3%	-13.6%	-14.0%	-12.6%	-14.2%	-11.9%	-12.9%	-12.8%	-14.6%
Ninemile Canal Baseline	N/A	mg/L	0.048	0.045	0.050	0.052	0.070	0.075	0.090	0.108	0.111	0.096	0.124	0.067
MASS-LINK	Upper Bound	mg/l	0.077	0.069	0.075	0.073	0.086	0.117	0.197	0.245	0.263	0.232	0.218	0.115
MASS-LINK	Upper Bound	% difference	60.3%	52.1%	48.8%	39.1%	23.1%	56.4%	118.9%	126.3%	138.1%	141.9%	76.0%	70.0%
MASS-LINK	Lower Bound	mg/l	0.045	0.043	0.048	0.050	0.068	0.071	0.081	0.096	0.097	0.084	0.115	0.063
MASS-LINK	Lower Bound	% difference	-5.9%	-5.0%	-4.7%	-3.8%	-2.3%	-5.1%	-10.4%	-11.2%	-12.1%	-12.5%	-7.4%	-6.7%
Pollywog Creek Baseline	N/A	mg/L	0.078	0.077	0.082	0.080	0.085	0.096	0.104	0.107	0.103	0.088	0.077	0.078
MASS-LINK	Upper Bound	mg/l	0.168	0.162	0.167	0.175	0.195	0.245	0.270	0.274	0.260	0.223	0.183	0.175
MASS-LINK	Upper Bound	% difference	114.7%	110.5%	104.7%	118.7%	127.6%	155.5%	159.3%	156.9%	152.9%	151.6%	137.6%	124.8%
MASS-LINK	Lower Bound	mg/l	0.044	0.044	0.050	0.049	0.054	0.070	0.077	0.077	0.071	0.057	0.046	0.045
MASS-LINK	Lower Bound	% difference	-44.4%	-42.9%	-38.7%	-38.7%	-36.5%	-27.5%	-25.6%	-27.8%	-30.5%	-35.2%	-40.1%	-42.5%
Scenario	**Change**	**Units**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Whiskey Creek Baseline	N/A	mg/L	0.105	0.082	0.107	0.091	0.088	0.101	0.086	0.127	0.143	0.103	0.114	0.127
MASS-LINK	Upper Bound	mg/l	0.163	0.127	0.166	0.143	0.140	0.155	0.137	0.195	0.216	0.159	0.174	0.193
MASS-LINK	Upper Bound	% difference	54.2%	54.3%	55.1%	56.7%	58.2%	53.7%	59.2%	53.3%	50.6%	54.6%	53.2%	52.1%
MASS-LINK	Lower Bound	mg/l	0.091	0.070	0.092	0.078	0.075	0.087	0.073	0.110	0.125	0.089	0.098	0.110
MASS-LINK	Lower Bound	% difference	-14.03%	-14.4%	-14.4%	-14.6%	-14.8%	-14.0%	-15.1%	-13.6%	-12.8%	-14.0%	-13.7%	-13.2%
Ninemile Canal Baseline	N/A	mg/L	0.039	0.061	0.096	0.051	0.044	0.103	0.089	0.062	0.074	0.056	0.052	0.053
MASS-LINK	Upper Bound	mg/l	0.088	0.126	0.204	0.102	0.095	0.197	0.180	0.111	0.148	0.108	0.109	0.100
MASS-LINK	Upper Bound	% difference	123.3%	107.0%	112.3%	101.8%	116.7%	92.0%	102.3%	77.8%	99.5%	93.0%	110.2%	88.9%
MASS-LINK	Lower Bound	mg/l	0.035	0.055	0.087	0.046	0.039	0.094	0.081	0.058	0.068	0.052	0.047	0.049
MASS-LINK	Lower Bound	% difference	-11.2%	-9.6%	-10.1%	-9.1%	-10.3%	-8.6%	-9.0%	-7.4%	-8.8%	-8.3%	-9.7%	-8.0%
Pollywog Creek Baseline	N/A	mg/L	0.083	0.084	0.086	0.085	0.091	0.089	0.093	0.094	0.084	0.084	0.092	0.079
MASS-LINK	Upper Bound	mg/l	0.201	0.202	0.207	0.199	0.227	0.220	0.199	0.249	0.197	0.198	0.212	0.190
MASS-LINK	Upper Bound	% difference	141.4%	139.4%	141.7%	134.4%	149.9%	146.7%	113.6%	163.6%	135.9%	134.9%	130.2%	139.9%
MASS-LINK	Lower Bound	mg/l	0.052	0.053	0.055	0.052	0.062	0.061	0.058	0.067	0.056	0.053	0.060	0.050
MASS-LINK	Lower Bound	% difference	-37.28%	-36.7%	-36.3%	-38.7%	-31.5%	-32.1%	-37.3%	-29.1%	-33.5%	-37.3%	-34.7%	-37.1%

TABLE 95: DAILY TP LOAD STATISTICAL COMPARISON FOR MASS-LINK

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	26,777.800	28.260	0.640	2.280	10.900	2.560
MASS-LINK	Upper Bound	pounds/day	35,822.510	39.570	0.990	3.570	17.310	3.940
MASS-LINK	Upper Bound	% difference	33.8%	40.0%	54.7%	56.6%	58.8%	53.9%
MASS-LINK	Lower Bound	pounds/day	24,657.910	25.490	0.550	1.940	9.220	2.190
MASS-LINK	Lower Bound	% difference	-7.9%	-9.8%	-14.1%	-14.9%	-15.4%	-14.5%
Ninemile Canal Baseline	N/A	pounds/day	1,378.750	16.200	2.100	5.230	15.200	5.790
MASS-LINK	Upper Bound	pounds/day	1,707.890	29.870	3.670	9.410	30.500	10.630
MASS-LINK	Upper Bound	% difference	23.9%	84.4%	74.8%	79.9%	100.7%	83.6%
MASS-LINK	Lower Bound	pounds/day	1,336.850	14.950	1.930	4.820	13.640	5.290
MASS-LINK	Lower Bound	% difference	-3.0%	-7.7%	-8.1%	-7.8%	-10.3%	-8.6%
Pollywog Creek Baseline	N/A	pounds/day	3,140.940	8.150	0.590	2.240	8.120	2.190
MASS-LINK	Upper Bound	pounds/day	4,011.060	18.760	1.320	5.310	20.870	5.130
MASS-LINK	Upper Bound	% difference	27.7%	130.2%	123.7%	137.1%	157.0%	134.2%
MASS-LINK	Lower Bound	pounds/day	2,886.540	5.860	0.350	1.330	5.380	1.370
MASS-LINK	Lower Bound	% difference	-8.1%	-28.1%	-40.7%	-40.6%	-33.7%	-37.4%

TABLE 96: MONTHLY AVERAGE AND YEARLY AVERAGE DO CONCENTRATION COMPARISON FOR IFLW AND GRND CONC AND BENOD

Scenario	Change	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskey Creek Baseline	N/A	mg/L	6.55	6.37	6.08	5.46	4.25	4.46	5.01	5.52	6.66	7.17	6.65	6.81
IFLW and GRND Conc	50%	mg/l	6.64	6.49	6.15	5.55	4.29	4.45	5.03	5.57	6.73	7.37	6.77	6.90
IFLW and GRND Conc	50%	% difference	1.4%	1.8%	1.1%	1.7%	0.9%	-0.2%	0.4%	0.9%	1.0%	2.8%	1.8%	1.3%
IFLW and GRND Conc	-50%	mg/l	6.41	6.21	5.97	5.34	4.19	4.48	5.01	5.49	6.53	6.83	6.49	6.67
IFLW and GRND Conc	-50%	% difference	-2.1%	-2.5%	-1.8%	-2.1%	-1.2%	0.3%	-0.1%	-0.6%	-2.0%	-4.7%	-2.5%	-2.0%
BENOD	50%	mg/l	5.41	5.20	4.90	4.16	2.94	3.57	4.38	4.98	6.17	6.33	5.56	5.73
BENOD	50%	% difference	-17.4%	-18.4%	-19.4%	-23.7%	-30.8%	-20.0%	-12.6%	-9.9%	-7.5%	-11.7%	-16.4%	-15.8%
BENOD	-50%	mg/l	7.70	7.57	7.29	6.84	5.80	5.50	5.66	6.07	7.16	7.98	7.74	7.89
BENOD	-50%	% difference	17.5%	18.7%	19.9%	25.3%	36.6%	23.3%	12.9%	9.9%	7.4%	11.3%	16.4%	15.8%
Ninemile Canal Baseline	N/A	mg/L	5.70	5.32	4.98	4.28	3.24	2.51	2.34	2.89	3.90	4.35	4.95	5.45
IFLW and GRND Conc	50%	mg/l	5.71	5.35	5.02	4.32	3.26	2.56	2.36	3.03	4.05	4.32	4.94	5.46
IFLW and GRND Conc	50%	% difference	0.3%	0.5%	0.9%	0.9%	0.5%	1.8%	0.5%	4.7%	3.7%	-0.6%	-0.4%	0.1%
IFLW and GRND Conc	-50%	mg/l	5.68	5.27	4.90	4.22	3.22	2.47	2.32	2.77	3.77	4.42	4.99	5.43
IFLW and GRND Conc	-50%	% difference	-0.3%	-1.0%	-1.6%	-1.4%	-0.7%	-1.8%	-0.9%	-4.2%	-3.4%	1.6%	0.8%	-0.4%
BENOD	50%	mg/l	4.15	3.70	3.35	2.58	1.72	1.30	1.23	1.55	2.37	2.78	3.37	3.85
BENOD	50%	% difference	-27.2%	-30.5%	-32.8%	-39.7%	-46.9%	-48.4%	-47.5%	-46.4%	-39.3%	-36.1%	-32.0%	-29.3%
BENOD	-50%	mg/l	7.28	7.01	6.73	6.24	5.41	4.75	4.41	5.01	5.88	6.21	6.66	7.11
BENOD	-50%	% difference	27.8%	31.6%	35.3%	45.8%	66.8%	89.0%	87.9%	73.2%	50.7%	42.8%	34.3%	30.4%
Pollywog Creek Baseline	N/A	mg/L	8.73	8.63	8.52	8.30	7.57	6.86	7.29	7.55	7.77	8.07	8.36	8.62
IFLW and GRND Conc	50%	mg/l	8.73	8.63	8.51	8.30	7.57	6.85	7.28	7.53	7.76	8.06	8.35	8.61
IFLW and GRND Conc	50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%	0.0%
IFLW and GRND Conc	-50%	mg/l	8.73	8.63	8.52	8.30	7.57	6.87	7.31	7.57	7.79	8.08	8.36	8.62
IFLW and GRND Conc	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.3%	0.2%	0.2%	0.1%	0.0%
BENOD	50%	mg/l	8.73	8.63	8.52	8.30	7.57	6.86	7.29	7.55	7.77	8.07	8.35	8.62
BENOD	50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BENOD	-50%	mg/l	8.73	8.63	8.52	8.30	7.57	6.86	7.29	7.55	7.77	8.07	8.36	8.62
BENOD	-50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Scenario	Change	Units	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Whiskey Creek Baseline	N/A	mg/L	6.04	6.20	6.66	5.65	5.59	6.21	5.68	6.42	5.93	5.70	5.94	6.05
IFLW and GRND Conc	50%	mg/l	6.16	6.33	6.78	5.74	5.69	6.31	5.73	6.54	5.99	5.75	6.02	6.14
IFLW and GRND Conc	50%	% difference	2.0%	2.2%	1.8%	1.6%	1.7%	1.5%	0.9%	2.0%	1.0%	1.0%	1.4%	1.5%
IFLW and GRND Conc	-50%	mg/l	5.86	6.03	6.47	5.53	5.49	6.08	5.61	6.24	5.82	5.60	5.82	5.92
IFLW and GRND Conc	-50%	% difference	-2.88%	-2.73%	-2.82%	-2.14%	-1.83%	-2.14%	-1.19%	-2.70%	-1.81%	-1.61%	-1.95%	-2.14%
BENOD	50%	mg/l	5.02	5.27	5.83	4.62	4.50	5.32	4.61	5.51	4.99	4.67	4.97	5.07
BENOD	50%	% difference	-16.9%	-15.0%	-12.4%	-18.2%	-19.6%	-14.4%	-18.7%	-14.1%	-15.9%	-18.0%	-16.3%	-16.2%
BENOD	-50%	mg/l	7.08	7.16	7.47	6.76	6.73	7.12	6.78	7.33	6.92	6.75	6.93	7.06
BENOD	-50%	% difference	17.25%	15.59%	12.20%	19.69%	20.35%	14.69%	19.39%	14.26%	16.67%	18.56%	16.70%	16.75%
Ninemile Canal Baseline	N/A	mg/L	3.76	4.32	4.26	4.09	4.24	4.42	4.71	4.43	4.55	4.42	4.21	3.93
IFLW and GRND Conc	50%	mg/l	3.82	4.35	4.23	4.13	4.29	4.37	4.82	4.50	4.67	4.51	4.28	4.00
IFLW and GRND Conc	50%	% difference	1.6%	0.7%	-0.7%	1.1%	1.2%	-1.2%	2.4%	1.5%	2.6%	2.2%	1.6%	1.6%
IFLW and GRND Conc	-50%	mg/l	3.70	4.29	4.28	4.05	4.19	4.51	4.60	4.34	4.43	4.29	4.13	3.85
IFLW and GRND Conc	-50%	% difference	-1.5%	-0.7%	0.3%	-0.9%	-1.2%	2.0%	-2.3%	-2.0%	-2.6%	-2.9%	-1.9%	-2.0%
BENOD	50%	mg/l	2.32	2.85	2.76	2.55	2.63	2.99	3.15	2.94	2.91	2.88	2.60	2.34
BENOD	50%	% difference	-38.4%	-34.2%	-35.3%	-37.5%	-38.0%	-32.3%	-33.2%	-33.5%	-36.0%	-34.9%	-38.3%	-40.4%
BENOD	-50%	mg/l	5.88	6.23	6.06	6.14	6.22	6.08	6.47	6.37	6.46	6.35	6.20	6.06
BENOD	-50%	% difference	56.5%	44.2%	42.1%	50.1%	46.8%	37.4%	37.5%	43.9%	42.2%	43.8%	47.3%	54.2%
Pollywog Creek Baseline	N/A	mg/L	8.27	8.13	8.23	8.03	7.85	8.26	8.35	7.89	7.80	7.98	8.03	8.05
IFLW and GRND Conc	50%	mg/l	8.26	8.12	8.22	8.03	7.85	8.25	8.34	7.89	7.79	7.97	8.03	8.04
IFLW and GRND Conc	50%	% difference	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
IFLW and GRND Conc	-50%	mg/l	8.28	8.14	8.24	8.04	7.85	8.27	8.36	7.89	7.81	7.99	8.04	8.06
IFLW and GRND Conc	-50%	% difference	0.11%	0.09%	0.13%	0.07%	0.03%	0.09%	0.10%	0.06%	0.11%	0.09%	0.09%	0.11%
BENOD	50%	mg/l	8.27	8.13	8.23	8.03	7.85	8.26	8.35	7.89	7.80	7.98	8.03	8.05
BENOD	50%	% difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BENOD	-50%	mg/l	8.27	8.13	8.23	8.03	7.85	8.26	8.35	7.89	7.80	7.98	8.03	8.05
BENOD	-50%	% difference	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%

TABLE 97: DAILY DO LOAD STATISTICAL COMPARISON FOR IFLW AND GRND CONC AND BENOD

Scenario	Change	Units	Max.	Avg.	25th Percentile	Med.	75th Percentile	Geometric Mean
Whiskey Creek Baseline	N/A	pounds/day	19873.71	515.90	49.66	154.00	563.19	166.19
IFLW and GRND Conc	50%	pounds/day	19907.64	517.05	50.57	156.14	568.12	168.12
IFLW and GRND Conc	50%	% difference	0.2%	0.2%	1.8%	1.4%	0.9%	1.2%
IFLW and GRND Conc	-50%	pounds/day	19841.21	513.34	48.08	149.96	548.53	163.28
IFLW and GRND Conc	-50%	% difference	-0.2%	-0.5%	-3.2%	-2.6%	-2.6%	-1.8%
BENOD	50%	pounds/day	19046.59	473.35	36.99	128.71	499.89	134.00
BENOD	50%	% difference	-4.2%	-8.2%	-25.5%	-16.4%	-11.2%	-19.4%
BENOD	-50%	pounds/day	20708.02	559.29	62.55	179.02	619.30	197.81
BENOD	-50%	% difference	4.2%	8.4%	26.0%	16.2%	10.0%	19.0%
Ninemile Canal Baseline	N/A	pounds/day	2961.70	490.24	233.90	403.32	640.96	380.73
IFLW and GRND Conc	50%	pounds/day	3000.01	490.80	232.12	399.16	631.95	377.74
IFLW and GRND Conc	50%	% difference	1.3%	0.1%	-0.8%	-1.0%	-1.4%	-0.8%
IFLW and GRND Conc	-50%	pounds/day	3276.90	493.16	232.48	402.76	653.34	380.66
IFLW and GRND Conc	-50%	% difference	10.6%	0.6%	-0.6%	-0.1%	1.9%	0.0%
BENOD	50%	pounds/day	2557.96	309.08	133.81	244.48	405.02	228.89
BENOD	50%	% difference	-13.6%	-37.0%	-42.8%	-39.4%	-36.8%	-39.9%
BENOD	-50%	pounds/day	3281.50	725.32	360.75	596.11	987.44	580.16
BENOD	-50%	% difference	10.8%	48.0%	54.2%	47.8%	54.1%	52.4%
Pollywog Creek Baseline	N/A	pounds/day	10150.590	542.220	60.940	206.360	778.560	206.200
IFLW and GRND Conc	50%	pounds/day	10125.820	541.260	60.940	206.320	777.140	206.030
IFLW and GRND Conc	50%	% difference	-0.2%	-0.2%	0.0%	0.0%	-0.2%	-0.1%
IFLW and GRND Conc	-50%	pounds/day	10180.950	543.470	60.940	206.410	780.200	206.410
IFLW and GRND Conc	-50%	% difference	0.3%	0.2%	0.0%	0.0%	0.2%	0.1%
BENOD	50%	pounds/day	10138.810	542.180	60.940	206.360	778.470	206.190
BENOD	50%	% difference	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
BENOD	-50%	pounds/day	10162.360	542.260	60.940	206.370	778.650	206.210
BENOD	-50%	% difference	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%

2.5 HSPF MODEL BACKGROUND SIMULATION

After completing the 2017 HSPF Model calibration, the model was used to create a background land use plus Lake Okeechobee at its TMDL (Background Plus) model. In the Background Plus Model, it was assumed that Lake Okeechobee achieved its TMDL for TP, with associated reductions to TN and total organic carbon (TOC). In addition, all anthropogenic land uses were converted to natural land uses, NPDES point source and reuse facilities were removed, septic systems were removed, and agricultural irrigation was removed. No other changes were made to the hydrology and hydraulics of the system, as it was assumed that weirs in the watershed and operations of pumps and weirs in the Industrial Canal and Caloosahatchee River would not be altered.

2.5.1 Land Use Coverage Modification

The 2017 HSPF Model land use was modified so that only natural land uses (Water, Wetlands, and Upland Forests) were simulated. As part of the modification, all areas classified as Water remained Water. Areas in the watershed that SSURGO classified with a hydric rating of "yes" were classified as Wetlands (**Figure 41)**. All other remaining areas in the watershed were classified as Upland Forests. By reclassifying the anthropogenic lands to Wetlands or Upland Forests land uses, the anthropogenic lands used the Wetland and Upland Forest parameterization for hydrology and surface, interflow, and ground water quality loading rates and concentrations. The land use composition in the 2017 HSPF Background Plus Model, after the above changes, is provided in **Table 98**.

TABLE 98: CALOOSAHATCHEE RIVER WATERSHED HSPF LAND USE COMPOSITION FOR THE 2017 HSPF BACKGROUND PLUS MODEL

HSPF Land Use Code	Land Use Description	Land Segment	Total Acreage	% of Area
14	Upland Forests	PERLND	501,595	57.0%
15	Wetlands	PERLND	364,850	41.4%
16	Water	PERLND	13,963	1.6%
N/A	Total	TOTAL	880,408	100.0%

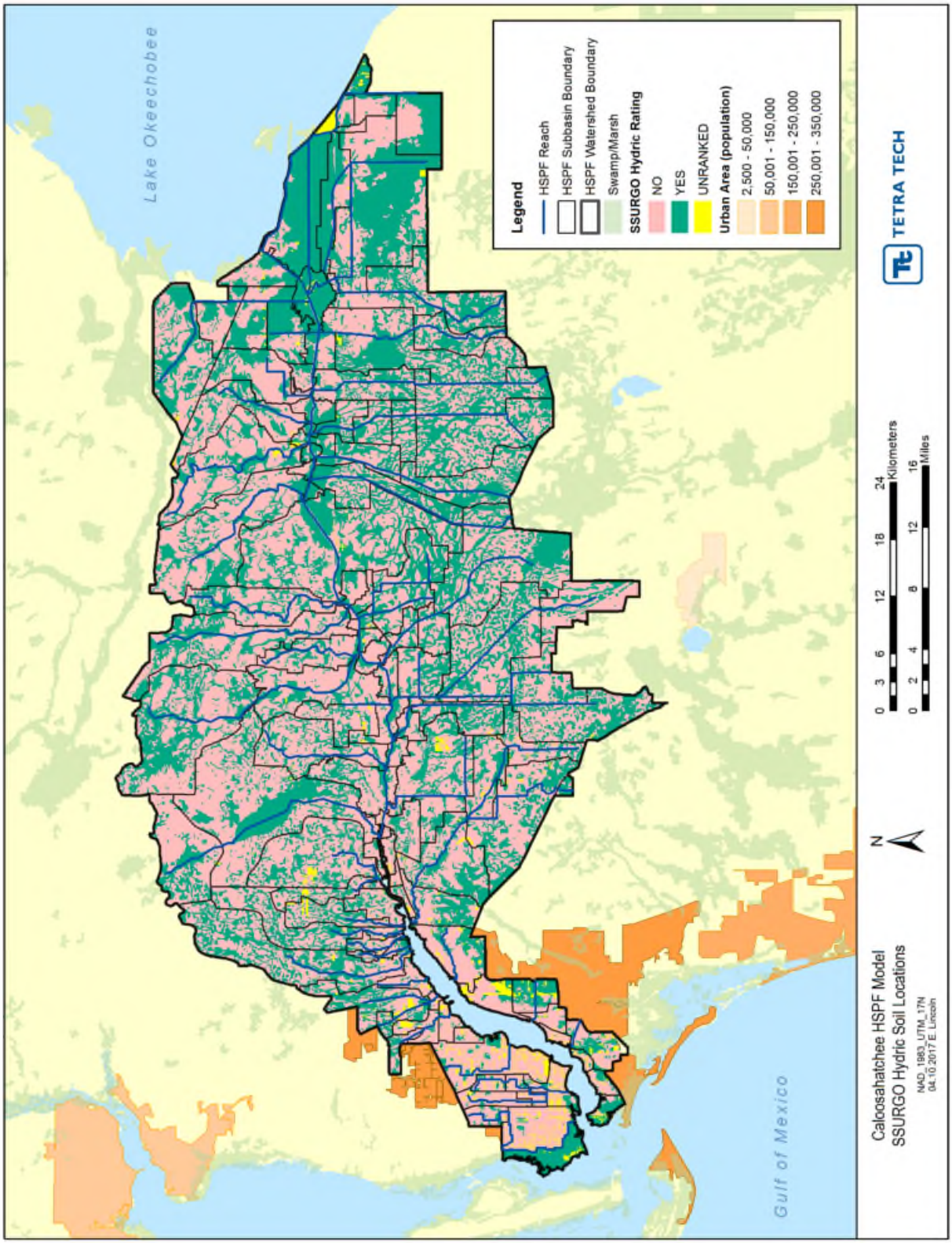

FIGURE 41: SSURGO HYDRIC SOIL CLASSIFICATIONS

2.5.2 Upstream Boundary Condition

Flows and water quality loads from Lake Okeechobee were input into the 2017 HSPF Model at three boundary locations: (1) the S-77 lock, (2) the S-310 lock, and (3) LD-1 seepage. In the Background Plus scenario, the hydraulics of the system at these locations were unchanged, however water quality conditions were modified to assume lower nutrient concentrations.

The Lake Okeechobee TMDL established a TP concentration of 0.04 mg/L (Department 2001); therefore, the TP concentration discharge from Lake Okeechobee for the Background Plus scenario was set at a constant value of 0.04 mg/L. Research on the TP speciation of Lake Okeechobee discharges at S-77 (station 21FLSFWMS77) indicated that 34% was PO_4 and 66% is OrgP. Therefore, the 0.04 mg/L TP concentration was speciated as 0.014 mg/L PO_4 and 0.026 mg/L OrgP at all of the Lake Okeechobee boundary locations in the 2017 HSPF Model.

Increases and decreases in TP are typically related to increases and decreases in other nutrients and water quality parameters, such as TOC and TN. Reductions in TP in Lake Okeechobee to meet the TMDL will likely be achieved through best management practices, such as reductions in fertilization, improved stream side management zones, and installation of green infrastructure/low impact development measures. These practices will likely reduce TN and TOC as well.

To determine the TOC concentration from Lake Okeechobee when it is meeting its TMDL, a regression relationship between TOC and TP was established (**Figure 42**) using measured water quality concentrations in Lake Okeechobee at S-77 (station 21FLSFWMS77). The regression relationship results in a TOC concentration of 17.89 mg/L when the TP concentration is 0.04 mg/L. This TOC concentration was specified in the Background Plus scenario as the constant concentration boundary coming from Lake Okeechobee at its TMDL.

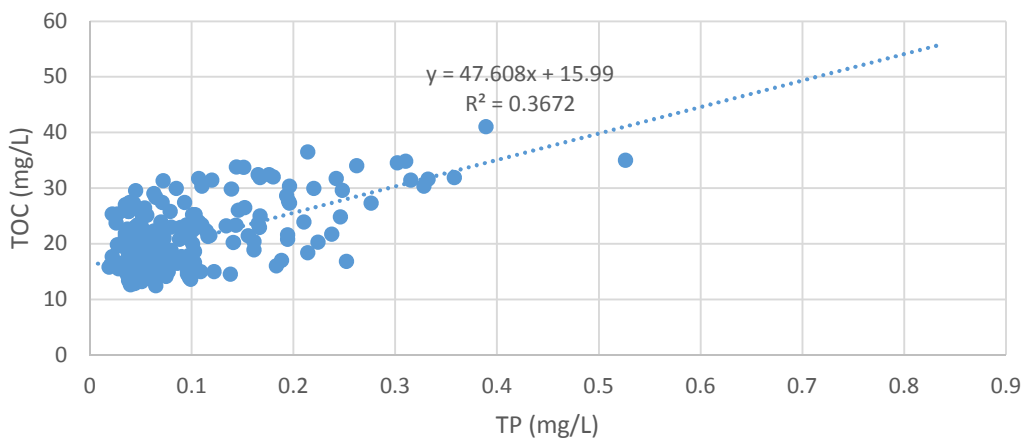

Figure 42: Lake Okeechobee outflow TP and TOC relationship

To determine the expected TN concentration of Lake Okeechobee when it is meeting its TMDL, historical records were reviewed and stakeholder feedback was sought. In 1973 and 1974, measured TP was 0.049 mg/L and TN was 1.63 mg/L and 1.45 mg/L (Canfield et al., 1988). These results correspond to TN:TP ratios of 33 and 30. Historic TN:TP ratios ranged between 30 and 35 in the 1970s (Smith et al., 1995). A TP concentration of 0.04 mg/L and a TN:TP ratio of 30 equates to a TN concentration of 1.2 mg/L. A TP

concentration of 0.04 mg/L and a TN:TP ratio of 35 equates to a TN concentration of 1.4 mg/L. The department's Caloosahatchee Estuary TMDL used a TN concentration of 1.2 mg/L for the Lake Okeechobee background condition (Department 2009); however, there was no documentation on how this concentration was derived. SFWMD, using recent (2005-2016) TN and TP data for discharges through S-77, calculated a TN concentration of 1.27 mg/L when TP is at 0.04 mg/L. Because of the unprecise nature of the TN concentration estimates, the department asked Tetra Tech to run one scenario with TN at 1.2 mg/L (Background Plus 1.2) and one scenario with TN at 1.4 mg/L (Background Plus 1.4).

Research on the TN speciation of the Lake Okeechobee discharges at S-77 indicated that 4% was NH_3, 6% was NOx, and 90% was OrgN. These percentages were used to determine the NH_3, NOx, and OrgN concentrations for the TN concentration of 1.2 mg/L and TN concentration of 1.4 mg/L conditions for the Lake Okeechobee boundary locations in the 2017 HSPF Model.

2.5.3 Model Parameterization

Hydrology and water quality parameterization in the Background Plus scenario was unchanged from the 2017 HSPF Model. However, the department requested a scenario where the Background Plus 1.2 had a reduction made to BENOD. Tim Wool with USEPA suggested a 40% reduction to BENOD based on previous modeling exercises and investigations in Florida (Wool 2010). This reduction was used in the Background Plus 1.2 BENOD scenario.

2.5.4 Calibrated Model and Background Plus Models Comparisons

The calibrated 2017 HSPF Model and the Background Plus 1.2 scenario were compared and are summarized below. The comparisons include average annual discharge volume, average annual loads, average annual concentrations, and percent difference between the 2017 HSPF Model and the Background Plus 1.2 scenario. **Table 99** presents the comparison for each RCHRES input into the EFDC model. **Table 100** presents the comparison for the subbasin inputs into the EFDC model via the HSPF model upland simulation. **Table 101** presents the comparison for verified impaired waterbodies. **Table 102** presents the comparison at the structures (S-77, S-78, and S-79) on the main stem of the Caloosahatchee River.

The comparison between the 2017 HSPF Model and the Background Plus 1.2 shows that mass (ac-ft/year for water, ton/year for sediment, and lbs/year for all other constituents) delivered to the estuary from streams was lower in the Background Plus 1.2 scenario than in the calibration (**Table 99)**. The reduction in mass delivered was largely due to the reduced volume of water delivered to the estuary.

Overall, concentrations delivered to the estuary from streams (**Table 99**) were reduced for the Background Plus 1.2 scenario compared to the 2017 HSPF Model for many of the water quality constituents, specifically TSS, BOD, TOC, NH_3, NOx, PO_4, and TP. However, for OrgN, OrgP, and TN concentrations were typically greater in the Background Plus 1.2 scenario. The natural land uses have a greater amount of organic matter compared to the anthropogenic land uses, which caused these loads to be greater in the scenario (refer to Section 3.6.4 in the Task 3 memo for additional details). In addition, the TN and TP unit area upland loads for the Forest, Wetland, and Water natural land uses are slightly lower than the Open Space, Pasture, Low Density Residential, and Medium Density Residential anthropogenic land uses (1 to 4 lbs/ac/yr for TN and 0.1 to 0.5 lbs/ac/yr for TP). Therefore, in subbasins with anthropogenic land uses that have relatively low unit area loadings, changing land use to natural did not produce a large reduction in nutrients.

In the Background Plus 1.2 scenario compared to 2017 HSPF Model, there was no systematic decrease or increase trend for DO concentration delivered to the estuary from streams (**Table 99**). Some RCHRES had an increase in DO concentrations, while others had a decrease in DO concentrations. In streams where concentrations increased, less DO was consumed via processes such as BOD decay and nitrification of ammonia. In reaches that had a decrease in DO, reductions in benthic algae likely reduced the amount of photosynthesis and DO production that occurred. In both cases, the change in stream energy and associated flow, which decreased in the scenario, influenced the benthic oxygen demand and reaeration potency in the stream. RCHRES with model weirs were typically most influenced by changes in flow, as the streams have slower velocities and are more sensitivity to changes in flow and any related impact to benthic oxygen demand and reaeration.

Subbasins input into the EFDC model via the HSPF model upland simulation (**Table 100**), verified impaired waterbodies (**Table 101**), and structures on the main stem of the Caloosahatchee River (**Table 102**), show similar results to those discussed for RCHRES input into the EFDC model.

In the Background Plus 1.2 and Background Plus 1.4 scenarios, TN in the Lake Okeechobee boundaries were increased from 1.2 mg/L to 1.4 mg/L. Results indicated that there were no changes to any reaches in the Caloosahatchee watershed model, with exception of those that receive, either directly or indirectly, loads from Lake Okeechobee. These include the Industrial Canal reaches and Caloosahatchee River (147 in **Table 104**; 197, 214, 216, and 219 in **Table 105**; and all RCHRES in **Table 106**). In these reaches, only NH_3, NOx, OrgN, and TN increased, and increases in loads and concentrations ranges from 4% to 17%. In the Caloosahatchee River, the highest changes in concentrations and loads occurred near S-77, and concentrations and loads then decreased moving towards the estuary due to dilution from load and concentrations from the watershed. The change in DO and BOD concentrations and loads were negligible.

In the Background Plus 1.2 and in the Background Plus 1.2 BENOD scenarios, BENOD was decreased by 40% in every reach. When BENOD was decreased, DO concentrations either increased or stayed the same (**Table 107** through **Table 110**). If no simulated weirs were present in the 2017 HSPF model in the reaches, decreasing BENOD did not have an impact on DO. If simulated weirs were present, either to represent weirs, structures, ponding, or other obstructions, stream velocities were slower and decreasing BENOD caused an increased in DO. In addition, in reaches where DO increased, NH_3 concentrations decreased and NOx concentrations increased. Nitrification (conversion of NH_3 to NOx) requires oxygen, and when more DO is available more NH_3 is converted to NOx.

For Deep Lagoon RCHRES 132, Disston Canal RCHRES 216, and Ninemile Canal RCH2RES14 decreasing BENOD by 40% caused large changes to DO, NH3 and NOx as compared to other locations analyzed in **Table 109**. These reaches all have weirs located on them in the 2017 HSPF Model setup, causing them to be sensitive to changes in benthic oxygen demand.

Figure 43 shows the in-stream DO concentrations for the 2017 HSPF Model, Background Plus 1.2, and Background Plus 1.2 BENOD scenarios for Deep Lagoon RCHRES 132. In the Background 1.2 scenario, DO decreased compared to the 2017 HSPF Model, likely due to a reduction in phytoplankton growth and respiration. DO concentrations during the summer months were low, less than 1 mg/L, and the 33% increase in DO concentrations in the Background Plus 1.2 BENOD scenario only increased low summer DO to 2 mg/L. and load is realistic when comparing the green and blue lines in **Figure 43**. The changes to NH_3 and NOx are attributed to the change in the DO instream concentrations, and while they show a high percent difference of change, the relative changes in concentration was small, approximately 0.01

mg/L. **Figure 44** shows the in-stream DO concentrations for the 2017 HSPF calibration, Background Plus 1.2, and Background Plus 1.2 BENOD scenarios for Ninemile Canal RCHRES 214, which responded similarly as the Disston Canal RCHRES 216 in the scenarios. The large increase in DO resulted in an approximate increase in DO of 2 mg/L, but concentrations during the summer period were low. Similar to Deep Lagoon, the changes to NH_3 and NOx are attributed to the change in the DO instream concentrations and while they show a high percent difference of change, the relative changes in concentration was small, approximately 0.01 mg/L.

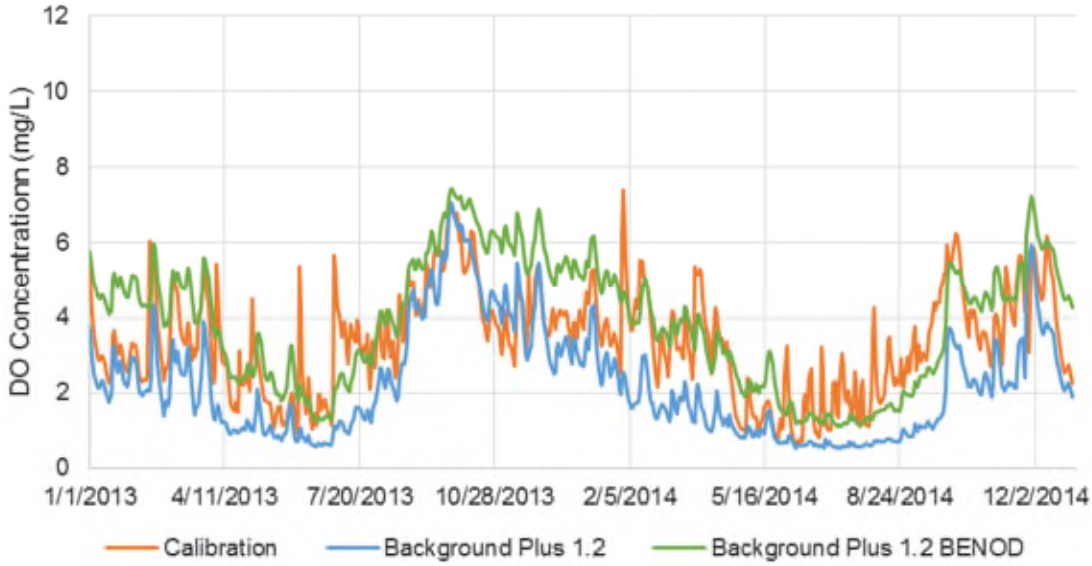

FIGURE 43: DEEP LAGOON RCHRES 132 DO CONCENTRATION COMPARISON FOR THE CALIBRATION, BACKGROUND PLUS 1.2, AND BACKGROUND PLUS 1.2 BENOD

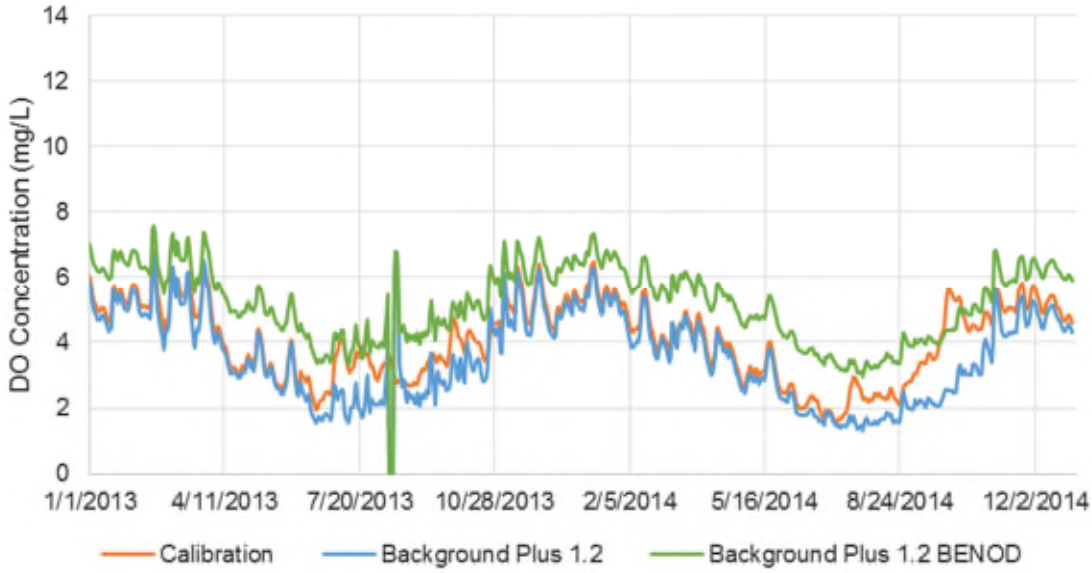

FIGURE 44: NINEMILE CANAL RCHRES 214 DO CONCENTRATION COMPARISON FOR THE CALIBRATION, BACKGROUND PLUS 1.2, AND BACKGROUND PLUS 1.2 BENOD

TABLE 99: COMPARISON OF THE 2017 HSPF CALIBRATION MODEL AND BACKGROUND PLUS 1.2 SCENARIO RESULTS FOR STREAM INPUTS

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
101	Calibration	31,539	954	22.2	676,202	7.88	166,273	1.94	397,724	5.12	6,360	0.07	12,940	0.15	62,755	0.73	82,055	0.96	19,199	0.22	4,306	0.05	23,506	0.27
101	Background	14,394	311	15.9	307,748	7.86	83,608	2.14	203,441	5.73	2,368	0.06	5,399	0.14	34,445	0.88	42,211	1.08	601	0.02	2,823	0.07	3,424	0.09
101	% Difference	-54%	-67%	-29%	-54%	0%	-50%	10%	-49%	12%	-63%	-18%	-58%	-9%	-45%	20%	-49%	13%	-97%	-93%	-34%	44%	-85%	-68%
105	Calibration	8,301	302	26.8	179,072	7.93	63,667	2.82	149,210	7.31	1,446	0.06	2,892	0.13	20,526	0.91	24,865	1.10	11,724	0.52	1,399	0.06	13,123	0.58
105	Background	3,192	70	16.1	68,533	7.90	24,426	2.81	55,651	7.11	526	0.06	1,103	0.13	9,490	1.09	11,119	1.28	137	0.02	782	0.09	918	0.11
105	% Difference	-62%	-77%	-40%	-62%	0%	-62%	0%	-63%	-3%	-64%	-5%	-62%	-1%	-54%	20%	-55%	16%	-99%	-97%	-44%	45%	-93%	-82%
106	Calibration	6,325	256	29.8	134,325	7.81	34,154	1.99	83,981	5.37	1,321	0.08	2,877	0.17	11,439	0.67	15,638	0.91	2,180	0.13	778	0.05	2,958	0.17
106	Background	2,651	58	16.1	56,486	7.84	17,402	2.41	41,420	6.34	439	0.06	987	0.14	7,029	0.98	8,455	1.17	115	0.02	577	0.08	692	0.10
106	% Difference	-58%	-77%	-46%	-58%	0%	-49%	22%	-51%	18%	-67%	-21%	-66%	-18%	-39%	47%	-46%	29%	-95%	-87%	-26%	77%	-77%	-44%
108	Calibration	28,743	1,256	32.1	615,042	7.87	200,905	2.57	479,969	6.78	6,098	0.08	12,669	0.16	65,856	0.84	84,623	1.08	17,883	0.23	4,474	0.06	22,357	0.29
108	Background	12,135	261	15.8	259,778	7.87	81,810	2.48	194,886	6.52	1,958	0.06	4,345	0.13	33,071	1.00	39,374	1.19	528	0.02	2,714	0.08	3,242	0.10
108	% Difference	-58%	-79%	-51%	-58%	0%	-59%	-4%	-59%	-4%	-68%	-24%	-66%	-19%	-50%	19%	-53%	10%	-97%	-93%	-39%	44%	-85%	-66%
111	Calibration	9,641	1,136	86.7	196,912	7.51	101,946	3.89	229,026	9.70	1,881	0.07	3,699	0.14	33,128	1.26	38,708	1.48	11,004	0.42	2,270	0.09	13,274	0.51
111	Background	4,521	664	108.0	93,704	7.62	37,276	3.03	83,016	7.50	787	0.06	1,571	0.13	14,193	1.15	16,551	1.35	297	0.02	1,171	0.10	1,468	0.12
111	% Difference	-53%	-42%	25%	-52%	1%	-63%	-22%	-64%	-23%	-58%	-11%	-58%	-9%	-57%	-9%	-57%	-9%	-97%	-94%	-48%	10%	-89%	-76%
113	Calibration	17,501	934	39.2	308,621	6.48	153,911	3.23	381,038	8.81	3,707	0.08	8,272	0.17	55,779	1.17	67,759	1.42	9,115	0.19	3,532	0.07	12,647	0.27
113	Background	8,244	240	21.4	138,826	6.19	48,884	2.18	124,729	6.10	1,388	0.06	3,249	0.14	21,014	0.94	25,651	1.14	387	0.02	1,716	0.08	2,103	0.09
113	% Difference	-53%	-74%	-45%	-55%	-5%	-68%	-33%	-67%	-31%	-63%	-21%	-61%	-17%	-62%	-20%	-62%	-20%	-96%	-91%	-51%	3%	-83%	-65%
116	Calibration	4,506	184	30.0	95,825	7.82	38,805	3.17	87,842	7.95	839	0.07	1,677	0.14	12,315	1.00	14,831	1.21	2,665	0.22	855	0.07	3,520	0.29
116	Background	1,991	41	15.1	42,951	7.93	15,958	2.95	35,234	7.24	317	0.06	650	0.12	6,030	1.11	6,997	1.29	74	0.01	498	0.09	572	0.11
116	% Difference	-56%	-78%	-50%	-55%	1%	-59%	-7%	-60%	-9%	-62%	-14%	-61%	-12%	-51%	11%	-53%	7%	-97%	-94%	-42%	32%	-84%	-63%
117	Calibration	23,041	656	20.9	496,810	7.93	263,254	4.20	601,846	10.67	5,636	0.09	11,120	0.18	97,742	1.56	114,498	1.83	9,373	0.15	5,500	0.09	14,873	0.24
117	Background	17,064	348	15.0	369,499	7.96	121,255	2.61	275,142	6.58	2,824	0.06	5,944	0.13	46,940	1.01	55,708	1.20	612	0.01	3,867	0.08	4,479	0.10
117	% Difference	-26%	-47%	-28%	-26%	0%	-54%	-38%	-54%	-38%	-50%	-32%	-47%	-28%	-52%	-35%	-51%	-34%	-93%	-91%	-30%	-5%	-70%	-59%
118	Calibration	1,823	65	26.4	38,870	7.84	20,128	4.06	46,633	10.41	449	0.09	923	0.19	7,164	1.44	8,536	1.72	1,040	0.21	406	0.08	1,446	0.29
118	Background	1,034	23	16.2	22,155	7.88	7,347	2.61	16,603	6.55	173	0.06	360	0.13	2,834	1.01	3,367	1.20	39	0.01	234	0.08	272	0.10
118	% Difference	-43%	-65%	-39%	-43%	1%	-64%	-36%	-64%	-37%	-61%	-32%	-61%	-31%	-60%	-30%	-61%	-30%	-96%	-93%	-43%	1%	-81%	-67%
119	Calibration	2,705	94	25.5	57,398	7.80	26,778	3.64	61,755	9.30	541	0.07	1,106	0.15	9,500	1.29	11,148	1.52	1,475	0.20	546	0.07	2,021	0.27
119	Background	1,505	32	15.7	32,393	7.91	10,936	2.67	24,673	6.69	248	0.06	515	0.13	4,212	1.03	4,975	1.22	56	0.01	347	0.08	403	0.10
119	% Difference	-44%	-66%	-38%	-44%	1%	-59%	-27%	-60%	-28%	-54%	-18%	-53%	-16%	-56%	-20%	-55%	-20%	-96%	-93%	-36%	14%	-80%	-64%
120	Calibration	11,712	375	23.5	190,278	5.97	124,559	3.91	291,313	10.17	2,694	0.08	4,726	0.15	47,342	1.49	54,761	1.72	4,936	0.15	2,620	0.08	7,555	0.24
120	Background	8,724	219	18.5	133,422	5.62	60,239	2.54	140,901	6.57	1,439	0.06	3,118	0.13	23,957	1.01	28,514	1.20	356	0.01	1,969	0.08	2,325	0.10
120	% Difference	-26%	-42%	-22%	-30%	-6%	-52%	-35%	-52%	-35%	-47%	-28%	-34%	-11%	-49%	-32%	-48%	-30%	-93%	-90%	-25%	1%	-69%	-59%
121	Calibration	6,485	378	42.8	75,266	4.27	76,616	4.34	196,873	12.24	1,756	0.10	3,740	0.21	30,142	1.71	35,638	2.02	2,634	0.15	1,643	0.09	4,277	0.24
121	Background	4,128	180	32.2	47,020	4.19	21,450	1.91	57,937	5.63	707	0.06	1,654	0.15	9,706	0.86	12,068	1.07	205	0.02	790	0.07	994	0.09
121	% Difference	-36%	-52%	-25%	-38%	-2%	-72%	-56%	-71%	-54%	-60%	-37%	-56%	-31%	-68%	-49%	-66%	-47%	-92%	-88%	-52%	-25%	-77%	-63%
123	Calibration	24,219	806	24.5	516,315	7.84	440,183	6.68	1,028,876	17.30	9,754	0.15	19,785	0.30	165,685	2.52	195,224	2.96	10,539	0.16	8,176	0.12	18,714	0.28
123	Background	17,363	292	12.4	373,835	7.92	112,645	2.39	260,895	6.12	2,816	0.06	5,996	0.13	44,408	0.94	53,219	1.13	495	0.01	3,652	0.08	4,148	0.09
123	% Difference	-28%	-64%	-49%	-28%	1%	-74%	-64%	-75%	-65%	-71%	-60%	-70%	-58%	-73%	-63%	-73%	-62%	-95%	-93%	-55%	-38%	-78%	-69%
127	Calibration	46,699	1,756	27.7	962,280	7.58	442,672	3.49	1,333,969	11.38	18,620	0.15	35,448	0.28	214,509	1.69	268,576	2.11	13,725	0.11	10,434	0.08	24,160	0.19
127	Background	37,291	1,193	23.5	776,211	7.65	167,636	1.65	469,653	5.04	6,204	0.06	15,146	0.15	78,424	0.77	99,775	0.98	1,570	0.02	6,371	0.06	7,941	0.08
127	% Difference	-20%	-32%	-15%	-19%	1%	-62%	-53%	-65%	-56%	-67%	-58%	-57%	-46%	-63%	-54%	-63%	-53%	-89%	-86%	-39%	-24%	-67%	-59%
132	Calibration	10,485	1,221	85.6	131,343	4.61	102,230	3.59	273,270	10.48	2,056	0.07	4,486	0.16	37,764	1.32	44,306	1.55	9,751	0.34	2,584	0.09	12,335	0.43
132	Background	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
132	% Difference	-57%	-88%	-71%	-63%	-13%	-79%	-50%	-75%	-42%	-66%	-21%	-63%	-13%	-70%	-30%	-69%	-28%	-98%	-95%	-64%	-17%	-91%	-78%
134	Calibration	16,951	2,283	99.1	336,461	7.30	212,399	4.61	497,888	11.95	3,712	0.08	7,710	0.17	68,137	1.48	79,558	1.73	20,872	0.45	4,595	0.10	25,466	0.55
134	Background	5,501	221	29.5	107,455	7.18	35,721	2.39	89,412	6.57	848	0.06	2,055	0.14	15,098	1.01	18,001	1.20	268	0.02	1,237	0.08	1,505	0.10
134	% Difference	-68%	-90%	-70%	-68%	-2%	-83%	-48%	-82%	-45%	-77%	-30%	-73%	-18%	-78%	-32%	-77%	-30%	-99%	-96%	-73%	-17%	-94%	-82%
137	Calibration	21,677	1,231	41.8	367,797	6.24	209,912	3.56	496,062	9.30	4,149	0.07	9,087	0.15	69,354	1.18	82,590	1.40	24,565	0.42	4,733	0.08	29,298	0.50
137	Background	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
137	% Difference	-64%	-86%	-62%	-67%	-9%	-74%	-29%	-73%	-25%	-70%	-16%	-67%	-7%	-67%	-9%	-67%	-9%	-99%	-96%	-61%	9%	-92%	-79%
139	Calibration	78,582	3,185	29.8	1,615,933	7.56	657,362	3.08	1,599,614	8.27	12,125	0.06	21,792	0.10	228,489	1.07	262,406	1.23	43,824	0.21	15,090	0.07	58,914	0.28
139	Background	34,938	2,055	43.3	714,863	7.52	334,836	3.52	810,121	9.40	5,804	0.06	13,248	0.14	137,246	1.44	156,299	1.65	3,864	0.04	11,254	0.12	15,118	0.16
139	% Difference	-56%	-35%	45%	-56%	-1%	-49%	15%	-49%	14%	-52%	8%	-39%	37%	-40%	35%	-40%	34%	-91%	-80%	-25%	68%	-74%	-42%
147 S-79	Calibration	1,145,146	30,664	19.7	11,985,628	3.85	4,364,568	1.40	46,209,502	15.36	209,103	0.07	1,041,931	0.33	4,902,803	1.57	6,153,836	1.98	271,418	0.09	234,606	0.08	506,024	0.16
147 S-79	Background	963,086	24,327	18.6	10,318,993	3.94	1,992,280	0.76	33,528,975	13.13	113,508	0.04	561,338	0.21	2,561,894	0.98	3,236,741	1.24	81,612	0.03	118,863	0.05	200,475	0.08
147 S-79	% Difference	-16%	-21%	-6%	-14%	2%	-54%	-46%	-27%	-15%	-46%	-35%	-46%	-36%	-48%	-38%	-47%	-37%	-70%	-64%	-49%	-40%	-60%	-53%

TABLE 100: COMPARISON OF THE 2017 HSPF CALIBRATION MODEL AND BACKGROUND PLUS 1.2 SCENARIO RESULTS FOR DIRECT LAND INPUTS

SWS ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
103	Calibration	6,262	210	24.7	132,282	7.77	77,432	4.55	1,359	0.08	2,557	0.15	9,332	0.55	13,247	0.78	985	0.06	543	0.03	1,528	0.09
103	Background	1,952	4	1.5	44,346	8.35	27,752	5.23	285	0.05	570	0.11	4,202	0.79	5,057	0.95	18	0.00	316	0.06	334	0.06
103	% Difference	-69%	-98%	-94%	-66%	8%	-64%	15%	-79%	-33%	-78%	-28%	-55%	44%	-62%	22%	-98%	-94%	-42%	87%	-78%	-30%
104	Calibration	2,041	71	25.6	42,894	7.73	25,816	4.65	435	0.08	824	0.15	3,041	0.55	4,300	0.77	397	0.07	171	0.03	568	0.10
104	Background	588	0	0.6	13,356	8.35	8,546	5.34	84	0.05	168	0.11	1,294	0.81	1,546	0.97	4	0.00	97	0.06	101	0.06
104	% Difference	-71%	-99%	-98%	-69%	8%	-67%	15%	-81%	-33%	-80%	-29%	-57%	48%	-64%	25%	-99%	-97%	-43%	98%	-82%	-38%
109	Calibration	2,123	60	20.9	43,844	7.60	27,655	4.79	387	0.07	736	0.13	3,488	0.60	4,611	0.80	352	0.06	216	0.04	568	0.10
109	Background	635	1	1.2	14,399	8.34	9,155	5.30	93	0.05	186	0.11	1,386	0.80	1,665	0.96	5	0.00	104	0.06	109	0.06
109	% Difference	-70%	-98%	-94%	-67%	10%	-67%	11%	-76%	-20%	-75%	-15%	-60%	33%	-64%	21%	-99%	-96%	-52%	61%	-81%	-36%
110	Calibration	3,905	155	29.2	82,879	7.80	54,548	5.14	796	0.07	1,524	0.14	6,531	0.62	8,851	0.83	996	0.09	378	0.04	1,375	0.13
110	Background	1,100	1	1.0	24,955	8.34	15,925	5.32	159	0.05	319	0.11	2,411	0.81	2,890	0.97	7	0.00	181	0.06	189	0.06
110	% Difference	-72%	-99%	-97%	-70%	7%	-71%	4%	-80%	-29%	-79%	-26%	-63%	31%	-67%	16%	-99%	-97%	-52%	70%	-86%	-51%
122	Calibration	2,709	31	8.3	54,887	7.45	46,740	6.34	639	0.09	1,270	0.17	6,436	0.87	8,345	1.13	247	0.03	279	0.04	526	0.07
122	Background	959	1	0.7	21,223	8.14	13,542	5.19	142	0.05	285	0.11	2,050	0.79	2,478	0.95	6	0.00	154	0.06	160	0.06
122	% Difference	-65%	-97%	-91%	-61%	9%	-71%	-18%	-78%	-37%	-78%	-37%	-68%	-10%	-70%	-16%	-98%	-93%	-45%	57%	-69%	-14%
126	Calibration	579	1	1.3	12,039	7.65	26,783	17.02	272	0.17	544	0.35	3,872	2.46	4,687	2.98	41	0.03	124	0.08	164	0.10
126	Background	289	0	0.6	6,414	8.15	4,097	5.20	42	0.05	84	0.11	620	0.79	746	0.95	2	0.00	47	0.06	48	0.06
126	% Difference	-50%	-79%	-58%	-47%	7%	-85%	-69%	-85%	-69%	-85%	-69%	-84%	-68%	-84%	-68%	-96%	-92%	-62%	-25%	-71%	-41%
129	Calibration	1,758	35	14.5	37,169	7.77	24,190	5.06	301	0.06	567	0.12	3,303	0.69	4,172	0.87	278	0.06	223	0.05	501	0.10
129	Background	868	3	2.8	19,123	8.10	12,101	5.13	143	0.06	283	0.12	1,832	0.78	2,258	0.96	14	0.01	138	0.06	152	0.06
129	% Difference	-51%	-90%	-81%	-49%	4%	-50%	1%	-53%	-4%	-50%	1%	-45%	12%	-46%	10%	-95%	-90%	-38%	25%	-70%	-39%
130	Calibration	5,113	91	13.1	111,320	8.01	61,840	4.45	810	0.06	1,635	0.12	7,342	0.53	9,786	0.70	5,923	0.43	424	0.03	6,346	0.46
130	Background	895	1	1.2	19,797	8.13	12,858	5.28	134	0.06	269	0.11	1,947	0.80	2,350	0.97	8	0.00	147	0.06	154	0.06
130	% Difference	-82%	-98%	-91%	-82%	2%	-79%	19%	-83%	-5%	-84%	-6%	-73%	51%	-76%	37%	-100%	-99%	-65%	97%	-98%	-86%
131	Calibration	1,534	41	19.8	31,707	7.60	20,985	5.03	282	0.07	564	0.14	2,628	0.63	3,474	0.83	441	0.11	168	0.04	610	0.15
131	Background	475	1	1.0	10,570	8.18	6,780	5.24	69	0.05	138	0.11	1,026	0.79	1,234	0.95	5	0.00	77	0.06	82	0.06
131	% Difference	-69%	-98%	-95%	-67%	8%	-68%	4%	-75%	-21%	-75%	-21%	-61%	26%	-64%	15%	-99%	-97%	-54%	48%	-87%	-57%
133	Calibration	2,263	47	15.2	47,072	7.65	25,460	4.14	387	0.06	752	0.12	3,076	0.50	4,215	0.68	1,261	0.20	183	0.03	1,444	0.23
133	Background	625	0	0.4	13,885	8.17	9,046	5.32	88	0.05	177	0.10	1,370	0.81	1,635	0.96	4	0.00	103	0.06	107	0.06
133	% Difference	-72%	-99%	-98%	-71%	7%	-64%	29%	-77%	-17%	-76%	-15%	-55%	61%	-61%	41%	-100%	-99%	-44%	104%	-93%	-73%
136	Calibration	10,208	426	30.7	209,451	7.55	128,564	4.63	2,402	0.09	4,485	0.16	15,396	0.55	22,283	0.80	1,959	0.07	866	0.03	2,825	0.10
136	Background	2,897	3	0.7	64,021	8.13	42,199	5.36	426	0.05	854	0.11	6,389	0.81	7,668	0.97	17	0.00	481	0.06	498	0.06
136	% Difference	-72%	-99%	-98%	-69%	8%	-67%	16%	-82%	-38%	-81%	-33%	-59%	46%	-66%	21%	-99%	-97%	-44%	96%	-82%	-38%
138	Calibration	5,500	118	15.8	115,504	7.72	112,104	7.50	1,470	0.10	2,906	0.19	15,140	1.01	19,517	1.30	737	0.05	699	0.05	1,435	0.10
138	Background	1,527	2	1.1	33,773	8.13	21,424	5.16	235	0.06	471	0.11	3,243	0.78	3,949	0.95	13	0.00	244	0.06	257	0.06
138	% Difference	-72%	-98%	-93%	-71%	5%	-81%	-31%	-84%	-42%	-84%	-42%	-79%	-23%	-80%	-27%	-98%	-94%	-65%	26%	-82%	-35%
144	Calibration	753	21	20.9	15,753	7.69	10,618	5.18	175	0.09	339	0.17	1,411	0.69	1,925	0.94	95	0.05	70	0.03	165	0.08
144	Background	236	0	0.5	5,231	8.15	3,339	5.20	34	0.05	68	0.11	506	0.79	608	0.95	1	0.00	38	0.06	39	0.06
144	% Difference	-69%	-99%	-98%	-67%	6%	-69%	0%	-81%	-38%	-80%	-36%	-64%	14%	-68%	1%	-99%	-96%	-46%	73%	-76%	-24%
145	Calibration	864	21	17.9	16,653	7.09	7,915	3.37	159	0.07	308	0.13	944	0.40	1,412	0.60	85	0.04	53	0.02	138	0.06
145	Background	172	0	0.2	3,819	8.16	2,446	5.23	24	0.05	48	0.10	370	0.79	442	0.95	1	0.00	28	0.06	29	0.06
145	% Difference	-80%	-100%	-99%	-77%	15%	-69%	55%	-85%	-24%	-84%	-22%	-61%	97%	-69%	57%	-99%	-96%	-47%	165%	-79%	4%
146	Calibration	1,439	26	13.3	28,135	7.19	19,541	4.99	300	0.08	586	0.15	2,557	0.65	3,442	0.88	129	0.03	117	0.03	247	0.06
146	Background	362	0	0.3	8,037	8.17	5,134	5.22	51	0.05	102	0.10	777	0.79	930	0.94	2	0.00	59	0.06	60	0.06
146	% Difference	-75%	-99%	-98%	-71%	14%	-74%	4%	-83%	-33%	-83%	-31%	-70%	21%	-73%	7%	-99%	-95%	-50%	98%	-76%	-3%
221	Calibration	202	1	5.0	4,176	7.62	1,672	3.05	22	0.04	42	0.08	217	0.40	281	0.51	12	0.02	11	0.02	23	0.04
221	Background	83	0	0.2	1,846	8.15	1,185	5.23	12	0.05	23	0.10	179	0.79	214	0.95	0	0.00	13	0.06	14	0.06
221	% Difference	-59%	-98%	-96%	-56%	7%	-29%	71%	-46%	30%	-45%	33%	-17%	100%	-24%	85%	-97%	-93%	25%	202%	-39%	47%

TABLE 101: COMPARISON OF THE 2017 HSPF CALIBRATION MODEL AND BACKGROUND PLUS 1.2 SCENARIO RESULTS FOR IMPAIRED WATERBODIES

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
Long Hammock RCH192	Calibration	22,862	391	12.6	431,290	6.94	391,062	6.29	1,000,246	17.87	9,631	0.15	19,572	0.31	165,041	2.65	194,264	3.12	4,743	0.08	7,672	0.12	12,415	0.20
Long Hammock RCH192	Background	11,760	198	12.4	203,472	6.36	61,309	1.92	160,893	5.51	1,757	0.05	4,480	0.14	27,034	0.85	33,272	1.04	301	0.01	2,205	0.07	2,507	0.08
Long Hammock RCH192	% Difference	-49%	-49%	-2%	-53%	-8%	-84%	-70%	-84%	-69%	-82%	-65%	-77%	-56%	-84%	-68%	-83%	-67%	-94%	-88%	-71%	-44%	-80%	-61%
Cypress Branch RCH181	Calibration	14,537	376	19.0	185,090	4.68	153,682	3.89	520,316	14.13	4,689	0.12	16,868	0.43	82,776	2.09	104,348	2.64	1,512	0.04	3,862	0.10	5,374	0.14
Cypress Branch RCH181	Background	10,548	288	20.1	156,209	5.45	38,113	1.33	130,872	4.89	1,220	0.04	4,906	0.17	21,475	0.75	27,601	0.96	368	0.01	1,722	0.06	2,090	0.07
Cypress Branch RCH181	% Difference	-27%	-23%	5%	-16%	16%	-75%	-66%	-75%	-65%	-74%	-64%	-71%	-60%	-74%	-64%	-74%	-64%	-76%	-66%	-55%	-39%	-61%	-46%
Townsend Canal RCH996	Calibration	60,365	4,755	57.9	1,000,250	6.09	697,324	4.25	2,395,162	15.88	23,691	0.14	78,478	0.48	377,332	2.30	479,788	2.92	46,450	0.28	17,337	0.11	63,787	0.39
Townsend Canal RCH996	Background	38,166	3,345	64.5	624,504	6.02	209,500	2.02	659,889	6.86	4,691	0.05	18,153	0.17	109,099	1.05	131,943	1.27	3,520	0.03	8,812	0.08	12,332	0.12
Townsend Canal RCH996	% Difference	-37%	-30%	11%	-38%	-1%	-70%	-52%	-72%	-57%	-80%	-69%	-77%	-63%	-71%	-54%	-72%	-57%	-92%	-88%	-49%	-20%	-81%	-69%
C-19 Canal RCH208	Calibration	18,298	284	11.4	337,413	6.78	305,982	6.15	825,459	18.43	7,531	0.15	14,260	0.29	135,727	2.73	157,530	3.17	2,665	0.05	6,098	0.12	8,763	0.18
C-19 Canal RCH208	Background	8,087	135	12.2	129,209	5.88	39,161	1.78	111,766	5.52	1,111	0.05	3,162	0.14	18,633	0.85	22,906	1.04	238	0.01	1,513	0.07	1,750	0.08
C-19 Canal RCH208	% Difference	-56%	-53%	7%	-62%	-13%	-87%	-71%	-86%	-70%	-85%	-67%	-78%	-50%	-86%	-69%	-85%	-67%	-91%	-80%	-75%	-44%	-80%	-55%
Lake Hicpochee RCH197	Calibration	775,708	18,373	17.4	6,798,690	3.22	2,568,103	1.22	35,098,832	17.39	117,261	0.06	544,426	0.26	3,247,299	1.54	3,909,261	1.85	121,770	0.06	169,582	0.08	291,352	0.14
Lake Hicpochee RCH197	Background	723,639	16,160	16.4	6,295,709	3.20	2,052,585	1.04	31,324,124	16.62	87,747	0.04	370,283	0.19	2,219,153	1.13	2,677,182	1.36	57,036	0.03	92,400	0.05	149,436	0.08
Lake Hicpochee RCH197	% Difference	-7%	-12%	-6%	-7%	-1%	-20%	-14%	-11%	-4%	-25%	-20%	-32%	-27%	-32%	-27%	-32%	-27%	-53%	-50%	-46%	-42%	-49%	-45%
S-4 Disston Canal RCH216	Calibration	25,795	1,280	36.5	217,655	3.10	45,616	0.65	529,848	7.73	4,822	0.07	19,360	0.28	74,636	1.06	98,858	1.41	4,386	0.06	2,838	0.04	7,224	0.10
S-4 Disston Canal RCH216	Background	9,029	312	25.4	82,074	3.34	2,645	0.11	84,050	3.45	386	0.02	4,891	0.20	7,454	0.30	12,731	0.52	497	0.02	401	0.02	897	0.04
S-4 Disston Canal RCH216	% Difference	-65%	-76%	-30%	-62%	8%	-94%	-83%	-84%	-55%	-92%	-77%	-75%	-28%	-90%	-71%	-87%	-63%	-89%	-68%	-86%	-60%	-88%	-65%
S-4 Ninemile Canal RCH214	Calibration	35,285	1,283	26.7	348,850	3.64	80,781	0.84	867,296	9.32	5,612	0.06	20,370	0.21	113,629	1.18	139,612	1.46	5,507	0.06	4,764	0.05	10,271	0.11
S-4 Ninemile Canal RCH214	Background	18,598	773	30.6	177,129	3.50	8,899	0.18	320,070	6.37	1,079	0.02	8,377	0.17	23,925	0.47	33,381	0.66	1,102	0.02	1,042	0.02	2,144	0.04
S-4 Ninemile Canal RCH214	% Difference	-47%	-40%	14%	-49%	-4%	-89%	-79%	-63%	-32%	-81%	-64%	-59%	-22%	-79%	-60%	-76%	-55%	-80%	-62%	-78%	-59%	-79%	-60%
S-4 Industrial Canal RCH219	Calibration	36,543	1,138	22.9	475,873	4.79	112,712	1.13	1,425,384	15.28	3,301	0.03	9,627	0.10	143,408	1.44	156,336	1.57	4,158	0.04	8,086	0.08	12,245	0.12
S-4 Industrial Canal RCH219	Background	32,105	997	22.8	407,510	4.67	94,631	1.08	1,341,631	16.29	3,115	0.04	9,134	0.10	97,441	1.12	109,690	1.26	1,631	0.02	4,334	0.05	5,966	0.07
S-4 Industrial Canal RCH219	% Difference	-12%	-12%	0%	-14%	-3%	-16%	-4%	-6%	7%	-6%	7%	-5%	8%	-32%	-23%	-30%	-20%	-61%	-55%	-46%	-39%	-51%	-45%
Billy Creek RCH137	Calibration	21,677	1,231	41.8	367,797	6.24	209,911	3.56	496,062	9.30	4,120	0.07	9,087	0.15	69,354	1.18	82,590	1.40	24,565	0.42	4,733	0.08	29,298	0.50
Billy Creek RCH137	Background	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
Billy Creek RCH137	% Difference	-64%	-86%	-62%	-67%	-9%	-74%	-29%	-73%	-25%	-70%	-16%	-67%	-7%	-67%	-9%	-67%	-9%	-99%	-96%	-61%	9%	-92%	-79%
Deep Lagoon RCH132	Calibration	10,485	1,221	85.6	131,343	4.61	102,230	3.59	273,270	10.48	2,015	0.07	4,486	0.16	37,764	1.32	44,306	1.55	9,751	0.34	2,584	0.09	12,335	0.43
Deep Lagoon RCH132	Background	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
Deep Lagoon RCH132	% Difference	-57%	-88%	-71%	-63%	-13%	-79%	-50%	-75%	-42%	-65%	-19%	-63%	-13%	-70%	-30%	-69%	-28%	-98%	-95%	-64%	-17%	-91%	-78%

TABLE 102: COMPARISON OF THE 2017 HSPF CALIBRATION MODEL AND BACKGROUND PLUS 1.2 SCENARIO RESULTS FOR MAIN STEM CALOOSAHATCHEE RIVER STRUCTURES

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
S-77 RCH215	Calibration	661,031	13,965	15.5	9,280,245	5.16	3,761,079	2.09	33,111,272	20.15	99,689	0.06	213,232	0.12	3,054,521	1.70	3,367,443	1.87	67,703	0.04	188,271	0.10	255,974	0.14
S-77 RCH215	Background	656,317	13,913	15.6	9,145,672	5.12	3,713,654	2.08	31,627,681	19.45	85,425	0.05	124,686	0.07	2,456,061	1.38	2,666,173	1.49	23,847	0.01	122,355	0.07	146,203	0.08
S-77 RCH215	% Difference	-1%	0%	0%	-1%	-0.7%	-1%	-1%	-4%	-3%	-14%	-14%	-42%	-41%	-20%	-19%	-21%	-20%	-65%	-65%	-35%	-35%	-43%	-42%
S-78 RCH 188	Calibration	825,744	19,165	17.1	7,336,612	3.27	2,813,040	1.25	36,463,254	16.92	131,857	0.06	609,761	0.27	3,450,535	1.54	4,192,441	1.87	133,494	0.06	177,107	0.08	310,602	0.14
S-78 RCH 188	Background	748,632	16,578	16.3	6,511,236	3.20	1,974,938	0.97	31,416,007	16.03	91,912	0.05	400,148	0.20	2,232,345	1.10	2,724,406	1.34	60,519	0.03	92,955	0.05	153,473	0.08
S-78 RCH 188	% Difference	-9%	-13%	-5%	-11%	-2%	-30%	-23%	-14%	-5%	-30%	-23%	-34%	-28%	-35%	-29%	-35%	-28%	-55%	-50%	-48%	-42%	-51%	-45%
S-79 RCH 147	Calibration	1,145,146	30,664	19.7	11,985,625	3.85	4,364,567	1.40	46,209,488	15.36	208,437	0.07	1,041,931	0.33	4,902,804	1.57	6,153,836	1.98	271,417	0.09	234,606	0.08	506,024	0.16
S-79 RCH 147	Background	963,086	24,327	18.6	10,318,995	3.94	1,992,280	0.76	33,528,971	13.13	113,508	0.04	561,338	0.21	2,561,894	0.98	3,236,741	1.24	81,612	0.03	118,863	0.05	200,475	0.08
S-79 RCH 147	% Difference	-16%	-21%	-6%	-14%	2%	-54%	-46%	-27%	-15%	-46%	-35%	-46%	-36%	-48%	-38%	-47%	-37%	-70%	-64%	-49%	-40%	-60%	-53%

TABLE 103: COMPARISON OF THE BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.4 SCENARIO RESULTS FOR STREAM INPUTS

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
101	Background 1.2	14,394	311	15.9	307,748	7.86	83,608	2.14	203,441	5.73	2,368	0.06	5,399	0.14	34,445	0.88	42,211	1.08	601	0.02	2,823	0.07	3,424	0.09
101	Background 1.4	14,394	311	15.9	307,748	7.86	83,608	2.14	203,441	5.73	2,368	0.06	5,399	0.14	34,445	0.88	42,211	1.08	601	0.02	2,823	0.07	3,424	0.09
101	% Difference	0%	0%	0%	0%	0.0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
105	Background 1.2	3,192	70	16.1	68,533	7.90	24,426	2.81	55,651	7.11	526	0.06	1,103	0.13	9,490	1.09	11,119	1.28	137	0.02	782	0.09	918	0.11
105	Background 1.4	3,192	70	16.1	68,533	7.90	24,426	2.81	55,651	7.11	526	0.06	1,103	0.13	9,490	1.09	11,119	1.28	137	0.02	782	0.09	918	0.11
105	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
106	Background 1.2	2,651	58	16.1	56,486	7.84	17,402	2.41	41,420	6.34	439	0.06	987	0.14	7,029	0.98	8,455	1.17	115	0.02	577	0.08	692	0.10
106	Background 1.4	2,651	58	16.1	56,486	7.84	17,402	2.41	41,420	6.34	439	0.06	987	0.14	7,029	0.98	8,455	1.17	115	0.02	577	0.08	692	0.10
106	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
108	Background 1.2	12,135	261	15.8	259,778	7.87	81,810	2.48	194,886	6.52	1,958	0.06	4,345	0.13	33,071	1.00	39,374	1.19	528	0.02	2,714	0.08	3,242	0.10
108	Background 1.4	12,135	261	15.8	259,778	7.87	81,810	2.48	194,886	6.52	1,958	0.06	4,345	0.13	33,071	1.00	39,374	1.19	528	0.02	2,714	0.08	3,242	0.10
108	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
111	Background 1.2	4,521	664	108.0	93,704	7.62	37,276	3.03	83,016	7.50	787	0.06	1,571	0.13	14,193	1.15	16,551	1.35	297	0.02	1,171	0.10	1,468	0.12
111	Background 1.4	4,521	664	108.0	93,704	7.62	37,276	3.03	83,016	7.50	787	0.06	1,571	0.13	14,193	1.15	16,551	1.35	297	0.02	1,171	0.10	1,468	0.12
111	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
113	Background 1.2	8,244	240	21.4	138,826	6.19	48,884	2.18	124,729	6.10	1,388	0.06	3,249	0.14	21,014	0.94	25,651	1.14	387	0.02	1,716	0.08	2,103	0.09
113	Background 1.4	8,244	240	21.4	138,826	6.19	48,884	2.18	124,729	6.10	1,388	0.06	3,249	0.14	21,014	0.94	25,651	1.14	387	0.02	1,716	0.08	2,103	0.09
113	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
116	Background 1.2	1,991	41	15.1	42,951	7.93	15,958	2.95	35,234	7.24	317	0.06	650	0.12	6,030	1.11	6,997	1.29	74	0.01	498	0.09	572	0.11
116	Background 1.4	1,991	41	15.1	42,951	7.93	15,958	2.95	35,234	7.24	317	0.06	650	0.12	6,030	1.11	6,997	1.29	74	0.01	498	0.09	572	0.11
116	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
117	Background 1.2	17,064	348	15.0	369,499	7.96	121,255	2.61	275,142	6.58	2,824	0.06	5,944	0.13	46,940	1.01	55,708	1.20	612	0.01	3,867	0.08	4,479	0.10
117	Background 1.4	17,064	348	15.0	369,499	7.96	121,255	2.61	275,142	6.58	2,824	0.06	5,944	0.13	46,940	1.01	55,708	1.20	612	0.01	3,867	0.08	4,479	0.10
117	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
118	Background 1.2	1,034	23	16.2	22,155	7.88	7,347	2.61	16,603	6.55	173	0.06	360	0.13	2,834	1.01	3,367	1.20	39	0.01	234	0.08	272	0.10
118	Background 1.4	1,034	23	16.2	22,155	7.88	7,347	2.61	16,603	6.55	173	0.06	360	0.13	2,834	1.01	3,367	1.20	39	0.01	234	0.08	272	0.10
118	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
119	Background 1.2	1,505	32	15.7	32,393	7.91	10,936	2.67	24,673	6.69	248	0.06	515	0.13	4,212	1.03	4,975	1.22	56	0.01	347	0.08	403	0.10
119	Background 1.4	1,505	32	15.7	32,393	7.91	10,936	2.67	24,673	6.69	248	0.06	515	0.13	4,212	1.03	4,975	1.22	56	0.01	347	0.08	403	0.10
119	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
120	Background 1.2	8,724	219	18.5	133,422	5.62	60,239	2.54	140,901	6.57	1,439	0.06	3,118	0.13	23,957	1.01	28,514	1.20	356	0.01	1,969	0.08	2,325	0.10
120	Background 1.4	8,724	219	18.5	133,422	5.62	60,239	2.54	140,901	6.57	1,439	0.06	3,118	0.13	23,957	1.01	28,514	1.20	356	0.01	1,969	0.08	2,325	0.10
120	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
121	Background 1.2	4,128	180	32.2	47,020	4.19	21,450	1.91	57,937	5.63	707	0.06	1,654	0.15	9,706	0.86	12,068	1.07	205	0.02	790	0.07	994	0.09
121	Background 1.4	4,128	180	32.2	47,020	4.19	21,450	1.91	57,937	5.63	707	0.06	1,654	0.15	9,706	0.86	12,068	1.07	205	0.02	790	0.07	994	0.09
121	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
123	Background 1.2	17,363	292	12.4	373,835	7.92	112,645	2.39	260,895	6.12	2,816	0.06	5,996	0.13	44,408	0.94	53,219	1.13	495	0.01	3,652	0.08	4,148	0.09
123	Background 1.4	17,363	292	12.4	373,835	7.92	112,645	2.39	260,895	6.12	2,816	0.06	5,996	0.13	44,408	0.94	53,219	1.13	495	0.01	3,652	0.08	4,148	0.09
123	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
127	Background 1.2	37,291	1,193	23.5	776,211	7.65	167,636	1.65	469,653	5.04	6,204	0.06	15,146	0.15	78,424	0.77	99,775	0.98	1,570	0.02	6,371	0.06	7,941	0.08
127	Background 1.4	37,291	1,193	23.5	776,211	7.65	167,636	1.65	469,653	5.04	6,204	0.06	15,146	0.15	78,424	0.77	99,775	0.98	1,570	0.02	6,371	0.06	7,941	0.08
127	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
132	Background 1.2	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
132	Background 1.4	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
132	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
134	Background 1.2	5,501	221	29.5	107,455	7.18	35,721	2.39	89,412	6.57	848	0.06	2,055	0.14	15,098	1.01	18,001	1.20	268	0.02	1,237	0.08	1,505	0.10
134	Background 1.4	5,501	221	29.5	107,455	7.18	35,721	2.39	89,412	6.57	848	0.06	2,055	0.14	15,098	1.01	18,001	1.20	268	0.02	1,237	0.08	1,505	0.10
134	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
137	Background 1.2	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
137	Background 1.4	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
137	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
139	Background 1.2	34,938	2,055	43.3	714,863	7.52	334,836	3.52	810,121	9.40	5,804	0.06	13,248	0.14	137,246	1.44	156,299	1.65	3,864	0.04	11,254	0.12	15,118	0.16
139	Background 1.4	34,938	2,055	43.3	714,863	7.52	334,836	3.52	810,121	9.40	5,804	0.06	13,248	0.14	137,246	1.44	156,299	1.65	3,864	0.04	11,254	0.12	15,118	0.16
139	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
147 S-79	Background 1.2	963,086	24,327	18.6	10,318,993	3.94	1,992,280	0.76	33,528,975	13.13	113,508	0.04	561,338	0.21	2,561,894	0.98	3,236,741	1.24	81,612	0.03	118,863	0.05	200,475	0.08
147 S-79	Background 1.4	963,086	24,327	18.6	10,320,822	3.94	1,993,283	0.76	33,531,988	13.13	117,860	0.05	590,864	0.23	2,849,914	1.09	3,558,637	1.36	81,273	0.03	119,088	0.05	200,362	0.08
147 S-79	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	4%	5%	5%	11%	11%	10%	10%	0%	0%	0%	0%	0%	0%

TABLE 104: COMPARISON OF THE BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.4 SCENARIO RESULTS FOR DIRECT LAND INPUTS

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)
103	Background 1.2	1,952	4	1.5	44,346	8.35	27,752	5.23	285	0.05	570	0.11	4,202	0.79	5,057	0.95	18	0.00	316	0.06	334	0.06
103	Background 1.4	1,952	4	1.5	44,346	8.35	27,752	5.23	285	0.05	570	0.11	4,202	0.79	5,057	0.95	18	0.00	316	0.06	334	0.06
103	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
104	Background 1.2	588	0	0.6	13,356	8.35	8,546	5.34	84	0.05	168	0.11	1,294	0.81	1,546	0.97	4	0.00	97	0.06	101	0.06
104	Background 1.4	588	0	0.6	13,356	8.35	8,546	5.34	84	0.05	168	0.11	1,294	0.81	1,546	0.97	4	0.00	97	0.06	101	0.06
104	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
109	Background 1.2	635	1	1.2	14,399	8.34	9,155	5.30	93	0.05	186	0.11	1,386	0.80	1,665	0.96	5	0.00	104	0.06	109	0.06
109	Background 1.4	635	1	1.2	14,399	8.34	9,155	5.30	93	0.05	186	0.11	1,386	0.80	1,665	0.96	5	0.00	104	0.06	109	0.06
109	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
110	Background 1.2	1,100	1	1.0	24,955	8.34	15,925	5.32	159	0.05	319	0.11	2,411	0.81	2,890	0.97	7	0.00	181	0.06	189	0.06
110	Background 1.4	1,100	1	1.0	24,955	8.34	15,925	5.32	159	0.05	319	0.11	2,411	0.81	2,890	0.97	7	0.00	181	0.06	189	0.06
110	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
122	Background 1.2	959	1	0.7	21,223	8.14	13,542	5.19	142	0.05	285	0.11	2,050	0.79	2,478	0.95	6	0.00	154	0.06	160	0.06
122	Background 1.4	959	1	0.7	21,223	8.14	13,542	5.19	142	0.05	285	0.11	2,050	0.79	2,478	0.95	6	0.00	154	0.06	160	0.06
122	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
126	Background 1.2	289	0	0.6	6,414	8.15	4,097	5.20	42	0.05	84	0.11	620	0.79	746	0.95	2	0.00	47	0.06	48	0.06
126	Background 1.4	289	0	0.6	6,414	8.15	4,097	5.20	42	0.05	84	0.11	620	0.79	746	0.95	2	0.00	47	0.06	48	0.06
126	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
129	Background 1.2	868	3	2.8	19,123	8.10	12,101	5.13	143	0.06	283	0.12	1,832	0.78	2,258	0.96	14	0.01	138	0.06	152	0.06
129	Background 1.4	868	3	2.8	19,123	8.10	12,101	5.13	143	0.06	283	0.12	1,832	0.78	2,258	0.96	14	0.01	138	0.06	152	0.06
129	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
130	Background 1.2	895	1	1.2	19,797	8.13	12,858	5.28	134	0.06	269	0.11	1,947	0.80	2,350	0.97	8	0.00	147	0.06	154	0.06
130	Background 1.4	895	1	1.2	19,797	8.13	12,858	5.28	134	0.06	269	0.11	1,947	0.80	2,350	0.97	8	0.00	147	0.06	154	0.06
130	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
131	Background 1.2	475	1	1.0	10,570	8.18	6,780	5.24	69	0.05	138	0.11	1,026	0.79	1,234	0.95	5	0.00	77	0.06	82	0.06
131	Background 1.4	475	1	1.0	10,570	8.18	6,780	5.24	69	0.05	138	0.11	1,026	0.79	1,234	0.95	5	0.00	77	0.06	82	0.06
131	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
133	Background 1.2	625	0	0.4	13,885	8.17	9,046	5.32	88	0.05	177	0.10	1,370	0.81	1,635	0.96	4	0.00	103	0.06	107	0.06
133	Background 1.4	625	0	0.4	13,885	8.17	9,046	5.32	88	0.05	177	0.10	1,370	0.81	1,635	0.96	4	0.00	103	0.06	107	0.06
133	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
136	Background 1.2	2,897	3	0.7	64,021	8.13	42,199	5.36	426	0.05	854	0.11	6,389	0.81	7,668	0.97	17	0.00	481	0.06	498	0.06
136	Background 1.4	2,897	3	0.7	64,021	8.13	42,199	5.36	426	0.05	854	0.11	6,389	0.81	7,668	0.97	17	0.00	481	0.06	498	0.06
136	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
138	Background 1.2	1,527	2	1.1	33,773	8.13	21,424	5.16	235	0.06	471	0.11	3,243	0.78	3,949	0.95	13	0.00	244	0.06	257	0.06
138	Background 1.4	1,527	2	1.1	33,773	8.13	21,424	5.16	235	0.06	471	0.11	3,243	0.78	3,949	0.95	13	0.00	244	0.06	257	0.06
138	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
144	Background 1.2	236	0	0.5	5,231	8.15	3,339	5.20	34	0.05	68	0.11	506	0.79	608	0.95	1	0.00	38	0.06	39	0.06
144	Background 1.4	236	0	0.5	5,231	8.15	3,339	5.20	34	0.05	68	0.11	506	0.79	608	0.95	1	0.00	38	0.06	39	0.06
144	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
145	Background 1.2	172	0	0.2	3,819	8.16	2,446	5.23	24	0.05	48	0.10	370	0.79	442	0.95	1	0.00	28	0.06	29	0.06
145	Background 1.4	172	0	0.2	3,819	8.16	2,446	5.23	24	0.05	48	0.10	370	0.79	442	0.95	1	0.00	28	0.06	29	0.06
145	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
146	Background 1.2	362	0	0.3	8,037	8.17	5,134	5.22	51	0.05	102	0.10	777	0.79	930	0.94	2	0.00	59	0.06	60	0.06
146	Background 1.4	362	0	0.3	8,037	8.17	5,134	5.22	51	0.05	102	0.10	777	0.79	930	0.94	2	0.00	59	0.06	60	0.06
146	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
221	Background 1.2	83	0	0.2	1,846	8.15	1,185	5.23	12	0.05	23	0.10	179	0.79	214	0.95	0	0.00	13	0.06	14	0.06
221	Background 1.4	83	0	0.2	1,846	8.15	1,185	5.23	12	0.05	23	0.10	179	0.79	214	0.95	0	0.00	13	0.06	14	0.06
221	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

TABLE 105: COMPARISON OF BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.4 SCENARIO RESULTS FOR IMPAIRED WATERBODIES

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
Long Hammock RCH192	Background 1.2	11,760	198	12.4	203,472	6.36	61,309	1.92	160,893	5.51	1,757	0.05	4,480	0.14	27,034	0.85	33,272	1.04	301	0.01	2,205	0.07	2,507	0.08
Long Hammock RCH192	Background 1.4	11,760	198	12.4	203,472	6.36	61,309	1.92	160,893	5.51	1,757	0.05	4,480	0.14	27,034	0.85	33,272	1.04	301	0.01	2,205	0.07	2,507	0.08
Long Hammock RCH192	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cypress Branch RCH181	Background 1.2	10,548	288	20.1	156,209	5.45	38,113	1.33	130,872	4.89	1,220	0.04	4,906	0.17	21,475	0.75	27,601	0.96	368	0.01	1,722	0.06	2,090	0.07
Cypress Branch RCH181	Background 1.4	10,548	288	20.1	156,209	5.45	38,113	1.33	130,872	4.89	1,220	0.04	4,906	0.17	21,475	0.75	27,601	0.96	368	0.01	1,722	0.06	2,090	0.07
Cypress Branch RCH181	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Townsend Canal RCH996	Background 1.2	38,166	3,345	64.5	624,504	6.02	209,500	2.02	659,889	6.86	4,691	0.05	18,153	0.17	109,099	1.05	131,943	1.27	3,520	0.03	8,812	0.08	12,332	0.12
Townsend Canal RCH996	Background 1.4	38,166	3,345	64.5	624,504	6.02	209,500	2.02	659,889	6.86	4,691	0.05	18,153	0.17	109,099	1.05	131,943	1.27	3,520	0.03	8,812	0.08	12,332	0.12
Townsend Canal RCH996	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
C-19 Canal RCH208	Background 1.2	8,087	135	12.2	129,209	5.88	39,161	1.78	111,766	5.52	1,111	0.05	3,162	0.14	18,633	0.85	22,906	1.04	238	0.01	1,513	0.07	1,750	0.08
C-19 Canal RCH208	Background 1.4	8,087	135	12.2	129,209	5.88	39,161	1.78	111,766	5.52	1,111	0.05	3,162	0.14	18,633	0.85	22,906	1.04	238	0.01	1,513	0.07	1,750	0.08
C-19 Canal RCH208	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lake Hicpochee RCH197	Background 1.2	723,639	16,160	16.4	6,295,709	3.20	2,052,585	1.04	31,324,124	16.62	87,747	0.04	370,283	0.19	2,219,153	1.13	2,677,182	1.36	57,036	0.03	92,400	0.05	149,436	0.08
Lake Hicpochee RCH197	Background 1.4	723,639	16,160	16.4	6,303,004	3.20	2,053,291	1.04	31,325,851	16.62	93,998	0.05	398,492	0.20	2,527,365	1.28	3,019,855	1.53	56,730	0.03	92,641	0.05	149,371	0.08
Lake Hicpochee RCH197	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	7%	8%	8%	14%	14%	13%	13%	-1%	-1%	0%	0%	0%	0%
S-4 Disston Canal RCH216	Background 1.2	9,029	312	25.4	82,074	3.34	2,645	0.11	84,050	3.45	386	0.02	4,891	0.20	7,454	0.30	12,731	0.52	497	0.02	401	0.02	897	0.04
S-4 Disston Canal RCH216	Background 1.4	9,029	312	25.4	82,033	3.34	2,642	0.11	84,050	3.45	395	0.02	5,147	0.21	8,053	0.33	13,595	0.55	495	0.02	401	0.02	895	0.04
S-4 Disston Canal RCH216	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2%	5%	5%	8%	8%	7%	7%	0%	0%	0%	0%	0%	0%
S-4 Ninemile Canal RCH214	Background 1.2	18,598	773	30.6	177,129	3.50	8,899	0.18	320,070	6.37	1,079	0.02	8,377	0.17	23,925	0.47	33,381	0.66	1,102	0.02	1,042	0.02	2,144	0.04
S-4 Ninemile Canal RCH214	Background 1.4	18,598	773	30.6	177,065	3.50	8,904	0.18	320,114	6.37	1,111	0.02	8,993	0.18	26,703	0.53	36,806	0.73	1,091	0.02	1,043	0.02	2,133	0.04
S-4 Ninemile Canal RCH214	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	3%	7%	7%	12%	12%	10%	10%	-1%	-1%	0%	0%	0%	0%
S-4 Industrial Canal RCH219	Background 1.2	32,105	997	22.8	407,510	4.67	94,631	1.08	1,341,631	16.29	3,115	0.04	9,134	0.10	97,441	1.12	109,690	1.26	1,631	0.02	4,334	0.05	5,966	0.07
S-4 Industrial Canal RCH219	Background 1.4	32,105	997	22.8	410,391	4.70	94,728	1.09	1,341,780	16.31	3,373	0.04	10,254	0.12	110,974	1.27	124,601	1.43	1,586	0.02	4,368	0.05	5,954	0.07
S-4 Industrial Canal RCH219	% Difference	0%	0%	0%	1%	1%	0%	0%	0%	0%	8%	8%	12%	12%	14%	14%	14%	14%	-3%	-3%	1%	1%	0%	0%
Billy Creek RCH137	Background 1.2	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
Billy Creek RCH137	Background 1.4	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
Billy Creek RCH137	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Deep Lagoon RCH132	Background 1.2	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
Deep Lagoon RCH132	Background 1.4	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
Deep Lagoon RCH132	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

TABLE 106: COMPARISON OF THE BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.4 SCENARIO RESULTS FOR MAIN STEM CALOOSAHATCHEE RIVER STRUCTURES

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
S-77 RCH215	Background 1.2	656,317	13,913	15.6	9,145,672	5.12	3,713,654	2.08	31,627,681	19.45	85,425	0.05	124,686	0.07	2,456,061	1.38	2,666,173	1.49	23,847	0.01	122,355	0.07	146,203	0.08
S-77 RCH215	Background 1.4	656,317	13,913	15.6	9,155,675	5.13	3,713,815	2.08	31,627,810	19.45	99,237	0.06	145,771	0.08	2,774,630	1.55	3,019,638	1.69	23,750	0.01	122,446	0.07	146,196	0.08
S-77 RCH215	% Difference	0%	0%	0%	0%	0.1%	0%	0%	0%	0%	16%	16%	17%	17%	13%	13%	13%	13%	0%	0%	0%	0%	0%	0%
S-78 RCH 188	Background 1.2	748,632	16,578	16.3	6,511,236	3.20	1,974,938	0.97	31,416,007	16.03	91,912	0.05	400,148	0.20	2,232,345	1.10	2,724,406	1.34	60,519	0.03	92,955	0.05	153,473	0.08
S-78 RCH 188	Background 1.4	748,632	16,578	16.3	6,516,431	3.20	1,975,678	0.97	31,417,891	16.04	97,763	0.05	428,696	0.21	2,537,757	1.25	3,064,217	1.51	60,212	0.03	93,190	0.05	153,402	0.08
S-78 RCH 188	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	6%	7%	7%	14%	14%	12%	12%	-1%	-1%	0%	0%	0%	0%
S-79 RCH 147	Background 1.2	963,086	24,327	18.6	10,318,995	3.94	1,992,280	0.76	33,528,971	13.13	113,508	0.04	561,338	0.21	2,561,894	0.98	3,236,741	1.24	81,612	0.03	118,863	0.05	200,475	0.08
S-79 RCH 147	Background 1.4	963,086	24,327	18.6	10,320,820	3.94	1,993,283	0.76	33,531,998	13.13	117,860	0.05	590,864	0.23	2,849,913	1.09	3,558,636	1.36	81,274	0.03	119,088	0.05	200,362	0.08
S-79 RCH 147	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	4%	5%	5%	11%	11%	10%	10%	0%	0%	0%	0%	0%	0%

TABLE 107: COMPARISON OF THE BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.2 BENOD SCENARIO RESULTS FOR STREAM INPUTS

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
101	Background 1.2	14,394	311	15.9	307,748	7.86	83,608	2.14	203,441	5.73	2,368	0.06	5,399	0.14	34,445	0.88	42,211	1.08	601	0.02	2,823	0.07	3,424	0.09
101	1.2 BENOD	14,394	311	15.9	307,786	7.86	83,608	2.14	203,441	5.73	2,368	0.06	5,399	0.14	34,445	0.88	42,211	1.08	601	0.02	2,823	0.07	3,424	0.09
101	% Difference	0%	0%	0%	0%	0.0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
105	Background 1.2	3,192	70	16.1	68,533	7.90	24,426	2.81	55,651	7.11	526	0.06	1,103	0.13	9,490	1.09	11,119	1.28	137	0.02	782	0.09	918	0.11
105	1.2 BENOD	3,192	70	16.1	68,535	7.90	24,426	2.81	55,651	7.11	526	0.06	1,103	0.13	9,490	1.09	11,119	1.28	137	0.02	782	0.09	918	0.11
105	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
106	Background 1.2	2,651	58	16.1	56,486	7.84	17,402	2.41	41,420	6.34	439	0.06	987	0.14	7,029	0.98	8,455	1.17	115	0.02	577	0.08	692	0.10
106	1.2 BENOD	2,651	58	16.1	56,493	7.84	17,402	2.41	41,420	6.34	439	0.06	987	0.14	7,029	0.98	8,455	1.17	115	0.02	577	0.08	692	0.10
106	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
108	Background 1.2	12,135	261	15.8	259,778	7.87	81,810	2.48	194,886	6.52	1,958	0.06	4,345	0.13	33,071	1.00	39,374	1.19	528	0.02	2,714	0.08	3,242	0.10
108	1.2 BENOD	12,135	261	15.8	259,791	7.87	81,810	2.48	194,886	6.52	1,958	0.06	4,345	0.13	33,071	1.00	39,374	1.19	528	0.02	2,714	0.08	3,242	0.10
108	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
111	Background 1.2	4,521	664	108.0	93,704	7.62	37,276	3.03	83,016	7.50	787	0.06	1,571	0.13	14,193	1.15	16,551	1.35	297	0.02	1,171	0.10	1,468	0.12
111	1.2 BENOD	4,521	664	108.0	95,190	7.74	37,276	3.03	83,016	7.50	782	0.06	1,576	0.13	14,193	1.15	16,551	1.35	297	0.02	1,171	0.10	1,468	0.12
111	% Difference	0%	0%	0%	2%	2%	0%	0%	0%	0%	-1%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
113	Background 1.2	8,244	240	21.4	138,826	6.19	48,884	2.18	124,729	6.10	1,388	0.06	3,249	0.14	21,014	0.94	25,651	1.14	387	0.02	1,716	0.08	2,103	0.09
113	1.2 BENOD	8,244	240	21.4	151,187	6.74	48,884	2.18	124,729	6.10	1,296	0.06	3,347	0.15	21,014	0.94	25,657	1.14	387	0.02	1,716	0.08	2,103	0.09
113	% Difference	0%	0%	0%	9%	9%	0%	0%	0%	0%	-7%	-7%	3%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
116	Background 1.2	1,991	41	15.1	42,951	7.93	15,958	2.95	35,234	7.24	317	0.06	650	0.12	6,030	1.11	6,997	1.29	74	0.01	498	0.09	572	0.11
116	1.2 BENOD	1,991	41	15.1	42,952	7.93	15,958	2.95	35,234	7.24	317	0.06	650	0.12	6,030	1.11	6,997	1.29	74	0.01	498	0.09	572	0.11
116	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
117	Background 1.2	17,064	348	15.0	369,499	7.96	121,255	2.61	275,142	6.58	2,824	0.06	5,944	0.13	46,940	1.01	55,708	1.20	612	0.01	3,867	0.08	4,479	0.10
117	1.2 BENOD	17,064	348	15.0	369,790	7.97	121,255	2.61	275,142	6.58	2,824	0.06	5,944	0.13	46,940	1.01	55,708	1.20	612	0.01	3,867	0.08	4,479	0.10
117	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
118	Background 1.2	1,034	23	16.2	22,155	7.88	7,347	2.61	16,603	6.55	173	0.06	360	0.13	2,834	1.01	3,367	1.20	39	0.01	234	0.08	272	0.10
118	1.2 BENOD	1,034	23	16.2	22,157	7.88	7,347	2.61	16,603	6.55	173	0.06	360	0.13	2,834	1.01	3,367	1.20	39	0.01	234	0.08	272	0.10
118	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
119	Background 1.2	1,505	32	15.7	32,393	7.91	10,936	2.67	24,673	6.69	248	0.06	515	0.13	4,212	1.03	4,975	1.22	56	0.01	347	0.08	403	0.10
119	1.2 BENOD	1,505	32	15.7	32,394	7.91	10,935	2.67	24,673	6.69	248	0.06	515	0.13	4,212	1.03	4,975	1.22	56	0.01	347	0.08	403	0.10
119	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
120	Background 1.2	8,724	219	18.5	133,422	5.62	60,239	2.54	140,901	6.57	1,439	0.06	3,118	0.13	23,957	1.01	28,514	1.20	356	0.01	1,969	0.08	2,325	0.10
120	1.2 BENOD	8,724	219	18.5	153,080	6.45	60,239	2.54	140,901	6.57	1,404	0.06	3,158	0.13	23,957	1.01	28,519	1.20	356	0.01	1,969	0.08	2,325	0.10
120	% Difference	0%	0%	0%	15%	15%	0%	0%	0%	0%	-2%	-2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
121	Background 1.2	4,128	180	32.2	47,020	4.19	21,450	1.91	57,937	5.63	707	0.06	1,654	0.15	9,706	0.86	12,068	1.07	205	0.02	790	0.07	994	0.09
121	1.2 BENOD	4,128	180	32.2	60,811	5.42	21,450	1.91	57,937	5.63	634	0.06	1,733	0.15	9,706	0.86	12,073	1.08	205	0.02	790	0.07	994	0.09
121	% Difference	0%	0%	0%	29%	29%	0%	0%	0%	0%	-10%	-10%	5%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
123	Background 1.2	17,363	292	12.4	373,835	7.92	112,645	2.39	260,895	6.12	2,816	0.06	5,996	0.13	44,408	0.94	53,219	1.13	495	0.01	3,652	0.08	4,148	0.09
123	1.2 BENOD	17,363	292	12.4	374,227	7.93	112,644	2.39	260,896	6.12	2,816	0.06	5,996	0.13	44,408	0.94	53,219	1.13	495	0.01	3,652	0.08	4,148	0.09
123	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
127	Background 1.2	37,291	1,193	23.5	776,211	7.65	167,636	1.65	469,653	5.04	6,204	0.06	15,146	0.15	78,424	0.77	99,775	0.98	1,570	0.02	6,371	0.06	7,941	0.08
127	1.2 BENOD	37,291	1,193	23.5	780,906	7.70	167,661	1.65	469,723	5.04	5,170	0.05	16,205	0.16	78,438	0.77	99,812	0.98	1,562	0.02	6,373	0.06	7,935	0.08
127	% Difference	0%	0%	0%	1%	1%	0%	0%	0%	0%	-17%	-17%	7%	7%	0%	0%	0%	0%	-1%	-1%	0%	0%	0%	0%
132	Background 1.2	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
132	1.2 BENOD	4,494	152	24.8	65,230	5.34	21,793	1.78	68,741	6.07	585	0.05	1,786	0.15	11,366	0.93	13,736	1.12	221	0.02	919	0.08	1,140	0.09
132	% Difference	0%	0%	0%	33%	33%	0%	0%	0%	0%	-16%	-16%	7%	7%	0%	0%	0%	0%	-1%	-1%	0%	0%	0%	0%
134	Background 1.2	5,501	221	29.5	107,455	7.18	35,721	2.39	89,412	6.57	848	0.06	2,055	0.14	15,098	1.01	18,001	1.20	268	0.02	1,237	0.08	1,505	0.10
134	1.2 BENOD	5,501	221	29.5	112,045	7.49	35,721	2.39	89,413	6.57	845	0.06	2,057	0.14	15,098	1.01	18,001	1.20	268	0.02	1,237	0.08	1,505	0.10
134	% Difference	0%	0%	0%	4%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
137	Background 1.2	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
137	1.2 BENOD	7,826	167	15.7	136,997	6.44	53,752	2.53	135,053	6.97	1,206	0.06	3,090	0.15	22,789	1.07	27,085	1.27	367	0.02	1,863	0.09	2,230	0.10
137	% Difference	0%	0%	0%	13%	13%	0%	0%	0%	0%	-4%	-4%	2%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
139	Background 1.2	34,938	2,055	43.3	714,863	7.52	334,836	3.52	810,121	9.40	5,804	0.06	13,248	0.14	137,246	1.44	156,299	1.65	3,864	0.04	11,254	0.12	15,118	0.16
139	1.2 BENOD	34,938	2,055	43.3	722,112	7.60	334,826	3.52	810,125	9.40	5,667	0.06	13,391	0.14	137,246	1.44	156,305	1.65	3,863	0.04	11,254	0.12	15,116	0.16
139	% Difference	0%	0%	0%	1%	1%	0%	0%	0%	0%	-2%	-2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
147 S-79	Background 1.2	963,086	24,327	18.6	10,318,993	3.94	1,992,280	0.76	33,528,975	13.13	113,508	0.04	561,338	0.21	2,561,894	0.98	3,236,741	1.24	81,612	0.03	118,863	0.05	200,475	0.08
147 S-79	1.2 BENOD	963,086	24,327	18.6	10,989,782	4.20	1,989,212	0.76	33,524,487	13.12	110,164	0.04	564,981	0.22	2,561,530	0.98	3,236,676	1.24	81,633	0.03	118,812	0.05	200,446	0.08
147 S-79	% Difference	0%	0%	0%	7%	7%	0%	0%	0%	0%	-3%	-3%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

TABLE 108: COMPARISON OF THE BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.2 BENOD SCENARIO RESULTS FOR DIRECT LAND INPUTS

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)
103	Background 1.2	1,952	4	1.5	44,346	8.35	27,752	5.23	285	0.05	570	0.11	4,202	0.79	5,057	0.95	18	0.00	316	0.06	334	0.06
103	1.2 BENOD	1,952	4	1.5	44,346	8.35	27,752	5.23	285	0.05	570	0.11	4,202	0.79	5,057	0.95	18	0.00	316	0.06	334	0.06
103	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
104	Background 1.2	588	0	0.6	13,356	8.35	8,546	5.34	84	0.05	168	0.11	1,294	0.81	1,546	0.97	4	0.00	97	0.06	101	0.06
104	1.2 BENOD	588	0	0.6	13,356	8.35	8,546	5.34	84	0.05	168	0.11	1,294	0.81	1,546	0.97	4	0.00	97	0.06	101	0.06
104	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
109	Background 1.2	635	1	1.2	14,399	8.34	9,155	5.30	93	0.05	186	0.11	1,386	0.80	1,665	0.96	5	0.00	104	0.06	109	0.06
109	1.2 BENOD	635	1	1.2	14,399	8.34	9,155	5.30	93	0.05	186	0.11	1,386	0.80	1,665	0.96	5	0.00	104	0.06	109	0.06
109	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
110	Background 1.2	1,100	1	1.0	24,955	8.34	15,925	5.32	159	0.05	319	0.11	2,411	0.81	2,890	0.97	7	0.00	181	0.06	189	0.06
110	1.2 BENOD	1,100	1	1.0	24,955	8.34	15,925	5.32	159	0.05	319	0.11	2,411	0.81	2,890	0.97	7	0.00	181	0.06	189	0.06
110	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
122	Background 1.2	959	1	0.7	21,223	8.14	13,542	5.19	142	0.05	285	0.11	2,050	0.79	2,478	0.95	6	0.00	154	0.06	160	0.06
122	1.2 BENOD	959	1	0.7	21,223	8.14	13,542	5.19	142	0.05	285	0.11	2,050	0.79	2,478	0.95	6	0.00	154	0.06	160	0.06
122	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
126	Background 1.2	289	0	0.6	6,414	8.15	4,097	5.20	42	0.05	84	0.11	620	0.79	746	0.95	2	0.00	47	0.06	48	0.06
126	1.2 BENOD	289	0	0.6	6,414	8.15	4,097	5.20	42	0.05	84	0.11	620	0.79	746	0.95	2	0.00	47	0.06	48	0.06
126	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
129	Background 1.2	868	3	2.8	19,123	8.10	12,101	5.13	143	0.06	283	0.12	1,832	0.78	2,258	0.96	14	0.01	138	0.06	152	0.06
129	1.2 BENOD	868	3	2.8	19,123	8.10	12,101	5.13	143	0.06	283	0.12	1,832	0.78	2,258	0.96	14	0.01	138	0.06	152	0.06
129	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
130	Background 1.2	895	1	1.2	19,797	8.13	12,858	5.28	134	0.06	269	0.11	1,947	0.80	2,350	0.97	8	0.00	147	0.06	154	0.06
130	1.2 BENOD	895	1	1.2	19,797	8.13	12,858	5.28	134	0.06	269	0.11	1,947	0.80	2,350	0.97	8	0.00	147	0.06	154	0.06
130	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
131	Background 1.2	475	1	1.0	10,570	8.18	6,780	5.24	69	0.05	138	0.11	1,026	0.79	1,234	0.95	5	0.00	77	0.06	82	0.06
131	1.2 BENOD	475	1	1.0	10,570	8.18	6,780	5.24	69	0.05	138	0.11	1,026	0.79	1,234	0.95	5	0.00	77	0.06	82	0.06
131	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
133	Background 1.2	625	0	0.4	13,885	8.17	9,046	5.32	88	0.05	177	0.10	1,370	0.81	1,635	0.96	4	0.00	103	0.06	107	0.06
133	1.2 BENOD	625	0	0.4	13,885	8.17	9,046	5.32	88	0.05	177	0.10	1,370	0.81	1,635	0.96	4	0.00	103	0.06	107	0.06
133	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
136	Background 1.2	2,897	3	0.7	64,021	8.13	42,199	5.36	426	0.05	854	0.11	6,389	0.81	7,668	0.97	17	0.00	481	0.06	498	0.06
136	1.2 BENOD	2,897	3	0.7	64,021	8.13	42,199	5.36	426	0.05	854	0.11	6,389	0.81	7,668	0.97	17	0.00	481	0.06	498	0.06
136	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
138	Background 1.2	1,527	2	1.1	33,773	8.13	21,424	5.16	235	0.06	471	0.11	3,243	0.78	3,949	0.95	13	0.00	244	0.06	257	0.06
138	1.2 BENOD	1,527	2	1.1	33,773	8.13	21,424	5.16	235	0.06	471	0.11	3,243	0.78	3,949	0.95	13	0.00	244	0.06	257	0.06
138	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
144	Background 1.2	236	0	0.5	5,231	8.15	3,339	5.20	34	0.05	68	0.11	506	0.79	608	0.95	1	0.00	38	0.06	39	0.06
144	1.2 BENOD	236	0	0.5	5,231	8.15	3,339	5.20	34	0.05	68	0.11	506	0.79	608	0.95	1	0.00	38	0.06	39	0.06
144	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
145	Background 1.2	172	0	0.2	3,819	8.16	2,446	5.23	24	0.05	48	0.10	370	0.79	442	0.95	1	0.00	28	0.06	29	0.06
145	1.2 BENOD	172	0	0.2	3,819	8.16	2,446	5.23	24	0.05	48	0.10	370	0.79	442	0.95	1	0.00	28	0.06	29	0.06
145	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
146	Background 1.2	362	0	0.3	8,037	8.17	5,134	5.22	51	0.05	102	0.10	777	0.79	930	0.94	2	0.00	59	0.06	60	0.06
146	1.2 BENOD	362	0	0.3	8,037	8.17	5,134	5.22	51	0.05	102	0.10	777	0.79	930	0.94	2	0.00	59	0.06	60	0.06
146	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
221	Background 1.2	83	0	0.2	1,846	8.15	1,185	5.23	12	0.05	23	0.10	179	0.79	214	0.95	0	0.00	13	0.06	14	0.06
221	1.2 BENOD	83	0	0.2	1,846	8.15	1,185	5.23	12	0.05	23	0.10	179	0.79	214	0.95	0	0.00	13	0.06	14	0.06
221	% Difference	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

TABLE 109: COMPARISON OF BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.2 BENOD SCENARIO RESULTS FOR IMPAIRED WATERBODIES

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
Long Hammock RCH192	Background 1.2	11,760	198	12.4	203,472	6.36	61,309	1.92	160,893	5.51	1,757	0.05	4,480	0.14	27,034	0.85	33,272	1.04	301	0.01	2,205	0.07	2,507	0.08
Long Hammock RCH192	1.2 BENOD	11,760	198	12.4	219,705	6.87	61,310	1.92	160,893	5.51	1,755	0.05	4,483	0.14	27,035	0.85	33,272	1.04	301	0.01	2,205	0.07	2,507	0.08
Long Hammock RCH192	% Difference	0%	0%	0%	8%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cypress Branch RCH181	Background 1.2	10,548	288	20.1	156,209	5.45	38,113	1.33	130,872	4.89	1,220	0.04	4,906	0.17	21,475	0.75	27,601	0.96	368	0.01	1,722	0.06	2,090	0.07
Cypress Branch RCH181	1.2 BENOD	10,548	288	20.1	176,796	6.16	38,113	1.33	130,872	4.89	1,220	0.04	4,906	0.17	21,475	0.75	27,601	0.96	368	0.01	1,722	0.06	2,090	0.07
Cypress Branch RCH181	% Difference	0%	0%	0%	13%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Townsend Canal RCH996	Background 1.2	38,166	3,345	64.5	624,504	6.02	209,500	2.02	659,889	6.86	4,691	0.05	18,153	0.17	109,099	1.05	131,943	1.27	3,520	0.03	8,812	0.08	12,332	0.12
Townsend Canal RCH996	1.2 BENOD	38,166	3,345	64.5	684,173	6.59	209,492	2.02	659,890	6.86	4,678	0.05	18,167	0.18	109,099	1.05	131,944	1.27	3,520	0.03	8,812	0.08	12,332	0.12
Townsend Canal RCH996	% Difference	0%	0%	0%	10%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
C-19 Canal RCH208	Background 1.2	8,087	135	12.2	129,209	5.88	39,161	1.78	111,766	5.52	1,111	0.05	3,162	0.14	18,633	0.85	22,906	1.04	238	0.01	1,513	0.07	1,750	0.08
C-19 Canal RCH208	1.2 BENOD	8,087	135	12.2	143,943	6.55	39,162	1.78	111,767	5.52	1,105	0.05	3,169	0.14	18,633	0.85	22,907	1.04	238	0.01	1,513	0.07	1,750	0.08
C-19 Canal RCH208	% Difference	0%	0%	0%	11%	11%	0%	0%	0%	0%	-1%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lake Hicpochee RCH197	Background 1.2	723,639	16,160	16.4	6,295,709	3.20	2,052,585	1.04	31,324,124	16.62	87,747	0.04	370,283	0.19	2,219,153	1.13	2,677,182	1.36	57,036	0.03	92,400	0.05	149,436	0.08
Lake Hicpochee RCH197	1.2 BENOD	723,639	16,160	16.4	6,581,050	3.34	2,049,393	1.04	31,321,654	16.61	85,997	0.04	372,153	0.19	2,219,040	1.13	2,677,189	1.36	57,037	0.03	92,385	0.05	149,421	0.08
Lake Hicpochee RCH197	% Difference	0%	0%	0%	5%	5%	0%	0%	0%	0%	-2%	-2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
S-4 Disston Canal RCH216	Background 1.2	9,029	312	25.4	82,074	3.34	2,645	0.11	84,050	3.45	386	0.02	4,891	0.20	7,454	0.30	12,731	0.52	497	0.02	401	0.02	897	0.04
S-4 Disston Canal RCH216	1.2 BENOD	9,029	312	25.4	120,976	4.93	2,645	0.11	84,052	3.45	141	0.01	5,168	0.21	7,454	0.30	12,763	0.52	496	0.02	401	0.02	896	0.04
S-4 Disston Canal RCH216	% Difference	0%	0%	0%	47%	47%	0%	0%	0%	0%	-64%	-64%	6%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
S-4 Ninemile Canal RCH214	Background 1.2	18,598	773	30.6	177,129	3.50	8,899	0.18	320,070	6.37	1,079	0.02	8,377	0.17	23,925	0.47	33,381	0.66	1,102	0.02	1,042	0.02	2,144	0.04
S-4 Ninemile Canal RCH214	1.2 BENOD	18,598	773	30.6	250,400	4.95	8,900	0.18	320,078	6.37	579	0.01	8,895	0.18	23,927	0.47	33,401	0.66	1,100	0.02	1,042	0.02	2,142	0.04
S-4 Ninemile Canal RCH214	% Difference	0%	0%	0%	41%	41%	0%	0%	0%	0%	-46%	-46%	6%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
S-4 Industrial Canal RCH219	Background 1.2	32,105	997	22.8	407,510	4.67	94,631	1.08	1,341,631	16.29	3,115	0.04	9,134	0.10	97,441	1.12	109,690	1.26	1,631	0.02	4,334	0.05	5,966	0.07
S-4 Industrial Canal RCH219	1.2 BENOD	32,105	997	22.8	466,781	5.35	94,649	1.08	1,341,672	16.29	2,991	0.03	9,199	0.11	97,477	1.12	109,667	1.26	1,623	0.02	4,339	0.05	5,962	0.07
S-4 Industrial Canal RCH219	% Difference	0%	0%	0%	15%	15%	0%	0%	0%	0%	-4%	-4%	1%	1%	0%	0%	0%	0%	-1%	-1%	0%	0%	0%	0%
Billy Creek RCH137	Background 1.2	7,826	167	15.7	120,793	5.68	53,751	2.53	135,052	6.97	1,253	0.06	3,040	0.14	22,789	1.07	27,082	1.27	367	0.02	1,863	0.09	2,230	0.10
Billy Creek RCH137	1.2 BENOD	7,826	167	15.7	136,997	6.44	53,752	2.53	135,053	6.97	1,206	0.06	3,090	0.15	22,789	1.07	27,085	1.27	367	0.02	1,863	0.09	2,230	0.10
Billy Creek RCH137	% Difference	0%	0%	0%	13%	13%	0%	0%	0%	0%	-4%	-4%	2%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Deep Lagoon RCH132	Background 1.2	4,494	152	24.8	49,016	4.01	21,785	1.78	68,732	6.06	697	0.06	1,677	0.14	11,364	0.93	13,738	1.12	222	0.02	919	0.08	1,141	0.09
Deep Lagoon RCH132	1.2 BENOD	4,494	152	24.8	65,230	5.34	21,793	1.78	68,741	6.07	585	0.05	1,786	0.15	11,366	0.93	13,736	1.12	221	0.02	919	0.08	1,140	0.09
Deep Lagoon RCH132	% Difference	0%	0%	0%	33%	33%	0%	0%	0%	0%	-16%	-16%	7%	7%	0%	0%	0%	0%	-1%	-1%	0%	0%	0%	0%

TABLE 110: COMPARISON OF THE BACKGROUND PLUS 1.2 AND BACKGROUND PLUS 1.2 BENOD SCENARIO RESULTS FOR MAIN STEM CALOOSAHATCHEE RIVER STRUCTURES

Reach ID	Type	Volume (ac-ft/yr)	Sediment (ton/yr)	Sediment (mg/L)	DO (lbs/yr)	DO (mg/L)	BOD (lbs/yr)	BOD (mg/L)	TOC (lbs/yr)	TOC (mg/L)	NH_3 (lbs/yr)	NH_3 (mg/L)	NOx (lbs/yr)	NOx (mg/L)	OrgN (lbs/yr)	OrgN (mg/L)	TN (lbs/yr)	TN (mg/L)	PO_4 (lbs/yr)	PO_4 (mg/L)	OrgP (lbs/yr)	OrgP (mg/L)	TP (lbs/yr)	TP (mg/L)
S-77 RCH215	Background 1.2	656,317	13,913	15.6	9,145,672	5.12	3,713,654	2.08	31,627,681	19.45	85,425	0.05	124,686	0.07	2,456,061	1.38	2,666,173	1.49	23,847	0.01	122,355	0.07	146,203	0.08
S-77 RCH215	1.2 BENOD	656,317	13,913	15.6	9,167,186	5.14	3,713,667	2.08	31,627,743	19.45	85,306	0.05	124,759	0.07	2,456,074	1.38	2,666,140	1.49	23,839	0.01	122,357	0.07	146,196	0.08
S-77 RCH215	% Difference	0%	0%	0%	0%	0.2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
S-78 RCH 188	Background 1.2	748,632	16,578	16.3	6,511,236	3.20	1,974,938	0.97	31,416,007	16.03	91,912	0.05	400,148	0.20	2,232,345	1.10	2,724,406	1.34	60,519	0.03	92,955	0.05	153,473	0.08
S-78 RCH 188	1.2 BENOD	748,632	16,578	16.3	6,830,489	3.36	1,970,222	0.97	31,412,262	16.03	90,002	0.04	402,220	0.20	2,232,176	1.10	2,724,400	1.34	60,525	0.03	92,932	0.05	153,456	0.08
S-78 RCH 188	% Difference	0%	0%	0%	5%	5%	0%	0%	0%	0%	-2%	-2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
S-79 RCH 147	Background 1.2	963,086	24,327	18.6	10,318,995	3.94	1,992,280	0.76	33,528,971	13.13	113,508	0.04	561,338	0.21	2,561,894	0.98	3,236,741	1.24	81,612	0.03	118,863	0.05	200,475	0.08
S-79 RCH 147	1.2 BENOD	963,086	24,327	18.6	10,989,782	4.20	1,989,212	0.76	33,524,487	13.12	110,164	0.04	564,981	0.22	2,561,530	0.98	3,236,676	1.24	81,633	0.03	118,812	0.05	200,446	0.08
S-79 RCH 147	% Difference	0%	0%	0%	7%	7%	0%	0%	0%	0%	-3%	-3%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Section 3.0 EFDC ESTUARY MODEL

3.1 ISSUES AND RECOMMENDATIONS

Tetra Tech reviewed the 2014 EFDC Model to identify data inputs and calibration parameters that could be revised to improve model representation of the Caloosahatchee Estuary. The 2017 EFDC Model revisions focused on addressing major department and stakeholder comments, as well as issues that Tetra Tech identified with the original model that would limit the model's ability to provide the information needed for the TMDL and BMAP. The department was unable to provide Tetra Tech with the original data processing sheets and information about processing methodologies; therefore all files had to be reprocessed to ensure that a consistent method was used for the full model simulation period (January 1, 1996 – December 31, 2014).

The major modifications and changes made by Tetra Tech to the EFDC model are as follows:

- Converted the 2014 EFDC Model from a proprietary version of EFDC to a public version of EFDC.
- Extended the model simulation period through December 31, 2014 (the 2014 EFDC Model ended on December 31, 2010).
- Added cells to the model grid to represent the tidally influenced streams/reaches in impaired WBIDs.
- Revised the model grid to better represent the topographical and hydrographical characteristics of the Caloosahatchee River Estuary.
- Updated the bathymetry using data from SFWMD.
- Updated the open, freshwater, north, and south model boundaries using the latest data.
- Processed NCDC SOD and NCDC SA weather data for precipitation, relative humidity, atmospheric temperature, cloud cover, solar radiation, atmospheric pressure, and wind speed and direction for use in the model.
- Updated the biological and chemical kinetic rates of the water quality model based on model calibration to observed datasets of nutrients, phytoplankton biomass, and DO.

3.2 EFDC MODEL CODE UPDATES

The 2007 EFDC and 2014 EFDC Models were in a proprietary version of EFDC. Tetra Tech converted the 2014 EFDC Model into a public domain application for the 2017 EFDC Model. In addition Tetra Tech incorporated the light module from the proprietary model into the public domain model. Prior to the full light module incorporation, the public domain EFDC model included only the following parameters:

ke_b = background light extinction (m^{-1})

ke_{TSS} = light extinction coefficient due to inorganic suspended solid (m^{-1})

ke_{Chla} = light extinction due to algae chlorophyll-*a* (m^{-1}), either self-shading equation or simple coefficient equation

As part of the updates to create the 2017 EFDC Model, the following parameters were added to the public domain model:

ke_{POC}= light extinction coefficient due to detrital particulate organic carbon (POC), which consists of refractory particulate organic carbon (RPOC) and labile particulate organic carbon (LPOC)

ke_{DOC}= light extinction coefficient due to dissolved organic carbon (DOC)

Therefore, the final light equation in the updated public domain EFDC model is:

$$Ke = ke_b + ke_{TSS}(TSS) + ke_{Chla}(Chla) + ke_{POC}(RPOC + LPOC) + ke_{DOC}(DOC)$$

The results from the light attenuation calibration are discussed in **Section 3.5.8**.

3.3 MODEL REVISIONS AND SETUP

3.3.1 Computational Grid

The EFDC model grid was modified to better represent the topographical and hydrographical characteristics of the Caloosahatchee River Estuary. The most relevant modifications included:

- Grid alignments to better represent the channel in the riverine region and the sub-channels within the embayment area. Examples of these changes to the grid alignment are shown in **Figure 45** and are highlighted by red polygons. The alignment was critical to ensure an appropriate bathymetrical connection between cells and to enable the model to transport salinity from the open areas to upstream areas of the river.
- Removal of cells and blockage of cells in no-flow areas. Several cells were removed from the model domain to reflect the presence of islands and obstructions restricting flow circulation in the system. In **Figure 45**, examples of these areas are highlighted by yellow arrows. The presence of thin obstructions, such as highways in the embayment area, were included in the grid by imposing a no flow condition in one of the sides of the computational cells. **Figure 46** shows the flow barriers included in the model.
- Reconfiguration of cells within marsh and mangrove areas. Although these areas have a continuous dynamic connectivity to open flow areas, such as the embayment and riverine portions of the Caloosahatchee River, in most cases the exchange of flow occurs through small channels or preferential paths, which convey water from the open areas into and out of these vegetated areas. To reflect this preferential flow condition, cells in the boundary between the vegetated areas and open water areas were removed leaving only cells above channel regions. Examples of these areas are shown in **Figure 45** with a purple curve.
- Incorporation of tributaries. In order to assist the department in developing TMDLs for the impaired WBIDs and to assist with model calibration, tributaries and inlets along the Caloosahatchee River were incorporated into the EFDC model grid (see **0** and **Section 2.2.3**). The following seven tributaries were added, and have bidirectional flow due to tidal propagation:
    - Cape Coral Canals
    - Deep Lagoon Canal
    - Yellow Fever Creek
    - Billy's Creek
    - Orange River
    - Popash Creek
    - Telegraph Creek

An additional four inlets were added to the model in the Deep Canal Lagoon WBID (3240A4), which corresponded to locations where measured water quality data were collected in the WBID. **Figure 47** shows the revised grid with the tributary and inlet extensions, as well as the locations of the impaired WBID and hydrodynamic/flow stations.

In addition to the changes discussed above to reconfigure the model grid, the model grid was changed from a Sigma grid to a generalized vertical coordinate (GVC) multi-layer grid.

The 2009 and 2014 EFDC Models used a sigma grid of four layers, which resulted in cell depths ranging from 0.1 meters to 5 meters. The 2017 EFDC Model was changed to a GVC grid with a maximum of five layers in any cell, with an average cell depth of about 1.5 meters. This adjustment increased the number of layers and the model's vertical resolution in the deeper areas, and decreased the number of layers in the shallower seagrass cells. GVC grids are in general less numerically dispersive than sigma grids particularly in regions where the flow transitions from shallow areas to deep areas such as natural sub channels or navigable channels. The number of layers used in each grid cell are shown in **Figure 48**.

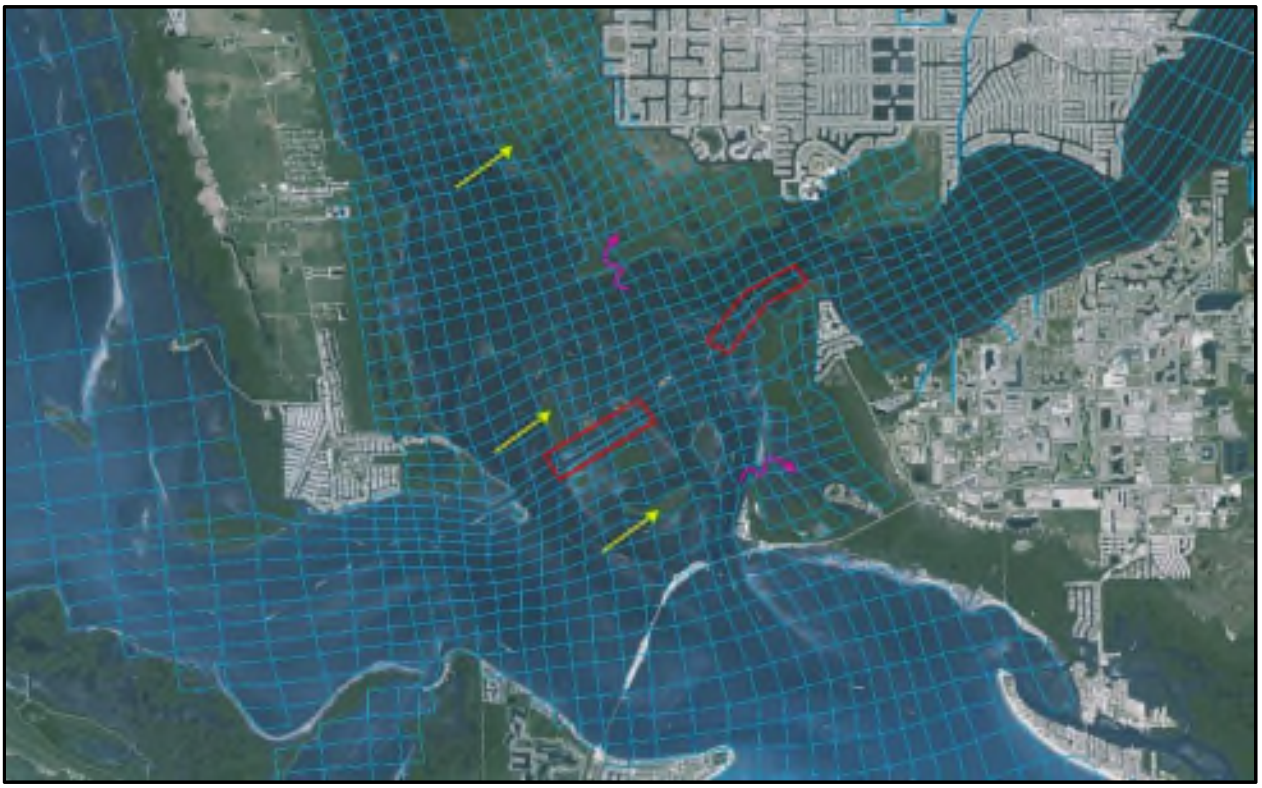

FIGURE 45: EXAMPLE OF UPDATES TO THE 2017 EFDC MODEL GRID

FIGURE 46: 2017 EFDC MODEL GRID AND FLOW BARRIERS

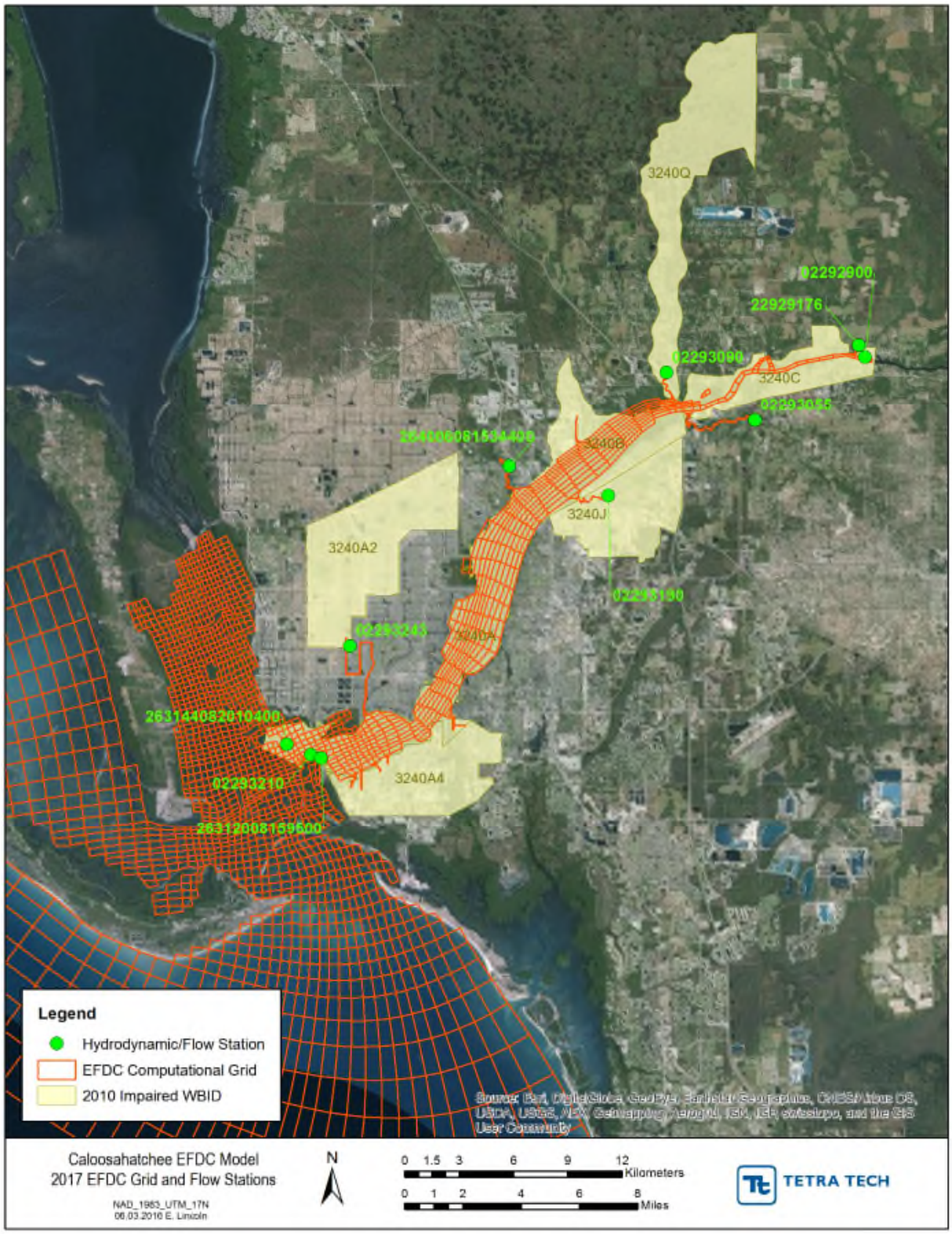

FIGURE 47: 2017 EFDC MODEL GRID TRIBUTARY AND INLET EXTENSION LOCATIONS

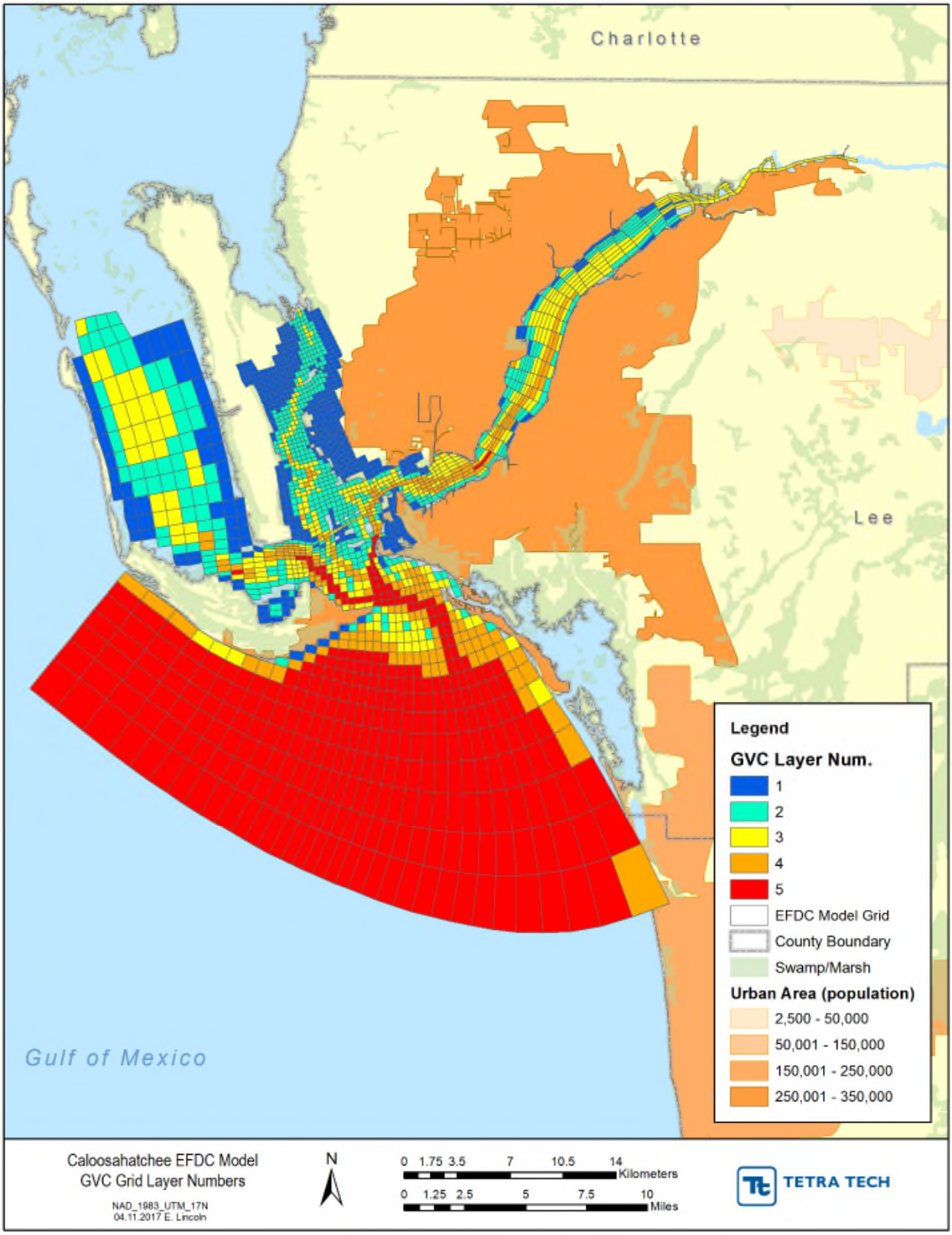

FIGURE 48: 2017 EFDC MODEL GRID GVC LAYER NUMBERS

3.3.2 Bathymetry

The bathymetry included in the updated model grid was obtained from SFWMD as a Light Detection and Ranging (LiDAR) data file. The file was a composite of topography and nearshore bathymetry at a resolution of a 100-foot cell. The data were downloaded from the SFWMD website at http://sfwmd.maps.arcgis.com/home/item.html?id=6990312b9775428094d1f81c31790096. The bathymetry was converted to a point shapefile and spatially processed in ArcGIS to assign the average bed elevation to each computation cell in the model grid. The resulting model bathymetry was then manually checked to ensure an appropriate representation of the main channel, which is critical to represent the levels of salinity intrusion observed in the system. The original LiDAR file had units of feet referenced to the North American Vertical Datum of 1988 (NAVD 88). Tetra Tech converted the data to meters and to Mean Sea Level (MSL) for its use in the EFDC model grid. The vertical difference between the NAVD 88 datum and the MSL datum in the Caloosahatchee River is 0.19 m (NAVD 88 – MSL = 0.19 m). This difference was obtained from datum information available at stations NOAA 8725110 (Naples FL) and NOAA 8725528 (Pine Island, Charlotte Harbor FL). The data conversion from NAVD 88 to MSL was performed by reducing the bathymetric depths by 0.19 m. **Figure 49** shows the bathymetry used in the 2017 EFDC Model setup.

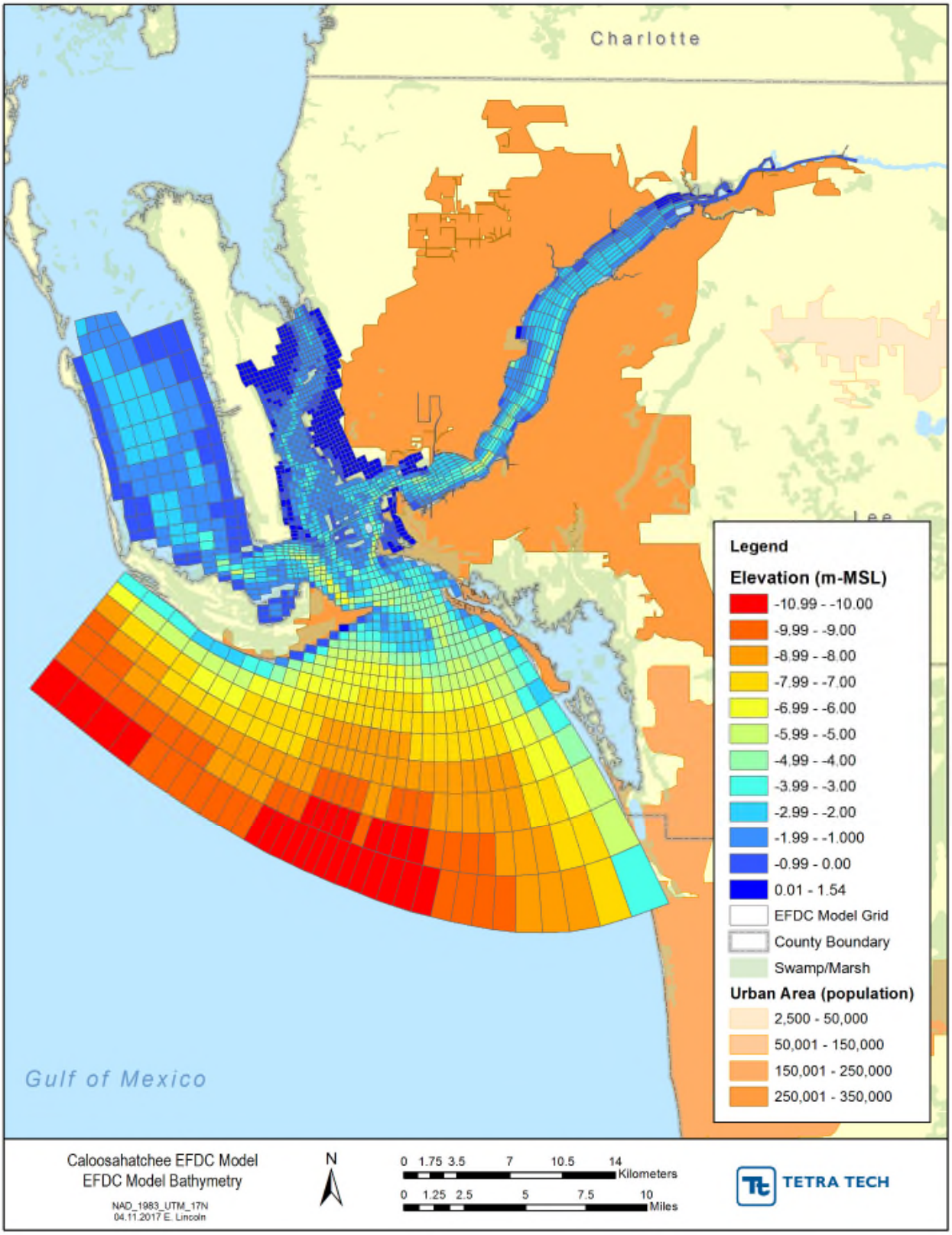

FIGURE 49: 2017 EFDC MODEL BATHYMETRY

3.3.3 Hydrodynamic Boundary Conditions

3.3.3.1 Tidal Forcings

The pressure boundary conditions (tidal forcing) along the north (Matlacha Pass and Pine Island Sound) and south (Gulf of Mexico) open boundaries were defined based upon available reports of tidal harmonic constituents and observed records of water surface elevations (WSE) from nearby NOAA stations. The principal tidal diurnal and semi-diurnal harmonic constituents reported at NOAA stations 8725506, Matlacha Pass (Bascule Bridge), station 8725528 Pineland (Pine Island), and 8725541 Bokellia, Charlotte Harbor, FL were used to construct a WSE time series referenced to MSL for the north open boundaries (**Figure 50**). A comparison between the harmonics-based prediction of water levels and the measured observations collected at NOAA station 8725541 during the period 6/1/1989 – 7/31/1989 (no observations in recent years), suggests that the harmonics reported by NOAA (**Table 111**) accurately describe the tide dynamics at this site. The observed discrepancies, related to non-periodic meteorological variations and other local variations are minor and represent only approximately between 0 and 10% of the predicted tidal range. The non-harmonic components were obtained from the measured tidal data from station 8725520, Fort Myers. A digital low pass filter was used to remove the diurnal and semi-diurnal harmonic components from the measured data at Fort Myers and a time series of only the long-term components of the WSE was obtained. The boundary conditions prescribed at the north open boundaries were then generated by adding the Fort Myers filtered data to the corresponding diurnal and semi-diurnal harmonics at each location.

The WSE records available at NOAA station 8725110 (Naples, FL) from the period 1/1/1996 – 12/31/2014 were directly used to force the south open boundary (**Figure 50**). The phase and amplitude of the WSE time series used to force the north and south model boundaries were adjusted during calibration in order to match the records of WSE available at different stations throughout the estuary. The model bathymetry and the forcing tidal conditions were referenced to Mean Sea Level datum.

TABLE 111: LIST OF PRINCIPAL TIDAL CONSTITUENTS AT NOAA STATION 8725541 BOKELLIA, CHARLOTTE HARBOR, FL

Harmonic (symbol)	Period (days)	Amplitude (m)
M2	0.518	0.1098
K1	0.997	0.1050
O1	1.076	0.0948
SA	365.243	0.0750
P1	1.003	0.0368
SSA	182.621	0.0300
S2	0.500	0.0279
N2	0.527	0.0201
Q1	1.120	0.0186
M1	1.035	0.0110
J1	0.962	0.0079
K2	0.499	0.0049
OO1	0.929	0.0023

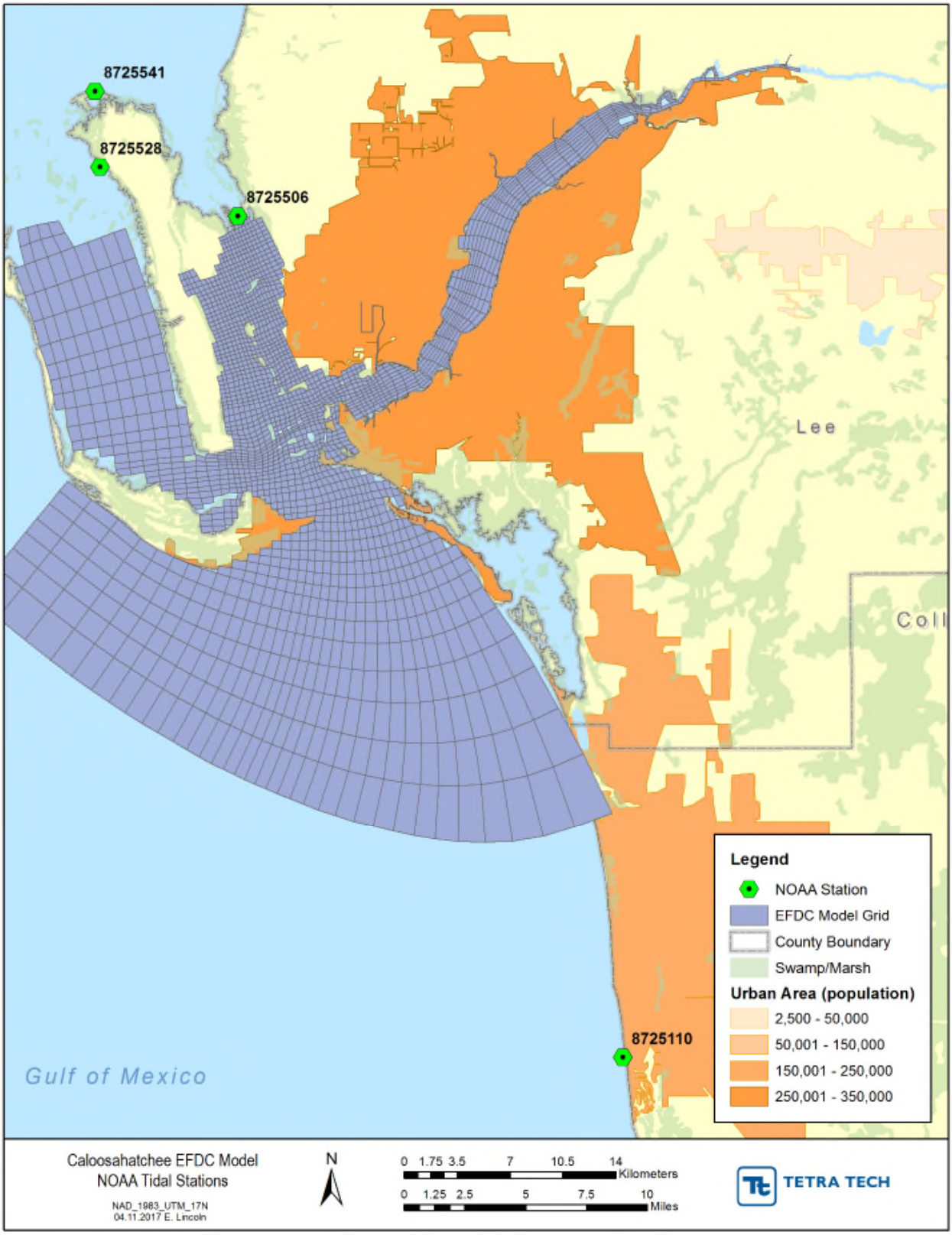

FIGURE 50: 2017 EFDC MODEL WSE BOUNDARY STATION LOCATIONS

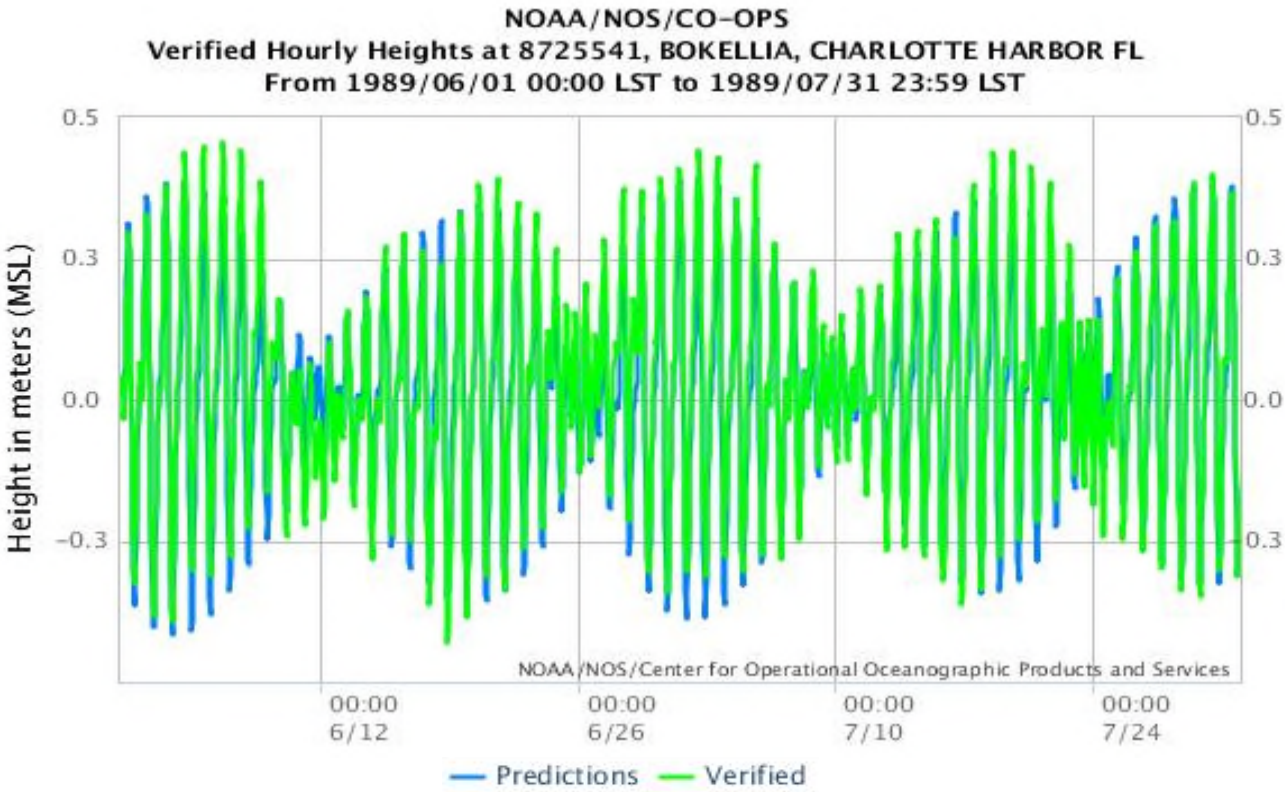

FIGURE 51: PREDICTED VERSUS OBSERVED WATER LEVELS AT NOAA STATION 8725541

3.3.3.2 Freshwater Flows

The freshwater flows at the upstream boundary of the Caloosahatchee River were defined by records available at USGS station 02292900 (Caloosahatchee River at S-79, Near Olga, FL). The measured S-79 flows were used as opposed to the modeled flows because the manual operation of the S-79 lock was not represented in the HSPF model (**Figure 52**). However, the flow records reported by USGS are only estimates and their accuracy is rated as "poor" in the annual water data report available at the station website. The uncertainty in these flow records stem from the fact that they are estimated based on gate operations, tidal conditions and water height. The EFDC model used the modeled water quality results from the HSPF model at S-79. The tributary flows were defined using the flow predictions from the 2017 HSPF Model. For subbasins where there was no representative reach draining to the Caloosahatchee River, runoff flows were divided and input into multiple EFDC cells along the subbasin boundary. The HSPF-EFDC linkages are provided in **Table 112** and shown in **Figure 53**.

The flows observed at the S-79 lock boundary represent between 70% and 80% of the total flows coming into the Caloosahatchee River Estuary while the remaining flows come from the system of tributaries and subbasins along the middle and lower portions of the river, below S-79 (**Figure 54 and Table 113**). A statistical summary of the freshwater inflows into the EFDC model for the simulated period is presented in **Table 113**.

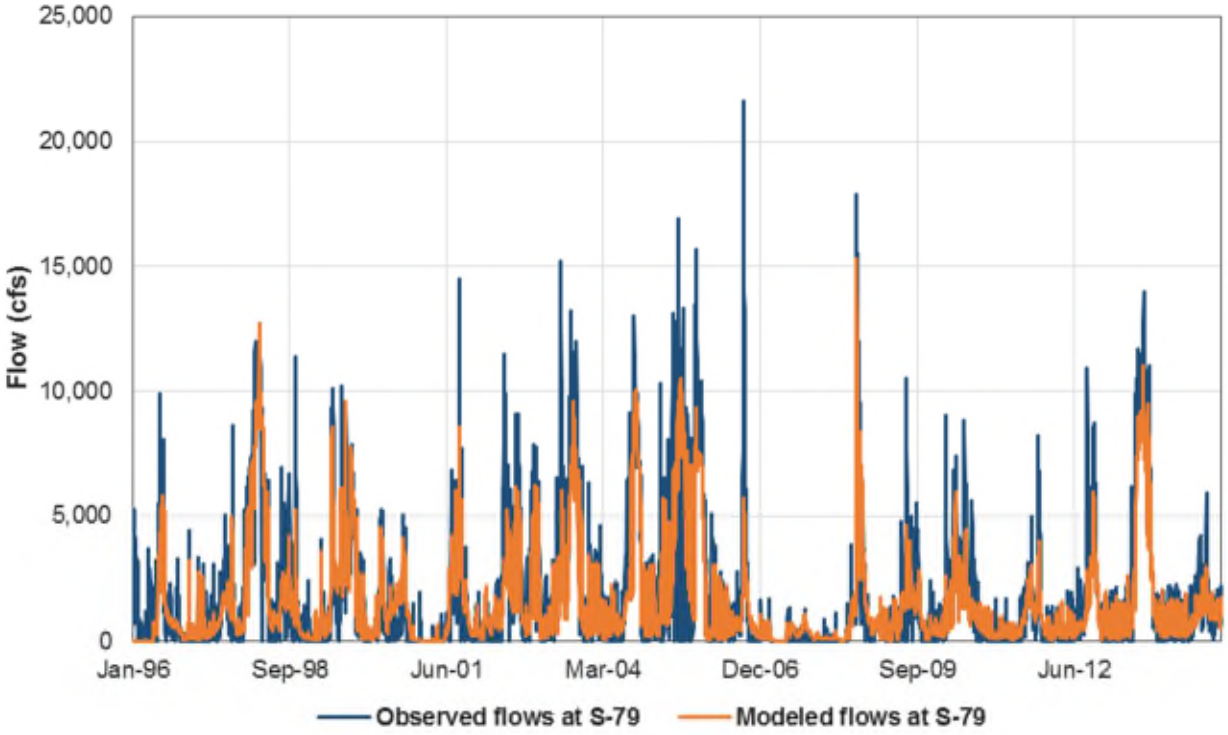

FIGURE 52: COMPARISON BETWEEN OBSERVED FLOWS AT USGS 02292900 VERSUS MODELED FLOWS FROM HSPF AT S-79

TABLE 112: 2017 HSPF-EFDC MODEL LINKAGES

HSPF Reach/Subbasin	EFDC Cell (I,J)	% Flow Used
101	(40,42)	100%
103	(49,47)	100%
104	(49,68)	100%
105	(49,80)	100%
106	(49,58)	100%
108	(61,39)	100%
109	(65,38)	100%
110	(68,45)	100%
111	(68,50)	100%
113	(70,37)	100%
116	(72,45)	100%
117	(75,36)	100%
118	(76,36)	100%
119	(77,35)	100%
120	(78,51)	100%
121	(79,33)	100%
122	(83,34)	100%
123	(90,34)	100%

HSPF Reach/Subbasin	EFDC Cell (I,J)	% Flow Used
126	(94,30)	100%
127	(97,42)	100%
129	(42,24)	50%
129	(38,33)	50%
130	(44,26)	30%
130	(46,26)	30%
130	(49,27)	40%
131	(52,29)	100%
132	(58,24)	50%
132	(54,22)	50%
133	(56,30)	100%
134	(59,29)	100%
136	(68,29)	30%
136	(64,29)	30%
136	(61,29)	40%
137	(70,7)	100%
138	(79,14)	100%
139	(79,5)	100%
144	(85,30)	50%
144	(82,30)	50%
145	(89,30)	100%
146	(95,30)	50%
146	(92,30)	50%
147	(98,30)	100%
221	(97,30)	100%

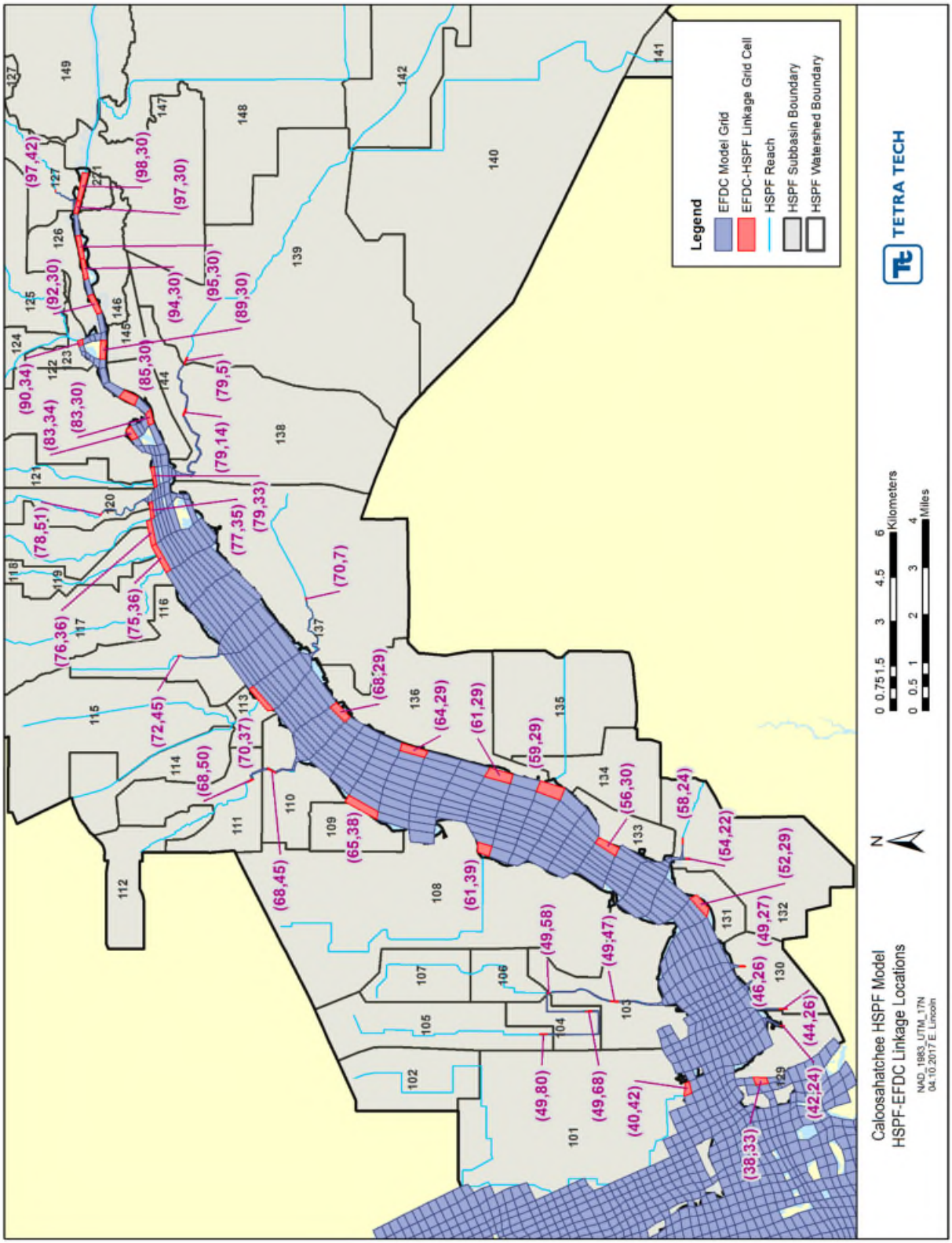

FIGURE 53: 2017 HSPF-EFDC MODEL LINKAGE LOCATIONS

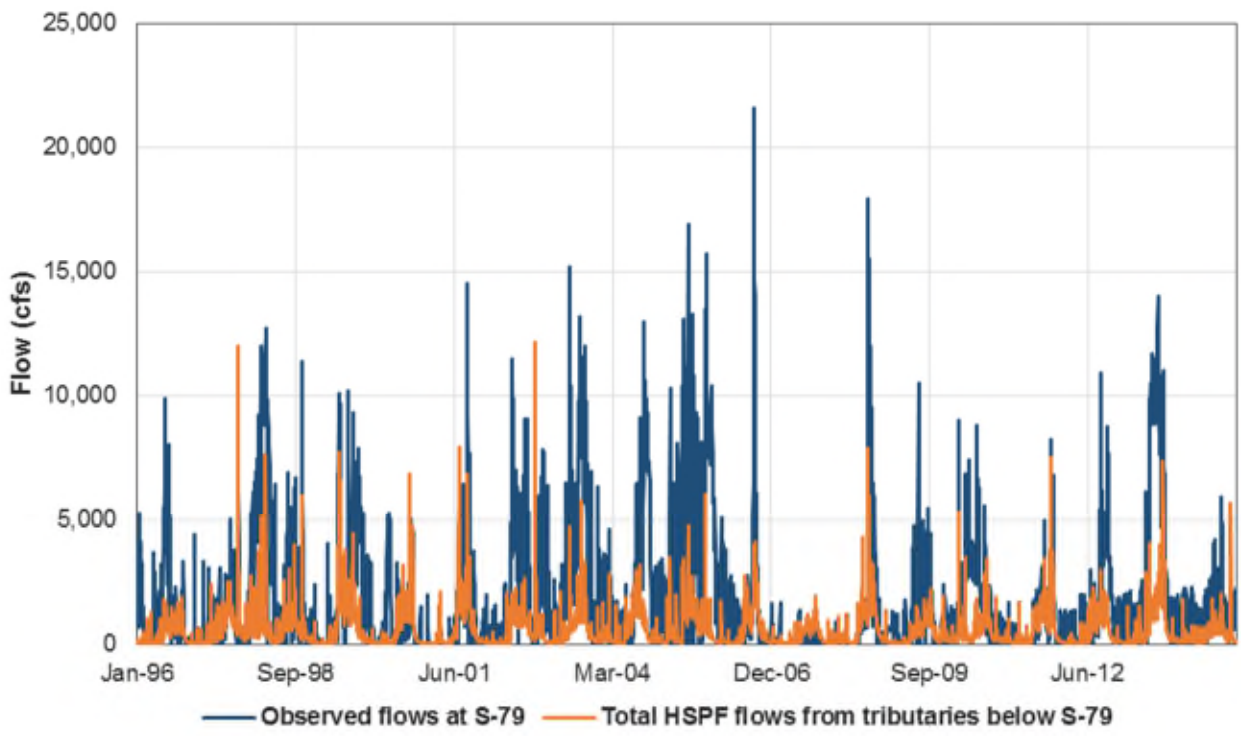

FIGURE 54: FRESHWATER INPUTS AT S-79 AND TOTAL TRIBUTARIES BELOW S-79 IN THE 2017 CALOOSAHATCHEE RIVER MODEL

TABLE 113: STATISTICAL SUMMARY OF FRESHWATER INFLOWS AT S-79 AND TRIBUTARIES BELOW S-79 IN THE CALOOSAHATCHEE RIVER DURING THE SIMULATED PERIOD

Year	Flow source	Average (cfs)	5th Percentile (cfs)	Median (cfs)	95th Percentile (cfs)
1996	S-79 Boundary	1,296.2	0.0	494.0	5,560.0
1996	Tributaries	356.9	44.4	138.2	1,055.4
1997	S-79 Boundary	1,038.1	0.0	457.0	3,822.0
1997	Tributaries	627.8	47.1	358.6	1,656.6
1998	S-79 Boundary	3,583.8	0.0	2,115.0	10,180.0
1998	Tributaries	706.5	86.6	509.8	2,003.4
1999	S-79 Boundary	2,177.5	0.0	1,135.0	7,350.0
1999	Tributaries	785.8	28.9	230.4	2,913.6
2000	S-79 Boundary	839.9	0.0	286.0	4,582.5
2000	Tributaries	539.0	34.0	89.6	2,075.7
2001	S-79 Boundary	1,120.4	0.0	193.0	5,360.0
2001	Tributaries	663.0	28.7	175.4	2,650.7
2002	S-79 Boundary	2,059.7	0.0	953.5	6,982.0
2002	Tributaries	583.5	32.8	348.1	1,745.9

Year	Flow source	Average (cfs)	5th Percentile (cfs)	Median (cfs)	95th Percentile (cfs)
2003	S-79 Boundary	3,577.2	0.0	2,260.0	10,300.0
2003	Tributaries	625.1	61.2	281.8	2,052.0
2004	S-79 Boundary	2,515.0	0.0	1,330.0	9,357.5
2004	Tributaries	568.8	43.2	259.4	1,898.6
2005	S-79 Boundary	4,699.3	0.0	3,800.0	11,180.0
2005	Tributaries	755.5	58.9	451.9	2,049.8
2006	S-79 Boundary	1,280.2	0.0	527.0	5,216.0
2006	Tributaries	551.7	26.1	183.2	2,492.2
2007	S-79 Boundary	130.8	0.0	0.0	529.6
2007	Tributaries	310.4	32.8	120.4	953.6
2008	S-79 Boundary	1,260.8	0.0	368.0	6,397.5
2008	Tributaries	712.6	44.1	229.6	2,649.0
2009	S-79 Boundary	1,077.5	0.0	522.5	3,972.0
2009	Tributaries	385.2	34.1	244.0	1,175.0
2010	S-79 Boundary	2,002.5	0.0	1,280.0	6,258.0
2010	Tributaries	515.3	96.5	280.4	1,656.7
2011	S-79 Boundary	749.2	0.0	282.5	2,832.0
2011	Tributaries	592.6	44.3	217.2	1,912.0
2012	S-79 Boundary	1,425.6	0.0	768.0	5,427.5
2012	Tributaries	454.1	43.9	159.3	1,537.7
2013	S-79 Boundary	3,409.4	0.0	1,455.0	11,000.0
2013	Tributaries	723.6	42.9	225.3	2,467.7
2014	S-79 Boundary	1,292.1	97.6	1,170.0	2,808.0
2014	Tributaries	371.3	65.5	211.9	1,018.0
1996-2014 Average	S-79 Boundary	1,870.0	5.14	1,025.5	6,270.8
1996-2014 Average	Tributaries	569.7	57.93	267.6	1,863.8

3.3.3.3 Water Temperature

The temperature boundary conditions at the freshwater boundaries, including the upstream boundary of the Caloosahatchee River, were defined using the 2017 HSPF Model predictions.

The temperature boundary conditions along the south open boundary of the model were defined based upon observed records of water temperature available from 11/15/2007 – 12/31/2014 at the Sanibel-Captiva Conservation Foundation (SCCF) Gulf of Mexico monitoring station (**Figure 55**). The records from this station were assumed to be representative of the conditions at the south open boundary. Data

gaps were filled with the multi-annual daily average temperature. The resulting time series of temperature had values ranging from 10 °C during winter periods to 32 °C during summer periods (**Figure 56)**.

The temperature boundary conditions for the north open boundaries were defined based upon observations available at the SCCF Redfish Pass monitoring station and at stations MP1A and MP3C (**Figure 55**). The temperature records from the Redfish Pass monitoring station were used to generate a time series for the Pine Island Sound boundary. Measured data were available from 10/25/2007 to 12/31/2014. Periods without data and data gaps were filled with multi-annual daily average temperature (**Figure 56**). The temperatures records from stations MP1A and MP3C were used to create the open boundary conditions at the Matlacha Pass boundary. Similar to the approach used to generate the temperature time series at Pine Island Sound, the multi-annual daily average temperatures were used to fill the periods with no data. Measured data were available from 9/26/2005 to 12/31/2014, and were used to generate the temperature forcing time series from December 1995 through February 2005 at Matlacha Pass (**Figure 57**).

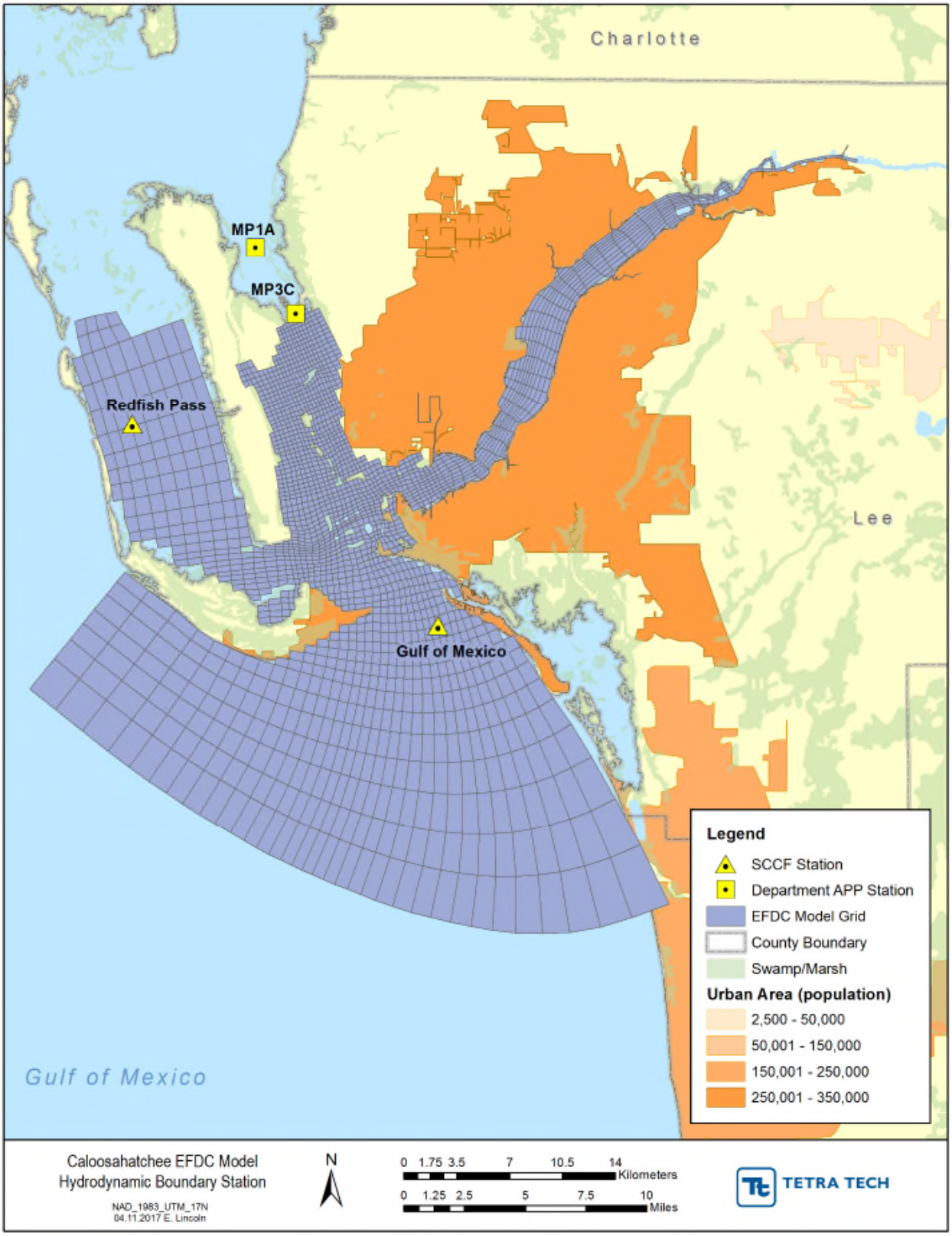

FIGURE 55: 2017 EFDC MODEL OPEN BOUNDARY HYDRODYNAMIC STATION LOCATIONS

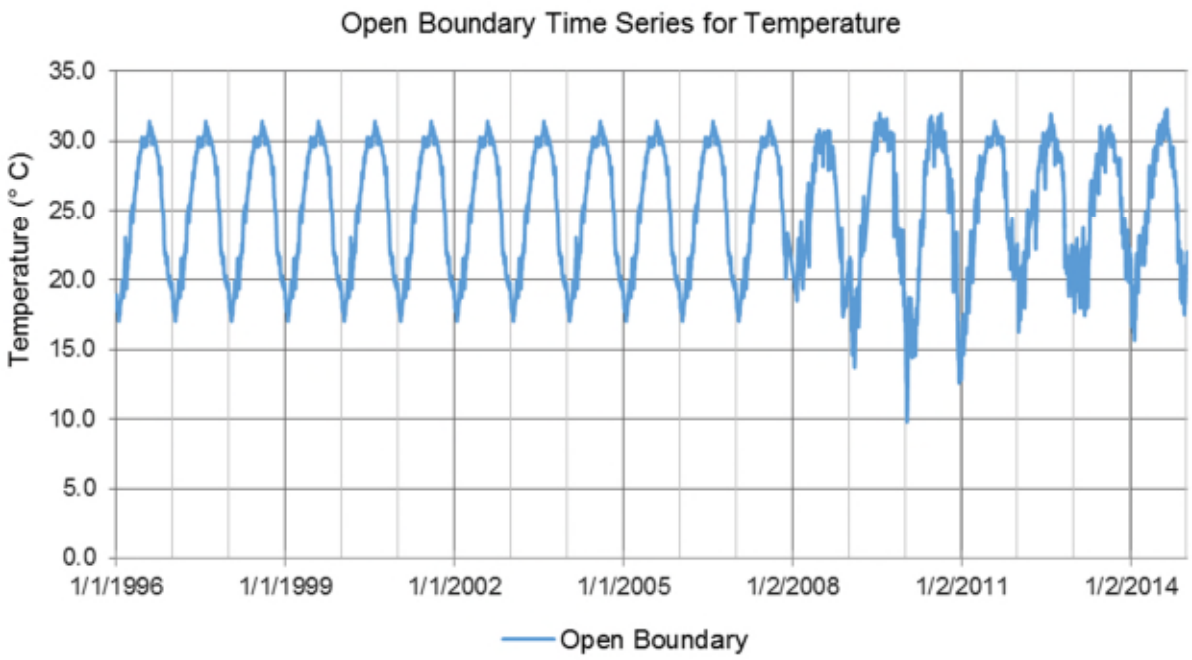

FIGURE 56: SOUTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR TEMPERATURE (°C)

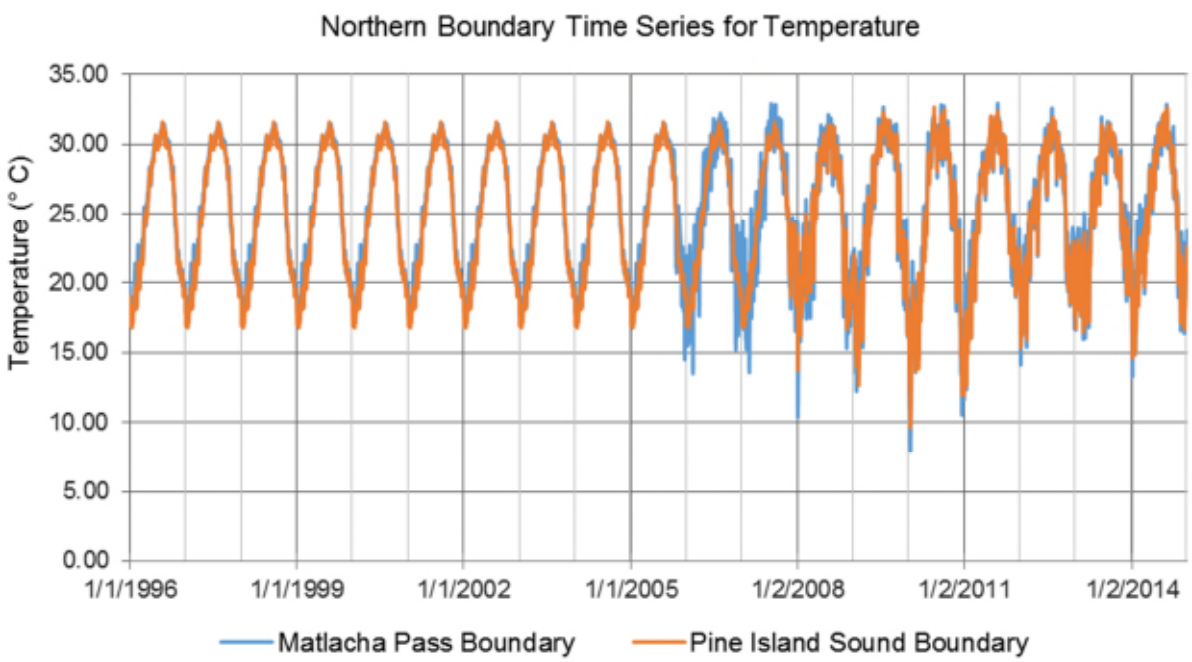

FIGURE 57: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR TEMPERATURE (°C)

3.3.3.4 Salinity

The boundary conditions for salinity at the south boundary were defined based upon continuous records of salinity available for the period 11/15/2007 – 12/31/2014 at the SCCF Gulf of Mexico station (**Figure 58**). Salinity concentrations at this station ranged from 29 PSU to 38 PSU for the period of observations. To force the model, the observations of salinity were slightly scaled to simulate a vertical salinity profile. The purpose was, in the absence of vertical salinity gradient data, to simulate a typical pattern of salinity observed in estuarine systems. In typical vertical gradients, there are high salinity concentrations close to the bottom and lower salinities close to the surface. The scaling was as follows, the time series of salinity was multiplied by 1.0 to force the top two layers and by 1.05 to force the three bottom layers. Data gaps in the time series were filed with the multi-annual daily average concentration of salinity (**Figure 58**).

The salinity concentrations at the north boundaries were defined based on observations of salinity collected from 10/25/2007 to 12/31/2014 at Redfish Pass station and from 9/26/2005 to 12/31/2014 at stations MP1A and MP3C (**Figure 59**). The observations available at the Redfish Pass station were used to construct the boundary time series of salinity for the Pine Island boundary, while the observations available at stations MP1A and MP3C were used to construct the time series for the Matlacha Pass. Data gaps in the time series were filed with the multi-annual daily average concentration of salinity (**Figure 59**).

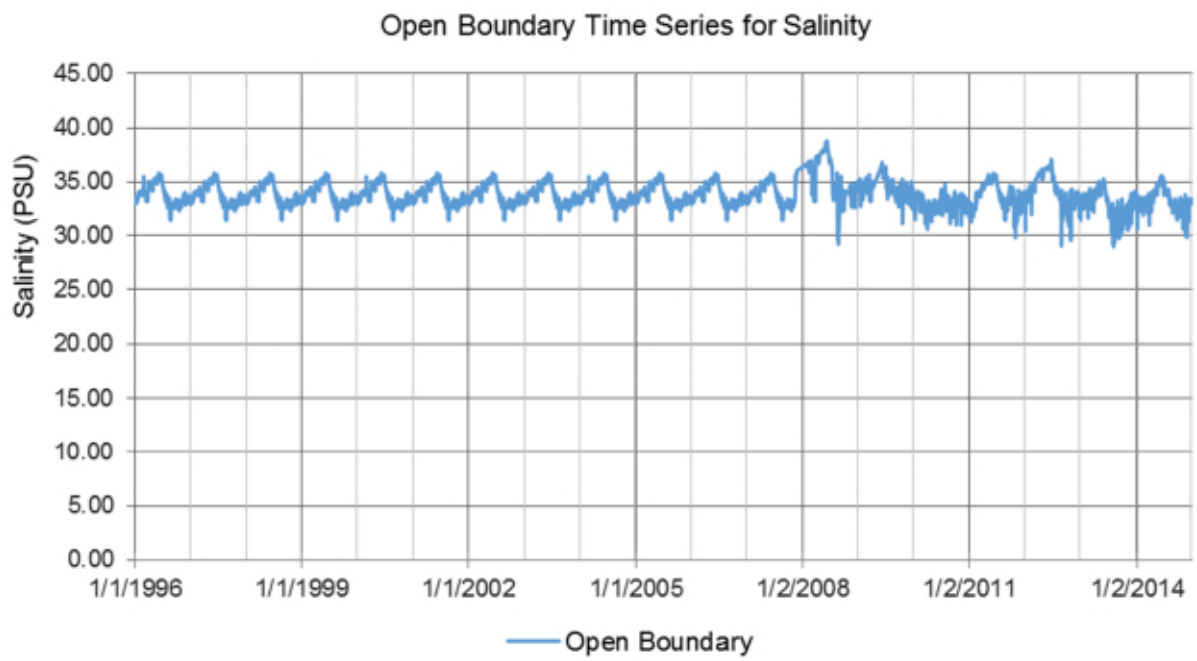

FIGURE 58: SOUTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR SALINITY (PSU)

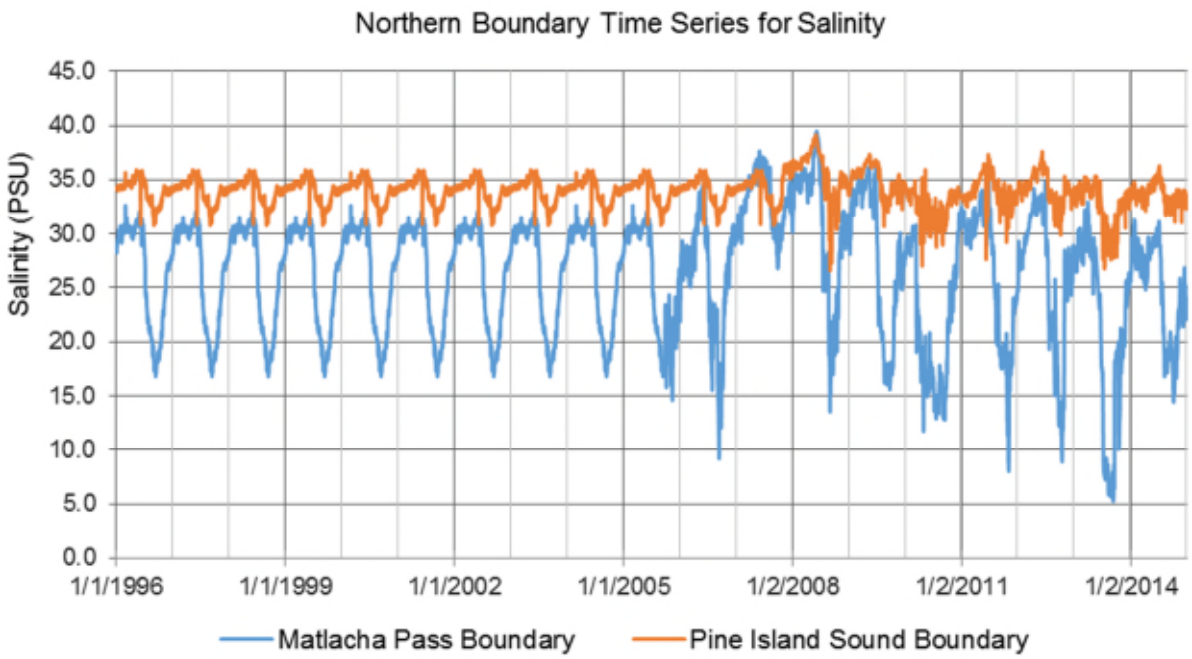

FIGURE 59: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR SALINITY (PSU)

3.3.4 Water Quality Boundary Conditions

3.3.4.1 Freshwater Boundary Conditions

The water quality boundary conditions for the different tributaries of the Caloosahatchee River were defined using the predictions from the HSPF model. However, given that in most cases the output water quality variables from the HSPF model do not directly match the variables simulated in the EFDC model, some processing was necessary to convert the outputs from the HSPF model into the forms simulated by the EFDC model. **Table 114** presents a summary of the conversion process conducted to link the HSPF and EFDC models. For subbasins with a reach, the HSPF model outputs from the RCHRES outputs were used to supply the HSPF model outputs to the EFDC model. For subbasins without a reach, the HSPF model unit area export loads were used to supply the HSPF model outputs to the EFDC model.

In **Table 114**, it is important to note that the organic forms of nitrogen, phosphorus, and carbon from the HSPF model are further discretized into refractory, labile, and dissolved forms. The HSPF model outputs total organic matter and dead refractory organic matter concentrations for each organic constituent (nitrogen, phosphorus, and carbon). The total organic matter output contains: (1) dead refractory organic, (2) labile organic (BOD), and (3) live organic (algae). For input into the EFDC model, the dead refractory organic concentrations were subtracted from the total organic concentrations to determine the labile particulate organic concentrations. Dead refractory organic matter was input as both refractory particulate organic and dissolved organic based on a partition coefficient. This HSPF to EFDC model linkage methodology ensures that all of the organic nutrient loads from the HSPF model are input into the EFDC model.

For phytoplankton, a constant “seeding” value of 0.05 mgC/L (1.25 µgChla/L) for green algae and 0.05 mgC/L (1.25 µgChla/L) for cyanobacteria (a total phytoplankton concentration of 2.5 µgChla/L for a

carbon-to-chlorophyll-*a* ratio of 0.04 mgC/µgChla) was prescribed in all freshwater boundaries. Carbon-to–chlorophyll-*a* ratios are highly variable depending on the nutrient and light conditions, and can vary seasonally. Under most circumstances, carbon-to–chlorophyll-*a* ratios range between 20 and 50 mgC/mgChla (0.02 and 0.05 mgC/µgChla) (Camacho et al. 2014; Lin et al. 2007, Lin et al. 2008; Park et al. 2005; Ambrose et. al. 1993; and Garcia et al. 2010).

The outputs from the HSPF model were not directly used to simulate phytoplankton populations from the watershed (freshwater) because freshwater species are usually different than those encountered in an estuary. The former are generally subject to salinity toxicity and substantial population decay in the estuarine environment. In general, freshwater algae populations can rarely sustain population growths in environments with salinity concentrations above 5 PSU (Sellner et. al., 1999; Otsuka et al., 1999) and even short term exposures (hours) to saline conditions can result in severe declines of population. The seeding methodology provided a representation of the salinity toxicity that likely occurs at the freshwater-estuarine interface.

TABLE 114: LIST OF WATER QUALITY VARIABLES SIMULATED IN THE HSPF AND EFDC MODELS AND CONVERSION PROCESS TO USE THE HSPF MODEL OUTPUTS AS BOUNDARIES CONDITIONS IN THE EFDC MODEL

Variable	Variable(s) Predicted in HSPF	Variable Simulated in EFDC and Process to Link HSPF to EFDC
Organic Nitrogen (**OrgN**)	• **$OrgN_{HSPF}$** = Total Organic Nitrogen • **RON_{HSPF}** = Refractory Organic Nitrogen In HSPF $OrgN_{HSPF}$ and RON_{HSPF} are assumed to be dissolved.	**$OrgN_{EFDC}$ = $RPON_{EFDC}$ + $LPON_{EFDC}$ + DON_{EFDC}** • **$RPON_{EFDC}$** = Refractory Particulate Organic Nitrogen: $RPON_{EFDC}=FP_N * RON_{HSPF}$ • **$LPON_{EFDC}$** = Labile Particulate Organic Nitrogen $LPON_{EFDC} = OrgN_{HSPF} - RON_{HSPF}$ • **DON_{EFDC}** = Dissolved Organic Nitrogen $DON_{EFDC}=FD_N * RON_{HSPF}$ FP_N and FD_N are prescribed fractions of particulate and dissolved phases of the RON_{HSPF} for EFDC: $FP_N=0.35$ $FD_N=0.65$
Ammonium (**NH_4**)	• **TAM_{HSPF} =** Total Ammonium	$NH4_{EFDC}=TAM_{HPSF}$
Nitrate + Nitrate (**NO_3 + NO_2**)	• **$NO3_{HSPF}$ + $NO2_{HSPF}$** Typically NO_2 is only a small fraction of NOx (<5%)	$NOx_{EFDC} = NO3_{HPSF} + NO2_{HPSF}$

Variable	Variable(s) Predicted in HSPF	Variable Simulated in EFDC and Process to Link HSPF to EFDC
Organic Phosphorus (**OrgP**)	• **$OrgP_{HSPF}$** = Total Organic Phosphorus • **ROP_{HSPF}** = Refractory Organic Phosphorus In HSPF $OrgP_{HSPF}$ and ROP_{HSPF} are assumed to be dissolved.	**$OrgP_{EFDC}$ = $RPOP_{EFDC}$ + $LPOP_{EFDC}$ + DOP_{EFDC}** • **$RPOP_{EFDC}$** = Refractory Particulate Organic Phosphorus: $RPOP_{EFDC}=FP_P * ROP_{HSPF}$ • **$LPOP_{EFDC}$** = Labile Particulate Organic Phosphorus $LPOP_{EFDC} = OrgP_{HSPF} - ROP_{HSPF}$ • **DOP_{EFDC}** = Dissolved Organic Phosphorus $DOP_{EFDC}=FD_P * ROP_{HSPF}$ FP_P and FD_P are prescribed fractions of particulate and dissolved phases of the ROP_{HSPF} for EFDC: FP=0.35 FD=0.65
Orthophosphate (**PO_4**)	• **$PO4_{HSPF}$**	• $PO4_{EFDC}= PO4_{HSPF}$
Organic Carbon (**OrgC**)	• **$OrgC_{HSPF}$** = Total Organic Carbon • **ROC_{HSPF}** = Refractory Organic Carbon In HSPF $OrgC_{HSPF}$ and ROC_{HSPF} are assumed to be dissolved.	**$OrgC_{EFDC}$ = $RPOC_{EFDC}$ + $LPOC_{EFDC}$ + DOC_{EFDC}** • **$RPOC_{EFDC}$** = Refractory Particulate Organic Carbon: $RPOP_{EFDC}=FP_C * ROP_{HSPF}$ • **$LPOC_{EFDC}$** = Labile Particulate Organic Carbon $LPOP_{EFDC} = OrgP_{HSPF} - ROP_{HSPF}$ • **DOC_{EFDC}** = Dissolved Organic Carbon $DOC_{EFDC}=FD_C * ROC_{HSPF}$ FP_C and FD_C are prescribed fractions of particulate and dissolved phases of the ROC_{HSPF} for EFDC: FPc=0.35 FDc=0.65
Dissolved Oxygen (**DO**)	• **DO_{HSPF}**	• $DO_{EFDC} = DO_{HSPF}$

3.3.4.2 Open Boundary Conditions

Tetra Tech used available observations near the Matlacha Pass and Pine Island Sound northern model boundaries to construct the boundary time series of water quality concentrations. Monitoring stations in the immediate vicinity of the boundaries were selected as the basis to construct the water quality time series for NO_X, NH_4, OrgN, PO_4, OrgP, chlorophyll-*a*, and DO. **Table 115** lists the stations used to

develop the water quality boundary, and the station locations are shown in **Figure 60**. The stations are in a variety of locations, including the deep channel and immediately adjacent to marsh outflows. By combining the available data from the stations into one time series, the open boundary is able to reflect the overall water quality inputs at the northern boundaries.

Continuous records of DO available from 3/26/2009 to 12/31/2014 at stations MPC3 and from 9/26/2005 to 3/26/2009 at station MP1A were used to construct the DO time series for the Matlacha Pass boundary. Existing data gaps were filled with the multi-annual week average DO concentration (**Figure 61**). In addition, continuous DO and chlorophyll-*a* monitoring data available from 10/25/2007 to 12/31/2014 at Redfish Pass Station were used to construct the boundary conditions time series for the Pine Island boundary. Existing data gaps were also filled with the multi-annual week average DO and chlorophyll-*a* concentrations (**Figure 61** and **Figure 62**). The water quality time series forced at the Matlacha Pass and Pine Island Sound open boundaries are presented for the remaining variables from **Figure 63** to **Figure 69**.

The available water quality concentration data at each station were used to construct the water quality boundary condition time series for the simulation period. The daily, monthly, and long-term water quality concentrations were similar among the stations. If data were available on a given day for more than one station, the data were averaged to provide a single water quality concentration value for that day for the boundary condition time series. In addition, if a reported concentration was at or below the detection limit, the detection limit concentration was used as the observed concentration. This applies for all water quality variables including the inorganic nutrients NH_4, NOx, and PO_4. The impacts of this assumption on the model performance should be minimal given that the major source of nutrients for the estuary is the watershed. The boundary conditions of phytoplankton biomass were constructed by converting the available observations of chlorophyll-*a* to carbon units using a carbon-to-chlorophyll-*a* ratio of 0.04 mgC/μgChla. This was necessary given that phytoplankton biomass is internally simulated in units of carbon in the EFDC model.

At the southern boundary, continuous DO and chlorophyll-*a* monitoring data available from 11/15/2007 to 12/31/2014 at the Gulf of Mexico station were used to force the EFDC model. Data gaps were filled with the multi-annual week average concentrations. The time series used to force the southern boundary are shown in **Figure 70** and **Figure 71**.

For other water quality variables, limited observations were available at the southern boundary to support the development of a water quality time series for the EFDC model. Therefore, the model was forced with constant concentrations for the different species of nutrients. Such concentrations were defined based on the concentrations used in the 2014 EFDC Model and on recently measured data. The concentrations prescribed in the 2014 EFDC model were only replaced if additional observations were available. Data at 12 stations close to the southern boundary (**Figure 60**) were reviewed to help define the constant concentrations. **Table 116** summarizes the values used in the 2017 EFDC Model compared to the values used in the 2014 Model.

In the absence of laboratory data to support a detailed partitioning of the organic nutrient fractions, the partitioning of the organic nutrients into refractory, labile, and dissolved forms (**Table 116)** were kept constant from previous EFDC models of the Caloosahatchee River and Estuary except those for OrgP, which were slightly adjusted during model calibration. The partitioning of an organic nutrient into dissolved, labile, and refractory can impact the velocity at which the nutrient is transformed into a

dissolved form. If 100% of an organic nutrient is assigned to the dissolved fraction, then 100% of the organic nutrient is ready to undergo mineralization. Otherwise, if a mass fraction is assigned to the labile and refractory forms, then the organic nutrient will be able to undergo settling and will have a fast (labile) and slow (refractory) dissolution rate.

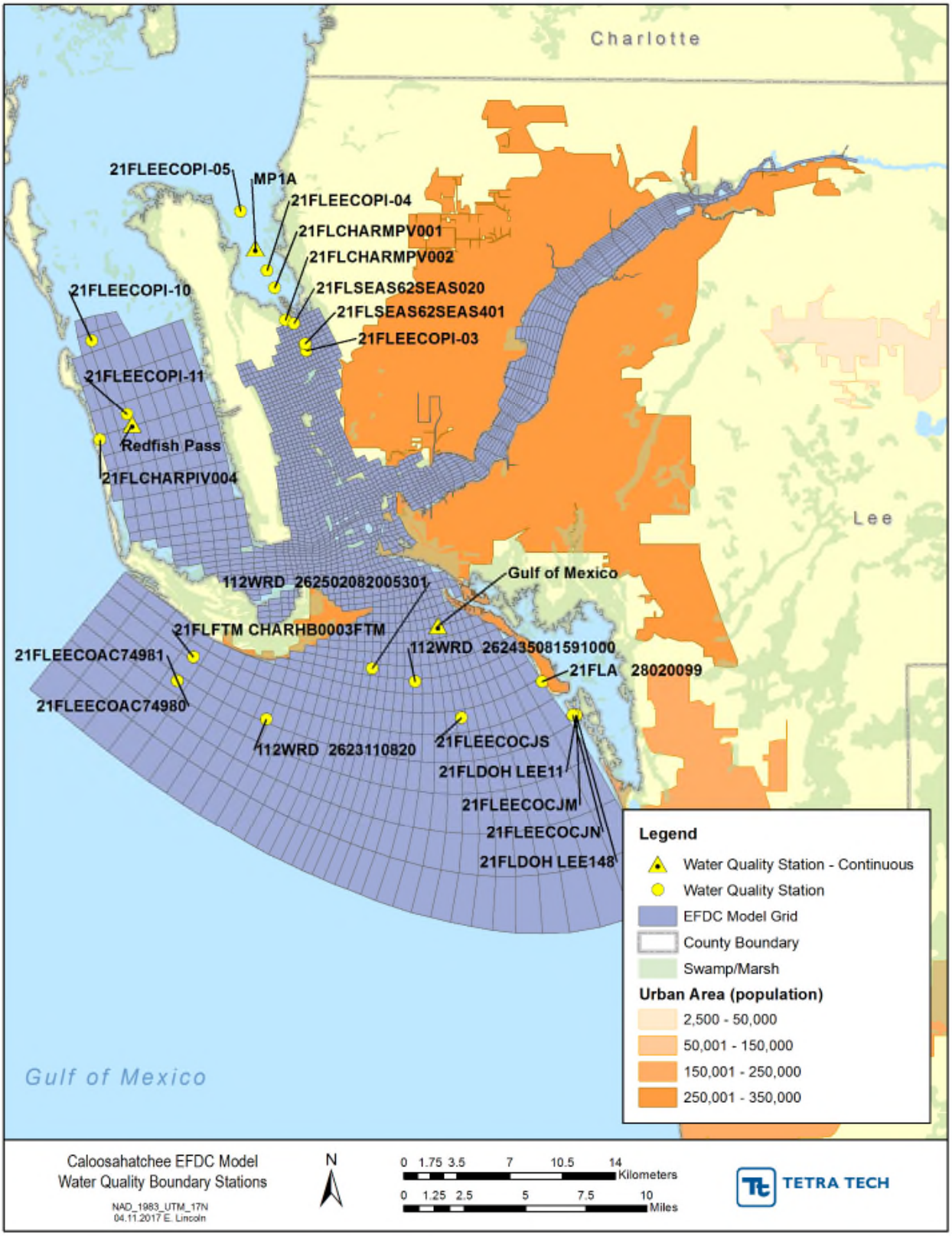

FIGURE 60: 2017 EFDC MODEL OPEN BOUNDARY WATER QUALITY STATION LOCATIONS

TABLE 115: MONITORING STATIONS USED TO DEVELOP THE WATER QUALITY TIME SERIES FOR THE NORTHERN BOUNDARY CELLS

Location	Station ID
Boundary conditions at boundary cells across J=82, Matlacha Pass	21FLCHARMPV001
Boundary conditions at boundary cells across J=82, Matlacha Pass	21FLCHARMPV002
Boundary conditions at boundary cells across J=82, Matlacha Pass	21FLEECOPI-03
Boundary conditions at boundary cells across J=82, Matlacha Pass	21FLEECOPI-04
Boundary conditions at boundary cells across J=82, Matlacha Pass	21FLEECOPI-05
Boundary conditions at boundary cells across J=82, Matlacha Pass	21FLSEAS62SEAS020
Boundary conditions at boundary cells across J=82, Matlacha Pass	21FLSEAS62SEAS401
Boundary conditions at boundary cells across J=82, Matlacha Pass	MPC3
Boundary conditions at boundary cells across J=82, Matlacha Pass	MP1A
Boundary conditions at boundary cells across J=44, Pine Island Sound	21FLCHARPIV004
Boundary conditions at boundary cells across J=44, Pine Island Sound	21FLEECOPI-10
Boundary conditions at boundary cells across J=44, Pine Island Sound	21FLEECOPI-11
Boundary conditions at boundary cells across J=44, Pine Island Sound	Redfish Pass

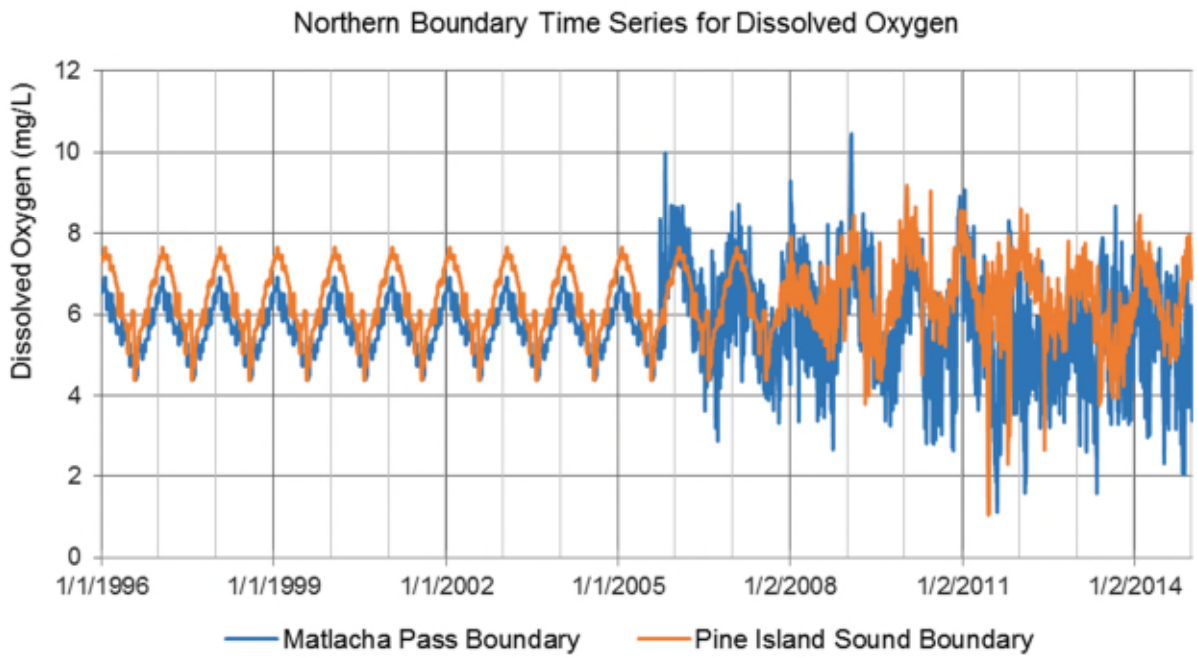

FIGURE 61: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR DO (MG/L)

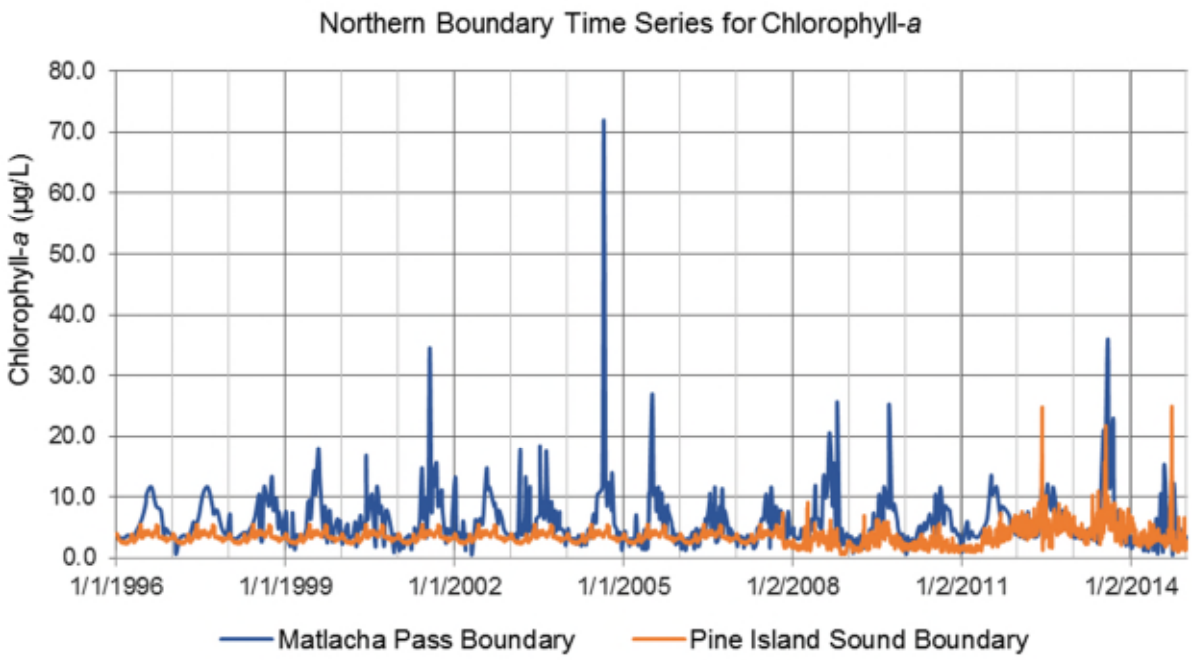

FIGURE 62: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR CHLOROPHYLL-*A* (µG/L)

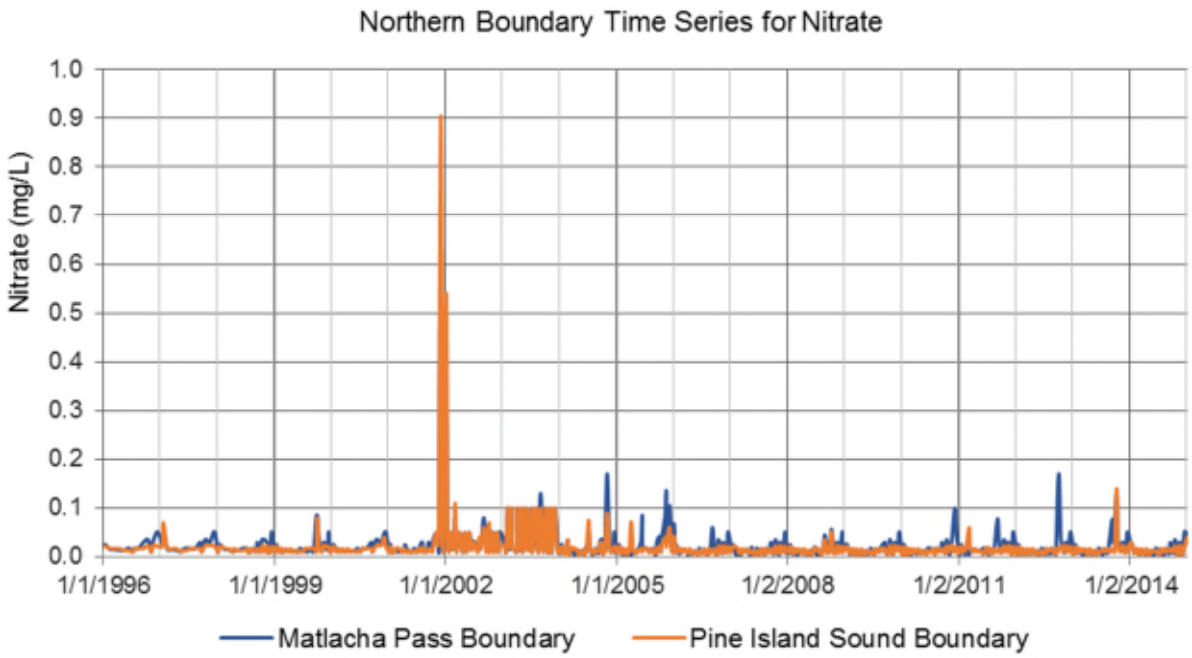

FIGURE 63: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR NO_3 (MG/L)

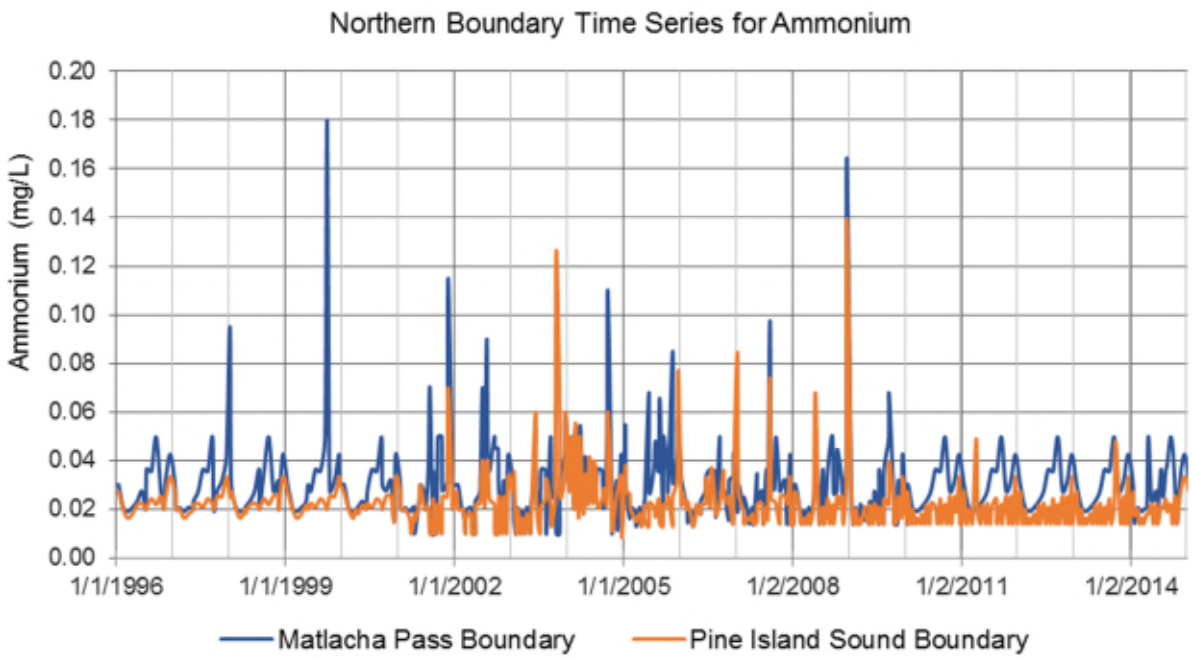

FIGURE 64: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR NH_4 (MG/L)

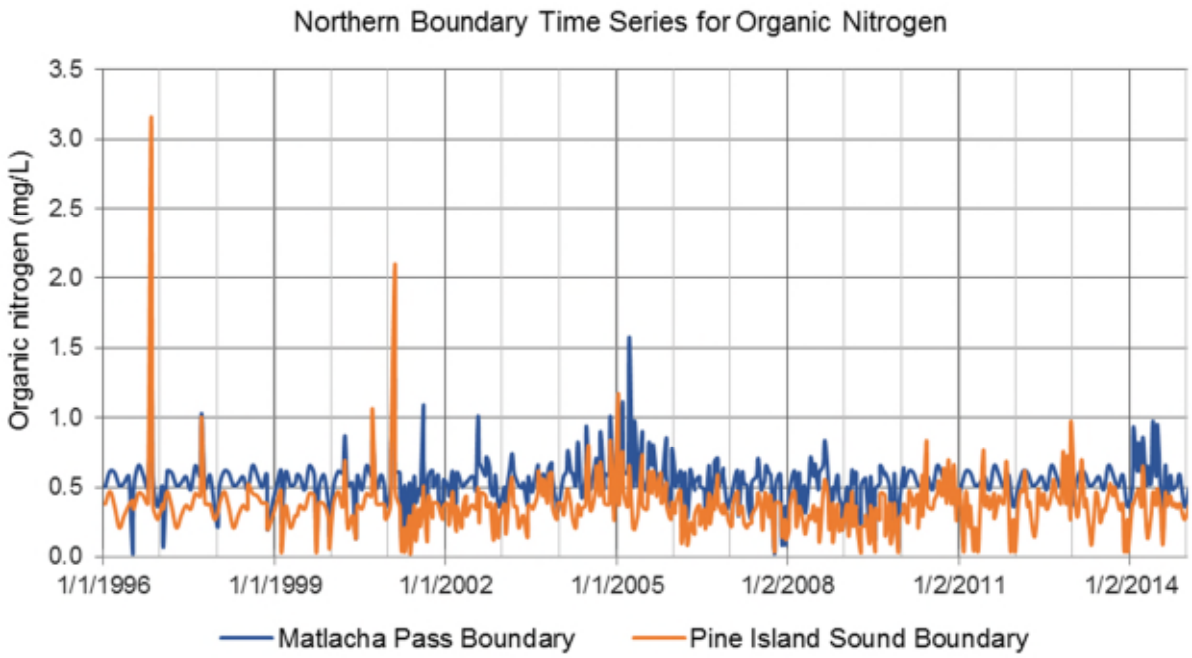

FIGURE 65: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR ORGN (MG/L)

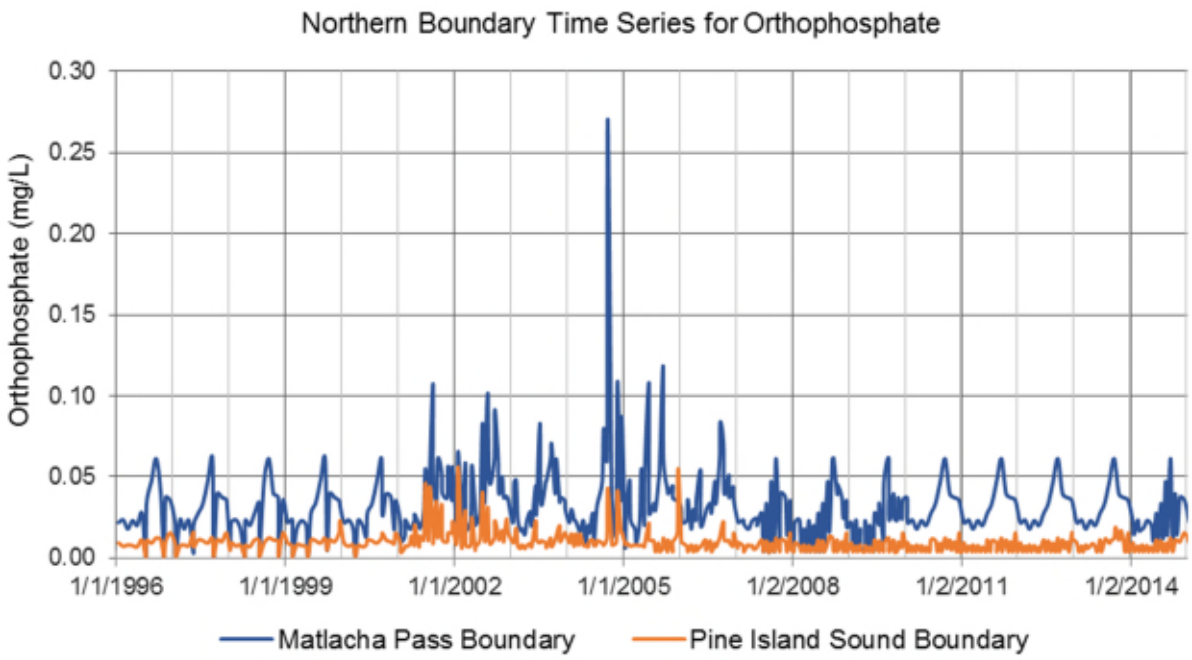

FIGURE 66: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR PO_4 (MG/L)

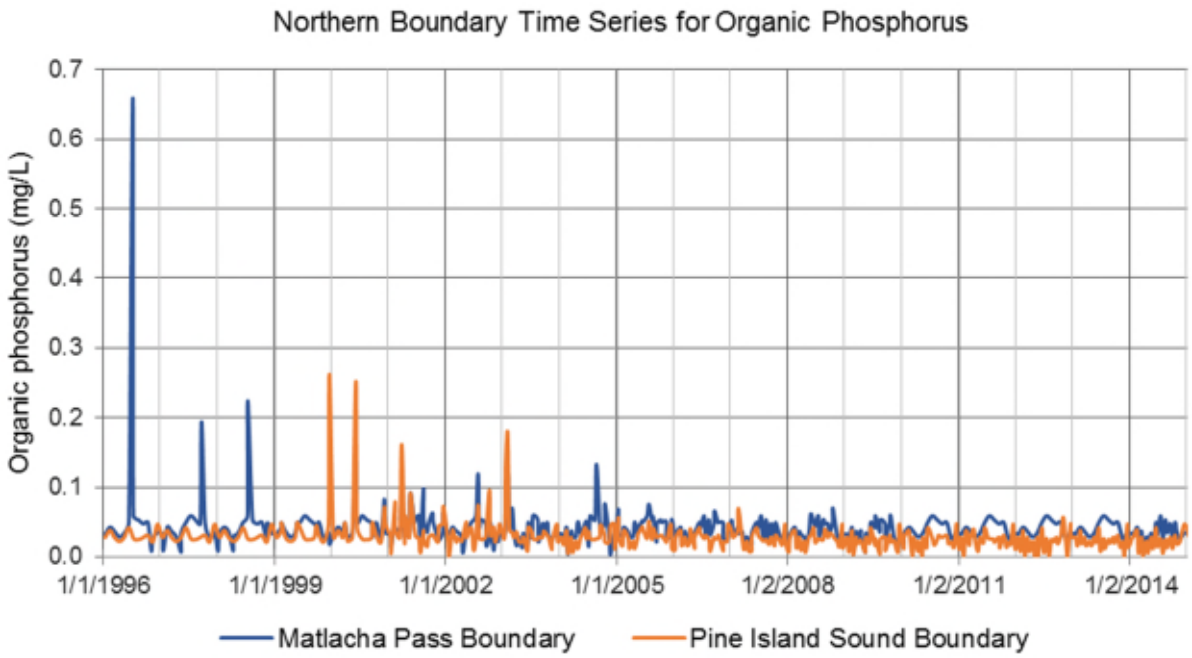

FIGURE 67: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR ORGP (MG/L)

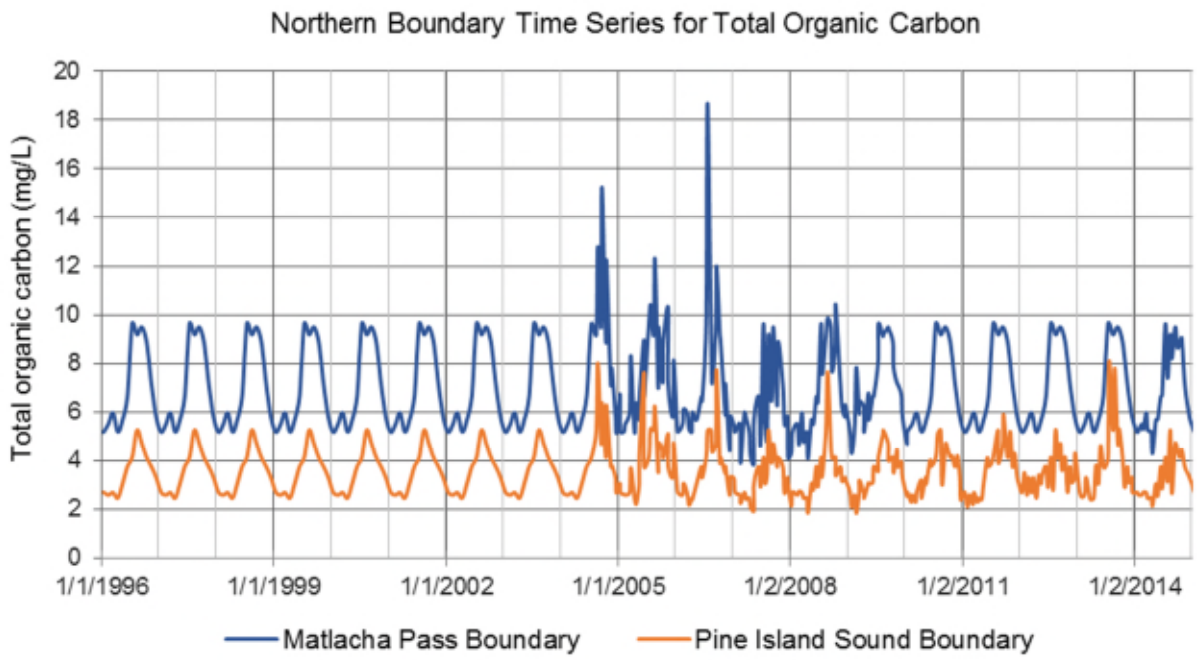

FIGURE 68: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR TOC (MG/L)

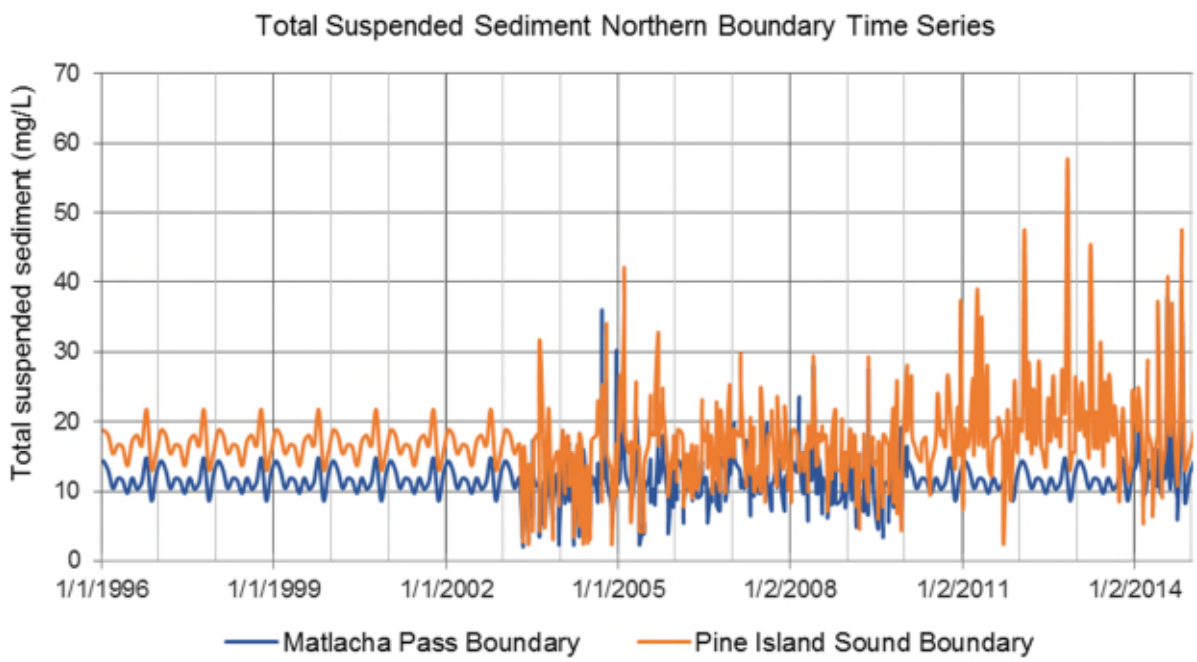

FIGURE 69: NORTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR TSS (MG/L)

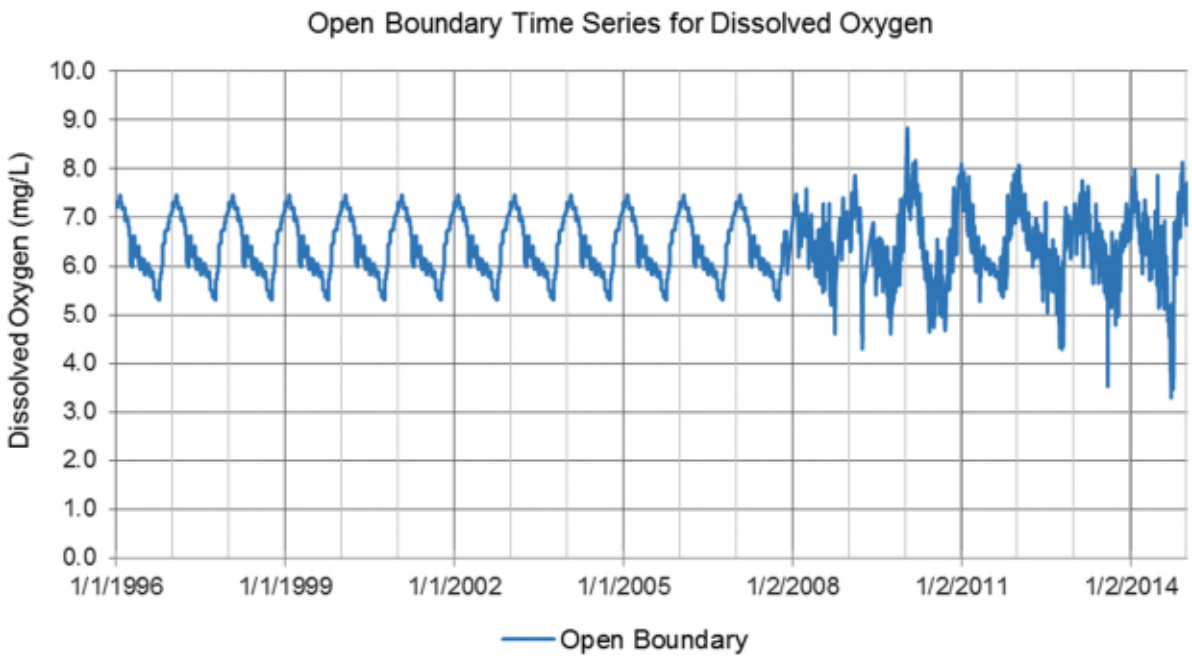

FIGURE 70: SOUTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR DO (MG/L)

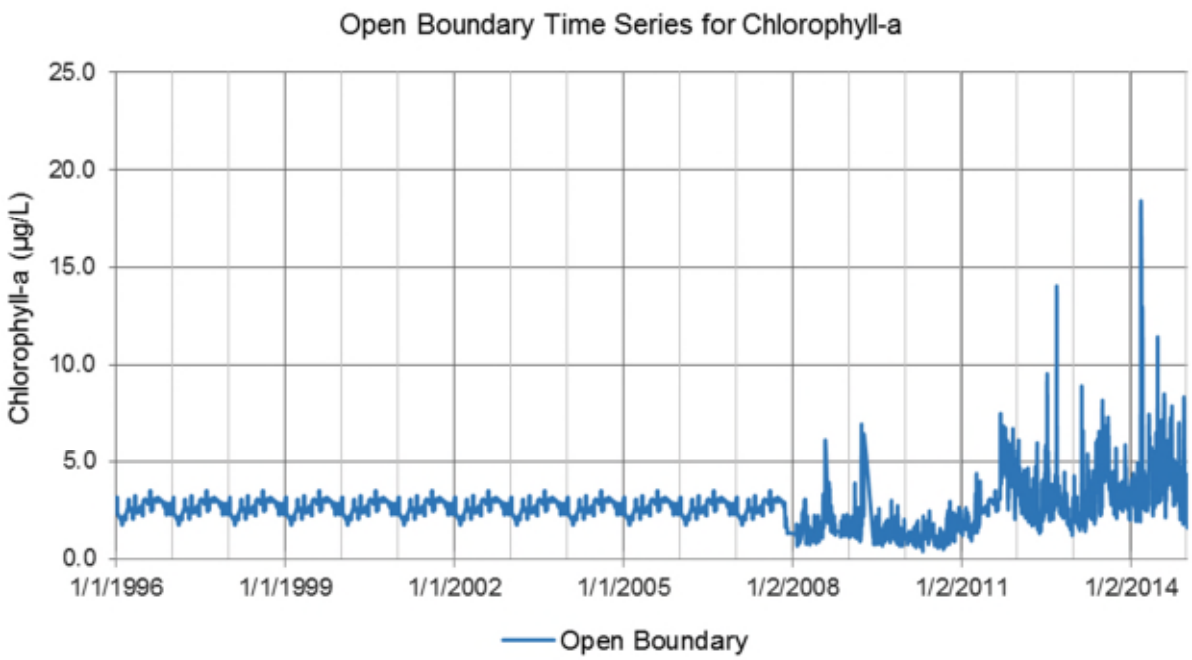

FIGURE 71: SOUTHERN BOUNDARY 2017 MODEL INPUT TIME SERIES FOR CHLOROPHYLL-*A* (µG/L)

TABLE 116: WATER QUALITY CONCENTRATIONS ASSIGNED AT THE SOUTHERN BOUNDARY CELLS

Parameter	2014 Model	2017 Model	Observations
NOx	Constant concentration of 0.01 mg/L in Card 33.	Not modified from 2014 Model setup.	The average concentration of the available records is 0.01mg/L, which is within range of the concentration used in the 2014 Model.
NH_4	Constant concentration of 0.02 mg/L in Card 33.	Constant concentration of 0.05 mg/L in Card 33.	The average concentration of the available records is 0.05 mg/L. This concentration has been included in the 2017 Model setup.
OrgN	Constant concentrations as follows: RPON = 0.3 mg/L LPON = 0.03 mg/L DON = 0.3 mg/L	Constant concentrations as follows: RPON = 0.17 mg/L LPON = 0.017 mg/L DON = 0.17 mg/L	The average OrgN concentration calculated from TN and TKN records is 0.35 mg/L. This concentration was partitioned into labile, refractory, and dissolved fractions using the same ratios as the 2014 Model.
PO_4	Constant concentration of 0.05 mg/L in Card 33.	Constant concentration of 0.03 mg/L in Card 33	The average concentration of the available records is 0.03 mg/L. Boundary PO_4 concentration has been updated to reflect the new value.
OrgP	Constant concentrations as follows: RPOP = 0.02 mg/L LPOP = 0.002 mg/L DOP = 0.02 mg/L	Constant concentrations as follows: RPOP = 0.005 mg/L LPOP = 0.002 mg/L DOP = 0.005 mg/L	The average concentration of the available Org P records is 0.012 mg/L. Boundary concentrations of RPOP, LPOP, and DOP have been updated to reflect the new values.
OrgC	Constant concentrations as follows: RPOC = 0.3 mg/L LPOC = 0.3 mg/L DOC = 2.5 mg/L	Not modified from 2014 Model setup.	Average concentration of available observations is 3.1 mg/L, which is the same concentration used in the 2014 Model.

3.3.5 Meteorological Conditions

The primary data sources used to create the 2017 EFDC Model weather files (ASER.inp and WSER.inp) for the Caloosahatchee Estuary included the NEXRAD and NCDC SA station, described in **Section 2.2.5**. The time series of precipitation, relative humidity, air temperature, cloud cover, solar radiation, and atmospheric pressure were defined in the ASER.inp file while the time series of wind speed and direction were defined in the WSER.inp file. The weather files were created from January 1, 1996 through December 31, 2014 using the date of December 31, 1995 as Julian day 0.

3.3.5.1 Precipitation

The precipitation time series used in the 2017 EFDC Model was developed using NEXRAD Zone 1 data, which represent the closest dataset to the project area and is consistent with the precipitation dataset used in the 2017 HSPF model. For information on the NEXRAD processing, see Section **2.2.5.1**.

3.3.5.2 Climate Conditions

The time series for the climate variables (relative humidity, air temperature, cloud cover, solar radiation, and atmospheric pressure) were developed using the same methodology used to develop the climate time series for the 2017 HSPF Model (**Section 2.2.5.5**). Available records from WBAN 12835 were used to develop these inputs. To fill in missing data records, if the data gap was less than 3 hours, the data were averaged using the data immediately before and after the gap. If the gap was more than 3 hours, information from the neighboring SA station WBAN 12842 (Tampa International Airport) was used. Gaps in data for more than 3 hours occurred predominantly between 1996 and 1998. Less than 1% of the data

were typically missing. For cloud cover, the verbal description of cloud cover was assigned numerical cloud cover estimates based on MetADAPT's numerical assignment methodology (**Section 2.2.5.5**). Solar radiation was computed using cloud cover and the latitude of station WBAN 12835, which was in closer proximity to the EFDC model grid than the SFWMD S78W weather station. CEQUAL-W2 method in MetADAPT was used to compute the solar radiation using sun angle relationships and shading from the cloud cover (Cole 2003). For wind direction data was reported as '***', indicating that the air was calm. All the '***' data were replaced with 0.

3.3.6 NPDES Facilities

For the NPDES facilities within the EFDC model listed in **Section 2.2.9** and shown in **Figure 72**, time series for both flows and water quality loads for these facilities were developed for these facilities and input into the model during initial model setup. When available, measured water quality data were used to represent the NPDES facility discharge flows and concentrations and to fill gaps in the data record. However, measured data were not available for many parameters. In order to provide parameter concentrations for the facilities, Tetra Tech identified default assumptions that were used for the NPDES facilities (see **Section 2.2.9.1**). These assumptions were based on available data from all facilities in the Caloosahatchee River Watershed, including those discharging directly to the HSPF model.

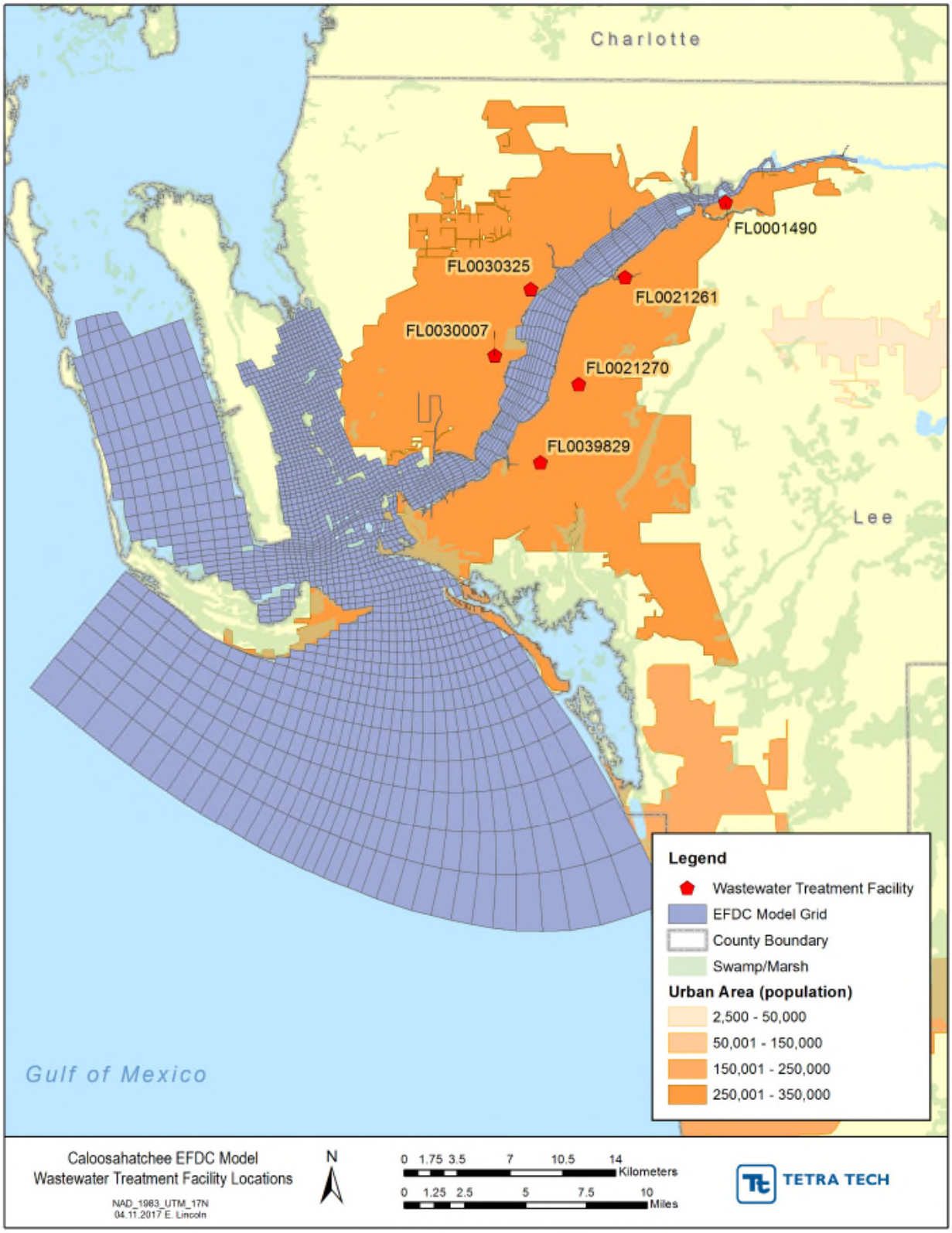

FIGURE 72: WASTEWATER FACILITIES INCLUDED IN THE EFDC MODEL

3.3.6.1 FL0001490

FL0001490 (Florida Power and Light Fort Myers) withdraws water from the main stem of the Caloosahatchee River, which is used for cooling purposes. After use, the water is subsequently discharged to the Orange River. To represent the operational activities of this facility, the loading conditions in the EFDC model were defined using the withdrawal-return pair option. Under this option, water withdrawals from one cell in the EFDC model can be transferred to another cell by defining the volume of water transferred between cells. The volume of water transferred from the source cell to the destination cell retains the water quality characteristics of the source cell as would occur in reality. Additional loads (deltas) added by the discharger above the background water quality characteristics from the source cell are added the water quality loads entering the source cell.

FL0001490 collected monthly data in 2014 to quantify the additional PO_4 and NH_4 loads added to the discharged water above the background water quality characteristics. The monthly loads were averaged to determine the pounds per million gallons (MG) loads of the facility, which were 0.000538 lbs PO_4/MG and 0.002272 lbs NH_4/MG. These loads were added to the discharge flows. The changes in temperature caused by the cooling operations were prescribed to the model by developing a time series of the delta between the measured FL0001490 intake and discharge temperatures and the modeled. The time series was constructed from measured data at the cooling facility from 1/1/2004 to 12/31/2014, and the daily average delta was used as the time series model input for the period prior to 1/1/2004 (**Figure 73**).

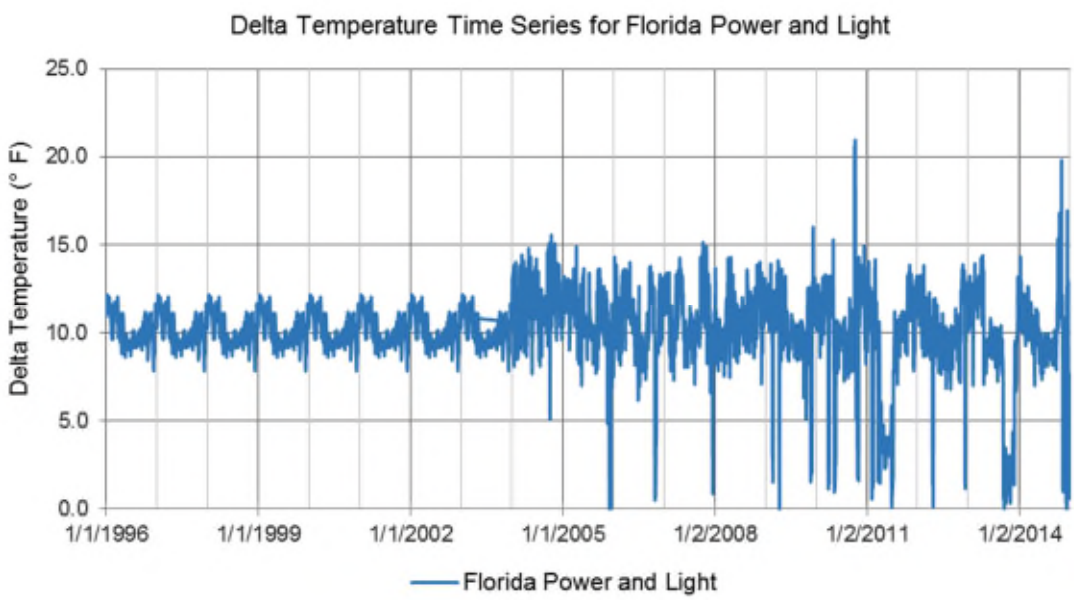

FIGURE 73: TIME SERIES OF DELTA TEMPERATURES PRESCRIBED IN THE 2017 EFDC MODEL FOR FL0001490

3.4 EFDC MODEL HYDRODYNAMIC CALIBRATION

Tetra Tech calibrated the 2017 EFDC Model to observations of hydrodynamic variables collected between January 1, 2010 and December 31, 2014. Tetra Tech compared modeled hydrodynamic outputs to measured hydrodynamic outputs at different monitoring stations located throughout the estuary, including Impaired Waters Rule (IWR), USGS, and NOAA stations (shown in **Section 3.4.1**). The following section contains the analyses of the calibration results at selected stations located in the Caloosahatchee River.

Additional calibration plots showing comparisons between observed and predicted time series of WSE, salinity, and temperature are provided in **Appendix C**. Model validation was conducted by comparing the model to observed IWR, USGS, NOAA, SCCF, and the department's Aquatic Preserve Program data for the entire modeling period of January 1, 1996 through December 31, 2014. Comparison plots between observed and predicted hydrodynamic variables for the full simulated period are included in **Appendix C**.

3.4.1 Calibration and Validation Stations

Tetra Tech calibrated the 2017 EFDC Model to observations of hydrodynamic variables collected between January 1, 2010 and December 31, 2014. Tetra Tech compared modeled hydrodynamic outputs to measured hydrodynamic outputs at different monitoring stations located throughout the estuary, including IWR, USGS, and NOAA stations (**Table 117** and **Figure 74** through **Figure 76**). The SCCF stations and Aquatic Preserve Program stations have continuous monitoring data and were used to derive the northern boundary conditions in the EFDC model.

TABLE 117: 2017 EFDC MODEL HYDRODYNAMIC CALIBRATION AND VALIDATION STATIONS

Station ID	Parameters	Purpose
NOAA 8725520	WSE	Calibration
USGS 02293205	WSE, Flows	Calibration
USGS 02293210	WSE, Flows	Calibration
USGS 02293055	WSE, Flows	Validation
USGS 02293090	WSE, Flows	Validation
USGS 02293190	WSE, Flows	Validation
USGS 022929176	WSE, Flows	Validation
USGS 264006081534400	WSE, Flows	Validation
USGS 2631440820810400	Flows	Calibration
21FLEECOCES03SUR	Temperature, Salinity	Calibration
21FLFTM CALUSA0008FTM	Temperature, Salinity	Calibration
21FLFTM CALUSA0011FTM	Temperature, Salinity	Calibration
21FLEECOCES06SUR	Temperature, Salinity	Calibration
21FLEECOCES10SUR	Temperature, Salinity	Calibration
21FLCHARMPV004	Temperature, Salinity	Calibration
21FLCHARSCV001	Temperature, Salinity	Validation
21FLEECO23-5GR	Temperature, Salinity	Validation
21FLEECO29-8GR	Temperature, Salinity	Validation
21FLEECOBILLGR20	Temperature, Salinity	Validation

Station ID	Parameters	Purpose
21FLEECODEEPGR10	Temperature, Salinity	Validation
21FLFTMCALUSA0023FTM	Temperature, Salinity	Validation
MP2B	Temperature, Salinity	Validation
MP3C	Temperature, Salinity	Validation
SCCF-1	Temperature	Validation
SCCF-2	Temperature	Validation
SCCF-4	Temperature	Validation
SCCF-6	Temperature	Validation
Redfish Pass	Salinity	Validation
Shell Point	Salinity	Validation
Fort Myers	Salinity	Validation
Buck Key Preserve	Salinity	Validation
South Florida Information Access (SOFIA) – USGS Telegraph Creek	Salinity	Validation
SOFIA – USGS Orange River	Salinity	Validation
SOFIA – USGS Hancock Creek	Salinity	Validation
SOFIA – USGS Marker 52	Salinity	Validation
SOFIA – USGS Punta Blanca	Salinity	Validation

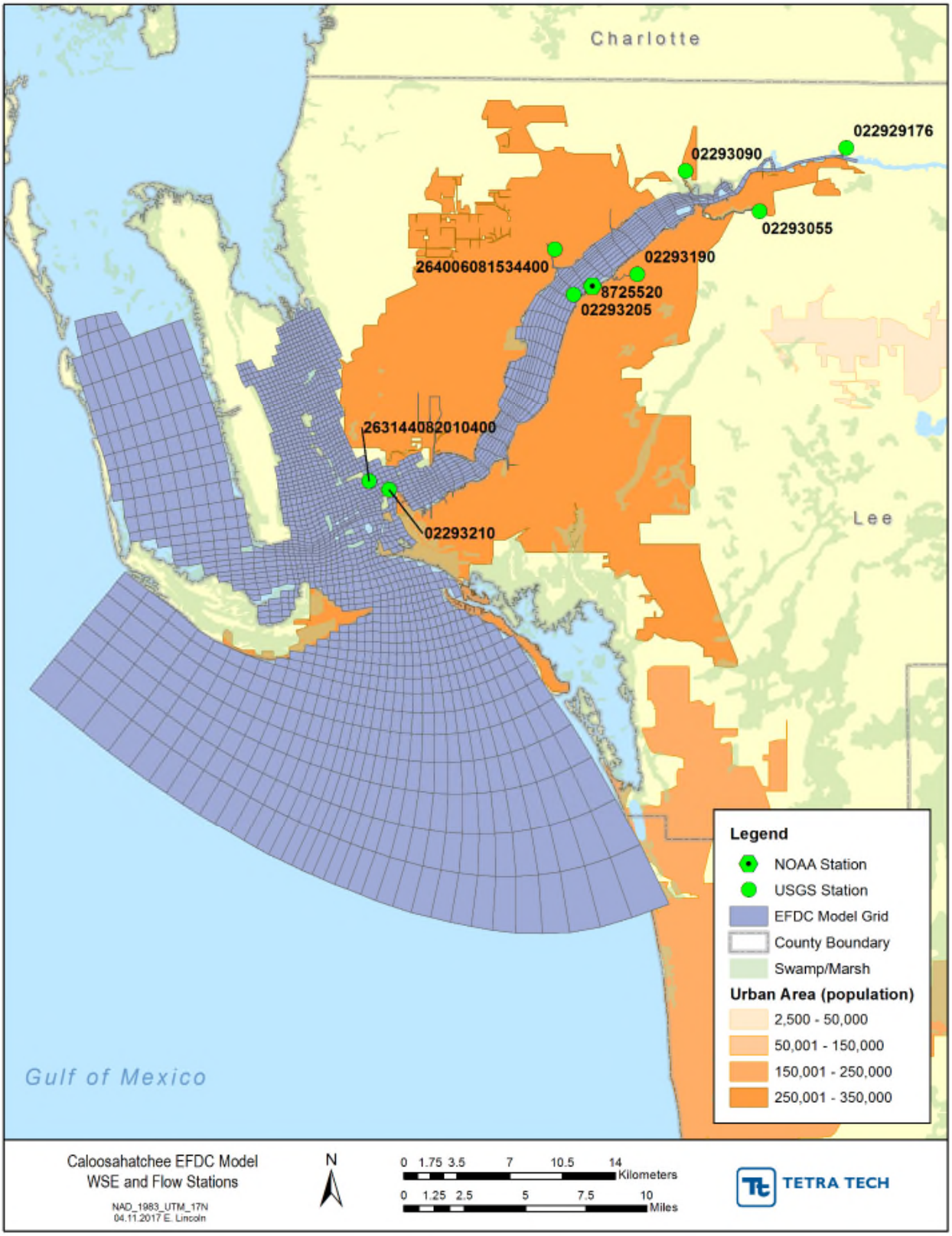

FIGURE 74: 2017 EFDC MODEL WSE AND FLOW COMPARISON STATION LOCATIONS

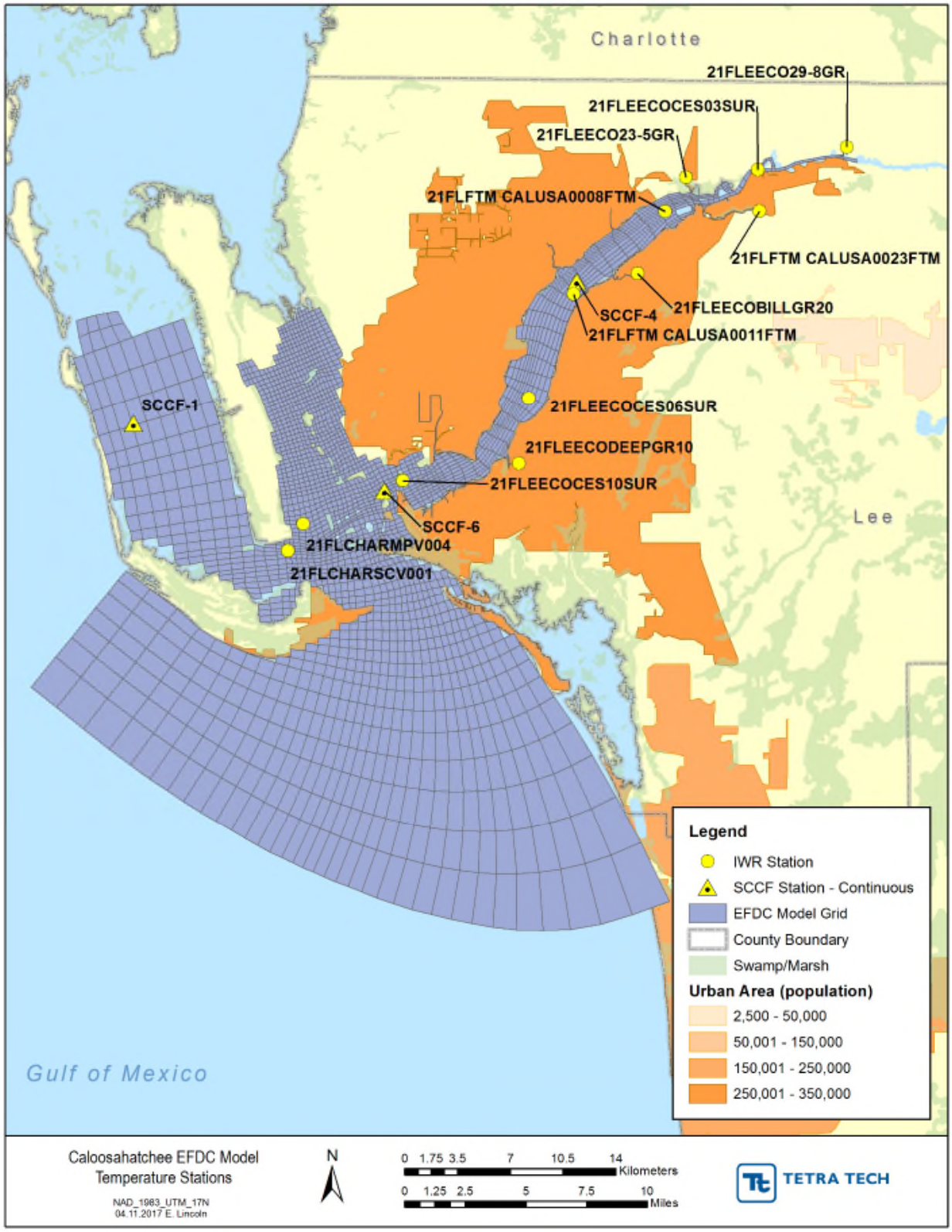

FIGURE 75: 2017 EFDC MODEL TEMPERATURE COMPARISON STATION LOCATIONS

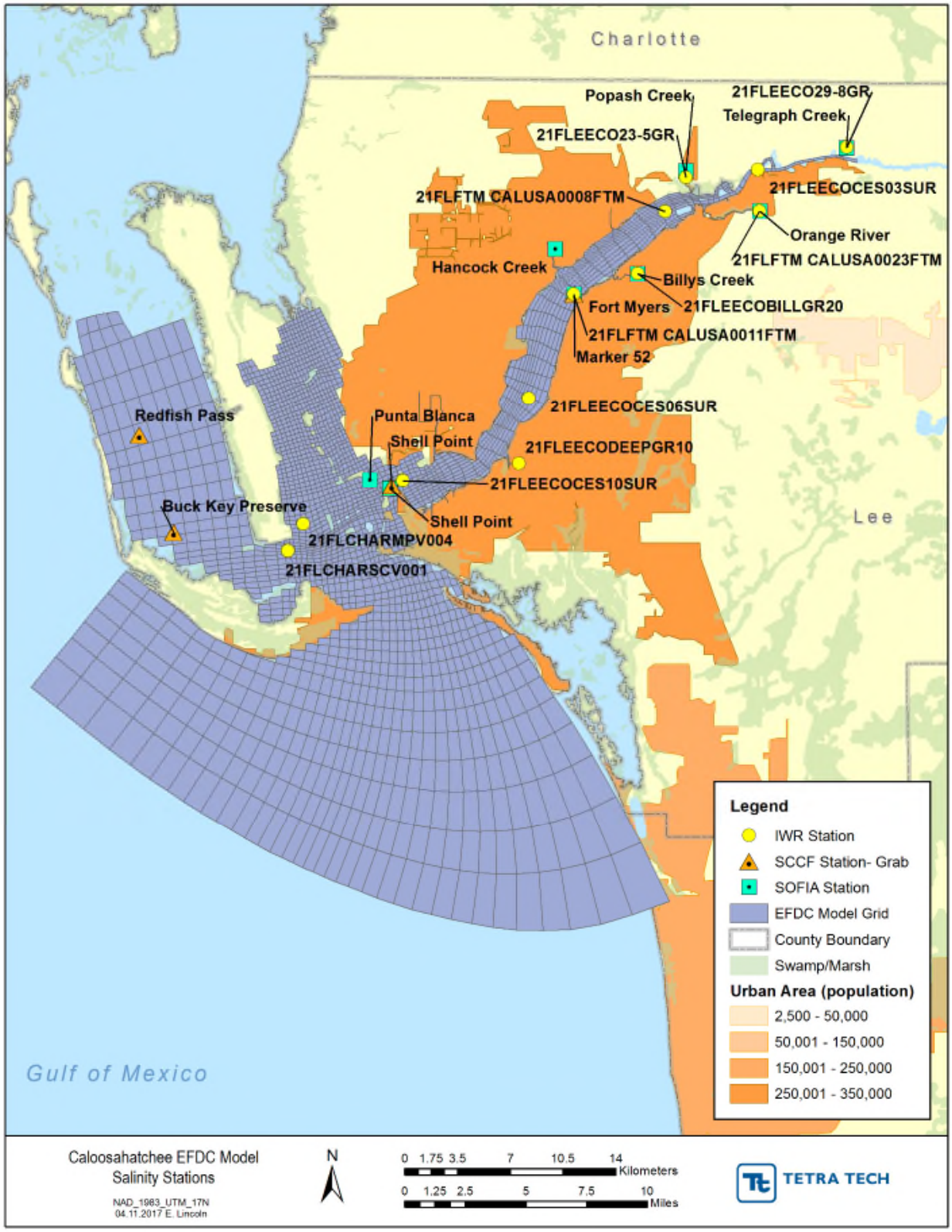

FIGURE 76: 2017 EFDC MODEL SALINITY COMPARISON STATION LOCATIONS

3.4.2 Calibration Methodology

The calibration of the model was based on graphical and statistical comparisons between the model predictions and the observations. An iterative process was performed to adjust parameters, such as the bottom roughness coefficient and background dispersion coefficient from the turbulence closure model. Initially, parameters were defined for the first model run, typically using values from the 2014 Model. Parameters were adjusted during subsequent runs, and typically one parameter was adjusted at a time quantify the impact of the change on model calibration. Following parameter adjustments, the model was executed and the results were post-processed for both visual and statistical comparisons. The results were analyzed to determine if there was or was not an improvement in the model calibration, i.e. model appeared to better capture trends and magnitudes of measured data, and/or statistics showed an over prediction or under prediction compared to measured data. If model performance was unsatisfactory, parameters were adjusted again. If model performance was satisfactory or if the further parameter adjustment could not improve model calibration, the model was considered calibrated.

The visual (temporal) analyses were performed using the postprocessor WRDB Graph (version 6.0.0.32), which creates comparison plots using the model results from the EFDC output file (*.BMD) and available field observations from a WRDB database (*.DBS). WRDB Graph was also used to generate the following goodness-of-fit statistics where P represents the time series of model predictions and O the time series of observations:

Correlation coefficient: $$R^2 = \frac{\left(n\sum_{i=1}^{n}\left(P_i \times O_i\right)\right) - \left(\sum_{i=1}^{n} O_i \times \sum_{i=1}^{n} P_i\right)}{\sqrt{\left[n\sum_{i=1}^{n}\left(P_i^2\right) - \sum_{i=1}^{n}\left(P_i\right)^2\right]} \times \sqrt{\left[n\sum_{i=1}^{n}\left(O_i^2\right) - \sum_{i=1}^{n}\left(O_i\right)^2\right]}}$$

Mean Absolute Error: $$MAE = \frac{\sum_{i=1}^{n}\left|P_i - O_i\right|}{n}$$

Root Mean Squared Error: $$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(P_i - O_i\right)^2}{n}}$$

Normalized Root Mean Squared Error: $$NRMSE = \frac{RMSE}{\overline{O}}$$

Index of Agreement: $$IA = 1.0 - \frac{\sum_{i=1}^{n}\left|P_i - O_i\right|^2}{\sum_{i=1}^{n}\left[\left|P_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right]^2}$$

Percent Error: $PE = \frac{\overline{O} - \overline{P}}{\overline{O}}$

The correlation coefficient and PE are described in **Section 2.3.2**.

The mean absolute error (MAE) and the root mean squared error (RMSE) are estimates of the average deviation of the model predictions from the observations. The normalized root mean squared error (NRMSE) provides an estimate of the relative importance of the errors with respect to the observations. The MAE, RMSE, and NRMSE constitute indicators of model prediction accuracy (Stow et al. 2003), and the smaller their values, the higher the agreement between the observations and the predictions. Finally, the IA evaluates the global agreement between the predictions and the observations. Values of the IA range between 0 and 1 with the highest value indicating a perfect match between the two time series. A value of zero indicates that the model predicts individual observations no better than the average of the observations.

3.4.3 Water Surface Elevation

In the EFDC model, the boundary conditions for WSE are imposed using a radiation–separation condition that allows an incoming wave at the EFDC model boundary (forced input) to be separated from an outgoing wave from inside the modeling domain. Without the radiation-separation condition, any wave propagating from inside the model to the open boundaries (model exit) could be trapped and magnified inside the model domain (Hamrick 1992). This boundary condition requires the forcing of the open boundaries with half of the incoming tidal wave. In practice this is achieved by scaling down the time series of WSE at the boundary by a factor of 0.5. This scaling factor of 0.5 applies only for situations where the model open boundaries are forced with WSEs observed exactly at the model boundaries. In other cases, the scaling factor must be adjusted. For the Caloosahatchee River and Estuary model, the scaling factor for the amplitude of the south open boundary conditions was slightly adjusted to 0.75. The scaling factors for the north open boundaries were set at 0.5. The scaling factors were defined in the input file PSER.inp.

During the calibration of the Caloosahatchee model, the bottom roughness coefficient was adjusted in order to match the phase and amplitude of the water level observations at NOAA station 8725520 and also at different USGS stations located throughout the estuary. Regarding the roughness coefficient, a constant calibrated value of 0.01 meters was specified in the model setup.

The model results are summarized in **Table 118** and **Figure 77** through **Figure 81**. In **Table 118**, the performance statistics for stations reporting only daily maximum and daily minimum water levels (USGS stations 02293205 and 02293210) were computed by comparing the observations against the simulated daily maximum and daily minimum water levels. The results indicated that the model was capable of reproducing the phase and amplitude of the tidal variations within the estuary. The calibration statistics were overall very good with RMSE on the order of few centimeters (0.07 – 0.13 m), and IA above 0.86 at most stations. The tidal range, which was the average difference between maximum and minimum water levels during a tidal cycle, varied between approximately 0.5 and 0.9 meters and is well captured by the model. The model matched the timing and amplitude of the tide during spring and neap periods as well as the inter-daily variations observed at the different evaluated stations.

Table 118: Model performance statistics for WSE

Station ID	Mean Measured (m MSL)	Median Measured (m MSL)	5th Percentile Measured (m MSL)	95th Percentile Measured (m MSL)	Mean Simulated (m MSL)	Median Simulated (m MSL)	5th Percentile Simulated (m MSL)	95th Percentile Simulated (m MSL)	R^2	MAE (m MSL)	RMSE (m MSL)	NRMSE	IA
8725520	0.08	0.10	-0.21	0.36	0.21	0.23	-0.08	0.53	0.77	0.14	0.16	0.77	0.82
02293205 - Max	0.32	0.33	0.08	0.55	0.40	0.40	0.13	0.66	0.87	0.09	0.12	0.09	0.87
02293205 - Min	-0.08	-0.07	-0.29	0.09	0.00	0.00	-0.21	0.19	0.83	0.08	0.10	0.08	0.84
02293210 - Max	0.35	0.35	0.14	0.55	0.38	0.37	0.12	0.63	0.92	0.05	0.07	0.06	0.94
02293210 - Min	-0.15	-0.15	-0.35	0.02	-0.05	-0.05	-0.25	0.15	0.89	0.10	0.12	0.11	0.81

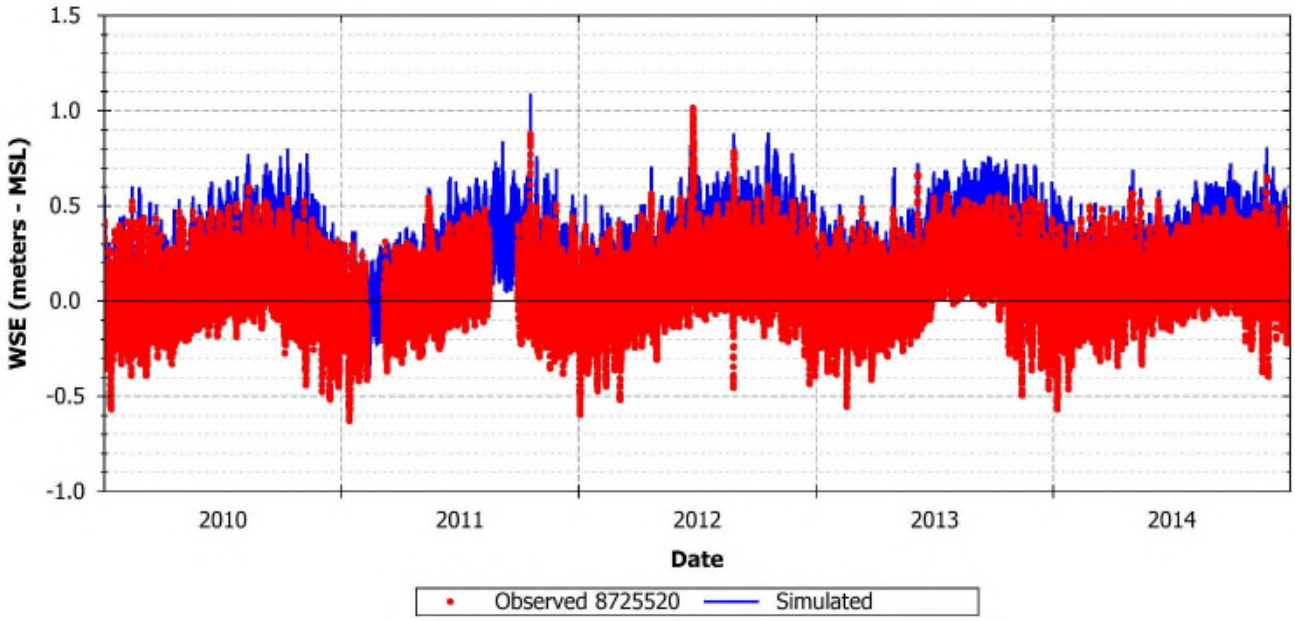

FIGURE 77: SIMULATED AND OBSERVED WSE AT NOAA STATION 8725520, 2010 – 2014

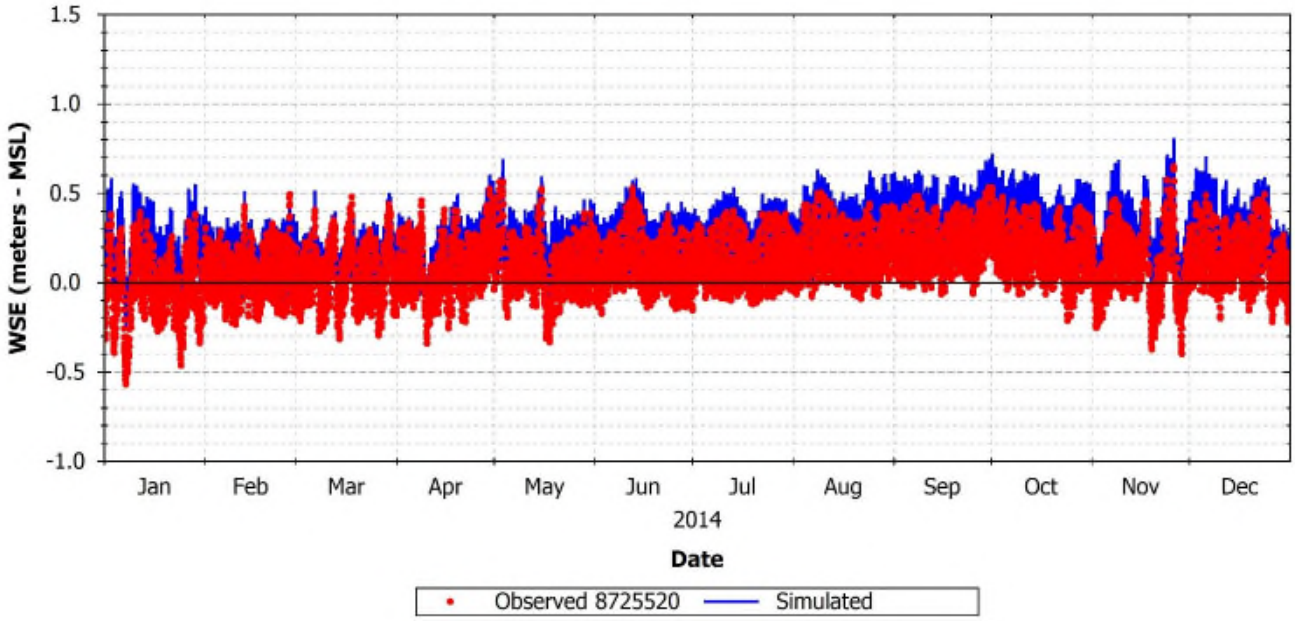

FIGURE 78: SIMULATED AND OBSERVED WSE AT NOAA STATION 8725520, 2014

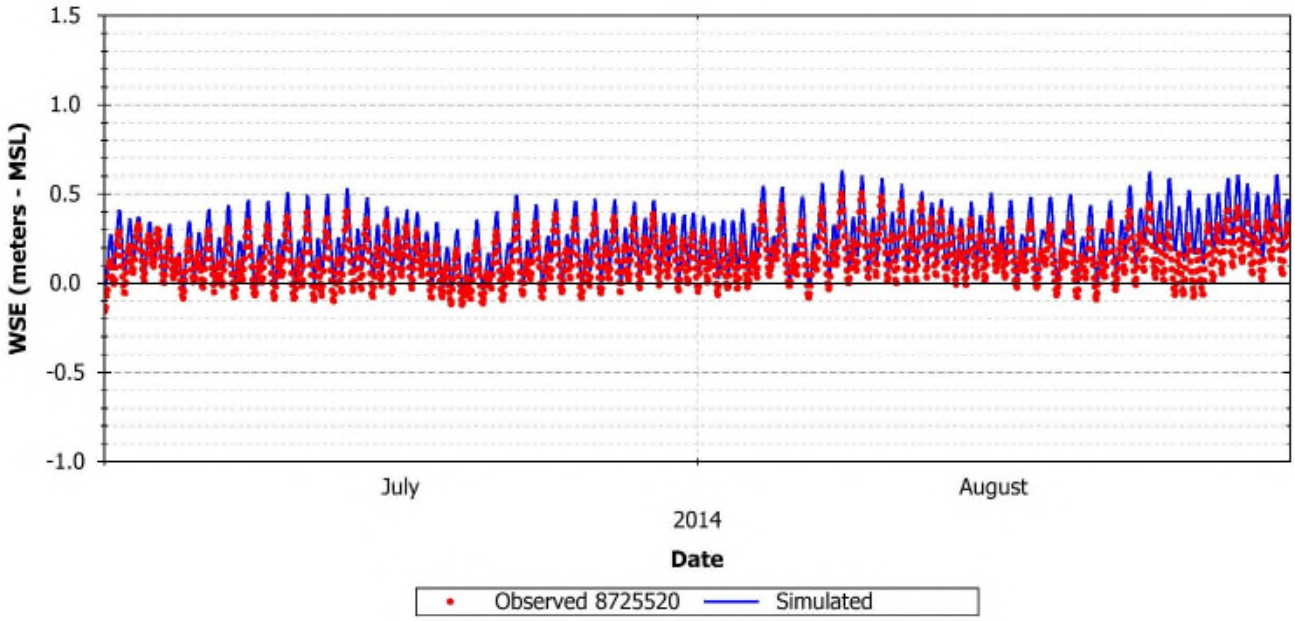

FIGURE 79: SIMULATED AND OBSERVED WSE AT NOAA STATION 8525520, JULY – AUGUST, 2014

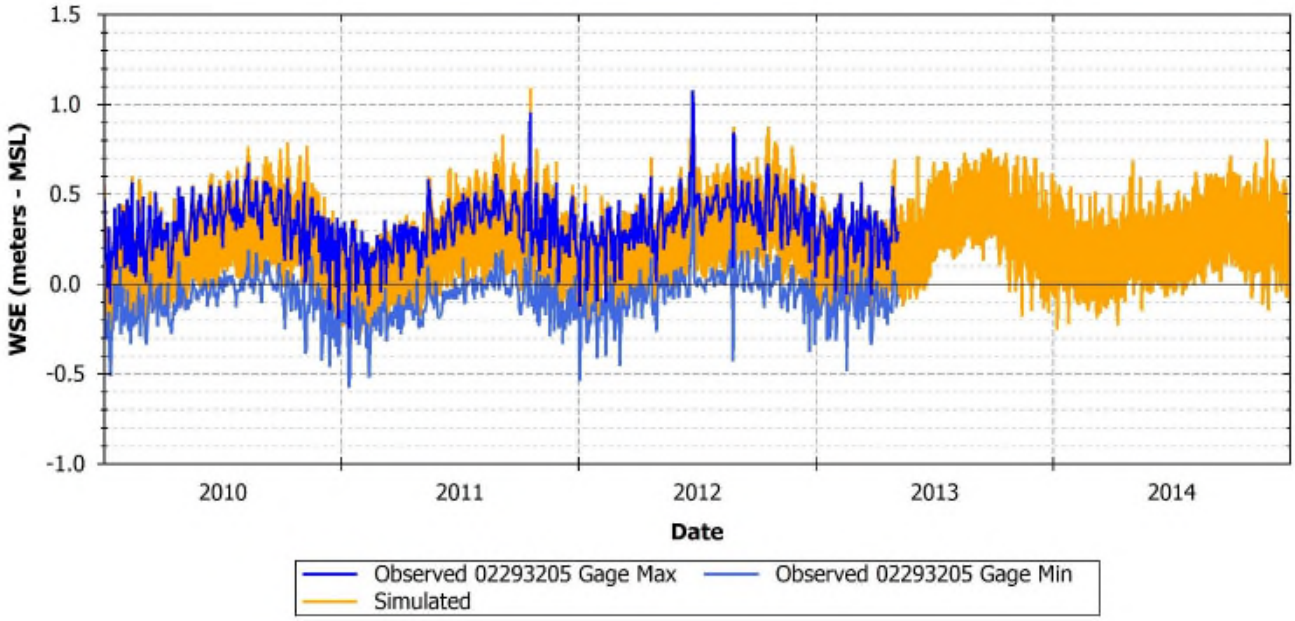

FIGURE 80: SIMULATED AND OBSERVED WSE AT USGS 02293205

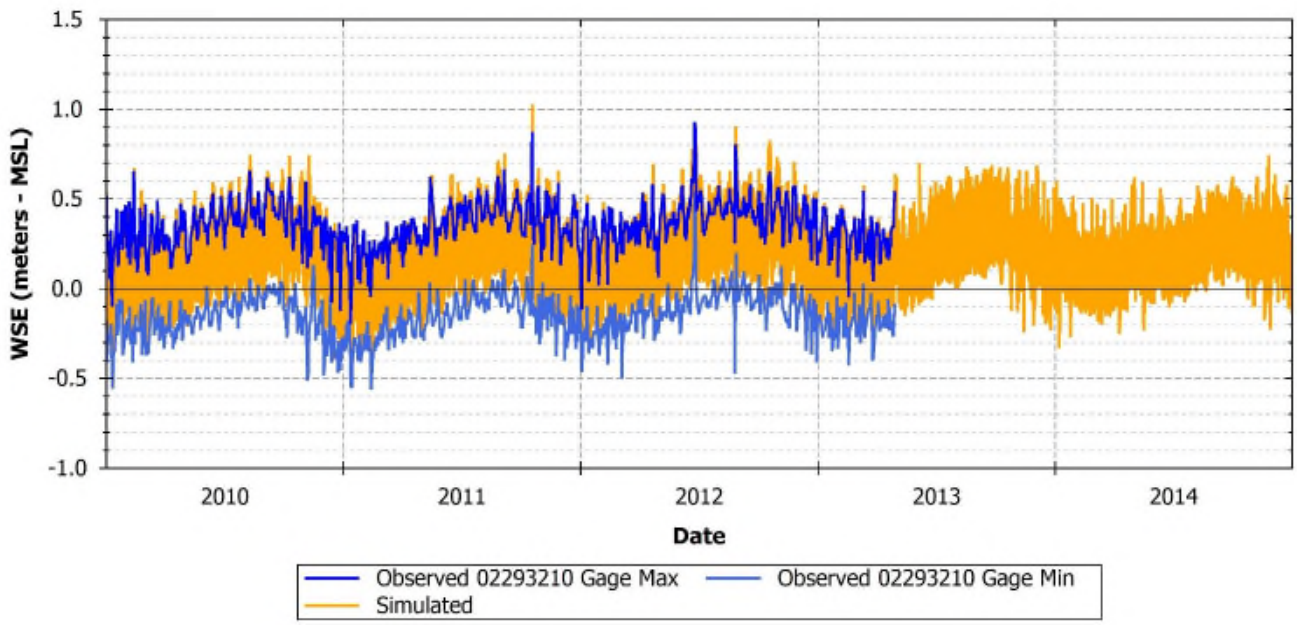

FIGURE 81: SIMULATED AND OBSERVED WSE AT USGS 02293210

3.4.4 Water Temperature

A good representation of the vertical and horizontal distribution of temperature and salinity in estuaries is important to correctly represent baroclinic transport resulting from water density variations. The 2017 EFDC Model was calibrated to reproduce temperature measurements collected at several monitoring stations located throughout the estuary. The parameters adjusted during the model calibration were the solar radiation attenuation coefficient and the heat transfer coefficient between the water column and the solid bed. These parameters control most of the vertical structure of heat in the model (Hamrick 1992; Ji 2008). A summary of the calibration results at selected stations is presented below in **Table 119** and **Figure 82** through **Figure 87**. The comparison period shown in these figures ranges from January 1, 2010 through December 31, 2014. The statistics of model performance at station 21FLCHARMPV004 did not include a 1 °C temperature measurement in April 2012 (**Figure 87)**. This value was considered a data error as the temperature records in nearby stations for the same period were consistently above 20 °C.

The calibration results show the model was able to reproduce the overall temperature variations observed in the Caloosahatchee Estuary. The model predictions followed the observed seasonal evolution of water temperature and general inter-daily temperature variations throughout the estuary (**Figure 82** through **Figure 84**). The performance statistics are in general very good with R^2 values above 0.9, IA above 0.9 and NRMSE values between 0.04 and 0.06.

TABLE 119: MODEL PERFORMANCE STATISTICS FOR WATER TEMPERATURE

Station ID	Mean Measured (°C)	Median Measured (°C)	5th Percentile Measured (°C)	95th Percentile Measured (°C)	Mean Simulated (°C)	Median Simulated (°C)	5th Percentile Simulated (°C)	95th Percentile Simulated (°C)	R^2	MAE (°C)	RMSE (°C)	NRMSE	IA
21FLEECOCES03SUR	25.10	26.80	17.17	30.51	25.43	27.29	17.69	31.29	0.96	0.66	0.92	0.04	0.99
21FLFTM CALUSA0008FTM	26.27	27.63	19.49	31.83	27.23	28.78	19.86	33.15	0.90	1.39	1.71	0.06	0.96
21FLFTM CALUSA0011FTM	24.82	26.92	16.19	31.03	25.71	27.81	17.72	32.30	0.95	1.07	1.47	0.06	0.98
21FLEECOCES06SUR	24.62	26.12	16.04	31.04	25.34	27.53	16.63	31.83	0.97	0.88	1.14	0.05	0.99
21FLEECOCES10SUR	25.00	27.21	16.20	30.81	25.85	28.03	17.29	32.39	0.97	0.98	1.24	0.05	0.98
21FLCHARMPV004	23.72	25.47	14.67	30.72	24.67	26.26	16.94	30.99	0.97	0.98	1.30	0.05	0.98

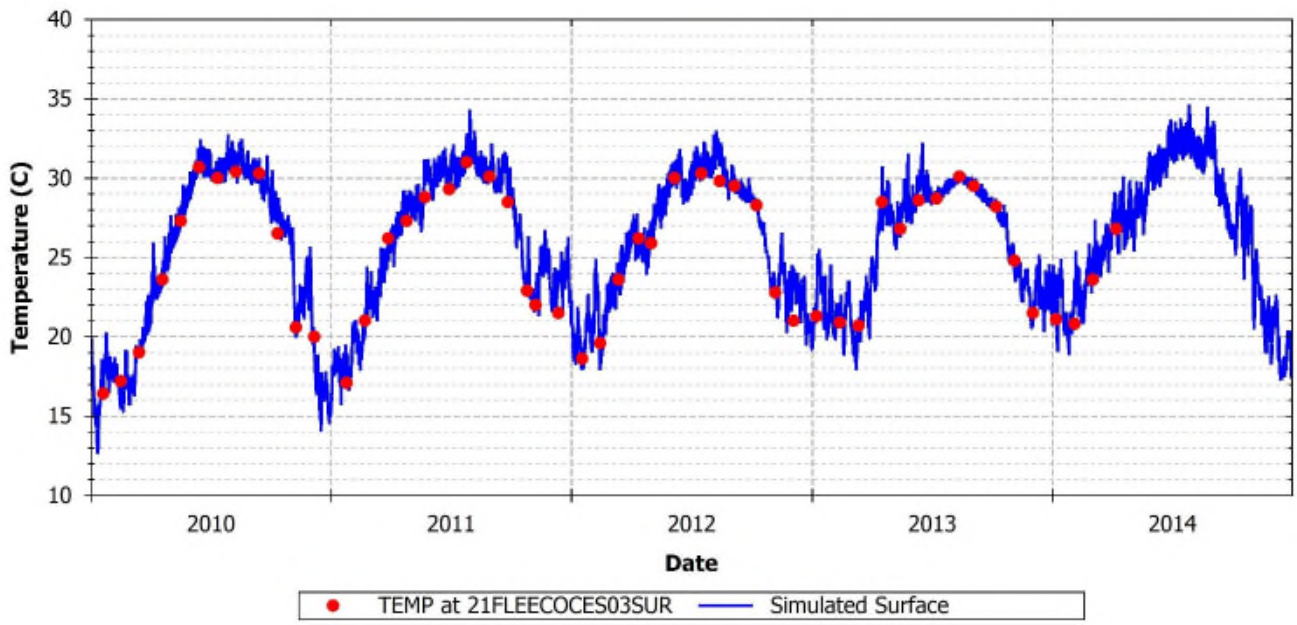

FIGURE 82: SIMULATED AND OBSERVED TEMPERATURE AT 21FLEECOCES03SUR

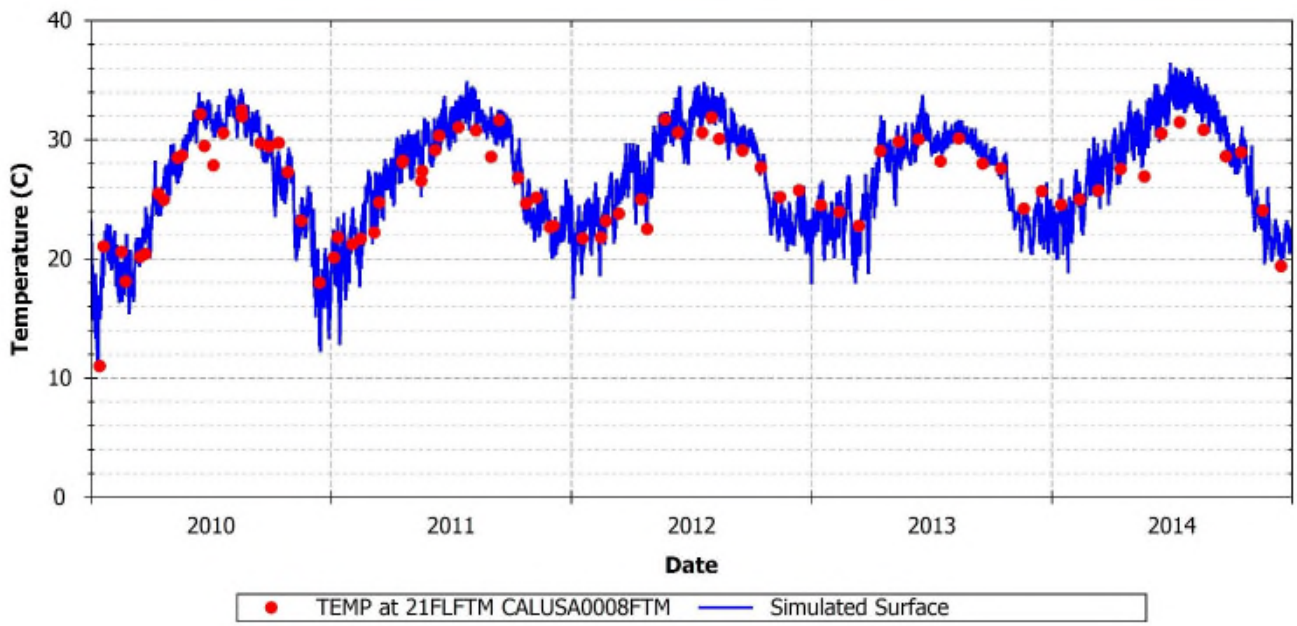

FIGURE 83: SIMULATED AND OBSERVED TEMPERATURE AT 21FLFTM CALUSA0008FTM

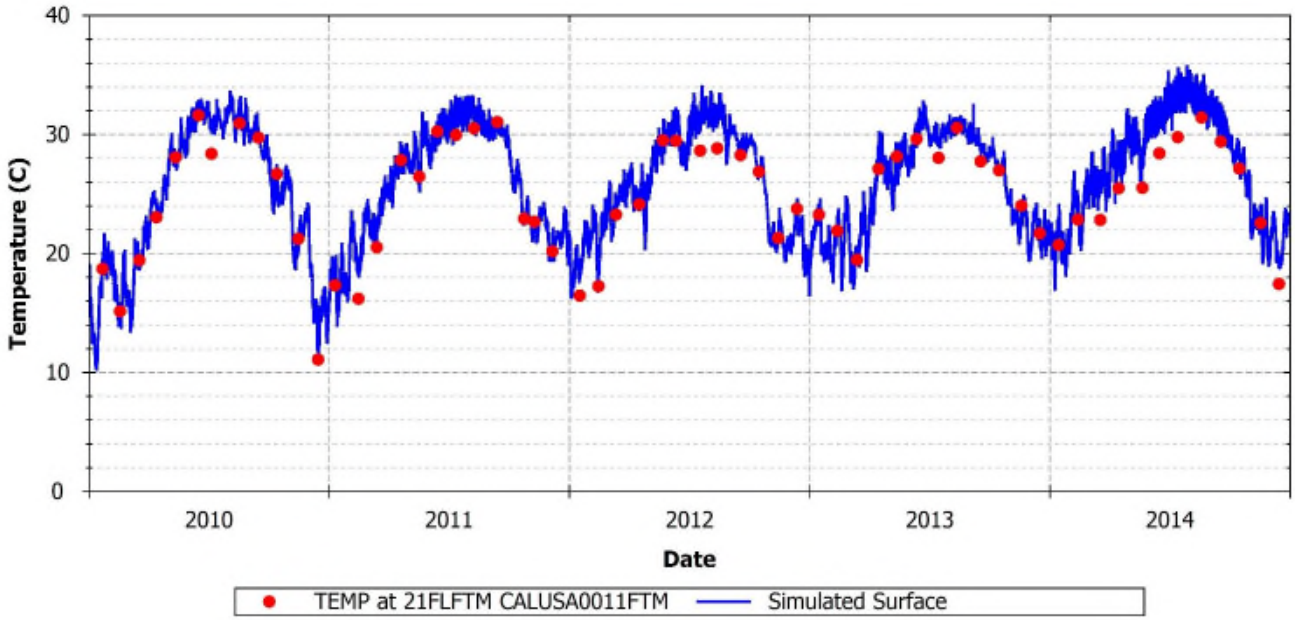

FIGURE 84: SIMULATED AND OBSERVED TEMPERATURE AT 21FLFTM CALUSA0011FTM

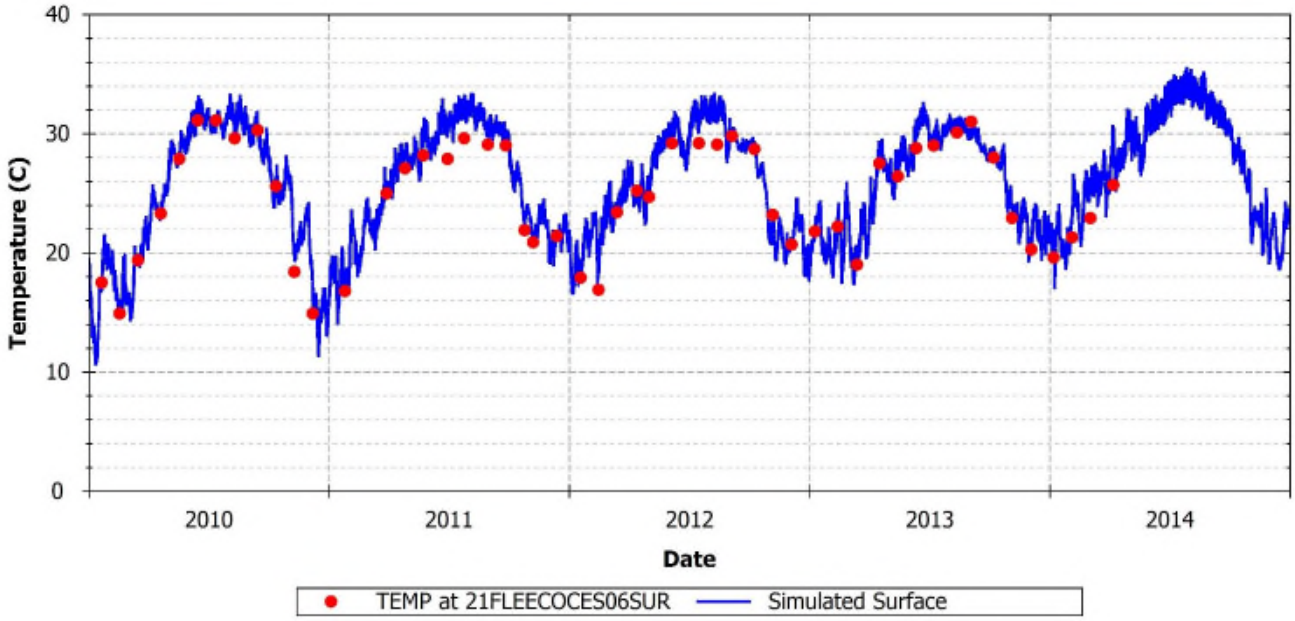

FIGURE 85: SIMULATED AND OBSERVED TEMPERATURE AT 21FLEECOCES06SUR

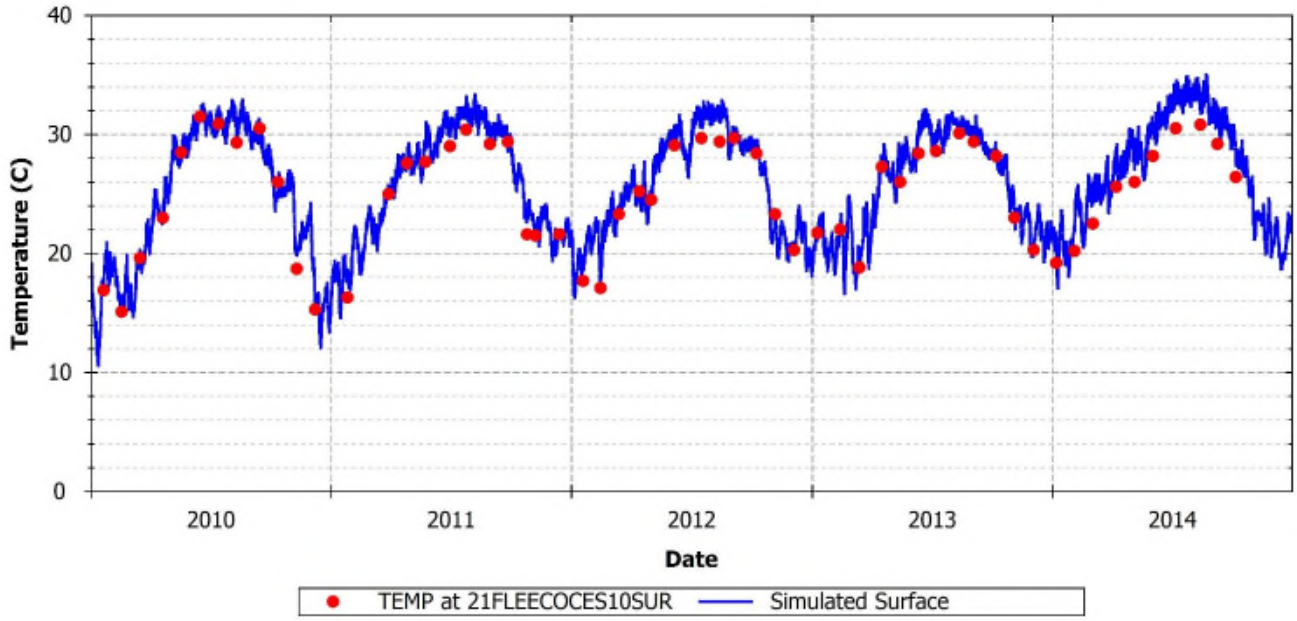

FIGURE 86: SIMULATED AND OBSERVED TEMPERATURE AT 21FLEECOCES10SUR

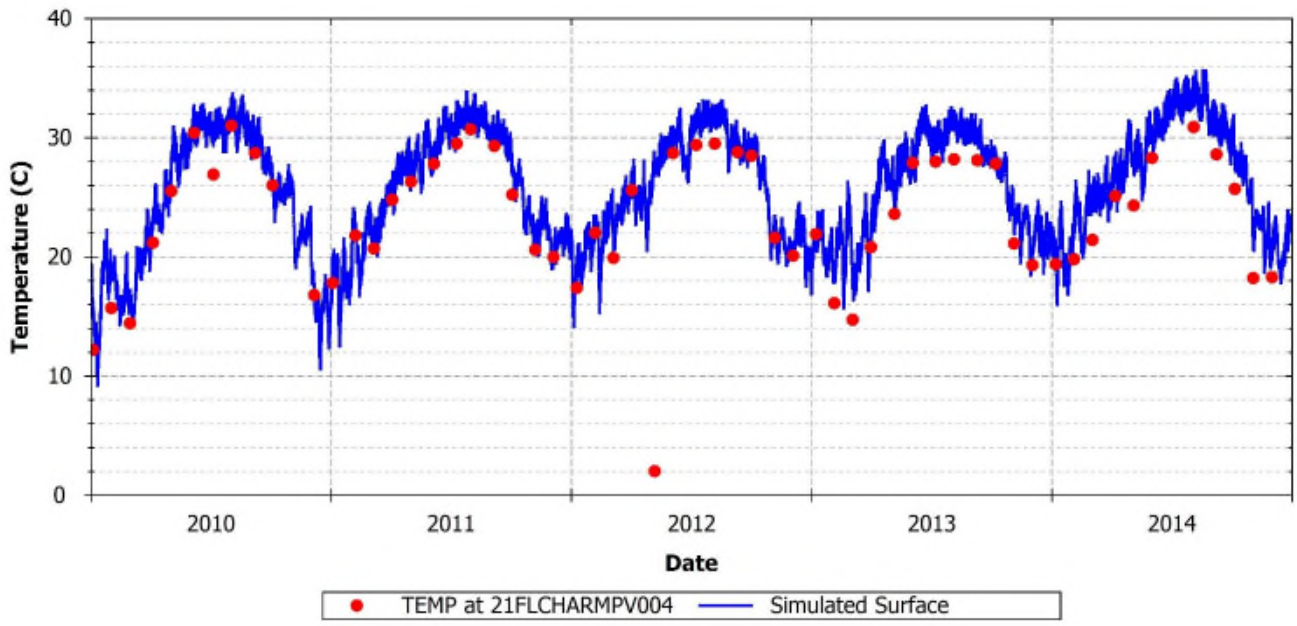

FIGURE 87: SIMULATED AND OBSERVED TEMPERATURE AT 21CHARMPV004

3.4.5 Salinity

Salinity is an indicator of mass transport in estuaries. The calibration of salinity is important to evaluate the capacity of a model to represent transport resulting from density gradients between the freshwater and the ocean water (i.e. baroclinic or density-driven currents), and to ensure a model is able to represent

vertical stratification in the system. A summary of the calibration results at selected stations is presented below in **Table 120** and **Figure 88** through **Figure 93**.

Calibration results showed the model had a good performance predicting salinity in the middle and lower portions of the estuary, along with tributaries in this region (**Figure 90** , **Figure 93,** and **Appendix C**). In these regions the model simulations were able to follow the seasonal trends and ranges of variation exhibited by the observations. The metrics of model performance were good with small differences between the observed and predicted means and also high IA (0.80 – 0.96). In the upper region of the estuary close to the upstream boundary at S-79 at stations 21FLEECOCES03SUR and 21FLFTM CALUSA008FTM, the model was able to capture the salinity intrusion both in magnitude and timing (**Figure 88**, **Figure 89,** and **Appendix C**). During the calibration period, the R^2 values range from 0.68 to 0.71 and the IA values range from 0.83 to 0.96.

The model performance outside the calibration period was also very good and the model was able to capture the trends, levels of salinity intrusion, and levels of stratification observed along the main stem. Comparisons between simulated and observed salinity concentrations at stations with available surface and bottom salinity measurements are included for the period 1996 – 2009 in **Appendix C**. Results at the USGS-SOFIA stations Orange River, Marker 52, Punta Blanca, and stations 21FLEECOCES03SUR 21FLFTMCALUSA0008FTM, and 21FLEECOCES06SUR indicated the model was able to reproduce the fundamental drivers of salinity transport and distribution across in the Caloosahatchee River and Estuary.

TABLE 120: MODEL PERFORMANCE STATISTICS FOR SALINITY

Station ID	Mean Measured (PSU)	Median Measured (PSU)	5th Percentile Measured (PSU)	95th Percentile Measured (PSU)	Mean Simulated (PSU)	Median Simulated (PSU)	5th Percentile Simulated (PSU)	95th Percentile Simulated (PSU)	R^2	MAE (PSU)	RMSE (PSU)	NRMSE	IA
21FLEECOCES03SUR	2.50	1.19	0.20	11.13	1.68	0.41	0.38	10.61	0.71	1.23	1.97	0.55	0.90
21FLFTM CALUSA0008FTM - Surface	3.42	3.07	0.17	12.69	2.05	0.88	0.40	11.66	0.68	1.75	2.48	0.62	0.86
21FLFTM CALUSA0008FTM -Bottom	10.46	12.55	0.23	25.73	5.59	5.06	0.40	17.17	0.83	4.92	6.14	0.61	0.83
21FLFTM CALUSA0011FTM	8.00	8.74	0.19	20.04	6.14	6.49	0.40	16.66	0.62	3.20	4.26	0.50	0.85
21FLEECOCES06SUR	10.34	12.29	0.20	23.94	10.80	12.90	0.40	23.47	0.91	1.86	2.36	0.19	0.97
21FLEECOCES10SUR	19.50	22.98	1.07	33.84	20.05	23.52	1.50	32.54	0.75	3.55	4.92	0.23	0.93
21FLCHARMPV004	26.33	28.30	10.00	35.53	27.43	30.20	11.93	34.48	0.66	3.33	4.28	0.16	0.89

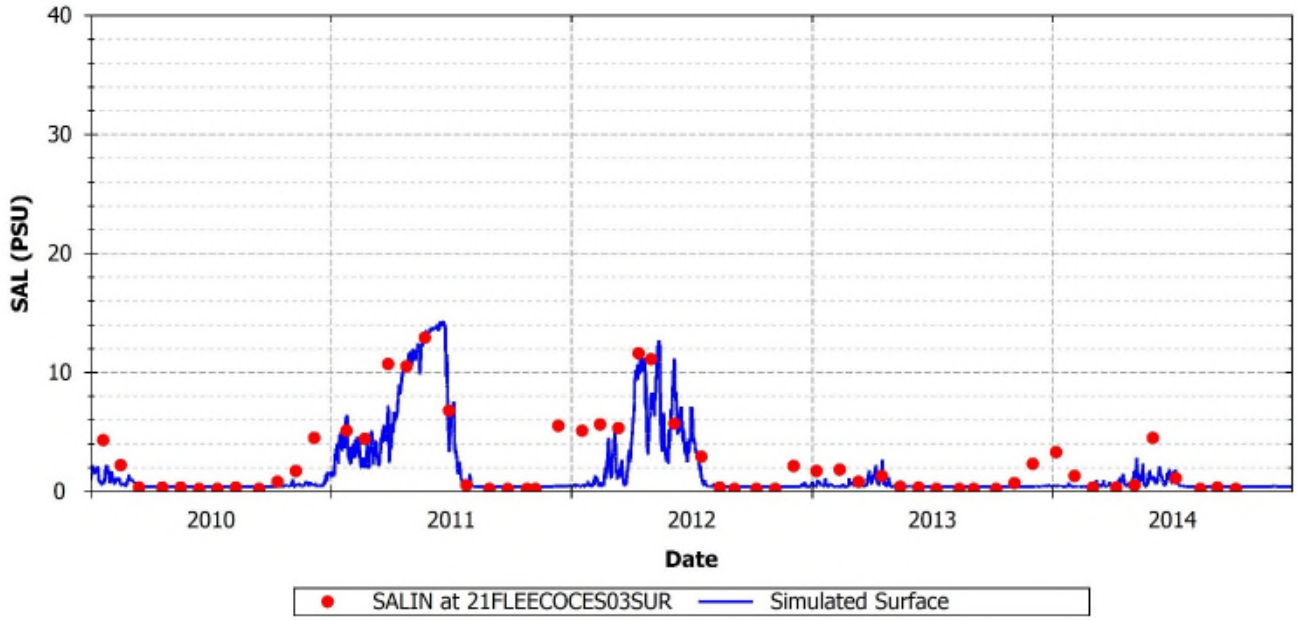

FIGURE 88: SIMULATED AND OBSERVED SALINITY AT 21FLEECOCES03SUR

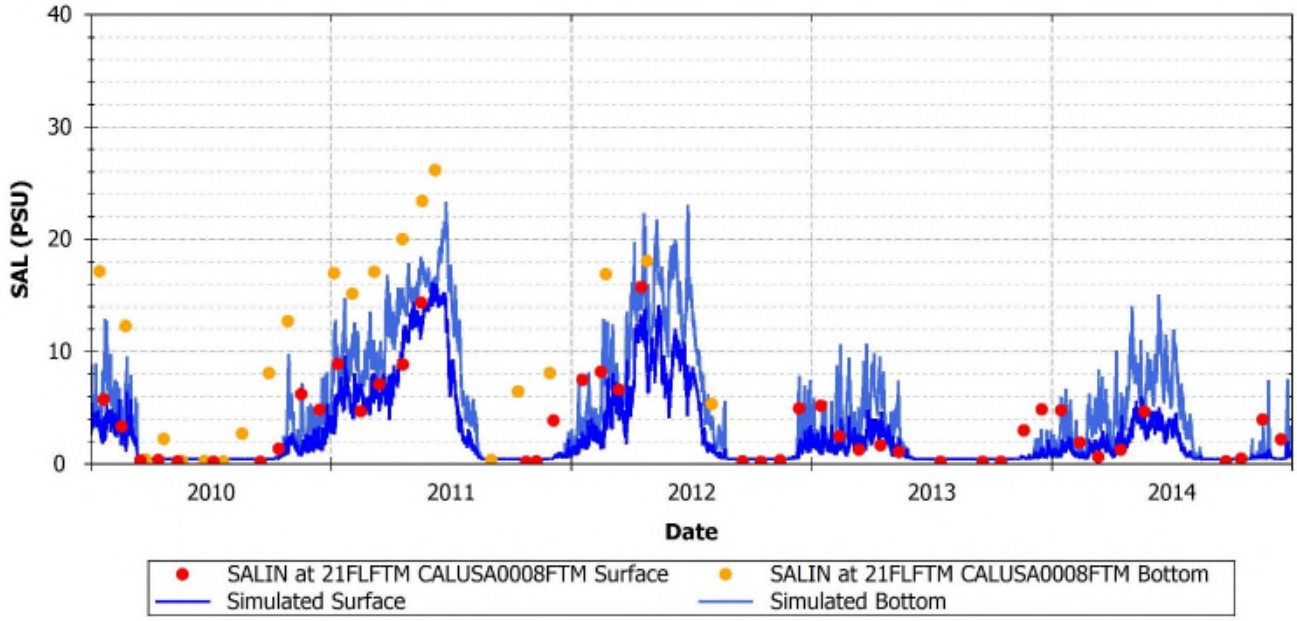

FIGURE 89: SIMULATED AND OBSERVED SALINITY AT 21FLFTM CALUSA0008FTM

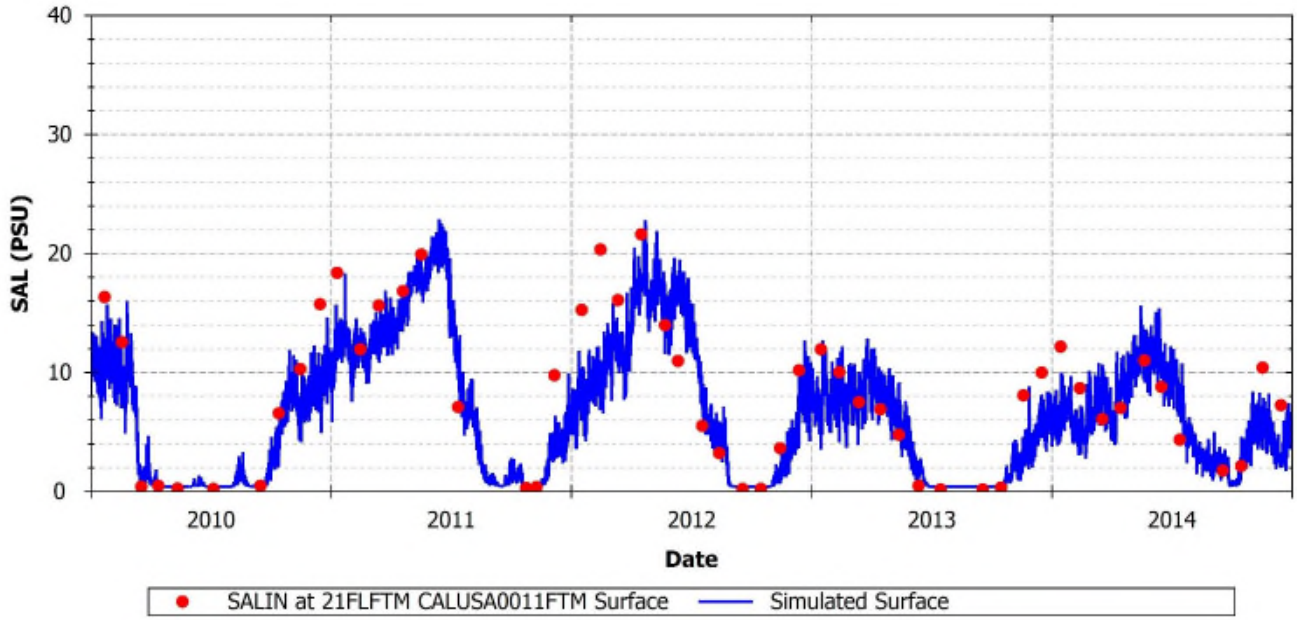

FIGURE 90: SIMULATED AND OBSERVED SALINITY AT 21FLFTM CALUSA0011FTM

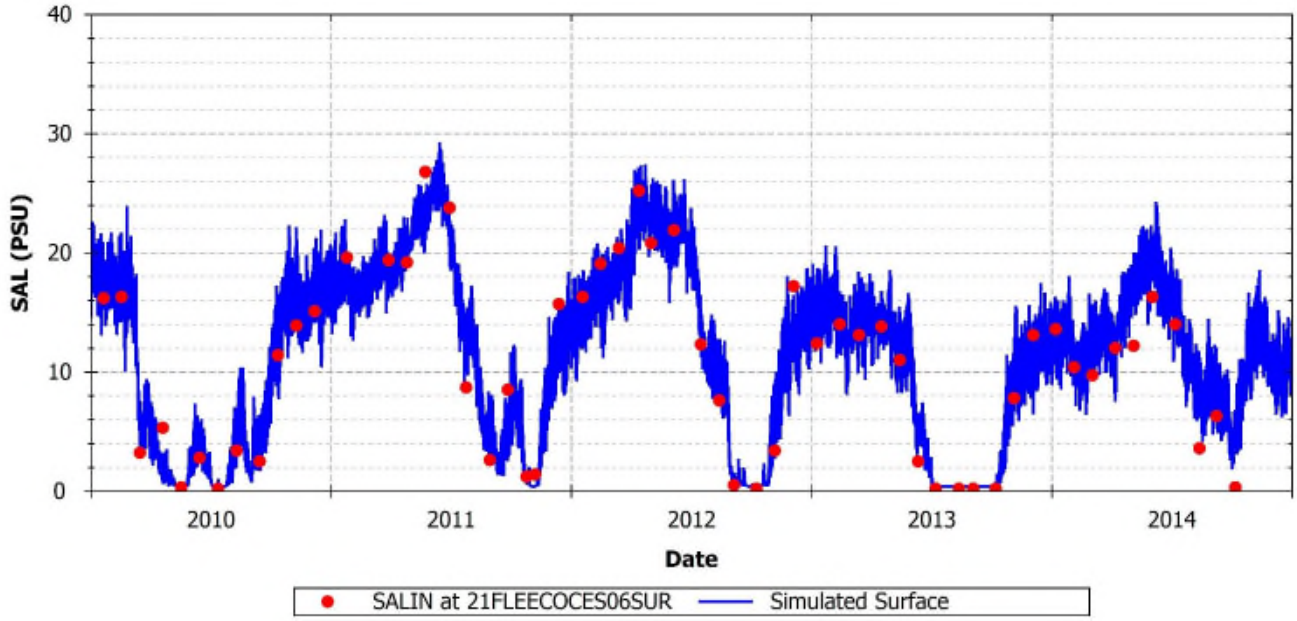

FIGURE 91: SIMULATED AND OBSERVED SALINITY AT 21FLEECOCES06SUR

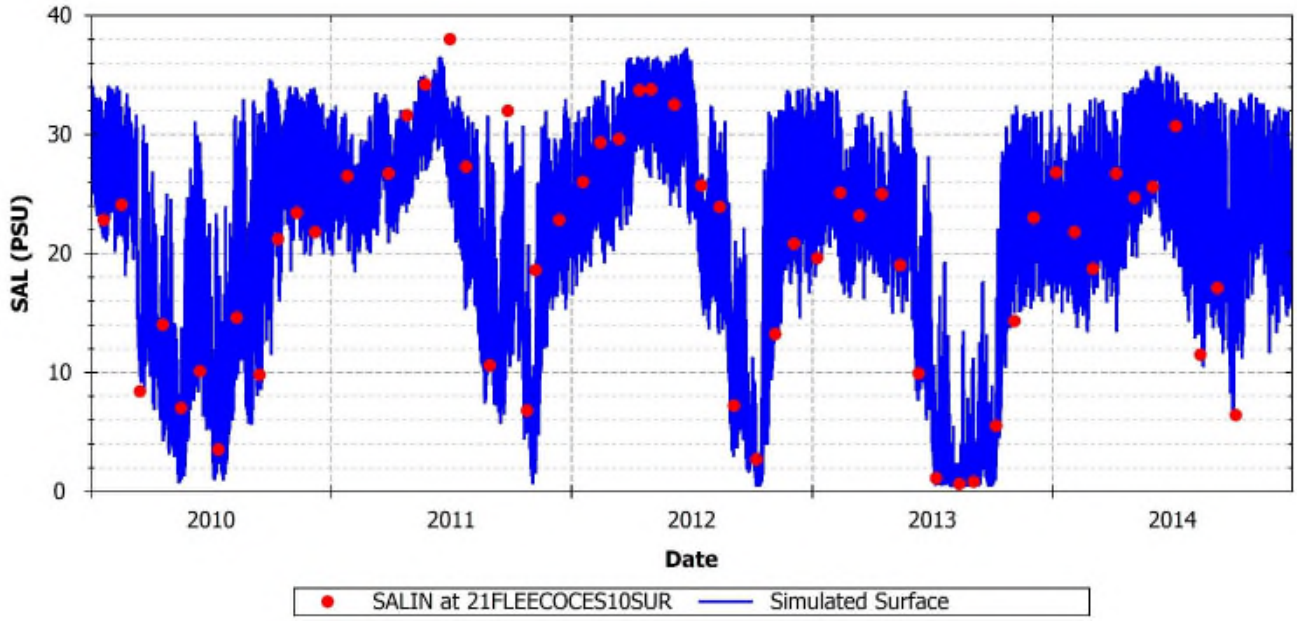

FIGURE 92: SIMULATED AND OBSERVED SALINITY AT 21FLEECOCES10SUR

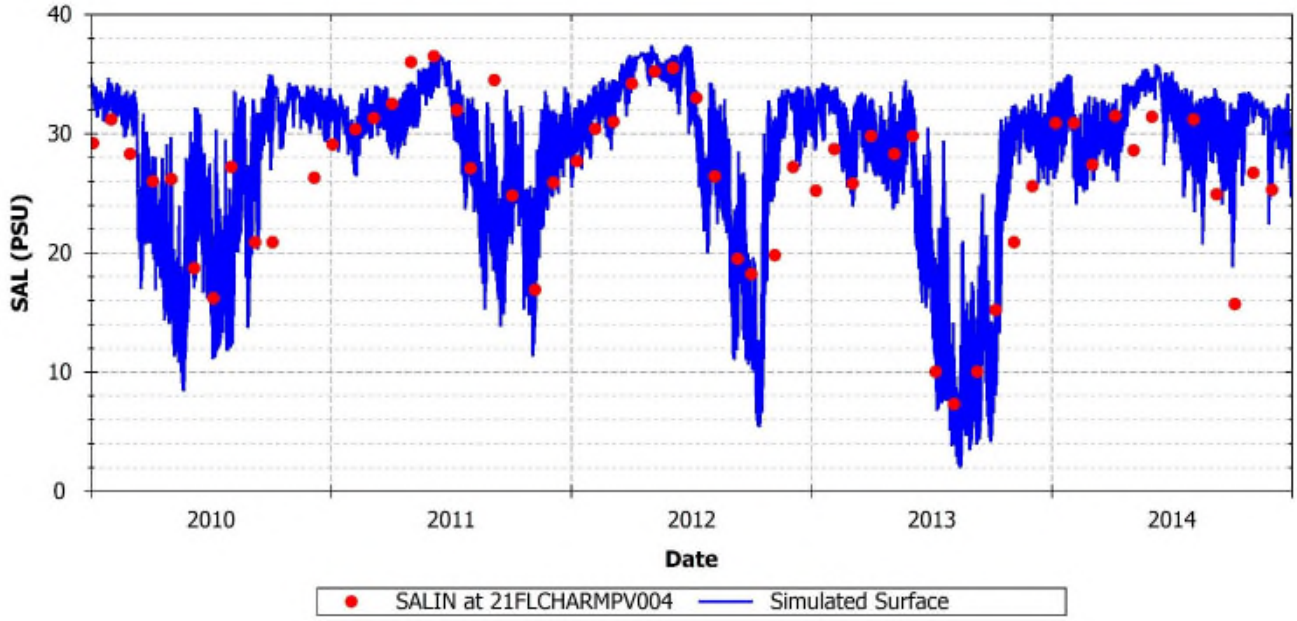

FIGURE 93: SIMULATED AND OBSERVED SALINITY AT 21CHARMPV004

3.4.6 Flows

The 2017 Caloosahatchee EFDC model was calibrated to reproduce observed records of tidal flows available at several USGS/USGS- SOFIA stations across the estuary. In general, the simulation of flows at a particular location was subject to a higher level of uncertainty than the simulation of other hydrodynamic variables such as water elevation, salinity, or temperature. This uncertainty results from

errors in the flow measurement/estimates used to adjust the model, and uncertainty in the forcing conditions of the model and model parameterization. In the first case, the flows reported by agencies, such as USGS, are generally computed based on rating curves relating cross section geometry and velocity derived from acoustic devices such as Acoustic Doppler Current Profilers (ADCPs) and other field measurements. The quality of the estimates can be negatively impacted by tidal circulation or extreme flow conditions, and in most cases the estimates are not 100% accurate. An example comparing the agreement between the observed flows and the curve derived flows at USGS 02293205 is presented in **Figure 94** and **Figure 95**. In this case, some discrepancies were observed, particularly in the peak flood and ebb flows.

When the flows derived from rating curves at a station are compared to the model predictions, other factors can impact the agreement between the two datasets. For instance, the discrepancies between observed and model predicted flows at USGS 02293205 (**Figure 96**) and other stations could be caused by errors in the freshwater boundary flow conditions at the S-79 upstream boundary. The flows used to force the model at this boundary were rated by the USGS as "poor" as they were impacted by several factors such as tidal circulation, gate operations, and water level changes.

Despite the limitations related with the measurement and model predictions of flow, in most cases there was an acceptable agreement between the measured flows and the estimated flows, and the continuous records derived from the rating curves can be used as a reference to calibrate a hydrodynamic model. For the 2017 Caloosahatchee River model, the continuous records of flows reported at USGS/USGS-SOFIA were used to evaluate the performance of the EFDC model to reproduce the magnitude of flood and ebb flows, to refine the bottom roughness of the model, and to refine the configuration of the model grid and bathymetry. The calibration results are summarized below in **Table 121** and from **Figure 96** through **Figure 98**.

In general, the model was able to represent the range and magnitude of the flows observed throughout the estuary. The model performed well during spring and neap periods, although there were small timing discrepancies between the observed and simulated flows which seem to have negatively impacted the model performance statistics, and in particular the MAE and NRMSE. The discrepancies observed at USGS station 02293205 were primarily caused by the uncertainty in the upstream boundary flows which came from observations at USGS 02292900. The accuracy of the records reported by USGS at this station were rated as "poor" in the annual water data report as they are impacted by gate operations, tidal circulation, and water height.

At most stations the model was able to reproduce the magnitude of the flood and ebb flows and at stations close to the mouth of the estuary the ebb flows seemed to be slightly over predicted (e.g. **Figure 98**).

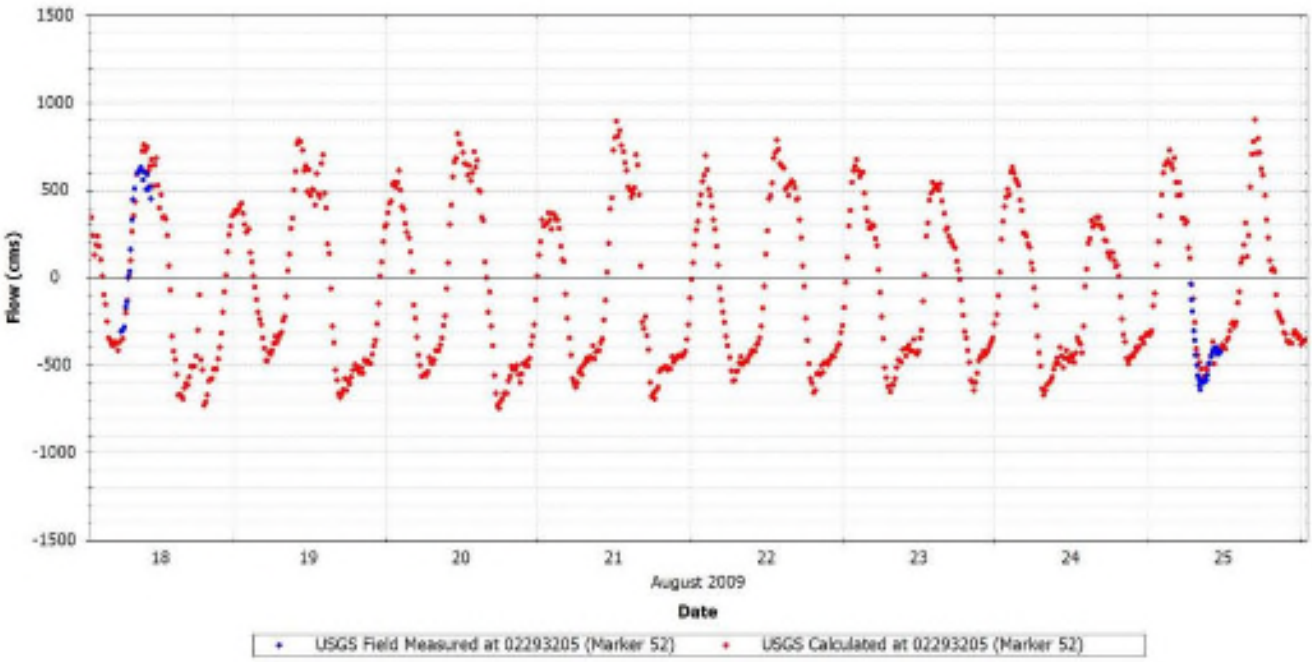

FIGURE 94: COMPARISON OF FLOWS MEASURED AND CALCULATED BY USGS AT STATION 02293205

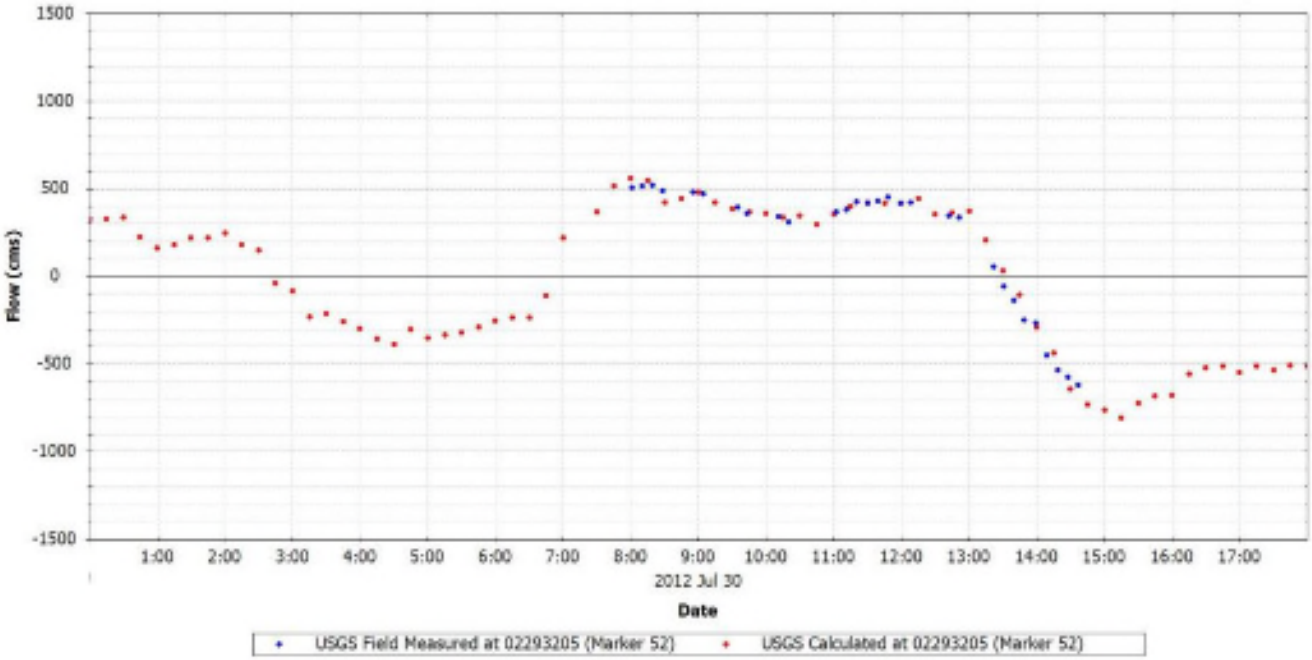

FIGURE 95: COMPARISON OF FLOWS MEASURED AND CALCULATED BY USGS AT STATION 02293205 (CONT.)

TABLE 121: MODEL PERFORMANCE STATISTICS FOR FLOW

Station ID	Mean Measured (cms)	Median Measured (cms)	5th Percentile Measured (cms)	95th Percentile Measured (cms)	Mean Simulated (cms)	Median Simulated (cms)	5th Percentile Simulated (cms)	95th Percentile Simulated (cms)	R^2	MAE (cms)	RMSE (cms)	NRMSE	IA
02293205 (Marker 52)	-52.96	-98.54	-526.69	498.38	-47.44	-82.61	-707.43	673.28	0.83	223.34	271.16	0.13	0.88
2631440820810400 (Punta Blanca)	-51.79	15.01	-1,010.91	896.23	-57.67	-23.73	-1,155.33	975.60	0.90	248.37	316.09	0.11	0.94
02293210 (Shell Point)	-28.77	9.83	-396.44	308.65	-37.95	6.20	-549.59	404.61	0.88	138.10	167.12	0.17	0.91

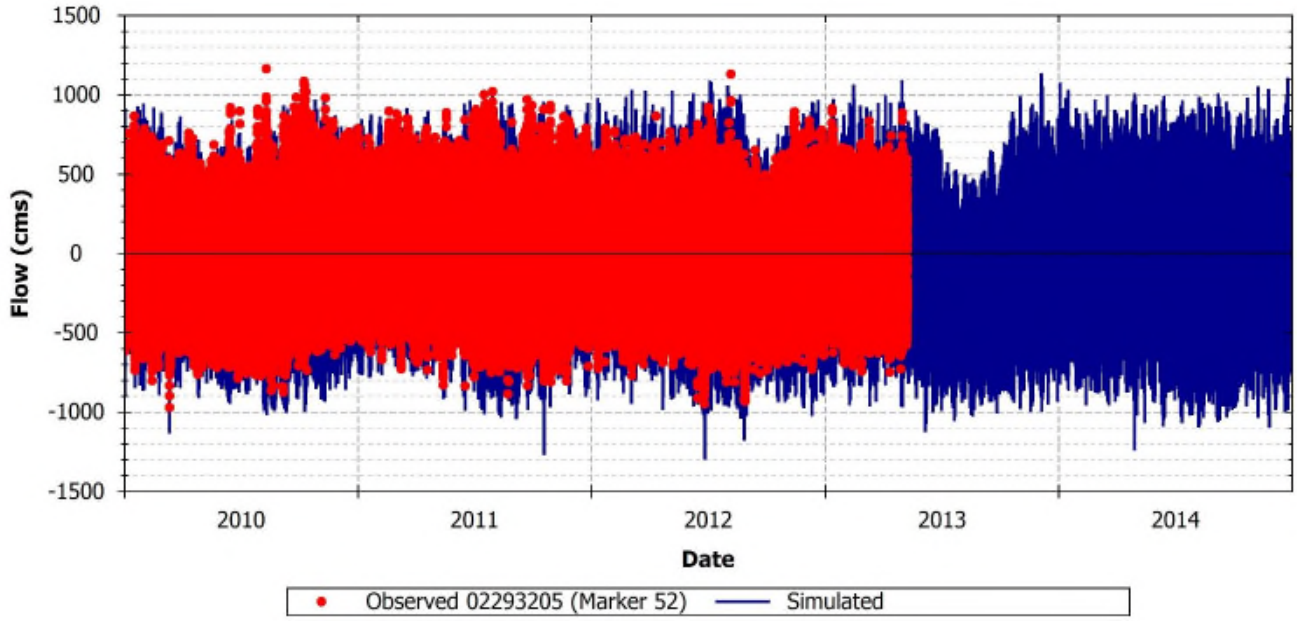

FIGURE 96: SIMULATED AND OBSERVED FLOW AT USGS 02293205 (MARKER 52), 2010 – 2014

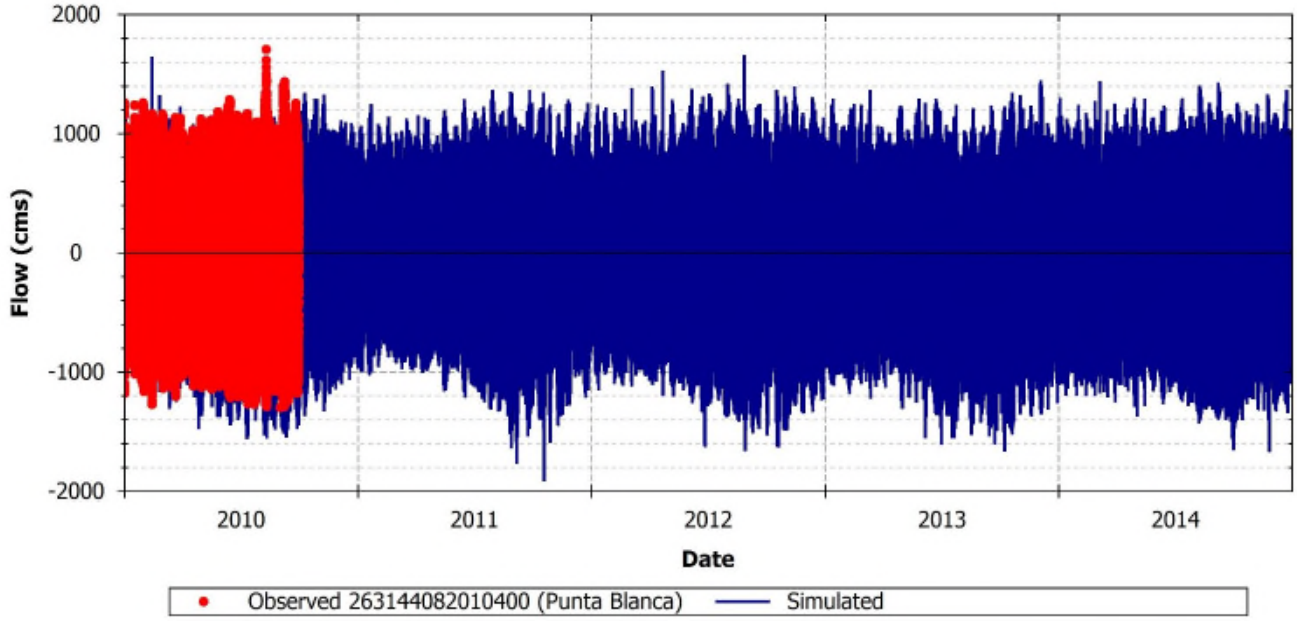

FIGURE 97: SIMULATED AND OBSERVED FLOW AT STATION 2631440820810400 (PUNTA BLANCA), 2010 – 2014

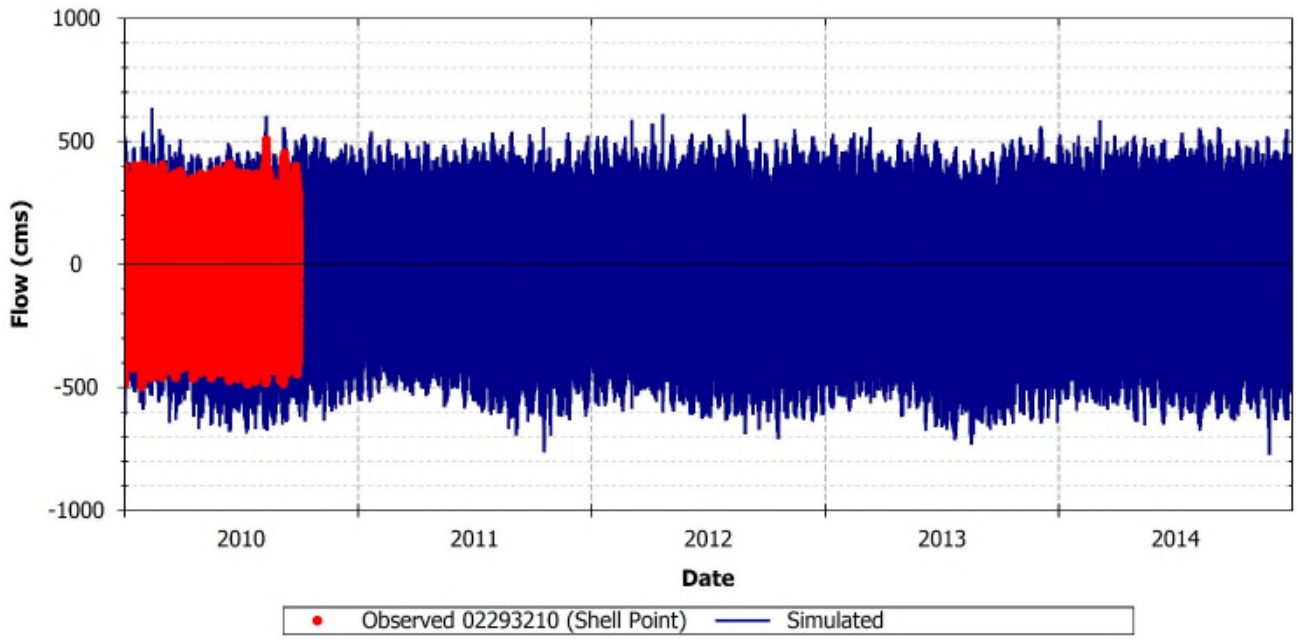

FIGURE 98: SIMULATED AND OBSERVED FLOW AT USGS 02293210 (SHELL POINT), 2010 – 2014

3.5 EFDC MODEL WATER QUALITY CALIBRATION

A schematic representation of the EFDC water quality module and simulated variables is presented in **Figure 2** and **Table 122**. The water quality module is able to simulate conventional eutrophication processes including several species of phytoplankton and macroalgae, fate and transport of metals, and simple and organic toxicants.

The eutrophication model (**Figure 2**) is based on the kinetics and processes included in the CE-QUAL-ICM model (Cerco and Cole 1995) and simulates in detail the impacts of nutrient enrichment on phytoplankton primary production and DO. This module simulates the fundamental biochemical processes controlling phytoplankton growth and death, nutrient cycling, and DO availability in the water column. The model in **Figure 2** is conceptually shown as a linear system where each box represents the pool of a specific water quality variable and the arrows indicate the internal sources and sinks. The DO module, for example, simulates DO as a function of several factors. The main sources of DO in the water column are atmospheric reaeration and phytoplankton and benthic algae production, while the major sinks are organic matter decomposition, nitrification, phytoplankton and benthic algae respiration, sediment oxygen demand, and under some circumstances oxygen release to the atmosphere. The external loads from point and nonpoint sources are also considered by the model, as well as the nutrient sediment fluxes (not shown in diagram). These loads are the ultimate forcing factors affecting the water quality of aquatic ecosystems.

A central component of the eutrophication module is the phytoplankton model. At present, the model can simulate up to three different groups of phytoplankton. The use of different phytoplankton groups allows the model to capture seasonal changes in productivity that occur as different phytoplankton populations grow or decay in response to nutrient availability, light, and temperature conditions. For the purpose of this project, only two different phytoplankton groups were activated in the EFDC model: (1) cyanobacteria and (2) green algae. The ultimate purpose of activating the two groups was to increase the flexibility of the model to capture (if necessary) off-seasonal peaks of phytoplankton (early spring or late fall blooms),

which are generally difficult to capture with only one group of algae. The use of two phytoplankton groups is reasonable given that, in practice, the measurement of phytoplankton is typically targeted to define the total levels of biomass (in units of chlorophyll-*a* or carbon) and rarely contains taxonomic analyses to identify the dominant groups of algae present at a particular location and time.

TABLE 122: DEFINITION OF WATER QUALITY VARIABLES SIMULATED IN EFDC

Variable/Definition	Simulated
Carbon	**-**
RPOC = Refractory Particulate Organic Carbon	Yes
LPOC = Labile Particulate Organic Carbon	Yes
DOC = Dissolved Organic Carbon	Yes
Algae	**-**
Bg = Green Algae	Yes
Bd = Diatom Algae	No
Bc = Cyanobacteria Algae	Yes
Bm = Macro Algae	No
Nitrogen	**-**
RPON = Refractory Particulate Organic Nitrogen	Yes
LPON = Labile Particulate Organic Nitrogen	Yes
DON = Dissolved Organic Nitrogen	Yes
NH4 = Ammonium	Yes
NOx = Nitrate + Nitrite	Yes
Oxygen	**-**
DO = Dissolved Oxygen	Yes
COD = Chemical Oxygen Demand	No
Phosphorus	**-**
RPOP = Refractory Particulate Organic Phosphorus	Yes
LPOP = Labile Particulate Organic Phosphorus	Yes
DOP = Dissolved Organic Phosphorus	Yes
PO4t = Total Orthophosphate	Yes
PO4d = Dissolved Orthophosphate	Yes
PO4p = Solid-sorbed/particulate Orthophosphate	No
Silica	**-**
SU = Unavailable Silica	No
SA = Available Biogenic Silica	No
SAd = Dissolved Available Silica	No
SAp = Particulate Available Silica	No
Metals	**-**
TAM = Total Active Metal	No
Solids	**-**
TSS = Total Suspended Solids	Yes
Biological	**-**
FCB = Fecal Coliform Bacteria	No

The processes simulated in **Figure 2** support the evaluation of eutrophication problems in aquatic ecosystems. Some of the most relevant constituents simulated include NOx, NH_4, OrgN, PO_4, OrgP, chlorophyll-*a*, DO, and carbon. In the EFDC model, the organic forms of nitrogen, phosphorus, and carbon are further discretized into refractory, labile, and dissolved forms, which reflect organic compounds of low, medium, and immediate availability for mineralization, respectively.

The fate and transport of nitrogen is modeled by using a mechanistic representation of the nitrogen cycle in natural environments. The EFDC model simulates the mineralization of OrgN, nitrification and denitrification of inorganic nitrogen, phytoplankton uptake of nitrogen, and recycle of phytoplankton nitrogen into the organic pool of nitrogen during phytoplankton respiration and death. The transformation rates are temperature dependent and calibrated for a particular location. Nitrogen has a direct impact in the phytoplankton dynamics and can be a limiting factor for development.

Phosphorus, like nitrogen, is a critical nutrient for phytoplankton development. In the EFDC model, phosphorus can mineralize from the organic forms into the inorganic forms and become available for phytoplankton uptake. The phytoplankton phosphorus can be recycled into the pool of OrgP during phytoplankton respiration and death.

Phytoplankton biomass is internally simulated in carbon units in the EFDC model but can be converted to chlorophyll-*a* units to allow for the comparison of model results against field observations. The conversion requires the definition of a carbon-to-chlorophyll-*a* ratio, which expresses a typical concentration of chlorophyll-*a* present in a phytoplankton cell per unit mass of carbon. This ratio was defined through calibration based on published values from similar estuarine water quality studies (Camacho et al. 2014; Lin et al. 2007, Lin et al. 2008; Park et al. 2005; Ambrose et. al. 1993; and Garcia et al. 2010).

Finally, the EFDC model simulates DO as a function of several factors. The main sources of DO in the water column are atmospheric reaeration and phytoplankton production, while the major sinks are organic matter oxidation, nitrification, phytoplankton respiration, and sediment oxygen demand.

3.5.1 Calibration and Validation Stations

The calibration of the 2017 EFDC water quality model was based on observations collected between January 1, 2010 and December 31, 2014, and validation to observations collected between January 1, 1996 and December 31, 2009. Tetra Tech compared modeled water quality outputs to measured records available at different monitoring stations located throughout the estuary (**Table 123** and **Figure 99** and **Figure 100**). The location of the SCCF stations used for the light extinction calibration and validation are provided in **Figure 140**.

TABLE 123: 2017 EFDC MODEL WATER QUALITY CALIBRATION AND VALIDATION STATIONS

Station ID	Station Name	Purpose
21FLEECO29-8GR	Telegraph Creek	Calibration, Validation
21FLEECOCES03SUR	Caloosahatchee Waterway at Route 31	Calibration, Validation
21FLFTM CALUSA0023FTM	Orange River	Calibration
21FLEECO23-5GR	Popash Creek	Calibration, Validation
21FLFTM CALUSA0008FTM	Caloosahatchee Waterway at Marker 22	Calibration, Validation
21FLEECOCES04SUR	Caloosahatchee Waterway at Marker 27	Calibration, Validation
21FLEECOBILLGR20	Billy Creek	Calibration, Validation

Station ID	Station Name	Purpose
21FLFTM CALUSA0011FTM	Caloosahatchee Waterway at Marker 52	Calibration, Validation
CAPECRD 350	Caloosahatchee Waterway east of Chantry Canal	Calibration, Validation
21FLEECOCES06SUR	Caloosahatchee Waterway at Marker 66	Calibration, Validation
21FLEECODEEPGR10	Deep Lagoon at McGregor Boulevard	Calibration, Validation
21FLFTM CALUSA0012FTM	Caloosahatchee Waterway at Marker 76	Calibration, Validation
21FLEECOCES10SUR	Caloosahatchee Waterway near mouth	Calibration, Validation
21FLFTM CALUSA0013FTM	Caloosahatchee Waterway at Marker 101	Calibration, Validation
21FLEECOPI-01	Caloosahatchee Waterway at Marker 13	Calibration, Validation
21FLEECOPI-14	Pine Island Station #14	Calibration, Validation
21FLCHARMPV004	Matlacha Pass at Marker 3	Calibration, Validation
21FLEECOPI-02	Pine Island Station #2	Calibration, Validation
21FLEECOPI-03	Pine Island Station #3	Calibration, Validation
21FLCHARSCV001	San Carlos Bay at Marker 12	Calibration, Validation
21FLEECOPI-13	Pine Island Station #13	Calibration, Validation
21FLEECOPI-12	Pine Island Station #12	Calibration, Validation
21FLCHARPIV007	Pine Island Sound	Calibration, Validation
21FLSFWMCES02	Caloosahatchee Waterway at Marker 2	Validation
21FLSFWMCES05	Caloosahatchee Waterway at Marker 54	Validation
21FLSFWMCES07	Caloosahatchee Waterway at Marker 83	Validation
21FLSFWMCES08	Caloosahatchee Waterway at Marker 96	Validation
21FLSFWMROOK474	Caloosahatchee Waterway at Marker 101	Validation
21FLSFWMCES09	Caloosahatchee Waterway at Marker 13	Validation
21FLSFWMROOK473	Caloosahatchee Waterway at Marker 13	Validation
21FLSFWMROOK471	Point Ybel R8	Validation
21FLSFWMROOK472	San Carlos Bay, R4	Validation
21FLSFWMROOK475	Pine Island Station #2	Validation
21FLSFWMROOK476	Daymarker 28	Validation
21FLSFWMROOK477	Pine Island Sound	Validation
BP	SCCF Buck Key Preserve (grab samples)	Calibration
FM	SCCF Fort Myers (grab samples)	Calibration
GOM	SCCF Gulf of Mexico (grab samples)	Calibration
RP	SCCF Redfish Pass (grab samples)	Calibration
SP	SCCF Shell Point (grab samples)	Calibration
TB	SCCF Tarpon Bay (grab samples)	Calibration

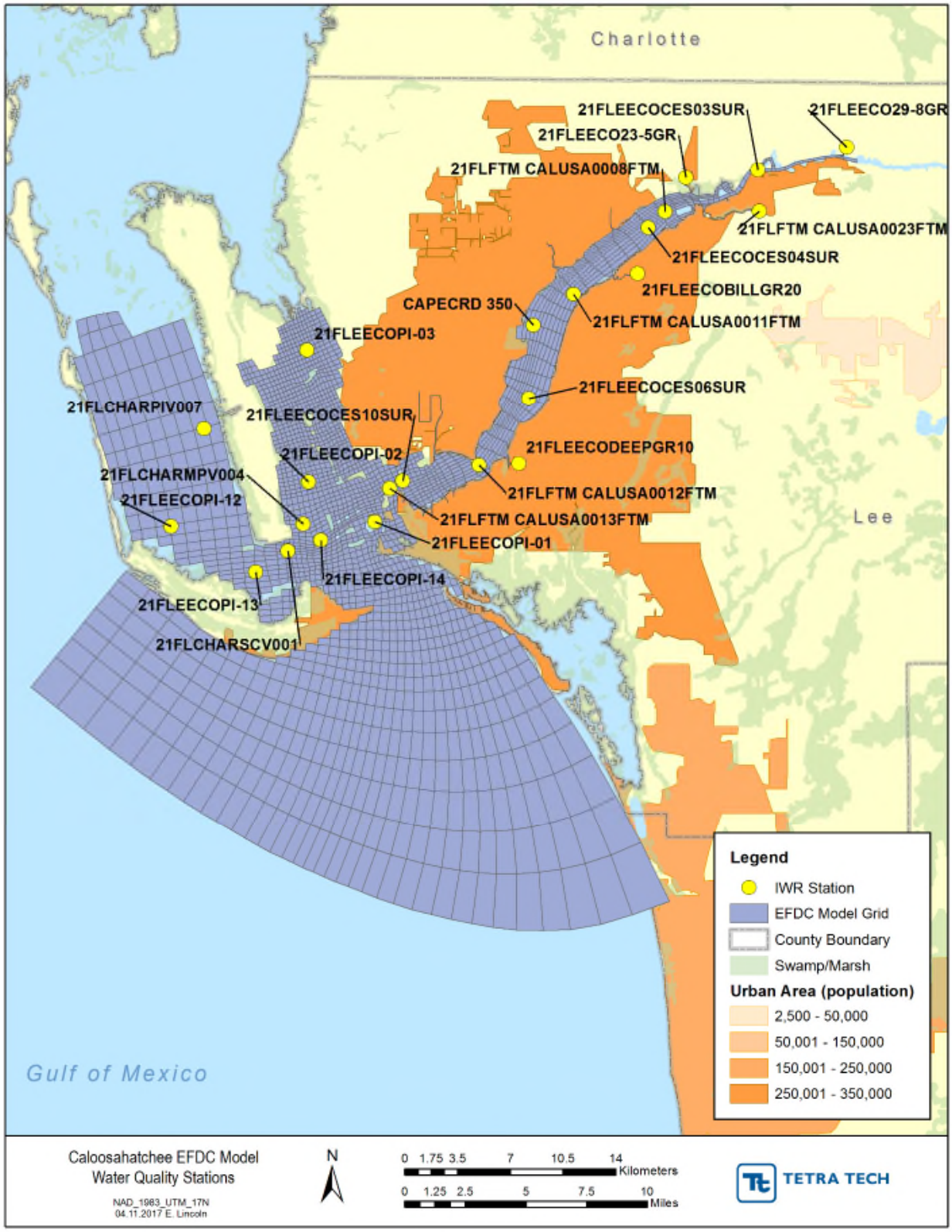

FIGURE 99: 2017 EFDC MODEL IWR WATER QUALITY CALIBRATION COMPARISON STATION LOCATIONS

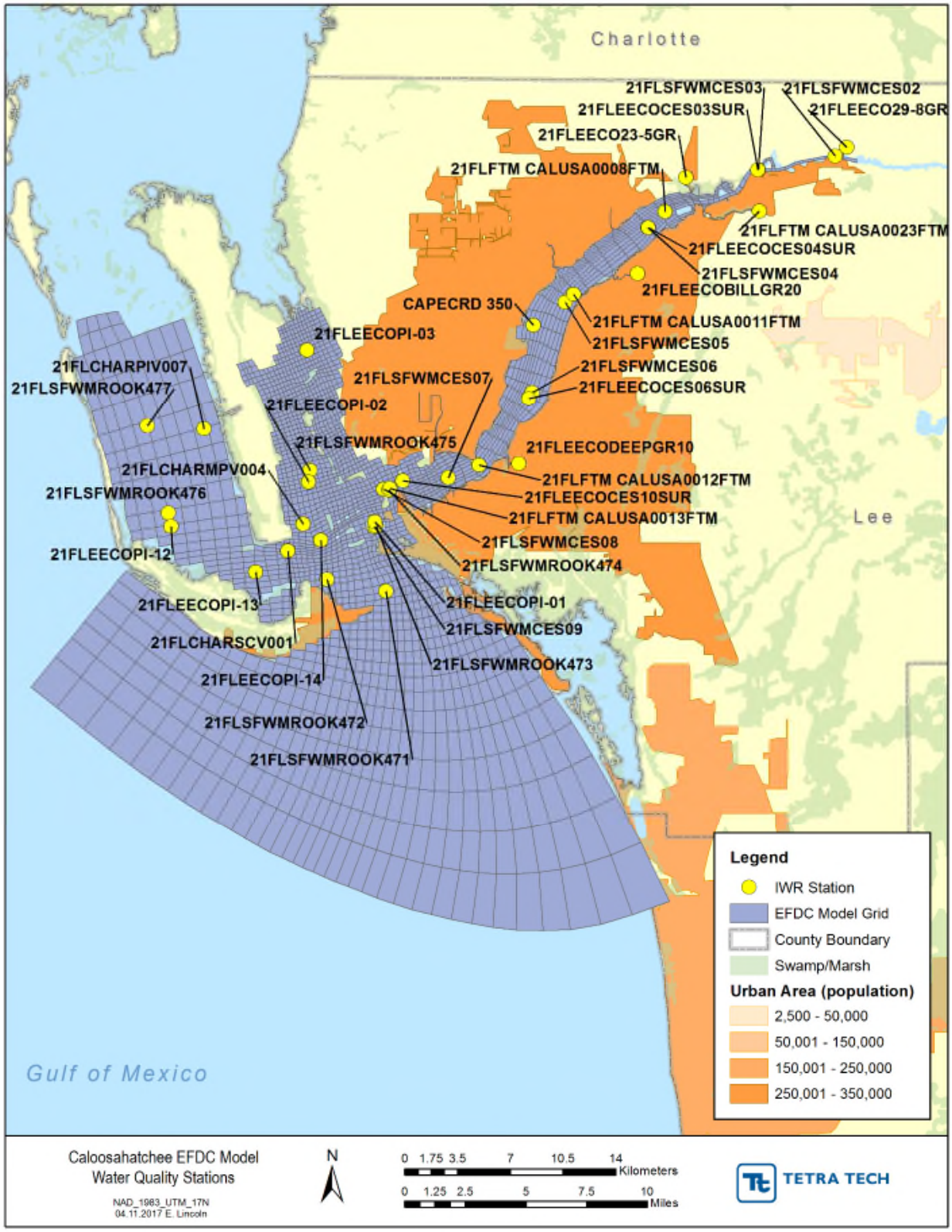

FIGURE 100: 2017 EFDC MODEL IWR WATER QUALITY VALIDATION COMPARISON STATION LOCATIONS

3.5.2 Calibration Methodology

To calibrate the water quality portion of the model, Tetra Tech used the same methodology as outlined in **Section 3.4.2** for the hydrodynamic portion of the model. A summary of the data available for the calibration of the water quality model (period 2010-2014) is presented in **Table 124**.

TABLE 124: SUMMARY OF AVAILABLE WATER QUALITY DATA FOR MODEL CALIBRATION (NUMBER OF OBSERVATIONS)

Station	Chla	DO	NH_4	NOx	TKN	TN	PO_4	TP	TOC	TSS
21FLCHARMPV004	55	58	-	57	55	55	-	55	-	-
21FLCHARPIV007	23	23	-	25	22	22	-	22	-	-
21FLCHARSCV001	47	48	-	49	48	48	-	47	-	-
21FLEECO23-5GR	58	58	58	58	58	58	58	58	-	58
21FLEECO29-8GR	51	51	51	51	51	51	51	51	-	51
21FLEECOBILLGR20	58	58	58	58	58	58	58	58	-	58
21FLEECOCES03SUR	58	58	-	58	58	58	-	58	58	-
21FLEECOCES04SUR	58	58	58	58	58	58	58	58	58	59
21FLEECOCES06SUR	57	57	-	57	57	57	-	56	57	57
21FLEECOCES10SUR	57	57	57	57	57	57	57	56	57	57
21FLEECODEEPGR10	57	57	57	57	57	57	57	57	-	57
21FLEECOPI-01	59	58	-	59	59	59	-	58	-	-
21FLEECOPI-02	11	11	-	11	11	11	-	11	-	-
21FLEECOPI-03	11	11	11	11	11	11	11	11	11	11
21FLEECOPI-12	11	11	-	11	11	11	-	11	-	-
21FLEECOPI-13	13	11	-	11	11	11	-	11	-	-
21FLEECOPI-14	11	11	-	11	11	11	-	11	-	-
21FLFTM CALUSA0008FTM	10	82	-	22	60	-	-	-	-	-
21FLFTM CALUSA0011FTM	60	60	-	59	59	59	-	59	-	60
21FLFTM CALUSA0012FTM	60	60	-	60	60	60	-	60	-	60
21FLFTM CALUSA0013FTM	61	60	-	61	61	61	-	61	-	60
21FLFTM CALUSA0023FTM	48	48	48	48	48	48	-	48	-	48
CAPECRD 350 (Surface)	119	174	-	48	241	241	-	229	-	-

During the calibration of the EFDC water quality model, Tetra Tech adjusted the parameters that control some of the most important chemical and biological processes related to nutrient cycling, phytoplankton production and respiration, and DO. The calibration was conducted as an iterative process. The parameters listed in the following section from **Table 125** to

Table 129 were manually adjusted during calibration in order to minimize the statistics MAE, RMSE, and NRMSE and to maximize the R^2 and IA. Similar to the calibration of the hydrodynamic model, model calibration was an iterative process. The parameters were defined for the first model run, typically using values from the 2014 Model. Parameters were adjusted during subsequent runs, and typically one parameter was adjusted at a time quantify the impact of the change on model calibration. Following parameter adjustments, the model was executed and the results were post-processed for both visual and statistical comparisons. The results were analyzed to determine if there was or was not an improvement in the model calibration, i.e. model appeared to better capture trends and magnitudes of measured data, and/or statistics showed an over prediction or under prediction compared to measured data. If model performance was unsatisfactory, parameters were adjusted again. If model performance was satisfactory or if the further parameter adjustment could not improve model calibration, the model was considered calibration.

The calibration adjustments were constrained to realistic parameter ranges and values reported in similar modeling studies (USEPA 2012; Camacho et al. 2014; Lin et al. 2007, Lin et al. 2008; Park et al. 2005; Ambrose et. al. 1993; and Garcia et al. 2010). **Table 125** through **Table 129** present a summary of the model parameter values used in the EFDC model.

The sediment fluxes of nitrogen, phosphorus, and oxygen demand were prescribed based on available measurements collected during 2008 (SMAST 2008) and 2014 (non-published SFWMD data, provided by department). The sediment oxygen demand rates included in the model were 0.4 mgO/m^2day in the region outside the mouth of the Caloosahatchee River, 0.6 mgO/m^2day in the Caloosahatchee River, 0.8 mgO/m^2day -day in the tributaries, and 0.8 mgO/m^2day -day in the marsh areas. The NH_4 rates included in the model were 0.001 mgN/m^2day in the region outside the mouth of the Caloosahatchee River, 0.0012 $mgN\ mgO/m^2day$ in the Caloosahatchee River, 0.01 mgN/m^2day -day in the tributaries, and 0.001 mgN/m^2day in the marsh areas. The NO_3 rates included in the model were 0.0001 mgN/m^2day in the region outside the mouth of the Caloosahatchee River, 0.003 $mgN\ mgO/m^2day$ in the Caloosahatchee River, 0.007 mgN/m^2day in the tributaries, and 0.007 mgN/m^2day in the marsh areas. The PO_4 rates included in the model were 0.0001 mgN/m^2day in the region outside the mouth of the Caloosahatchee River, 0.001 $mgN\ mgO/m^2day$ in the Caloosahatchee River, 0.001 mgN/m^2day in the tributaries, and 0.001 mgN/m^2day in the marsh areas. The sediment flux rates were referenced at 20°C and corrected for temperature using an Arrhenius model with coefficient factor of 1.047.

In the EFDC model, the impacts of temperature on the biological and kinetic water quality rates are simulated using Gaussian probability models with adjustable parameters instead of temperature corrections based on the Arrhenius equation. The rate of phytoplankton growth (P), for example, which is simulated as a function of nutrients (f_1), light (f_2) and temperature (f_3) by $P = P_{Max} * f_1 * f_2 * f_3$ (P_{Max} is the maximum growth rate), uses the following model for temperature:

$$f_3 = \begin{cases} \exp^{-KTG_1(T-T_1)^2} & : \quad T \leq T_1 \\ 1 & : T_1 < T < T_2 \\ \exp^{-KTG_2(T-T_2)^2} & : \quad T \geq T_2 \end{cases}$$

The above expression means that the phytoplankton production can occur at the maximum or optimum growth rate P_{Max} if the ambient water temperature is within a suitable range of temperatures T_1 and T_2. At lower or higher temperatures, the rate is reduced according to the Gaussian models defined above, but phytoplankton growth is still occurring. The change in growth rate depends on the values of the parameters KTG_1 and KTG_2, which are subject to calibration. The smaller the value, the smaller the attenuation of the growth rate.

TABLE 125: CONSTANTS AND PARAMETERS FOR ALGAE

Constant	EFDC Card	Cyanobacteria	Green Algae
Nitrogen Half-Saturation (mg/L)	08	0.01	0.01
Phosphorus Half-Saturation (mg/L)	08	0.001	0.001
Silica Half-Saturation (mg/L)	08	N/A	N/A
Carbon to Chlorophyll-*a* Ratio (mg C/ µg Chla)	09	0.040	0.040
Optimal Depth for Growth (m)	09	1.0	1.0
Lower Optimal Temperature for Growth (^{O}C)	11	20	24
Upper Optimal Temperature for Growth (^{O}C)	11	24	30
Suboptimal Temperature Coeff. for Growth	12	0.045	0.045

Constant	EFDC Card	Cyanobacteria	Green Algae
Super-optimal Temperature Coeff. for Growth	12	0.045	0.045
Reference Temperature for Metabolism (^{O}C)	13	20.0	20.0
Temperature Coeff. for Metabolism	13	0.069	0.069
Carbon Dist. Coeff. for Metabolism	14	0.350	0.100
Half-Saturation Const. for DOC Excretion (gO^2/m^3)	14	0.500	0.500
Phosphorus Dist. Coeff. of RPOP for Metabolism	18	0.100	0.100
Phosphorus Dist. Coeff. of LPOP for Metabolism	18	0.100	0.100
Phosphorus Dist. Coeff. of DOP for Metabolism	20	0.600	0.600
Phosphorus Dist. Coeff. of PO_4 for Metabolism	20	0.200	0.200
Nitrogen Dist. Coeff. of RPON for Metabolism	22	0.050	0.050
Nitrogen Dist. Coeff. of LPON for Metabolism	22	0.250	0.250
Nitrogen Dist. Coeff. of DON for Metabolism	24	0.300	0.300
Nitrogen Dist. Coeff. of DIN for Metabolism	24	0.400	0.400
Nitrogen to Carbon Ratio (mg N/ mg C)	24	0.200	0.200
Maximum Growth Rate (1/day)	NA	NA	NA
Open region outside estuary mouth	algaegro.inp	1.0	2.5
Riverine area	algaegro.inp	1.2	2.0
Tributaries	algaegro.inp	1.0	2.0
Marshes	algaegro.inp	1.0	2.0
Basal Metabolism Rate (1/day)	NA	NA	NA
Open region outside estuary mouth	algaegro.inp	0.12	0.08
Riverine area	algaegro.inp	0.12	0.12
Tributaries	algaegro.inp	0.07	0.07
Marshes	algaegro.inp	0.12	0.12
Predation Rate (1/day)	NA	NA	NA
Open region outside estuary mouth	algaegro.inp	0.08	0.1
Riverine area	algaegro.inp	0.08	0.1
Tributaries	algaegro.inp	0.06	0.06
Marshes	algaegro.inp	0.08	0.1
Settling Velocity (m/day)	46	0.020	0.020
Settling Velocity for Refractory POM (m/day)	46	0.050	

TABLE 126: CONSTANTS AND PARAMETERS FOR CARBON

Constant	EFDC Card	Value
Carbon Dist. Coeff. for Algae Predation – RPOC	14	0.350
Carbon Dist. Coeff. for Algae Predation – LPOC	14	0.550
Carbon Dist. Coeff. for Algae Predation – DOC	14	0.100
Minimum Dissolution Rate of RPOC (1/day)	16	0.005
Minimum Dissolution Rate of LPOC (1/day)	16	0.075
Minimum Dissolution Rate of DOC (1/day)*	16	0.050
Const. Relating RPOC Dissolution Rate to Total Chla	16	0.000
Const. Relating LPOC Dissolution Rate to Total Chla	16	0.000
Const. Relating POC Dissolution Rate to Total Chla	16	0.000
Reference Temperature for Hydrolysis (^{O}C)	17	20.0
Reference Temperature for Mineralization (^{O}C)	17	20.0
Temperature effect Const. for Hydrolysis	17	0.069
Temperature effect Const. for Mineralization	17	0.069

Constant	EFDC Card	Value
Oxic Respiration Half-Saturation Const. for DO (gO^2/m^3)	17	1.000
Half-Saturation Const. for Denitrification (gN/m^3)	17	0.100
Ratio of Denitrification Rate to Oxic DOC Respiration Rate	17	0.750

TABLE 127: CONSTANTS AND PARAMETERS FOR PHOSPHORUS

Constant	EFDC Card	Value
Phosphorus Dist. Coeff. for Algae Predation – RPOP	18	0.350
Phosphorus Dist. Coeff. for Algae Predation – LPOP	18	0.250
Phosphorus Dist. Coeff. for Algae Predation – DOP	18	0.200
Phosphorus Dist. Coeff. for Algae Predation – Inorganic P	18	0.200
Minimum Hydrolysis Rate (1/day) of RPOP	21	0.005
Minimum Hydrolysis Rate (1/day) of LPOP	21	0.075
Minimum Hydrolysis Rate (1/day) of DOP	21	0.100
Const. Relating Hydrolysis Rate of RPOP to Algae	21	0.000
Const. Relating Hydrolysis Rate of LPOP to Algae	21	0.000
Const. Relating Hydrolysis Rate of DOP to Algae	21	0.200
Constant 1 in determining Phosphorus to Carbon Ratio	21	42.0
Constant 2 in determining Phosphorus to Carbon Ratio	21	85.0
Constant 3 in determining Phosphorus to Carbon Ratio	21	200.0

TABLE 128: CONSTANTS AND PARAMETERS FOR NITROGEN

Constant	EFDC Card	Value
Nitrogen Dist. Coeff. for Algae Predation – RPON	22	0.150
Nitrogen Dist. Coeff. for Algae Predation – LPON	22	0.350
Nitrogen Dist. Coeff. for Algae Predation – DON	22	0.250
Nitrogen Dist. Coeff. for Algae Predation – Inorganic N	22	0.250
Maximum Nitrification Rate ($gN/m^3/day$)	25	0.05
Nitrification Half-Saturation Const. for DO	25	1.000
Nitrification Half-Saturation Const. for NH4	25	0.050
Reference Temperature for Nitrification (^OC)	25	27.0
Suboptimal Temperature Effect Const. for Nitrification	25	0.0045
Super-optimal Temperature Effect Const. for Nitrification	25	0.0045
Minimum Hydrolysis Rate (1/day) of RPON	26	0.005
Minimum Hydrolysis Rate (1/day) of LPON	26	0.0075
Minimum Hydrolysis Rate (1/day) of DON	26	0.01
Const. Relating Hydrolysis Rate of RPON to Algae	26	0.000
Const. Relating Hydrolysis Rate of LPON to Algae	26	0.000
Const. Relating Hydrolysis Rate of DON to Algae	26	0.000

TABLE 129: CONSTANTS AND PARAMETERS FOR DO

Constant	EFDC Card	Value
Stoichiometric Algae Oxygen to Carbon (gO^2/gC)	28	2.670
Stoichiometric Algae Oxygen to Nitrogen (gO^2/gN)	28	4.330
Reaeration Constant	28	3.933
Temperature Rate Constant for Reaeration	28	1.024
Reaeration Adjustment Factor	46	1.000

The calibration of the 2017 EFDC water quality model was based on observations collected between January 1, 2010 and December 31, 2014, and validation to observations collected between January 1, 1996 and December 31, 2009. Tetra Tech compared modeled water quality outputs to measured records available at different monitoring stations located throughout the estuary (summarized in **Section 3.5.1**). The following section contains the statistical analyses of the final calibration results, and select time series plots from stations located in the Caloosahatchee River. Time series results for all stations with observed data between January 1, 2010 and December 31, 2014, as well as time series results for all stations with observed data between January 1, 1996 and December 31, 2009 are presented in **Appendix D**.

The statistical analysis of the daily paired concentrations along were compared to Donigian (2002) and McCutcheon et. al. 1990 performance metrics and given a qualitative rating of Very Good (VG), Good (G), Fair (F), and Poor (P) (refer to **Section 1.2** for the details on these metrics). The summary of the annual comparison of DO, chlorophyll-*a*, TN, and TP concentrations during the calibration period are shown in **Table 130** and **Table 131**.

TABLE 130: SUMMARY OF DO AND CHLOROPHYLL-A CONCENTRATION COMPARISONS

Station ID	Station Name	DO Mean % Error	DO Mean % Error Rating	DO IA	DO IA Rating	Chla Mean % Error	Chla Mean % Error Rating	Chla IA	Chla IA Rating
21FLCHARMPV004	Matlacha Pass at Marker 3	4.8%	VG	0.77	VG	-9.7%	G	0.48	F
21FLCHARPIV007	Pine Island Sound	5.7%	VG	0.49	F	-39.6%	G	0.43	F
21FLCHARSCV001	San Carlos Bay at Marker 12	0.1%	VG	0.84	VG	-67.5%	P	0.12	P
21FLEECO23-5GR	Popash Creek	28.1%	G	0.50	F	17.6%	VG	0.65	G
21FLEECO29-8GR	Telegraph Creek	32.6%	F	0.58	F	45.6%	F	0.41	F
21FLEECOBILLGR20	Billy Creek	89.6%	P	0.43	F	-19.2%	VG	0.20	P
21FLEECOCES03SUR	Caloosahatchee Waterway at Route 31	-13.1%	VG	0.79	G	-25.7%	VG	0.30	P
21FLEECOCES04SUR	Caloosahatchee Waterway at Marker 27	-5.4%	VG	0.92	VG	46.7%	F	0.36	F
21FLEECOCES06SUR	Caloosahatchee Waterway at Marker 66	-10.1%	VG	0.78	G	28.7%	VG	0.30	P
21FLEECOCES10SUR	Caloosahatchee Waterway near mouth	0.3%	VG	0.86	VG	115.2%	P	0.39	F
21FLEECODEEPGR10	Deep Lagoon at McGregor Boulevard	11.8%	VG	0.64	F	62.9%	P	0.40	F
21FLEECOPI-01	Caloosahatchee Waterway at Marker 13	-0.1%	VG	0.92	VG	24.3%	VG	0.43	F
21FLEECOPI-02	Pine Island Station #2	4.8%	VG	0.90	VG	117.3%	P	0.28	P
21FLEECOPI-03	Pine Island Station #3	-0.2%	VG	0.93	VG	44.9%	G	0.29	P
21FLEECOPI-12	Pine Island Station #12	-13.1%	VG	0.81	VG	33.6%	G	0.69	G
21FLEECOPI-13	Pine Island Station #13	-16.5%	G	0.76	VG	31.5%	G	0.72	G
21FLEECOPI-14	Pine Island Station #14	-15.1%	G	0.71	G	94.8%	P	0.35	F
21FLFTM CALUSA0008FTM	Caloosahatchee Waterway at Marker 22	-18.9%	G	0.77	VG	-67.4%	P	0.28	P
21FLFTM CALUSA0011FTM	Caloosahatchee Waterway at Marker 52	-14.9%	VG	0.68	G	-36.0%	G	0.28	P
21FLFTM CALUSA0012FTM	Caloosahatchee Waterway at Marker 76	-9.4%	VG	0.55	F	-16.2%	VG	0.13	P
21FLFTM CALUSA0013FTM	Caloosahatchee Waterway at Marker 101	-2.2%	VG	0.70	G	0.7%	VG	0.25	P
21FLFTM CALUSA0023FTM	Orange River	5.6%	VG	0.35	F	-37.0%	G	0.23	P
CAPECRD 350	Caloosahatchee Waterway east of Chantry Canal	0.9%	VG	0.71	G	no data	no data	no data	no data

TABLE 131: SUMMARY OF TN AND TP CONCENTRATION COMPARISONS

Station ID	Station Name	TN Mean % Error	TN Mean % Error Rating	TN IA	TN IA Rating	TP Mean % Error	TP Mean % Error Rating	TP IA	TP IA Rating
21FLCHARMPV004	Matlacha Pass at Marker 3	-28.8%	VG	0.59	F	16.7%	VG	0.57	F
21FLCHARPIV007	Pine Island Sound	-33.2%	G	0.26	P	66.7%	P	0.38	F
21FLCHARSCV001	San Carlos Bay at Marker 12	-16.9%	VG	0.70	VG	25.0%	VG	0.60	F
21FLEECO23-5GR	Popash Creek	-27.6%	VG	0.37	F	-23.8%	VG	0.13	P
21FLEECO29-8GR	Telegraph Creek	10.2%	VG	0.59	F	42.9%	G	0.22	P
21FLEECOBILLGR20	Billy Creek	-38.2%	G	0.33	P	-14.8%	VG	0.35	F
21FLEECOCES03SUR	Caloosahatchee Waterway at Route 31	-14.7%	VG	0.71	G	0.0%	VG	0.41	F
21FLEECOCES04SUR	Caloosahatchee Waterway at Marker 27	-17.7%	VG	0.72	G	0.0%	VG	0.40	F
21FLEECOCES06SUR	Caloosahatchee Waterway at Marker 66	-13.0%	VG	0.74	G	37.5%	G	0.54	F
21FLEECOCES10SUR	Caloosahatchee Waterway near mouth	-4.4%	VG	0.73	G	50.0%	F	0.57	F
21FLEECODEEPGR10	Deep Lagoon at McGregor Boulevard	-27.8%	VG	0.51	F	30.0%	G	0.44	F
21FLEECOPI-01	Caloosahatchee Waterway at Marker 13	-12.4%	VG	0.55	F	50.0%	F	0.49	F
21FLEECOPI-02	Pine Island Station #2	12.0%	VG	0.55	F	25.0%	VG	0.36	F
21FLEECOPI-03	Pine Island Station #3	-8.8%	VG	0.66	G	66.7%	P	0.22	P
21FLEECOPI-12	Pine Island Station #12	-24.3%	VG	0.19	P	100.0%	P	0.10	P
21FLEECOPI-13	Pine Island Station #13	-24.0%	VG	0.19	P	100.0%	P	0.09	P
21FLEECOPI-14	Pine Island Station #14	-18.2%	VG	0.39	F	66.7%	P	0.27	P
21FLFTM CALUSA0011FTM	Caloosahatchee Waterway at Marker 52	4.9%	VG	0.75	VG	10.0%	VG	0.54	F
21FLFTM CALUSA0012FTM	Caloosahatchee Waterway at Marker 76	7.6%	VG	0.86	VG	37.5%	G	0.61	F
21FLFTM CALUSA0013FTM	Caloosahatchee Waterway at Marker 101	3.2%	VG	0.85	VG	33.3%	G	0.67	G
21FLFTM CALUSA0023FTM	Orange River	-0.9%	VG	0.47	F	40.0%	G	0.35	F
CAPECRD 350	Caloosahatchee Waterway east of Chantry Canal	36.2%	G	0.42	F	266.7%	P	0.39	F

3.5.3 DO

The average concentration of DO in the Caloosahatchee River and Estuary was approximately 7.5 mg/L and varies seasonally between 2 mg/L and 10 mg/L (**Figure 101** through **Figure 105**). The highest concentrations occurred during the winter and spring seasons, with observed concentrations typically above 7 mg/L across the estuary, while the minimum concentrations occurred during the summer and early fall seasons. During these periods, concentrations were typically below 6 mg/L and dropped as low as 2 mg/L, particularly in the upper regions of the system (e.g. station 21FLEECOCES03SUR in **Figure 101**).

The comparison between the model predictions and the available observations indicated that the model was able to predict the temporal dynamics and spatial variability of DO in the Caloosahatchee River and Estuary (**Figure 101** through **Figure 105**, **Table 132**, and **Appendix D**). Nearly 75% of the stations had percent error differences in the Very Good range.

The model successfully captured the trends and ranges of DO variation observed during the calibration period, as well as the timing and magnitude of important changes in DO levels, such as the seasonal drops of oxygen concentrations observed at stations in the Caloosahatchee River. In most stations, particularly those located in the main stem of the Caloosahatchee River, the model predictions matched the observations within a ± 1 mg/L error range (**Table 132**). The model also performed very well at matching the observations in Matlacha Pass and Pine Island Sound, with the observations typically within a ± 1 mg/L error range. In other stations, particularly located in the system of small tributaries (see **Appendix D**), the model tended to slightly over predict the levels of DO.

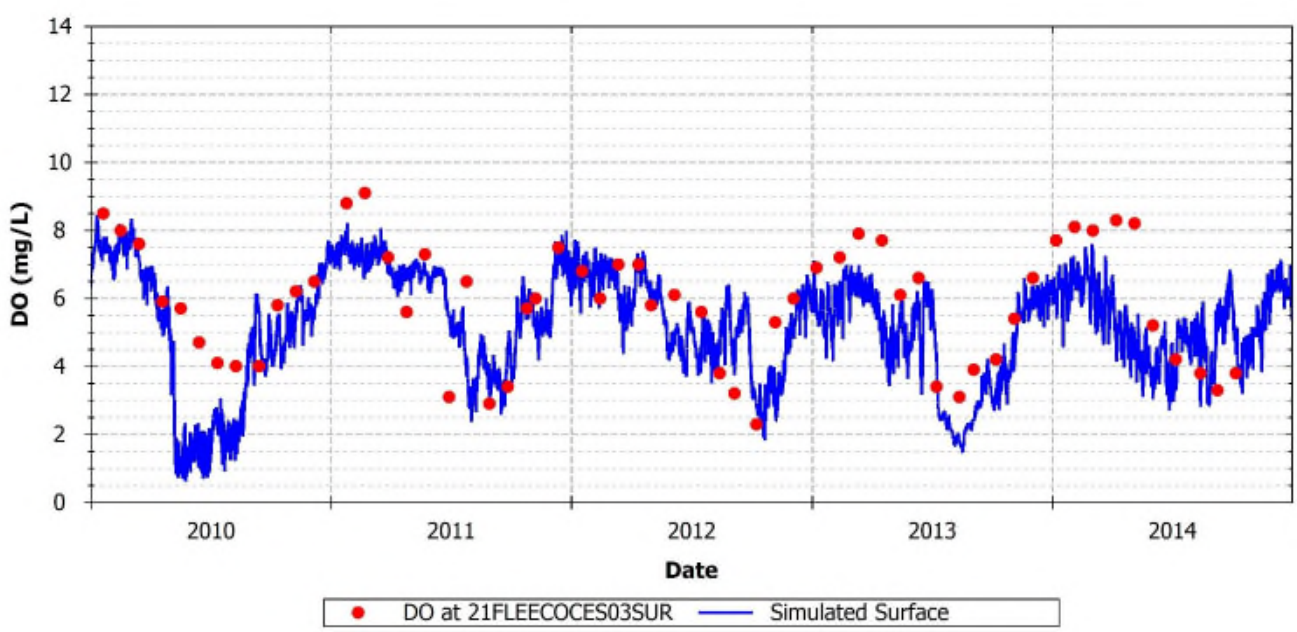

FIGURE 101: SIMULATED AND OBSERVED DO AT 21FLEECOCES03SUR

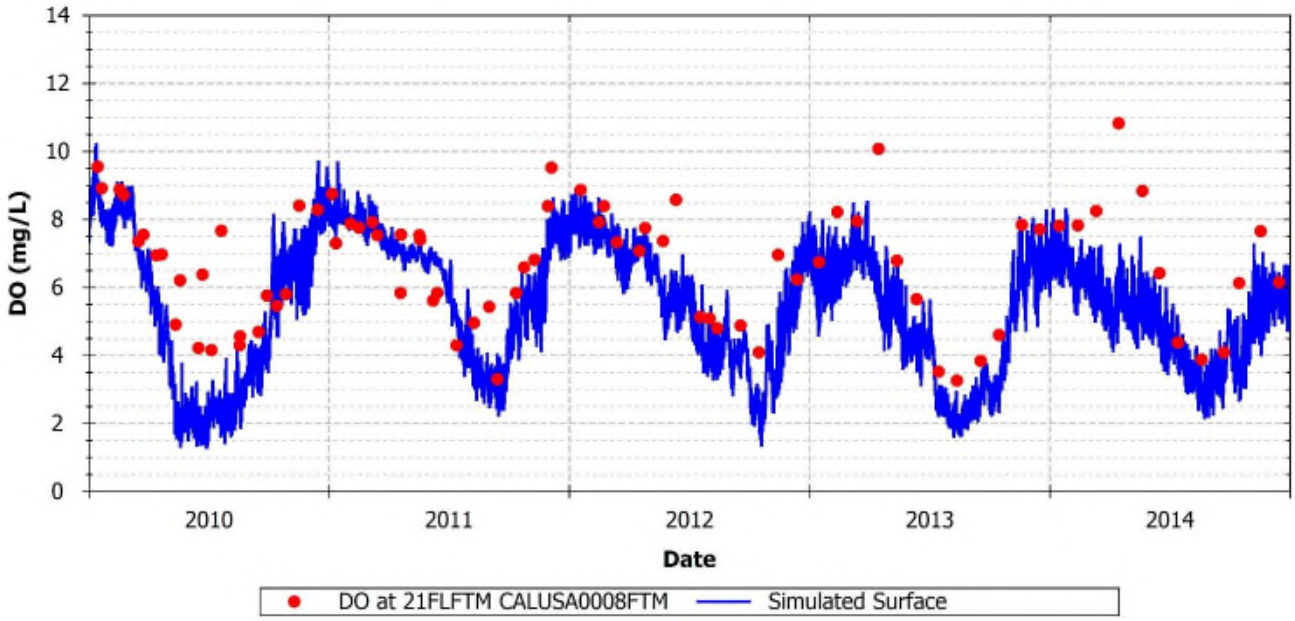

FIGURE 102: SIMULATED AND OBSERVED DO AT 21FLFTM CALUSA0008FTM

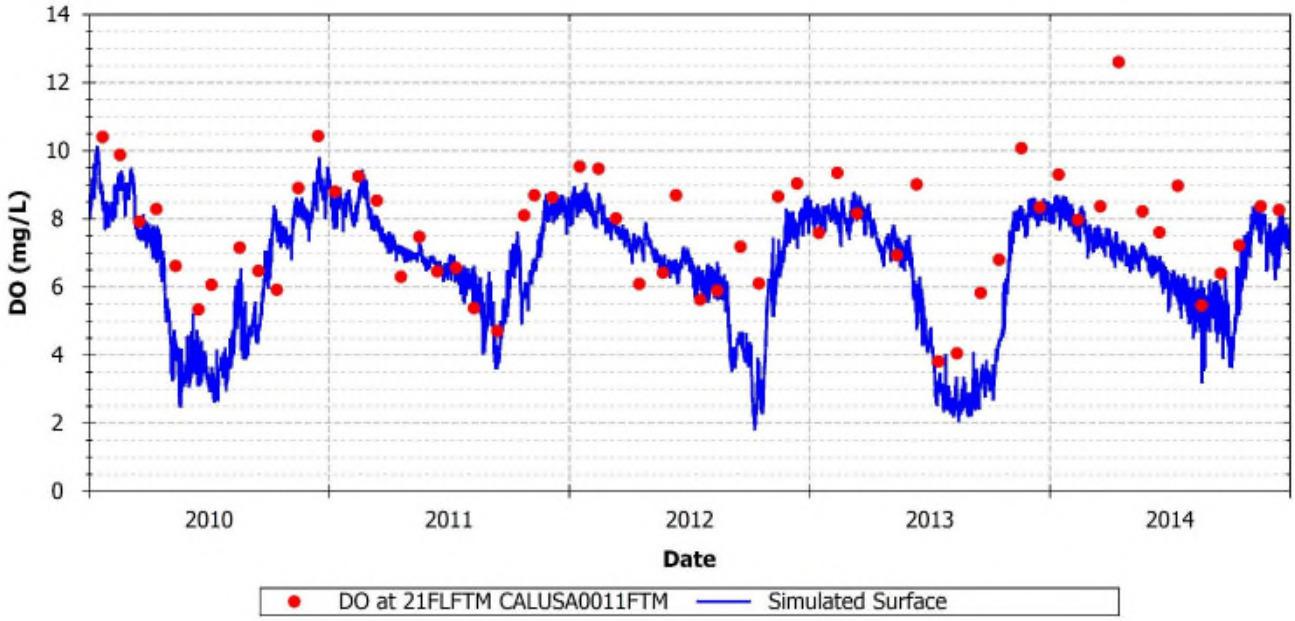

FIGURE 103: SIMULATED AND OBSERVED DO AT 21FLFTM CALUSA0011FTM

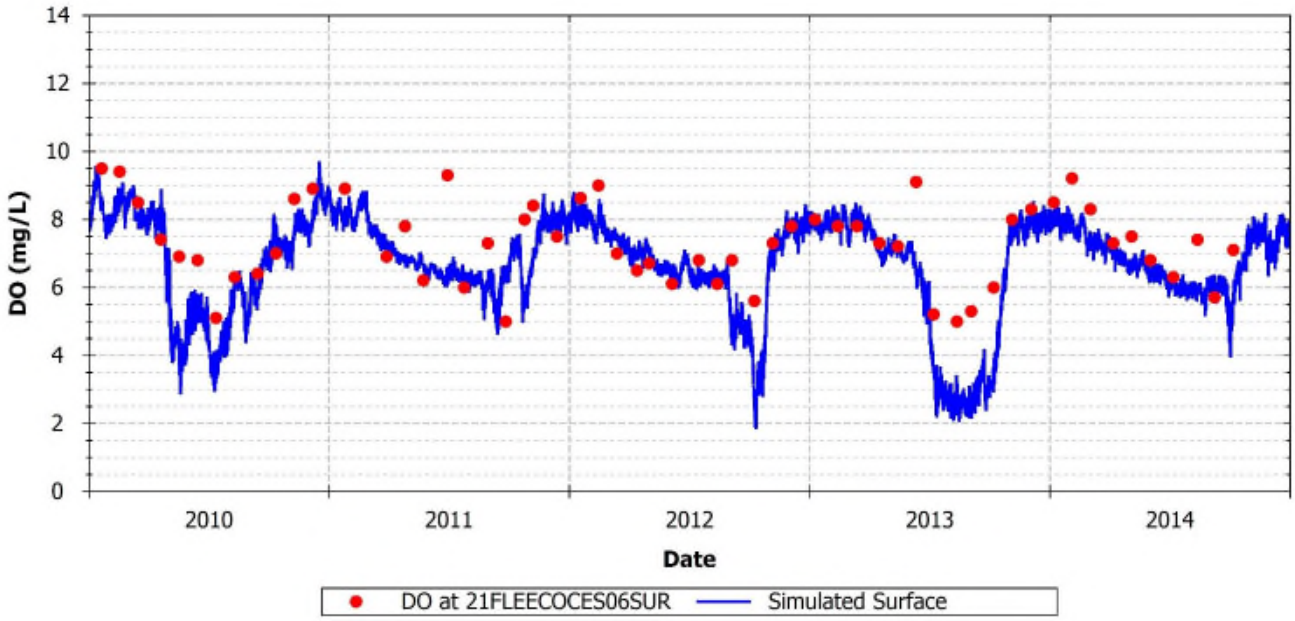

FIGURE 104: SIMULATED AND OBSERVED DO AT 21FLEECOCES06SUR

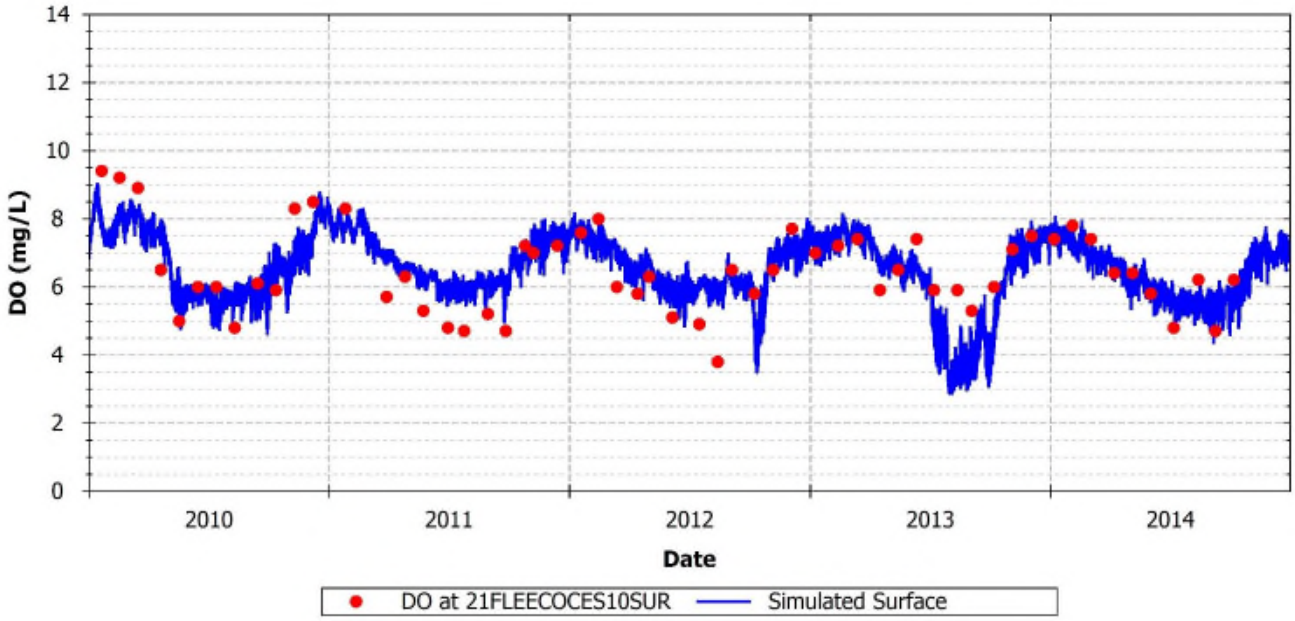

FIGURE 105: SIMULATED AND OBSERVED DO AT 21FLEECOCES10SUR

TABLE 132: CALIBRATION STATISTICS FOR DO

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLCHARMPV004	6.31	6.35	5.20	7.91	6.62	6.80	5.54	7.76	0.43	0.59	0.71	0.11	0.77	4.8%
21FLCHARPIV007	6.29	6.32	4.16	8.78	6.64	6.46	5.86	8.01	0.12	1.07	1.31	0.20	0.49	5.7%
21FLCHARSCV001	6.13	6.10	5.00	7.51	6.14	6.40	4.64	7.51	0.53	0.48	0.58	0.09	0.84	0.1%
21FLEECO23-5GR	4.24	4.60	1.70	6.31	5.43	5.98	2.49	7.91	0.02	1.67	2.25	0.47	0.50	28.1%
21FLEECO29-8GR	4.85	5.00	2.30	7.96	6.42	7.00	3.77	8.34	0.22	1.76	2.17	0.38	0.58	32.6%
21FLEECOBILLGR20	3.13	2.84	1.10	6.42	5.93	6.20	3.56	7.70	0.25	2.92	3.15	0.71	0.43	89.6%
21FLEECOCES03SUR	5.84	6.10	3.09	8.52	5.07	5.51	1.75	7.45	0.49	1.21	1.54	0.27	0.79	-13.1%
21FLEECOCES04SUR	6.15	6.80	3.59	8.21	5.82	6.55	2.11	8.65	0.79	0.74	0.98	0.16	0.92	-5.4%
21FLEECOCES06SUR	7.29	7.39	5.09	9.31	6.56	7.00	2.86	8.35	0.53	0.95	1.30	0.19	0.78	-10.1%
21FLEECOCES10SUR	6.44	6.40	4.70	8.93	6.46	6.66	4.62	8.10	0.58	0.66	0.80	0.12	0.86	0.3%
21FLEECODEEPGR10	5.07	4.97	1.27	10.68	5.67	6.05	3.55	7.62	0.42	1.91	2.31	0.42	0.64	11.8%
21FLEECOPI-01	6.38	6.55	4.60	8.24	6.37	6.58	4.66	8.04	0.75	0.44	0.55	0.09	0.92	-0.1%
21FLEECOPI-02	6.20	6.34	4.40	8.80	6.50	6.42	5.64	7.98	0.92	0.62	0.76	0.12	0.90	4.8%
21FLEECOPI-03	6.65	6.84	5.05	8.45	6.63	6.54	5.78	8.09	0.82	0.40	0.54	0.08	0.93	-0.2%
21FLEECOPI-12	6.94	7.00	5.50	8.55	6.03	5.87	4.88	7.81	0.79	0.91	1.03	0.16	0.81	-13.1%
21FLEECOPI-13	6.93	6.88	5.85	8.55	5.78	5.74	4.08	7.75	0.85	1.14	1.25	0.20	0.76	-16.5%
21FLEECOPI-14	7.29	7.06	6.20	8.85	6.19	6.27	5.01	7.93	0.57	1.10	1.30	0.19	0.71	-15.1%
21FLFTM CALUSA0008FTM	6.66	7.31	3.84	9.43	5.41	5.98	2.27	8.23	0.56	1.42	1.82	0.29	0.77	-18.9%
21FLFTM CALUSA0011FTM	7.82	8.19	4.74	10.43	6.65	7.22	3.14	8.78	0.35	1.42	2.09	0.28	0.68	-14.9%
21FLFTM CALUSA0012FTM	7.42	7.73	4.63	9.68	6.72	7.14	3.73	8.36	0.20	1.27	2.04	0.29	0.55	-9.4%
21FLFTM CALUSA0013FTM	6.68	6.87	3.96	10.26	6.54	6.56	4.91	8.06	0.41	0.99	1.43	0.21	0.70	-2.2%
21FLFTM CALUSA0023FTM	6.16	6.21	3.20	9.17	6.50	6.85	4.17	8.09	0.00	1.97	2.35	0.37	0.35	5.6%
CAPECRD 350	6.69	6.99	3.97	9.01	6.75	7.17	3.51	8.71	0.28	1.15	1.50	0.22	0.71	0.9%

3.5.4 Phytoplankton Biomass/Chlorophyll-a

The levels of phytoplankton biomass (in chlorophyll-*a* units) observed along the main stem of the Caloosahatchee River and Estuary generally fell within the range of 0.5 µg/L – 20 µg/L, while the values observed in the offshore area including the San Carlos Bay were lower and typically below 10 µg/L (**Figure 106** through **Figure 111**). Peaks of phytoplankton biomass during the calibration period reflect the existence of highly productive periods, potentially associated with algae blooms in the system. These highly productive events can occur at different periods each year, and may only occur at some locations in the Caloosahatchee River. For example, in 2013 an early spring bloom occurred at 21FLFTM CALUSA0011FTM but was not registered in other Caloosahatchee River stations. In 2010, the bloom appeared to occur in the fall.

The model predictions were in general able to reproduce the ranges of variation of phytoplankton biomass at the different stations evaluated (**Figure 106** through **Figure 114, Table 133**, and **Appendix D**). The productivity periods occurred in the model beginning in the fall through the spring seasons most years and at most stations. However, the measured data indicated that blooms occurred at different periods at each station throughout the modeling period, and typically began in the summer. Several model performance statistics, such as the R^2 and IA are directly impacted by the discrepancies in the timing of the productive season (**Table 133**). Other model performance statistics, such as MAE and the percent difference, were generally good and indicated that the model was able to capture the range of the measured data.

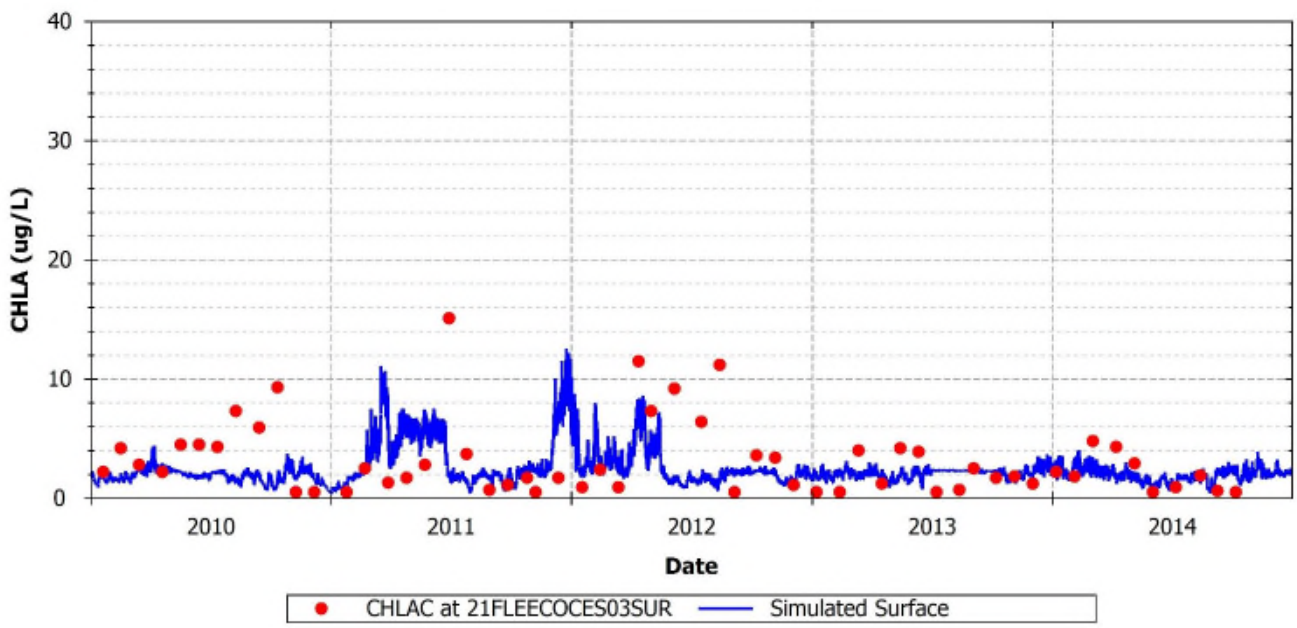

FIGURE 106: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLEECOCES03SUR

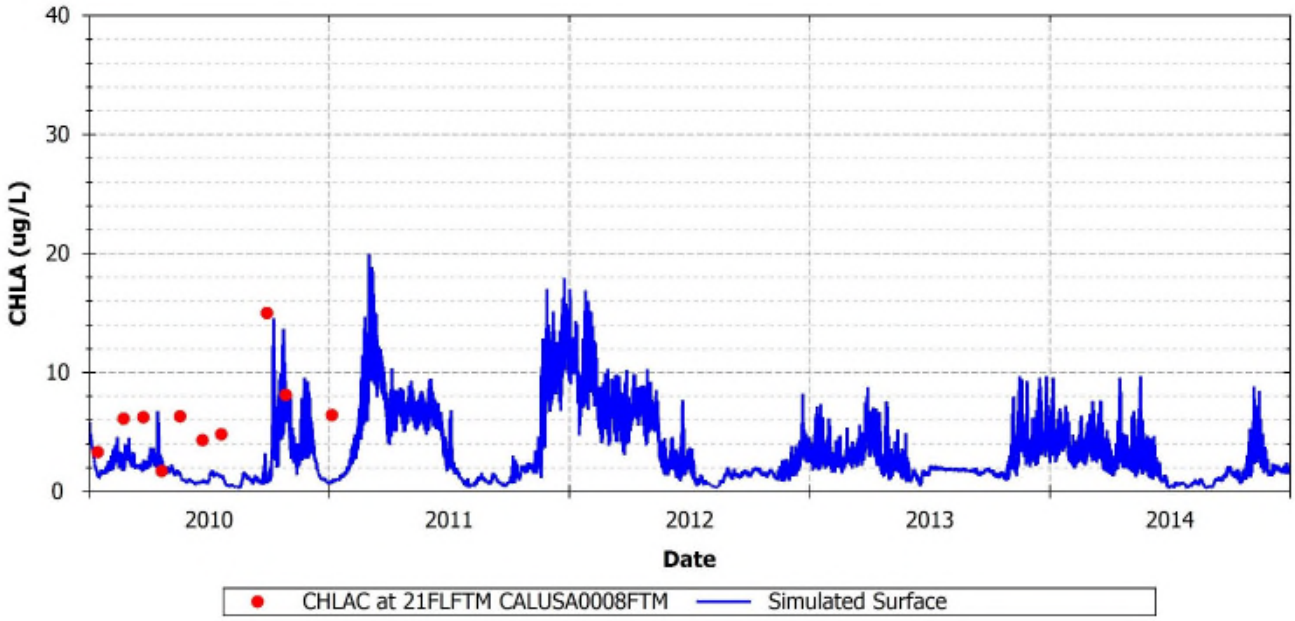

FIGURE 107: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLFTM CALUSA0008FTM

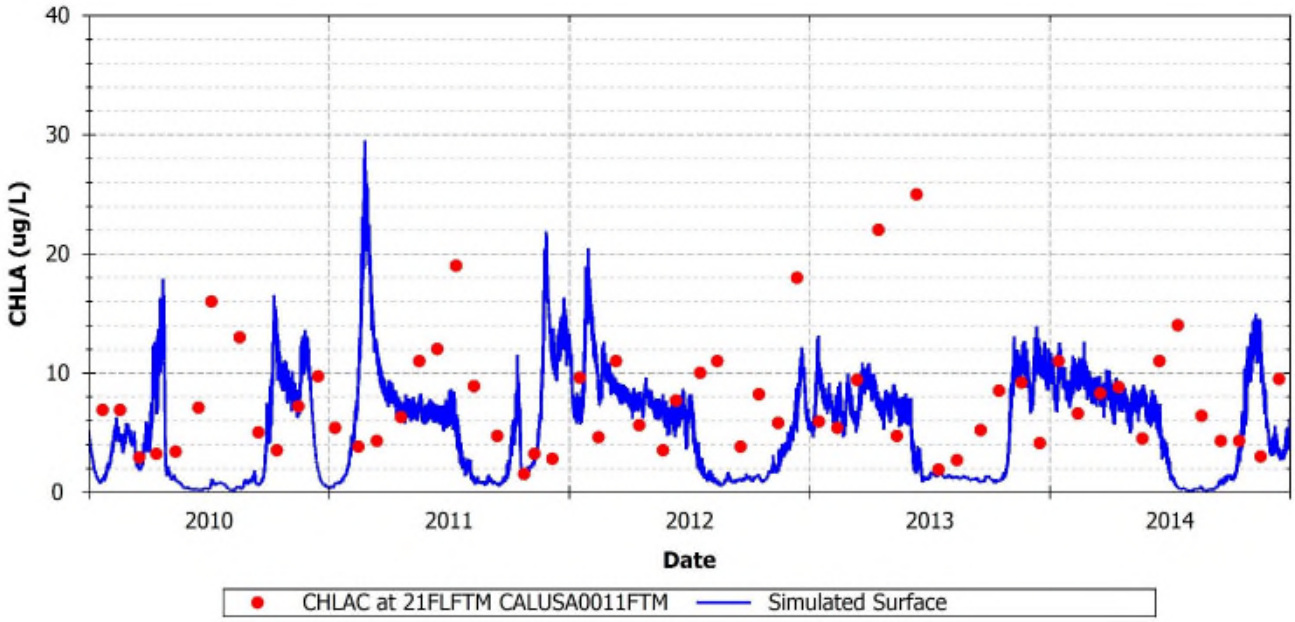

FIGURE 108: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLFTM CALUSA0011FTM

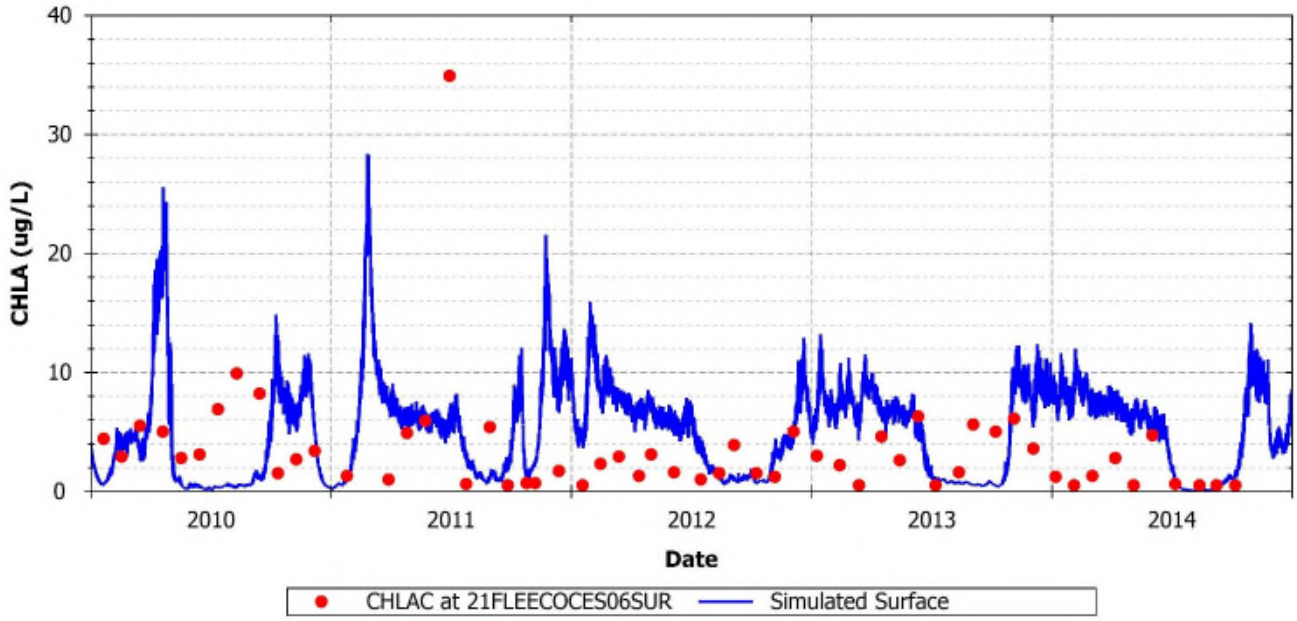

FIGURE 109: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLEECOCES06SUR

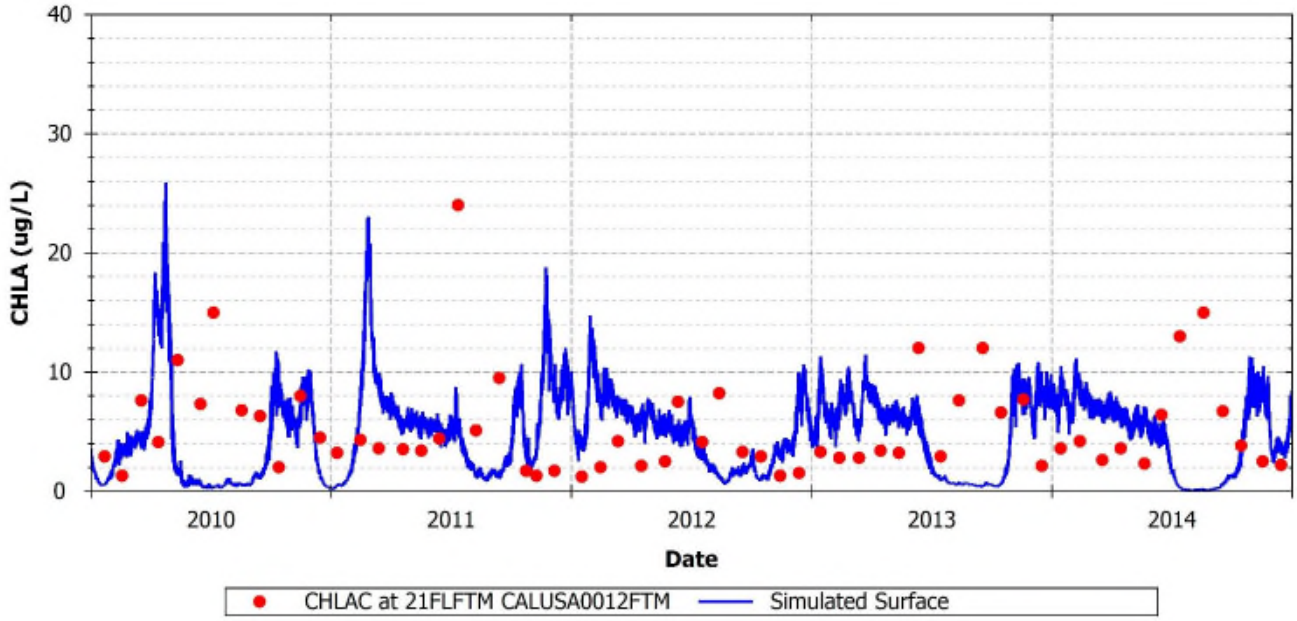

FIGURE 110: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLFTM CALUSA0012FTM

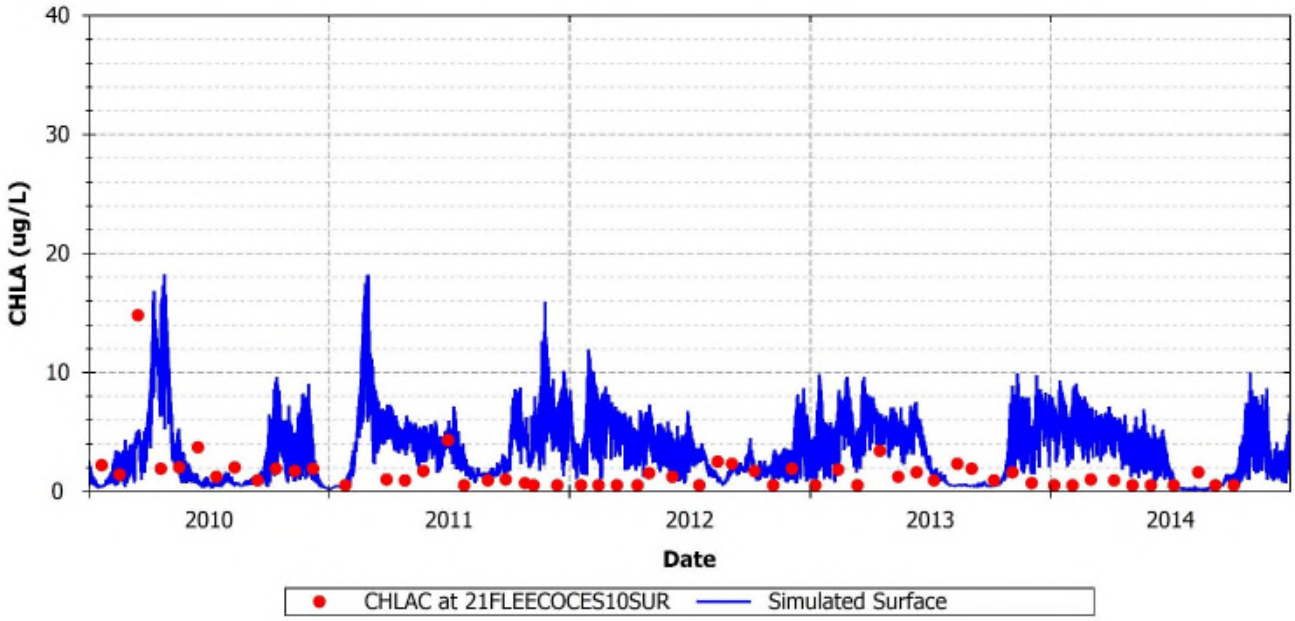

FIGURE 111: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLEECOCES10SUR

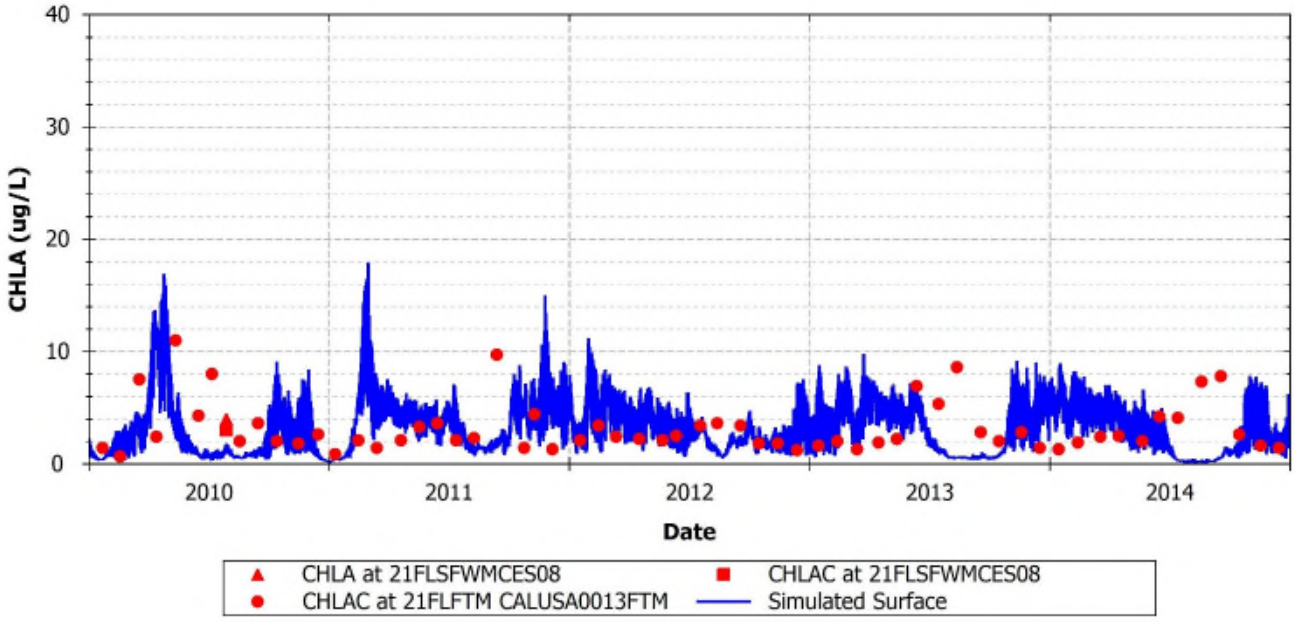

FIGURE 112: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLFTM CALUSA0013FTM

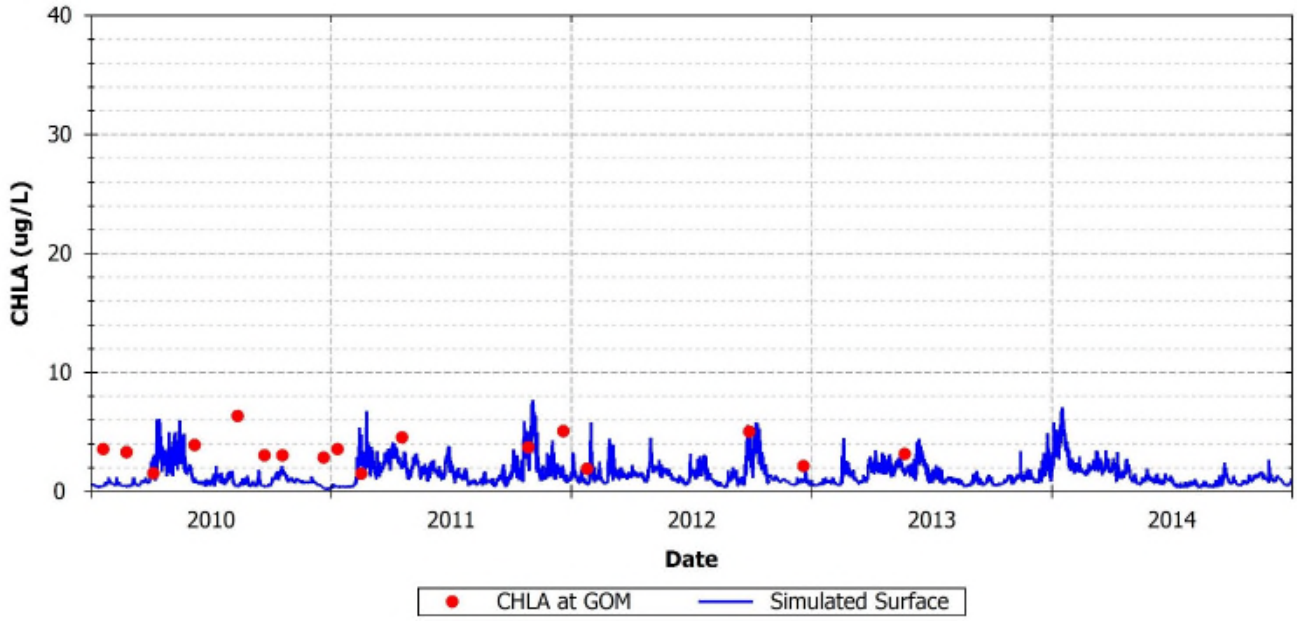

FIGURE 113: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT GULF OF MEXICO (GOM)

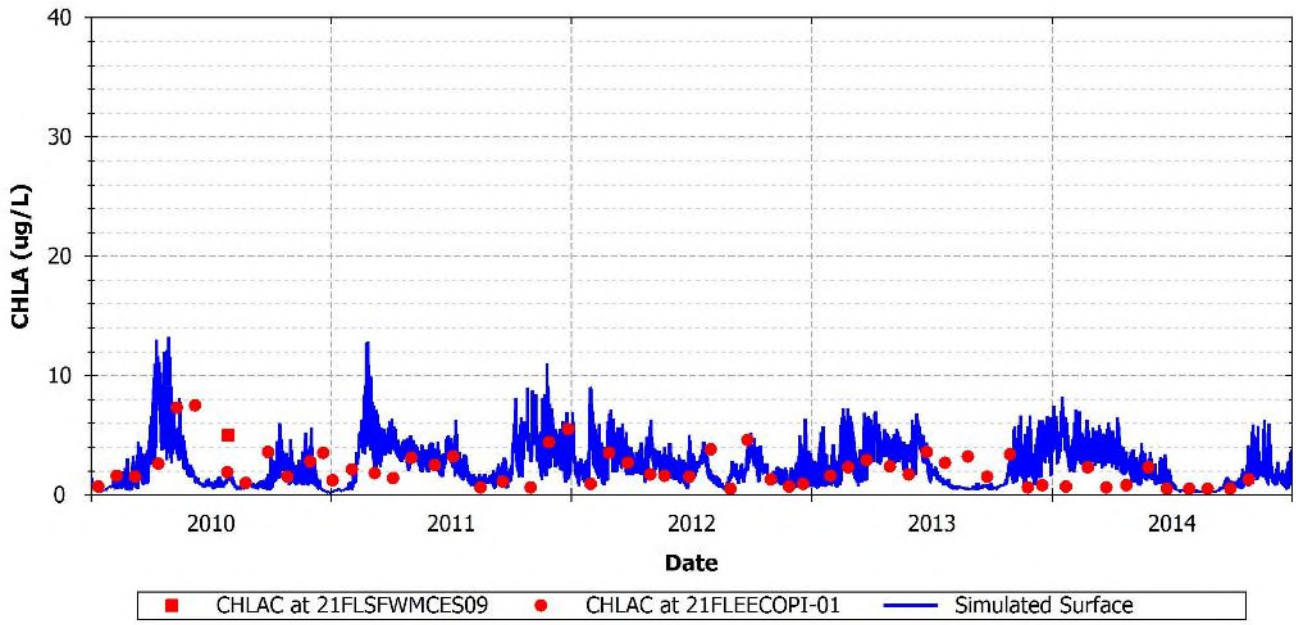

FIGURE 114: SIMULATED AND OBSERVED PHYTOPLANKTON BIOMASS AT 21FLSFWCES09 AND 21FLEECOPI-01

TABLE 133: CALIBRATION STATISTICS FOR PHYTOPLANKTON BIOMASS

Station	Measured Mean (µg/L)	Measured Median (µg/L)	Measured 5th %tile (µg/L)	Measured 95th %tile (µg/L)	Simulated Mean (µg/L)	Simulated Median (µg/L)	Simulated 5th %tile (µg/L)	Simulated 95th %tile (µg/L)	R^2	MAE (µg/L)	RMSE (µg/L)	NRMSE	IA	Percent Diff. (%)
21FLCHARMPV004	3.00	2.28	0.88	8.92	2.70	2.36	0.27	6.92	0.03	2.11	2.95	0.98	0.48	-9.7%
21FLCHARPIV007	5.22	4.58	0.59	13.60	3.16	3.46	0.36	6.75	0.13	3.14	4.19	0.97	0.43	-39.6%
21FLCHARSCV001	5.05	3.68	1.70	13.60	1.64	1.56	0.40	4.02	0.00	3.65	6.36	2.23	0.12	-67.5%
21FLEECO23-5GR	4.01	2.50	0.50	13.88	4.72	3.24	2.46	11.75	0.20	3.15	4.53	0.89	0.64	17.6%
21FLEECO29-8GR	2.22	0.90	0.50	5.74	3.24	2.59	1.55	8.71	0.13	2.69	5.28	1.56	0.41	45.6%
21FLEECOBILLGR20	4.06	2.60	0.50	19.37	3.28	2.82	2.41	5.86	0.03	3.17	6.27	1.64	0.20	-19.2%
21FLEECOCES03SUR	3.16	2.45	0.50	11.22	2.34	2.10	1.21	6.91	0.00	2.28	3.41	1.23	0.30	-25.7%
21FLEECOCES04SUR	2.61	2.09	0.50	11.15	3.83	3.86	0.47	9.66	0.01	3.08	4.33	1.41	0.36	46.7%
21FLEECOCES06SUR	3.41	2.80	0.50	8.37	4.39	5.29	0.32	9.61	0.00	3.97	5.93	1.51	0.30	28.7%
21FLEECOCES10SUR	1.52	1.20	0.50	3.76	3.27	3.61	0.41	6.57	0.00	2.65	3.49	1.54	0.39	115.2%
21FLEECODEEPGR10	3.34	2.47	0.50	11.90	5.45	6.25	1.09	11.99	0.00	4.31	5.77	1.38	0.40	62.9%
21FLEECOPI-01	2.13	1.85	0.50	5.59	2.65	2.49	0.29	5.89	0.01	1.75	2.49	1.03	0.43	24.3%
21FLEECOPI-02	1.03	0.80	0.50	2.60	2.23	2.53	0.15	4.41	0.25	2.13	2.41	1.88	0.28	117.3%
21FLEECOPI-03	1.72	1.20	0.50	5.20	2.49	3.23	0.08	5.01	0.03	2.52	3.04	1.60	0.29	44.9%
21FLEECOPI-12	1.34	1.32	0.50	2.90	1.79	1.79	0.28	3.83	0.31	0.99	1.21	0.69	0.69	33.6%
21FLEECOPI-13	1.23	1.06	0.50	2.70	1.61	1.64	0.33	3.28	0.35	0.82	0.99	0.63	0.72	31.5%
21FLEECOPI-14	0.96	0.80	0.50	1.90	1.88	2.19	0.27	3.59	0.11	1.41	1.76	1.40	0.35	94.8%
21FLFTM CALUSA0008FTM	6.22	6.21	2.42	11.90	2.03	1.41	0.71	4.39	0.00	4.37	5.68	1.60	0.28	-67.4%
21FLFTM CALUSA0011FTM	7.70	7.01	2.71	18.95	4.93	5.98	0.37	11.79	0.01	5.31	6.98	1.16	0.28	-36.0%
21FLFTM CALUSA0012FTM	5.26	4.10	1.30	14.90	4.41	5.17	0.31	9.01	0.12	4.86	6.13	1.42	0.13	-16.2%
21FLFTM CALUSA0013FTM	3.16	2.40	1.21	8.57	3.18	3.01	0.37	6.31	0.06	2.78	3.58	1.21	0.25	0.7%
21FLFTM CALUSA0023FTM	4.72	3.10	0.90	15.65	2.98	2.56	1.67	7.43	0.01	3.17	5.29	1.38	0.23	-37.0%

3.5.5 Nitrogen

The available TN observations in the Caloosahatchee River and Estuary in general varied between 0.4 mg/L and 2.5 mg/L for the simulation period (**Figure 115** through **Figure 124**). The availability of nitrogen is higher in the upstream riverine portion of the system where the average TN concentration was approximately 1.5 mg/L (e.g. stations 21FLEECOCES02SUR and 21FLEECOCES03SUR) and lower in the downstream riverine area and embayment area where the average concentration was approximately 0.7 mg/L (e.g. station 21FLEECOCES10SUR). The maximum concentrations of nitrogen typically occurred during the summer and fall seasons. The comparison between the model predictions and observations of TN indicated that the model successfully captured the timing, seasonal variability, and concentration levels observed during the calibration period throughout the estuary, including in San Carlos Bay, Matlacha Pass, and Pine Island Sound (**Figure 115** through **Figure 124, Table 134**, and **Appendix D**).

An evaluation of the observed species distribution of nitrogen suggested that the dominant form of nitrogen in the Caloosahatchee River was organic, while the inorganic forms, available for phytoplankton production, were substantially lower. Available observations of inorganic nitrogen showed levels of NH_4 frequently ranging between 0.015 mg/L and 0.36 mg/L, with average and median values close to 0.05 mg/L (**Table 136**). Levels of NOx frequently ranged between 0.01 mg/L and 0.33 mg/L, with average and median values of approximately 0.04 mg/L (**Table 136**). Concentrations of inorganic nitrogen (NH_4+NOx) were highest in tributaries and in the upper reach of the Caloosahatchee River, and decreased moving towards the open boundaries. Combined, the observed concentrations of inorganic nitrogen represent between 10% and 30% of the total TN budget. Although the organic forms of nitrogen can represent up to, or even more than, two-thirds of the TN budget, the observed levels of inorganic nitrogen in the system may be higher than in other estuaries of the Gulf of Mexico where nitrogen can act as a limiting factor for phytoplankton growth, such as in the St. Louis Bay Estuary, Mississippi (Tetra Tech 2013). A comparison of the model predictions and observations of NH_4 and NOx (**Figure 119** through **Figure 124**, **Table 135** and **Table 136, Appendix D**) indicated that the model was in general able to capture the seasonal patterns and concentration levels observed across the system.

3.5.5.1 TN

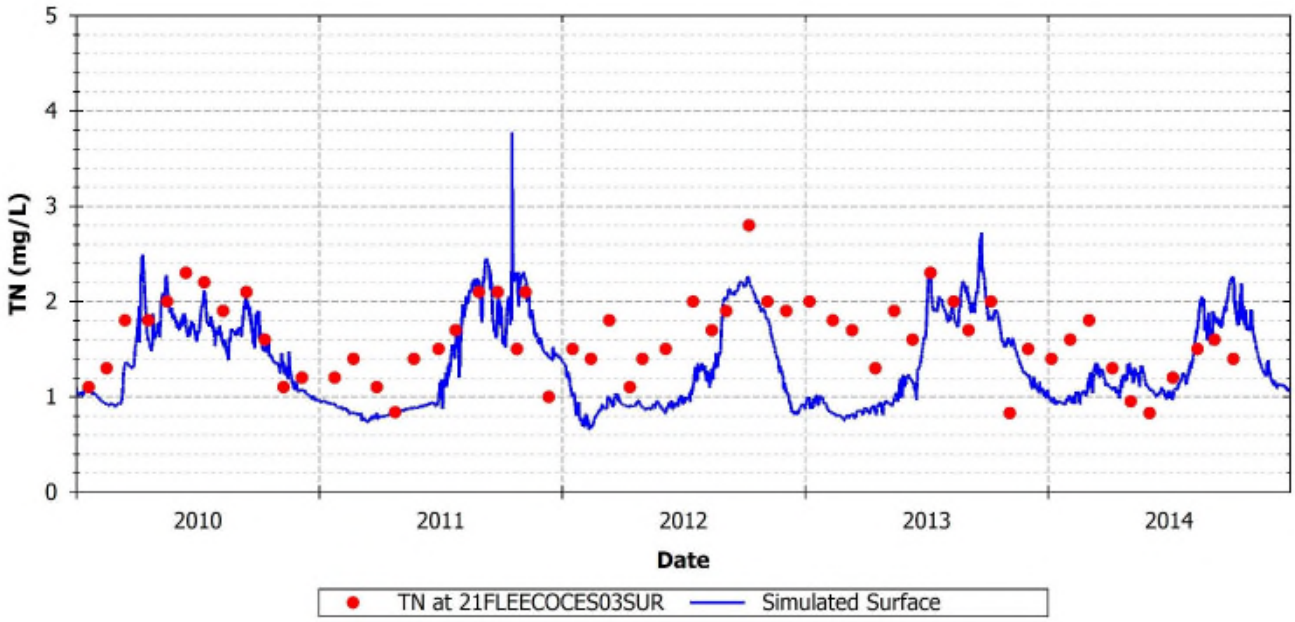

FIGURE 115: SIMULATED AND OBSERVED TN AT 21FLEECOCES03SUR

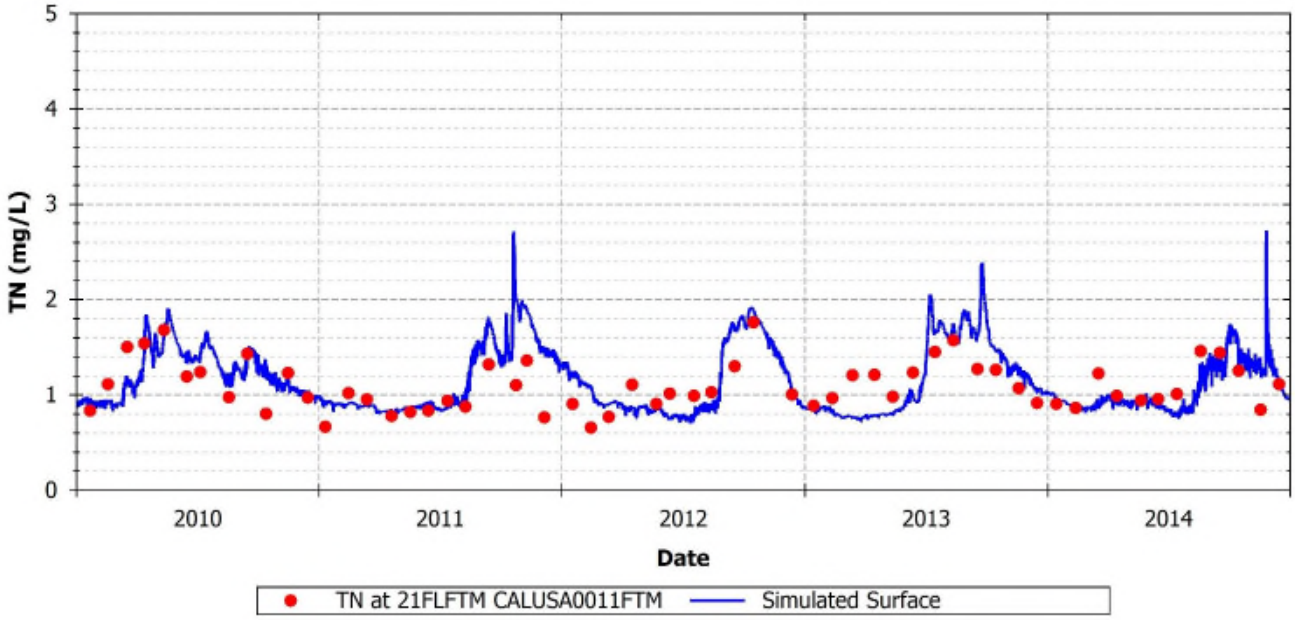

FIGURE 116: SIMULATED AND OBSERVED TN AT 21FLFTM CALUSA0011FTM

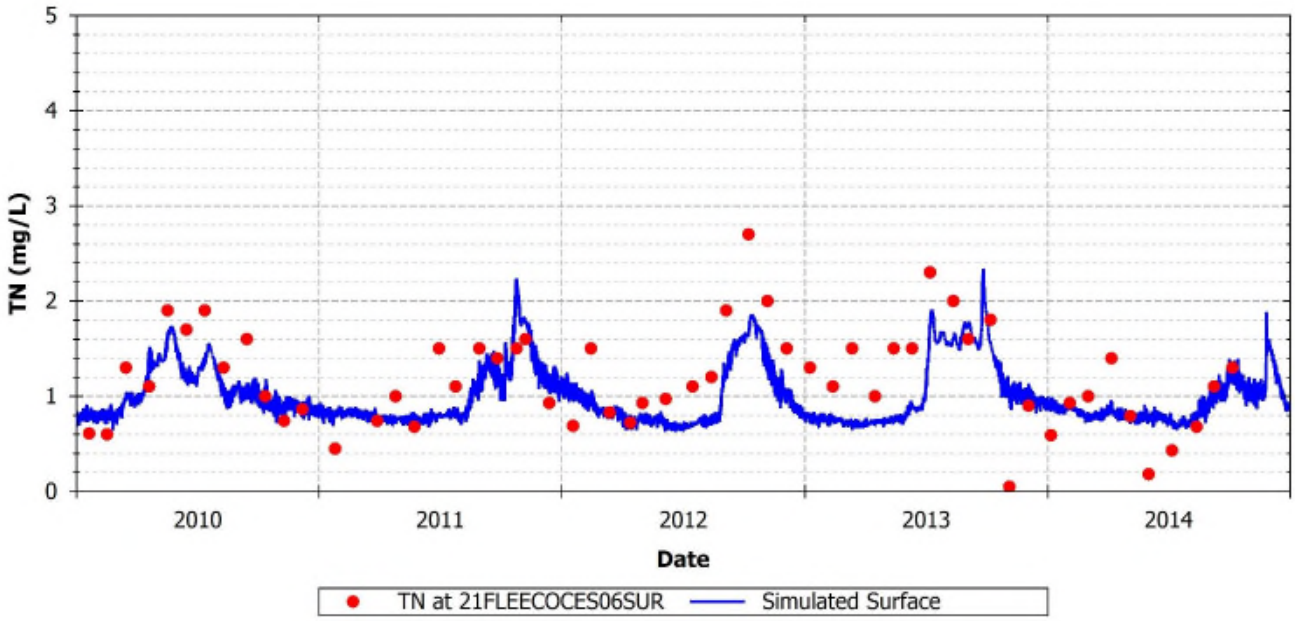

FIGURE 117: SIMULATED AND OBSERVED TN AT 21FLEECOCES06SUR

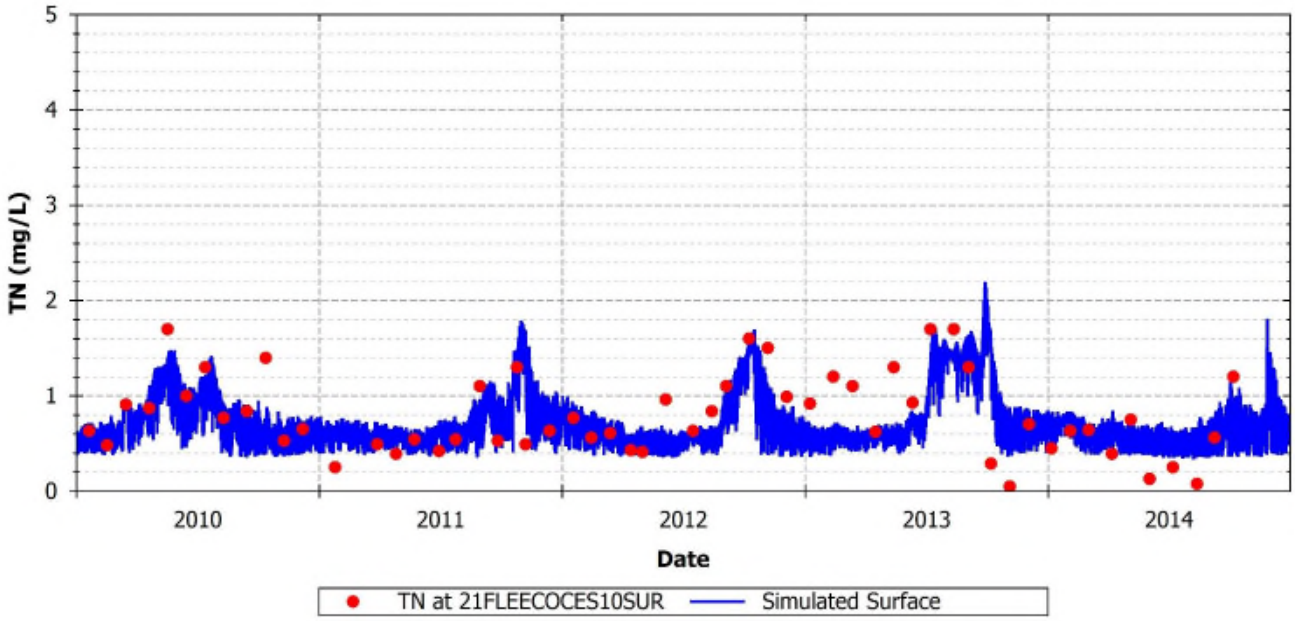

FIGURE 118: SIMULATED AND OBSERVED TN AT 21FLEECOCES10SUR

TABLE 134: CALIBRATION STATISTICS FOR TN

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLCHARMPV004	0.75	0.70	0.42	1.52	0.53	0.46	0.38	1.11	0.28	0.26	0.36	0.55	0.59	-28.8%
21FLCHARPIV007	0.59	0.58	0.41	0.98	0.40	0.38	0.30	0.57	0.03	0.20	0.24	0.49	0.26	-33.2%
21FLCHARSCV001	0.52	0.49	0.35	0.91	0.43	0.39	0.35	0.74	0.35	0.12	0.16	0.32	0.70	-16.9%
21FLEECO23-5GR	1.46	1.50	0.72	2.10	1.06	1.05	0.37	1.68	0.03	0.71	1.03	0.82	0.37	-27.6%
21FLEECO29-8GR	1.51	1.50	0.89	2.28	1.66	1.64	0.97	2.40	0.12	0.38	0.49	0.31	0.59	10.2%
21FLEECOBILLGR20	1.31	1.40	0.65	1.80	0.81	0.82	0.49	1.25	0.01	0.55	0.65	0.63	0.33	-38.2%
21FLEECOCES03SUR	1.61	1.70	0.84	2.30	1.38	1.31	0.82	2.25	0.32	0.41	0.49	0.32	0.71	-14.7%
21FLEECOCES04SUR	1.52	1.50	0.86	2.31	1.25	1.22	0.80	2.04	0.34	0.38	0.48	0.34	0.72	-17.7%
21FLEECOCES06SUR	1.19	1.29	0.41	2.03	1.04	0.98	0.69	1.75	0.41	0.35	0.43	0.37	0.74	-13.0%
21FLEECOCES10SUR	0.79	0.77	0.13	1.70	0.76	0.66	0.47	1.45	0.29	0.25	0.36	0.44	0.73	-4.4%
21FLEECODEEPGR10	1.19	1.30	0.61	1.70	0.86	0.77	0.63	1.41	0.15	0.39	0.47	0.46	0.51	-27.8%
21FLEECOPI-01	0.61	0.58	0.06	1.31	0.54	0.50	0.36	0.98	0.22	0.26	0.37	0.62	0.55	-12.4%
21FLEECOPI-02	0.44	0.41	0.17	0.80	0.50	0.46	0.43	0.68	0.32	0.16	0.19	0.39	0.55	12.0%
21FLEECOPI-03	0.60	0.56	0.36	0.89	0.55	0.51	0.45	0.78	0.23	0.14	0.19	0.32	0.66	-8.8%
21FLEECOPI-12	0.49	0.52	0.17	0.83	0.37	0.37	0.34	0.42	0.22	0.20	0.25	0.57	0.19	-24.3%
21FLEECOPI-13	0.50	0.52	0.25	0.69	0.38	0.38	0.34	0.42	0.02	0.16	0.19	0.45	0.19	-24.0%
21FLEECOPI-14	0.52	0.62	0.12	0.86	0.42	0.43	0.35	0.59	0.21	0.21	0.25	0.53	0.39	-18.2%
21FLFTM CALUSA0011FTM	1.09	1.07	0.76	1.57	1.14	1.09	0.76	1.89	0.36	0.21	0.28	0.24	0.75	4.9%
21FLFTM CALUSA0012FTM	0.86	0.81	0.49	1.53	0.93	0.84	0.63	1.71	0.59	0.17	0.21	0.23	0.86	7.6%
21FLFTM CALUSA0013FTM	0.65	0.61	0.34	1.41	0.67	0.59	0.41	1.38	0.52	0.15	0.20	0.29	0.85	3.2%
21FLFTM CALUSA0023FTM	0.76	0.73	0.54	1.15	0.75	0.74	0.48	1.20	0.02	0.18	0.25	0.32	0.47	-0.9%
CAPECRD 350	0.81	0.90	0.10	1.47	1.11	1.04	0.78	1.78	0.02	0.44	0.59	0.61	0.42	36.2%

3.5.5.2 NOx

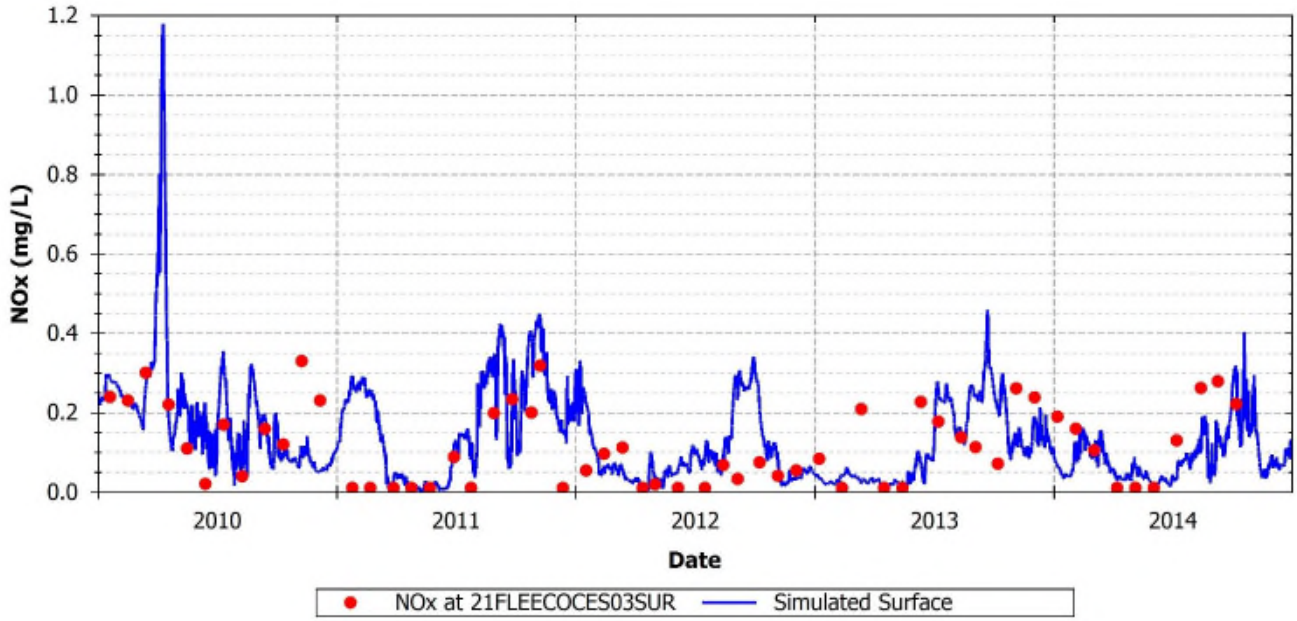

FIGURE 119: SIMULATED AND OBSERVED NOX AT 21FLEECOCES03SUR

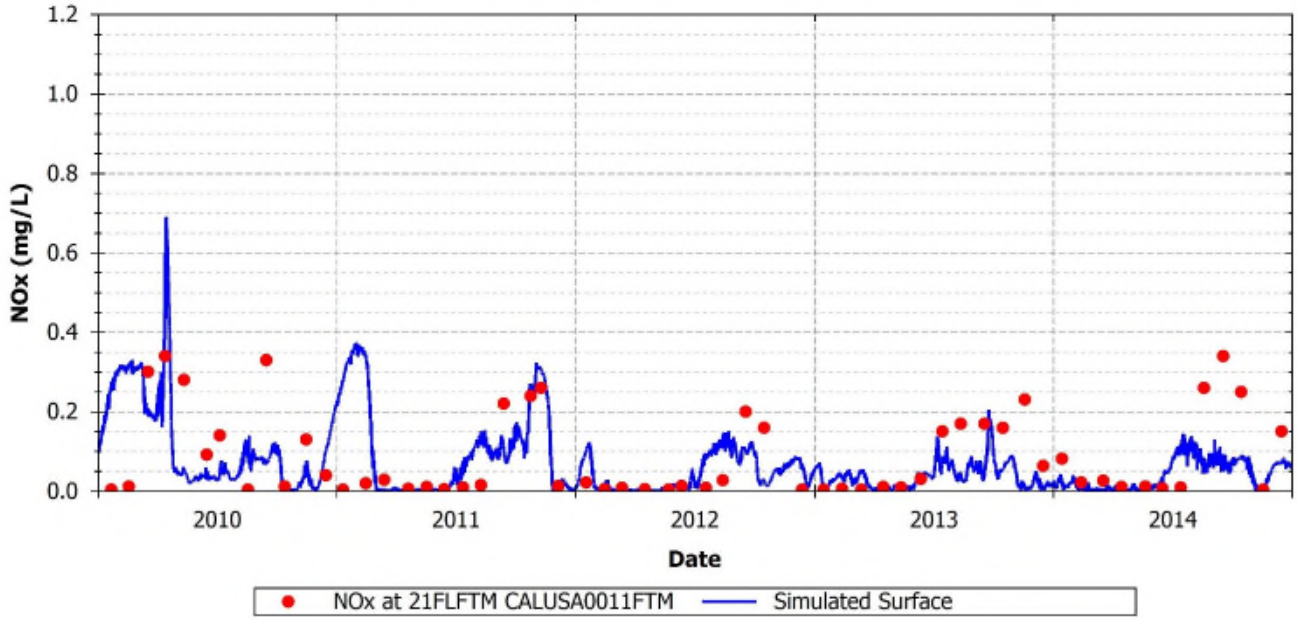

FIGURE 120: SIMULATED AND OBSERVED NOX AT 21FLFTM CALUSA0011FTM

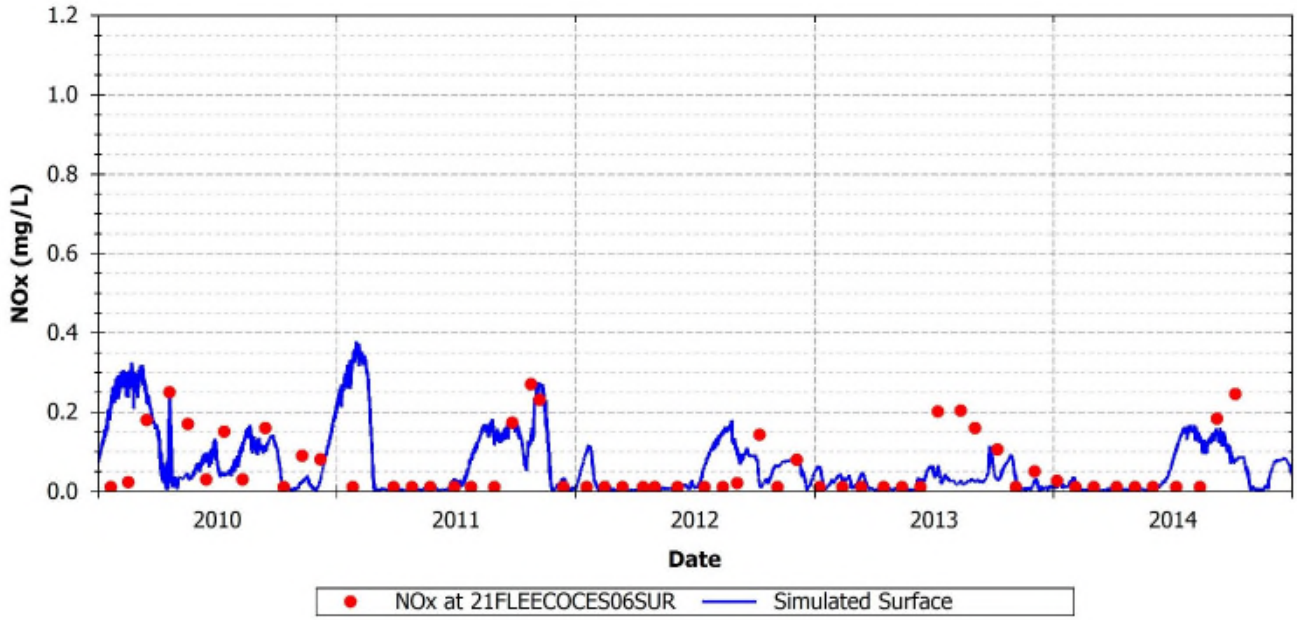

FIGURE 121: SIMULATED AND OBSERVED NOX AT 21FLEECOCES06SUR

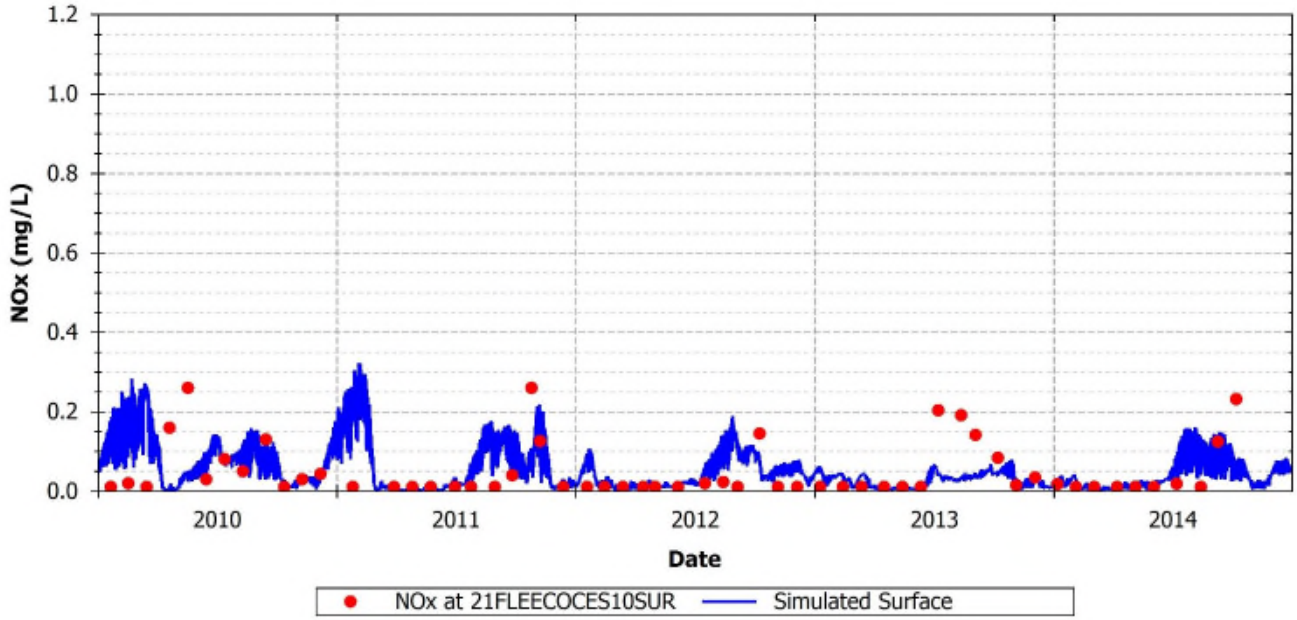

FIGURE 122: SIMULATED AND OBSERVED NOX AT 21FLEECOCES10SUR

TABLE 135: CALIBRATION STATISTICS FOR NOX

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLCHARMPV004	0.03	0.01	0.00	0.13	0.04	0.04	0.00	0.12	0.02	0.04	0.05	1.46	0.43	33.3%
21FLCHARPIV007	0.01	0.01	0.00	0.02	0.02	0.01	0.00	0.07	0.03	0.01	0.02	2.81	0.38	100.0%
21FLCHARSCV001	0.01	0.01	0.00	0.04	0.03	0.03	0.00	0.09	0.06	0.03	0.03	1.74	0.45	200.0%
21FLEECO23-5GR	0.07	0.08	0.01	0.19	0.10	0.13	0.00	0.16	0.01	0.06	0.08	0.88	0.47	42.9%
21FLEECO29-8GR	0.04	0.03	0.01	0.11	0.21	0.24	0.04	0.32	0.11	0.17	0.19	2.06	0.42	425.0%
21FLEECOBILLGR20	0.06	0.04	0.01	0.17	0.12	0.13	0.04	0.20	0.10	0.09	0.11	1.44	0.31	100.0%
21FLEECOCES03SUR	0.12	0.11	0.01	0.30	0.14	0.13	0.01	0.34	0.22	0.08	0.11	0.75	0.7	16.7%
21FLEECOCES04SUR	0.10	0.08	0.01	0.27	0.09	0.06	0.00	0.31	0.15	0.07	0.10	0.96	0.65	-10.0%
21FLEECOCES06SUR	0.06	0.01	0.01	0.25	0.07	0.04	0.00	0.27	0.10	0.06	0.09	1.16	0.61	16.7%
21FLEECOCES10SUR	0.05	0.01	0.01	0.24	0.06	0.04	0.00	0.21	0.00	0.06	0.09	1.59	0.39	20.0%
21FLEECODEEPGR10	0.04	0.03	0.01	0.13	0.09	0.08	0.01	0.22	0.11	0.06	0.08	1.20	0.55	125.0%
21FLEECOPI-01	0.04	0.01	0.01	0.18	0.04	0.03	0.00	0.12	0.06	0.03	0.06	1.25	0.45	0.0%
21FLEECOPI-02	0.03	0.01	0.01	0.09	0.04	0.03	0.00	0.10	0.12	0.03	0.04	1.12	0.62	33.3%
21FLEECOPI-03	0.02	0.01	0.01	0.05	0.04	0.01	0.00	0.11	0.08	0.03	0.05	1.61	0.56	100.0%
21FLEECOPI-12	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.04	0.00	0.02	0.02	1.18	0.41	100.0%
21FLEECOPI-13	0.01	0.01	0.01	0.01	0.03	0.02	0.02	0.04	0.01	0.02	0.02	1.16	0.38	200.0%
21FLEECOPI-14	0.02	0.01	0.01	0.08	0.03	0.03	0.01	0.07	0.17	0.02	0.04	1.12	0.56	50.0%
21FLFTM CALUSA0008FTM	0.08	0.01	0.00	0.33	0.09	0.06	0.00	0.27	0.01	0.10	0.13	1.44	0.48	12.5%
21FLFTM CALUSA0011FTM	0.09	0.03	0.00	0.33	0.08	0.05	0.00	0.32	0.10	0.09	0.12	1.20	0.59	-11.1%
21FLFTM CALUSA0012FTM	0.06	0.02	0.00	0.25	0.07	0.04	0.00	0.25	0.04	0.07	0.10	1.36	0.53	16.7%
21FLFTM CALUSA0013FTM	0.05	0.02	0.00	0.21	0.05	0.04	0.01	0.16	0.01	0.05	0.08	1.56	0.39	0.0%
21FLFTM CALUSA0023FTM	0.07	0.05	0.00	0.20	0.09	0.09	0.04	0.17	0.00	0.06	0.08	1.02	0.34	28.6%
CAPECRD 350	0.08	0.05	0.01	0.26	0.04	0.01	0.00	0.15	0.22	0.06	0.07	1.02	0.59	-50.0%

3.5.5.3 NH_4

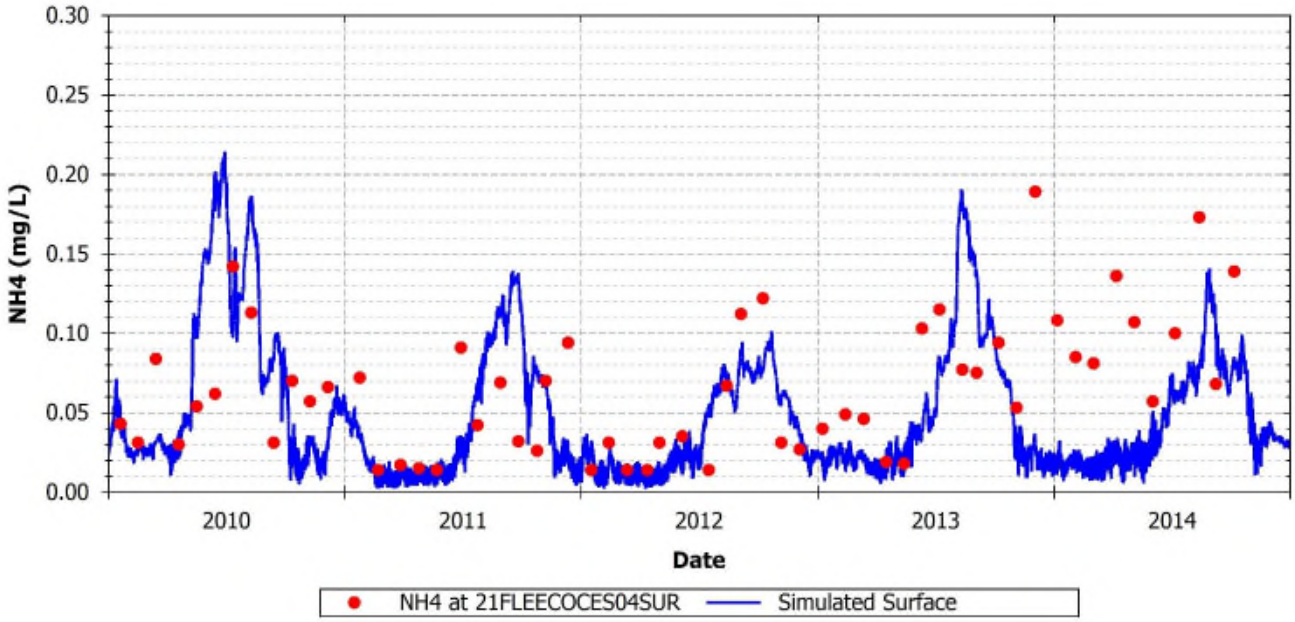

FIGURE 123: SIMULATED AND OBSERVED NH_4 AT 21FLEECOCES04SUR

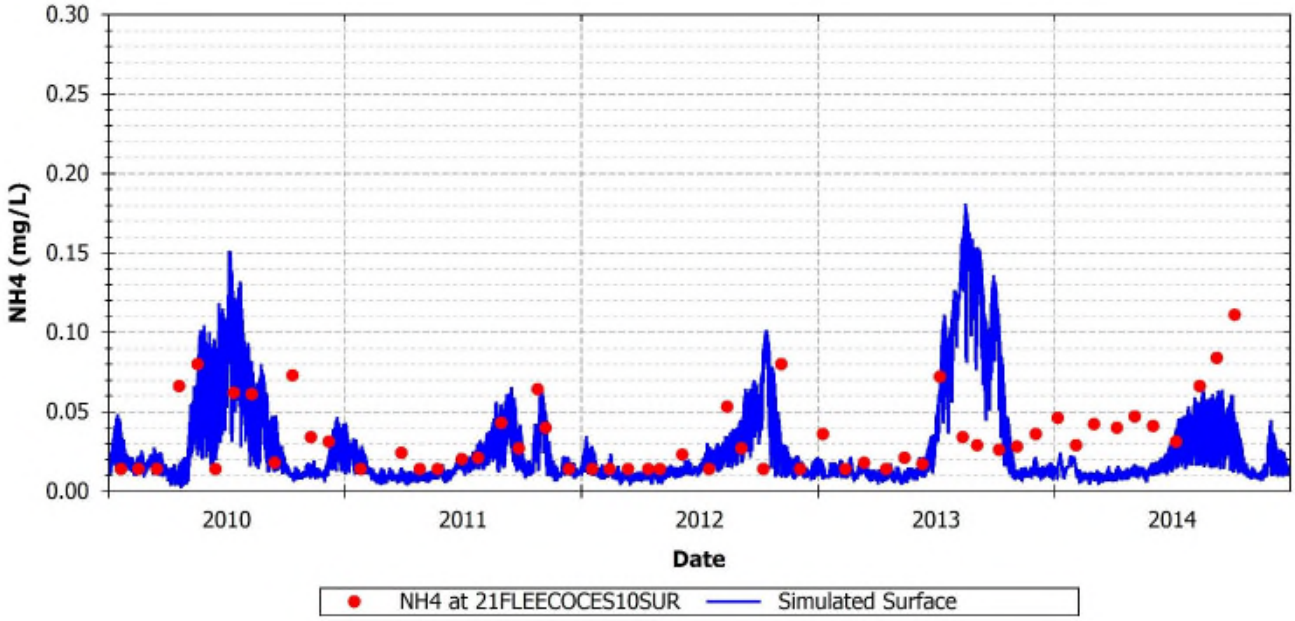

FIGURE 124: SIMULATED AND OBSERVED NH_4 AT 21FLEECOCES10SUR

TABLE 136: CALIBRATION STATISTICS FOR NH_4

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLEECO23-5GR	0.06	0.05	0.01	0.12	0.05	0.06	0.00	0.11	0.03	0.04	0.05	1.10	0.30	-16.7%
21FLEECO29-8GR	0.05	0.05	0.01	0.14	0.09	0.07	0.02	0.17	0.01	0.06	0.07	1.17	0.41	80.0%
21FLEECOBILLGR20	0.10	0.09	0.02	0.23	0.05	0.05	0.02	0.10	0.01	0.06	0.09	1.35	0.19	-50.0%
21FLEECOCES04SUR	0.07	0.07	0.01	0.14	0.05	0.04	0.01	0.18	0.08	0.04	0.05	0.84	0.54	-28.6%
21FLEECOCES10SUR	0.03	0.03	0.01	0.08	0.03	0.02	0.01	0.10	0.03	0.02	0.03	1.01	0.41	0.0%
21FLEECODEEPGR10	0.13	0.12	0.03	0.36	0.04	0.04	0.01	0.08	0.30	0.09	0.12	1.57	0.32	-69.2%
21FLEECOPI-03	0.03	0.03	0.01	0.04	0.02	0.02	0.01	0.03	0.00	0.01	0.02	0.82	0.43	-33.3%
21FLFTM CALUSA0023FTM	0.04	0.04	0.01	0.11	0.04	0.04	0.01	0.07	0.00	0.03	0.03	0.88	0.36	0.0%

3.5.5.4 TKN

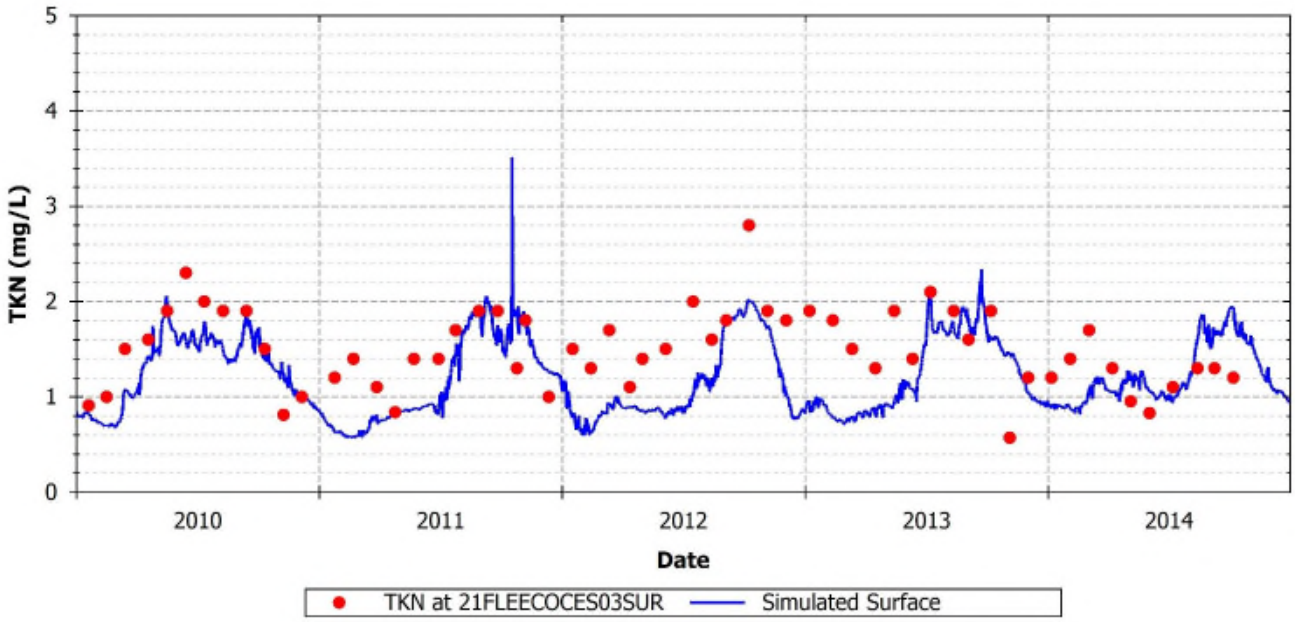

FIGURE 125: SIMULATED AND OBSERVED TKN AT 21FLEECOCES03SUR

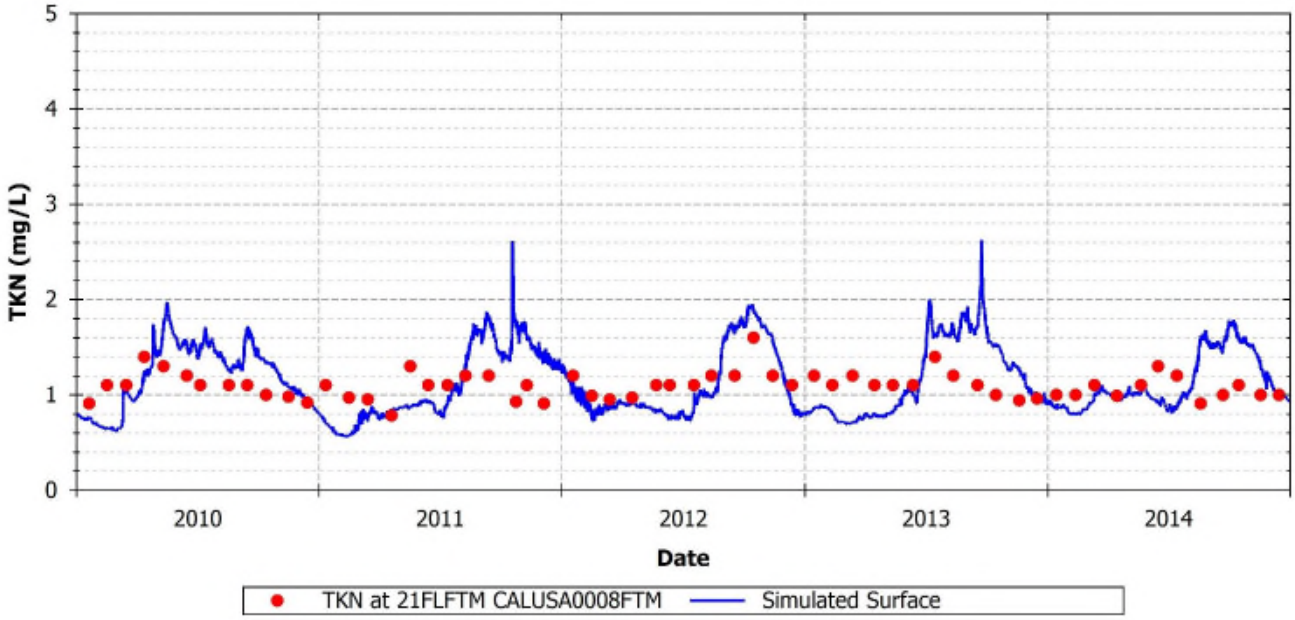

FIGURE 126: SIMULATED AND OBSERVED TKN AT 21FLFTM CALUSA0008FTM

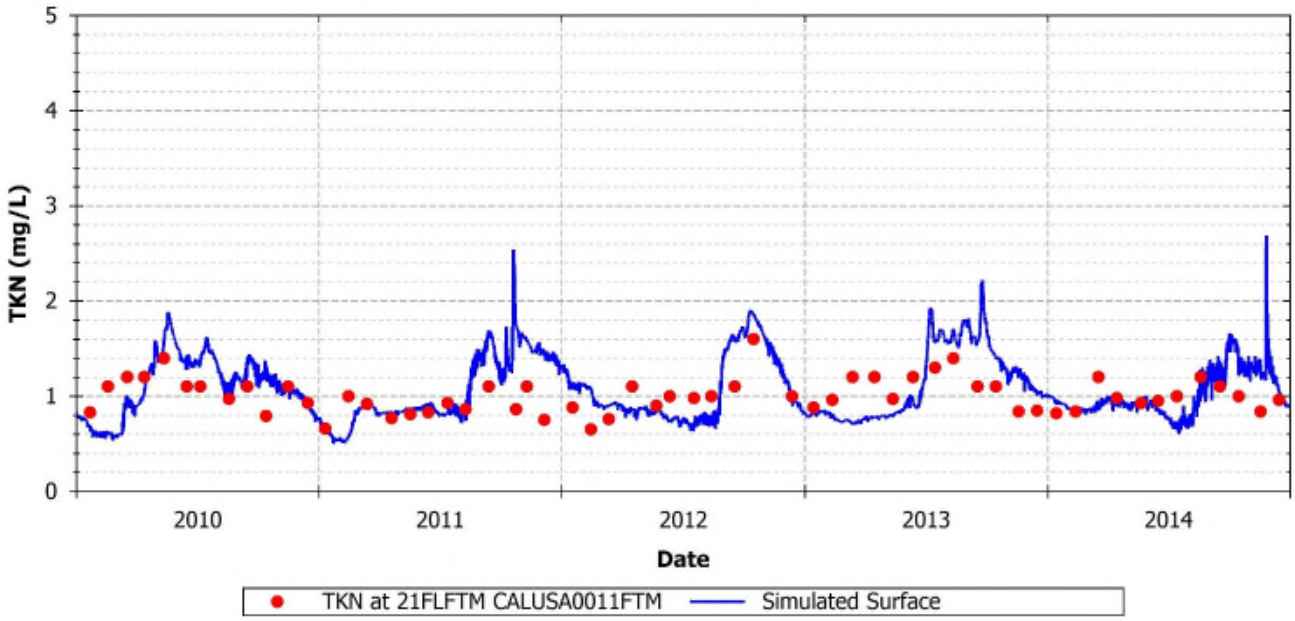

FIGURE 127: SIMULATED AND OBSERVED TKN AT 21FLFTM CALUSA0011FTM

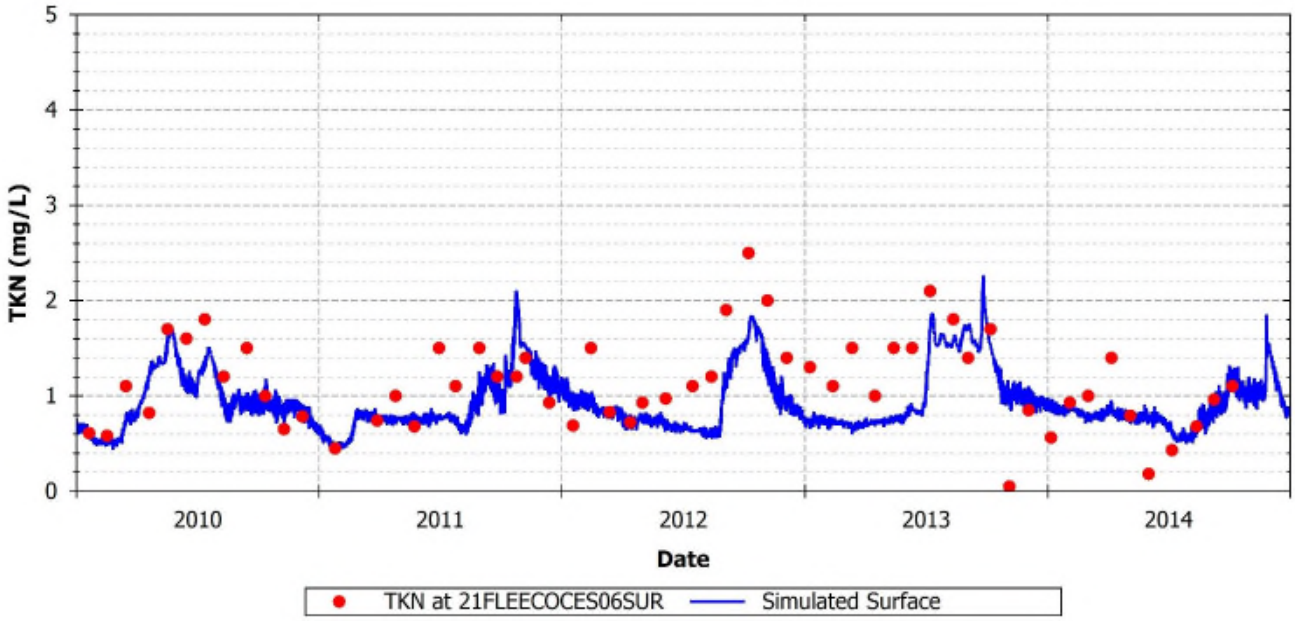

FIGURE 128: SIMULATED AND OBSERVED TKN AT 21FLEECOCES06SUR

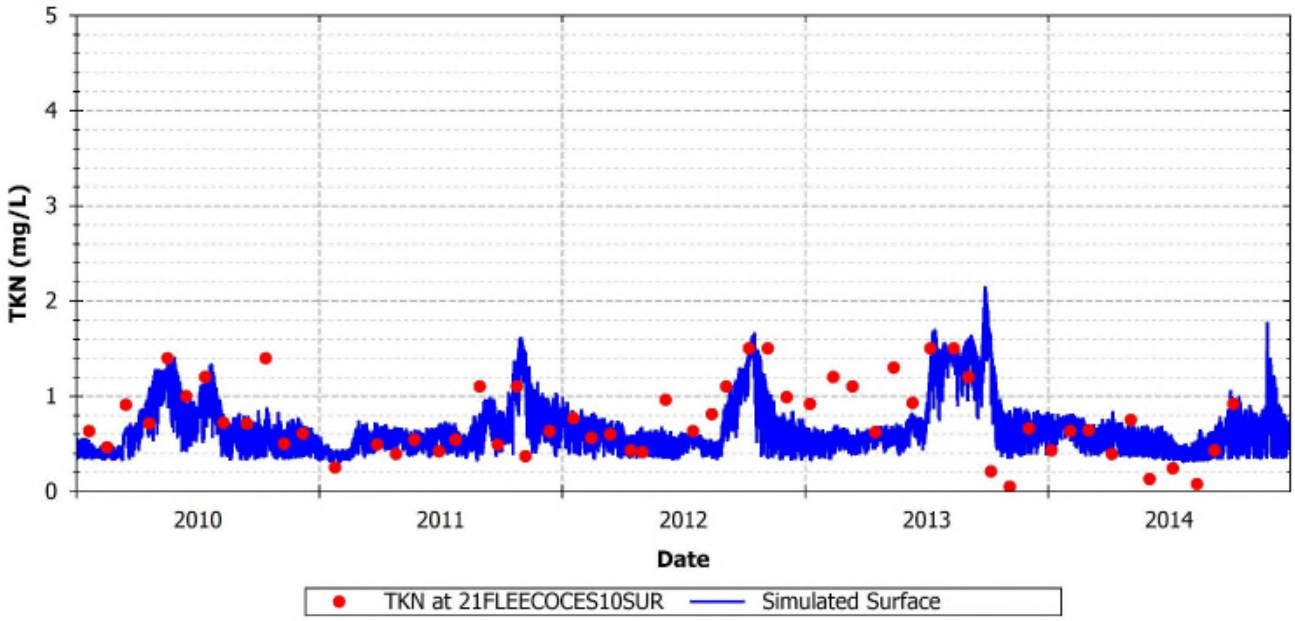

FIGURE 129: SIMULATED AND OBSERVED TKN AT 21FLEECOCES10SUR

TABLE 137: CALIBRATION STATISTICS FOR TKN

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLCHARMPV004	0.72	0.66	0.41	1.38	0.50	0.43	0.31	1.05	0.22	0.27	0.36	0.58	0.56	-31.1%
21FLCHARPIV007	0.59	0.58	0.41	0.97	0.38	0.37	0.25	0.57	0.07	0.22	0.25	0.52	0.30	-35.4%
21FLCHARSCV001	0.51	0.49	0.35	0.89	0.40	0.36	0.28	0.70	0.31	0.13	0.17	0.37	0.65	-22.1%
21FLEECO23-5GR	1.39	1.40	0.69	2.10	0.95	0.94	0.34	1.53	0.02	0.72	1.03	0.88	0.37	-31.2%
21FLEECO29-8GR	1.49	1.50	0.87	2.24	1.45	1.39	0.89	2.16	0.10	0.37	0.46	0.31	0.56	-2.2%
21FLEECOBILLGR20	1.26	1.40	0.63	1.70	0.69	0.69	0.43	1.08	0.00	0.60	0.68	0.73	0.30	-45.1%
21FLEECOCES03SUR	1.50	1.50	0.83	2.11	1.24	1.17	0.63	1.97	0.23	0.41	0.50	0.36	0.66	-17.7%
21FLEECOCES04SUR	1.43	1.50	0.76	2.21	1.16	1.13	0.64	1.91	0.27	0.40	0.49	0.37	0.68	-18.6%
21FLEECOCES06SUR	1.13	1.10	0.41	2.01	0.97	0.88	0.57	1.69	0.34	0.34	0.43	0.39	0.71	-14.6%
21FLEECOCES10SUR	0.75	0.71	0.13	1.50	0.70	0.61	0.37	1.38	0.23	0.25	0.36	0.47	0.69	-6.6%
21FLEECODEEPGR10	1.15	1.29	0.61	1.60	0.77	0.71	0.51	1.23	0.13	0.42	0.51	0.53	0.46	-32.9%
21FLEECOPI-01	0.58	0.54	0.06	1.12	0.50	0.46	0.31	0.93	0.16	0.25	0.36	0.64	0.53	-14.2%
21FLEECOPI-02	0.42	0.37	0.16	0.80	0.46	0.45	0.36	0.63	0.45	0.15	0.18	0.39	0.65	8.3%
21FLEECOPI-03	0.59	0.56	0.35	0.89	0.51	0.50	0.35	0.76	0.10	0.17	0.22	0.40	0.57	-14.6%
21FLEECOPI-12	0.49	0.52	0.17	0.83	0.35	0.35	0.30	0.41	0.29	0.21	0.25	0.60	0.24	-28.9%
21FLEECOPI-13	0.50	0.52	0.25	0.68	0.35	0.35	0.31	0.40	0.11	0.17	0.20	0.49	0.22	-29.1%
21FLEECOPI-14	0.50	0.55	0.12	0.86	0.39	0.39	0.31	0.54	0.28	0.20	0.25	0.55	0.42	-22.1%
21FLFTM CALUSA0008FTM	1.09	1.10	0.91	1.40	1.14	1.03	0.70	1.76	0.09	0.30	0.35	0.31	0.47	3.9%
21FLFTM CALUSA0011FTM	1.00	1.00	0.75	1.40	1.07	1.04	0.65	1.70	0.16	0.24	0.31	0.30	0.59	6.3%
21FLFTM CALUSA0012FTM	0.80	0.77	0.48	1.30	0.86	0.81	0.51	1.51	0.45	0.18	0.23	0.27	0.79	7.7%
21FLFTM CALUSA0013FTM	0.60	0.57	0.32	1.20	0.62	0.56	0.37	1.34	0.46	0.14	0.20	0.31	0.82	2.7%
21FLFTM CALUSA0023FTM	0.69	0.68	0.48	1.06	0.66	0.65	0.39	1.06	0.00	0.20	0.26	0.38	0.36	-4.1%
CAPECRD 350	0.76	0.90	0.10	1.30	1.04	1.01	0.59	1.61	0.00	0.44	0.59	0.66	0.39	37.4%

3.5.6 Phosphorus

Available water quality observations at different locations of the Caloosahatchee River showed that the average and median TP concentration in the system were approximately 0.07 mg/L, and measured concentrations varied between 0.01 mg/L and 0.5 mg/L. The analysis of the calibration results indicated that the model predictions successfully capture the average values and range of variability of TP (**Table 138**). The model was also able to capture the timing and seasonal variability of the observations in all stations evaluated (**Figure 130** through **Figure 133, Appendix D**). The sharp spikes in concentration corresponded to large increases in the watershed boundary loads and reflected nutrient pulses occurring during storm events. The impact of these sharp concentration spikes on the overall performance of the model is limited as they quickly dissipate in time.

The inorganic form of phosphorus, PO_4, which was available for nutrient uptake, varied between 0.01 mg/L and 0.1 mg/L. These PO_4 levels are in general well represented by the model as can be observed in **Table 139**, **Figure 134** and **Figure 135**, and **Appendix D**.

3.5.6.1 TP

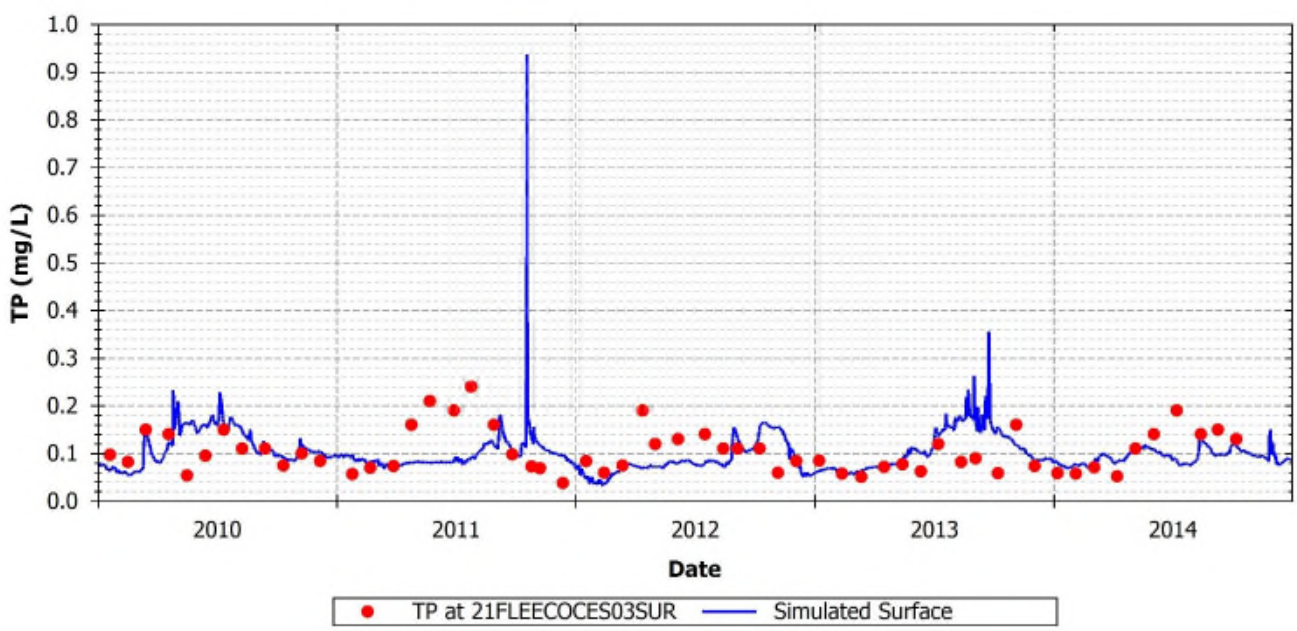

FIGURE 130: SIMULATED AND OBSERVED TP AT 21FLEECOCES03SUR

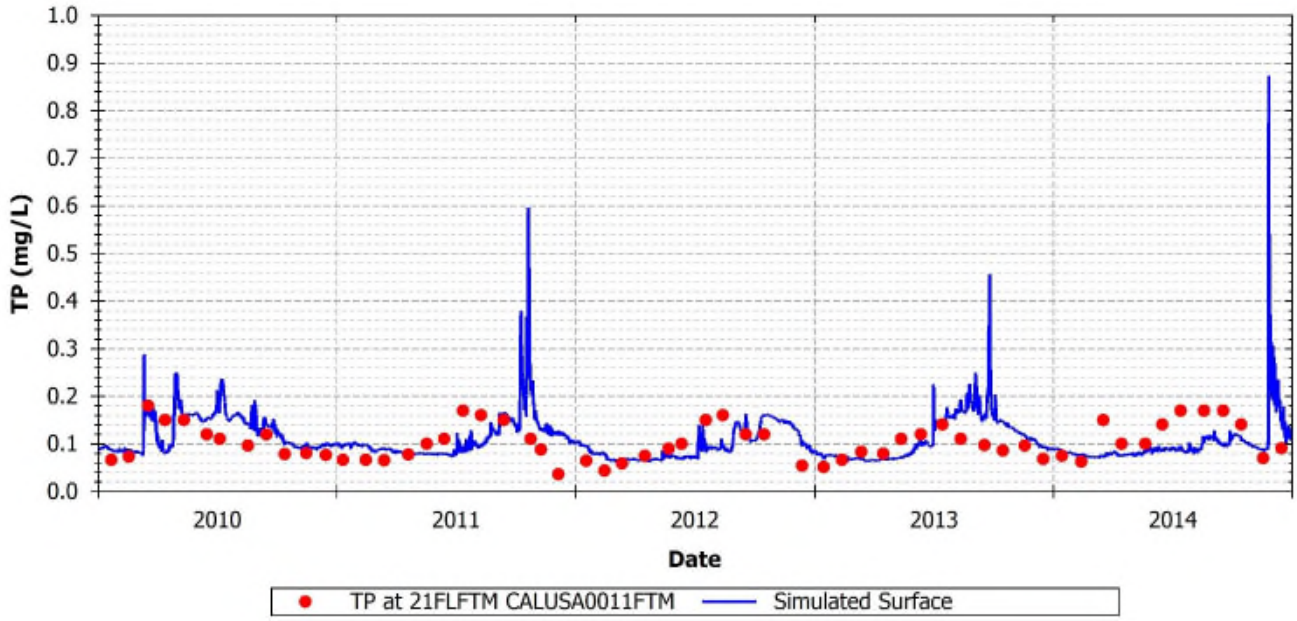

FIGURE 131: SIMULATED AND OBSERVED TP AT 21FLFTM CALUSA0011FTM

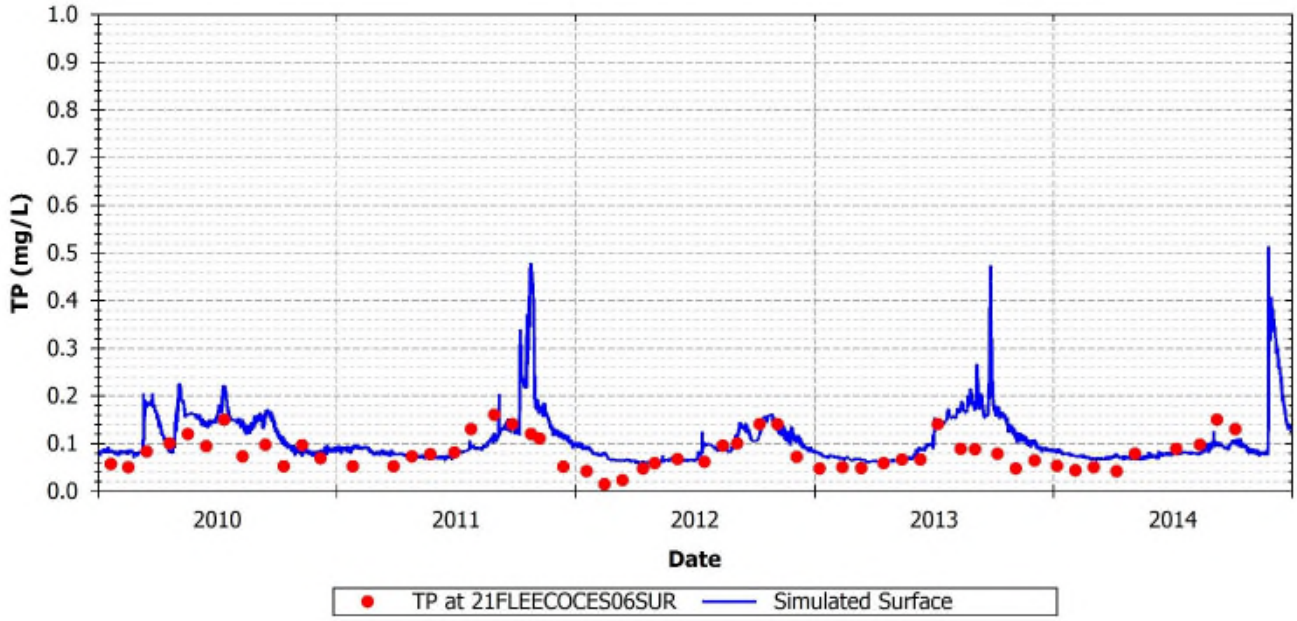

FIGURE 132: SIMULATED AND OBSERVED TP AT 21FLEECOCES06SUR

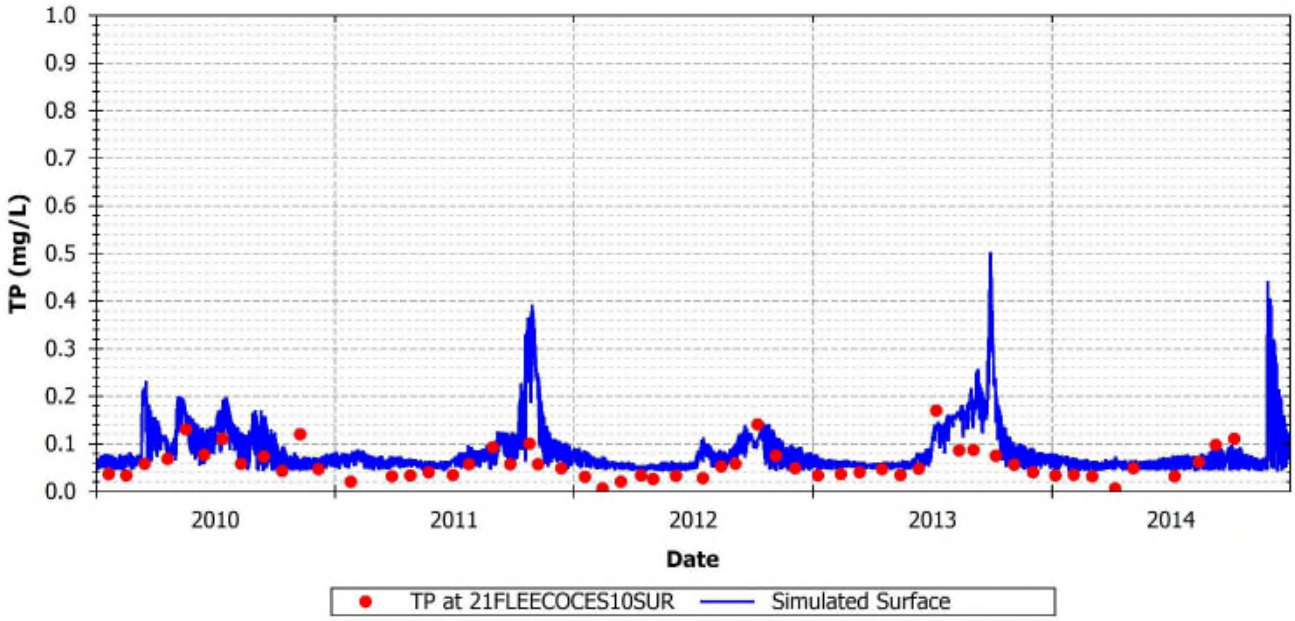

FIGURE 133: SIMULATED AND OBSERVED TP AT 21FLEECOCES10SUR

TABLE 138: CALIBRATION STATISTICS FOR TP

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLCHARMPV004	0.06	0.05	0.03	0.13	0.07	0.05	0.04	0.16	0.13	0.02	0.04	0.59	0.57	16.7%
21FLCHARPIV007	0.03	0.03	0.01	0.05	0.05	0.05	0.03	0.07	0.06	0.02	0.02	0.64	0.38	66.7%
21FLCHARSCV001	0.04	0.04	0.03	0.08	0.05	0.05	0.04	0.10	0.20	0.01	0.02	0.40	0.60	25.0%
21FLEECO23-5GR	0.21	0.18	0.06	0.50	0.16	0.06	0.03	0.17	0.02	0.24	0.70	3.31	0.13	-23.8%
21FLEECO29-8GR	0.07	0.05	0.02	0.23	0.10	0.10	0.07	0.14	0.00	0.06	0.09	1.12	0.22	42.9%
21FLEECOBILLGR20	0.27	0.27	0.14	0.42	0.23	0.21	0.05	0.56	0.00	0.13	0.18	0.70	0.35	-14.8%
21FLEECOCES03SUR	0.10	0.10	0.05	0.19	0.10	0.10	0.05	0.16	0.00	0.04	0.05	0.53	0.41	0.0%
21FLEECOCES04SUR	0.11	0.10	0.06	0.19	0.11	0.10	0.06	0.18	0.00	0.04	0.05	0.49	0.40	0.0%
21FLEECOCES06SUR	0.08	0.08	0.04	0.15	0.11	0.10	0.06	0.19	0.19	0.04	0.06	0.63	0.54	37.5%
21FLEECOCES10SUR	0.06	0.05	0.02	0.13	0.09	0.07	0.05	0.21	0.24	0.04	0.06	0.75	0.57	50.0%
21FLEECODEEPGR10	0.10	0.10	0.04	0.17	0.13	0.10	0.07	0.39	0.17	0.05	0.09	0.78	0.44	30.0%
21FLEECOPI-01	0.04	0.04	0.01	0.08	0.06	0.06	0.04	0.13	0.19	0.03	0.04	0.70	0.49	50.0%
21FLEECOPI-02	0.04	0.03	0.03	0.07	0.05	0.05	0.05	0.06	0.41	0.02	0.02	0.40	0.36	25.0%
21FLEECOPI-03	0.03	0.03	0.01	0.06	0.05	0.06	0.05	0.06	0.19	0.03	0.03	0.79	0.22	66.7%
21FLEECOPI-12	0.02	0.02	0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.76	0.10	100.0%
21FLEECOPI-13	0.02	0.02	0.01	0.03	0.04	0.04	0.04	0.04	0.00	0.02	0.03	0.87	0.09	100.0%
21FLEECOPI-14	0.03	0.03	0.01	0.05	0.05	0.05	0.04	0.06	0.47	0.02	0.03	0.70	0.27	66.7%
21FLFTM CALUSA0011FTM	0.10	0.10	0.05	0.17	0.11	0.10	0.07	0.17	0.08	0.04	0.05	0.42	0.54	10.0%
21FLFTM CALUSA0012FTM	0.08	0.07	0.04	0.15	0.11	0.09	0.06	0.20	0.25	0.04	0.05	0.56	0.61	37.5%
21FLFTM CALUSA0013FTM	0.06	0.05	0.03	0.13	0.08	0.06	0.05	0.19	0.37	0.03	0.04	0.55	0.67	33.3%
21FLFTM CALUSA0023FTM	0.05	0.04	0.02	0.17	0.07	0.07	0.05	0.15	0.01	0.04	0.05	0.85	0.35	40.0%
CAPECRD 350	0.03	0.03	0.00	0.06	0.11	0.10	0.07	0.22	0.00	0.09	0.10	1.76	0.39	266.7%

3.5.6.2 PO_4

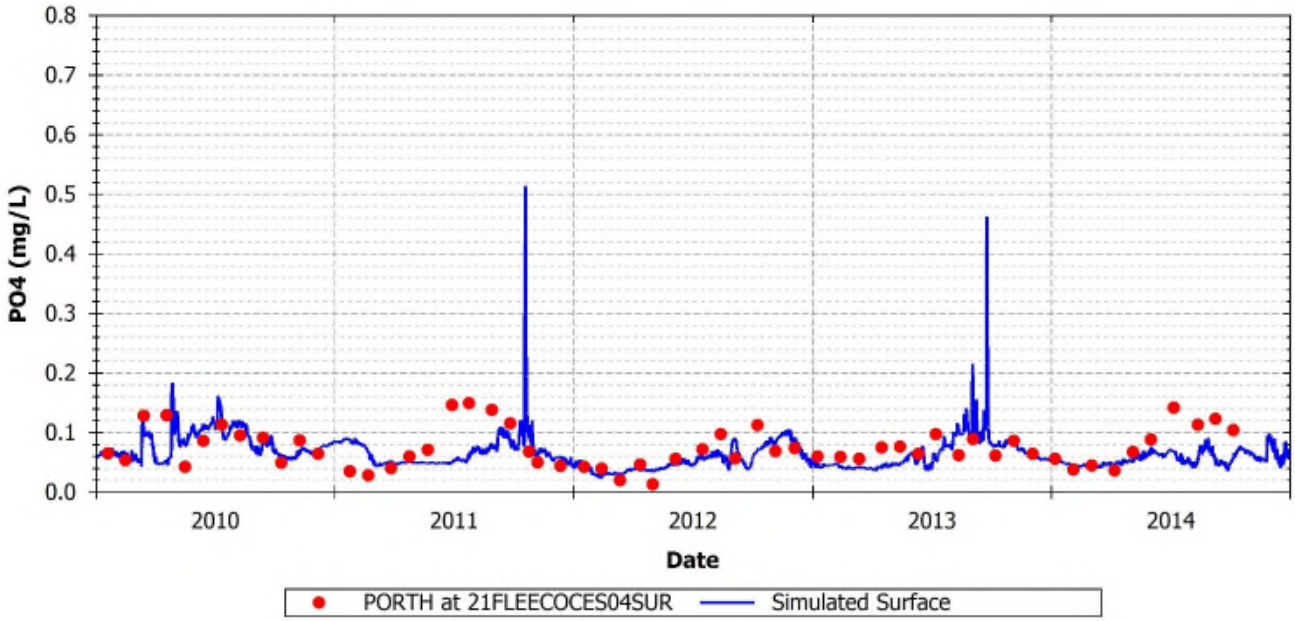

FIGURE 134: SIMULATED AND OBSERVED PO_4 AT 21FLEECOCES04SUR

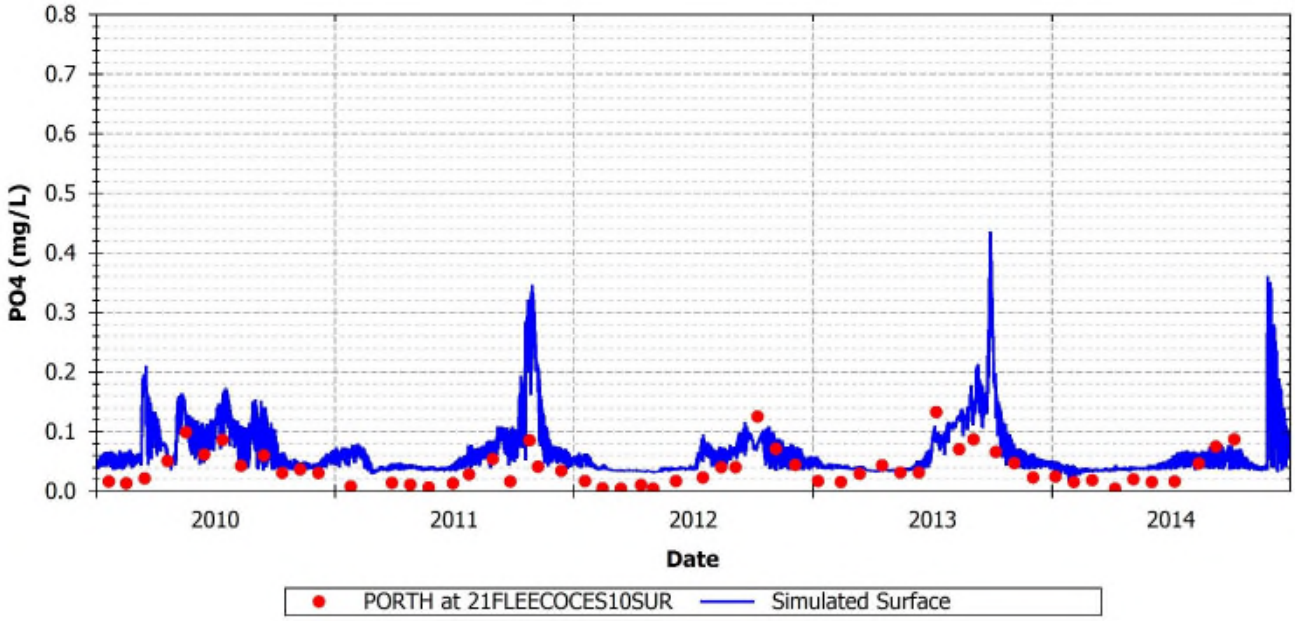

FIGURE 135: SIMULATED AND OBSERVED PO_4 AT 21FLEECOCES10SUR

TABLE 139: CALIBRATION STATISTICS FOR PO_4

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLEECO23-5GR	0.10	0.08	0.03	0.35	0.12	0.02	0.01	0.13	0.07	0.16	0.63	3.92	0.14	11.7%
21FLEECO29-8GR	0.04	0.03	0.01	0.17	0.04	0.03	0.01	0.06	0.00	0.03	0.07	1.65	0.18	-4.8%
21FLEECOBILLGR20	0.20	0.21	0.09	0.33	0.19	0.18	0.02	0.53	0.02	0.12	0.16	0.80	0.37	-2.5%
21FLEECOCES04SUR	0.07	0.07	0.03	0.14	0.07	0.06	0.04	0.12	0.11	0.03	0.04	0.49	0.55	-12.2%
21FLEECOCES10SUR	0.04	0.03	0.00	0.10	0.07	0.06	0.03	0.18	0.26	0.04	0.05	0.90	0.58	81.6%
21FLEECODEEPGR10	0.07	0.07	0.02	0.13	0.10	0.08	0.04	0.31	0.18	0.04	0.08	0.90	0.44	42.0%
21FLEECOPI-03	0.01	0.00	0.00	0.03	0.04	0.04	0.02	0.05	0.09	0.03	0.03	1.62	0.34	344.4%

3.5.7 TSS

Comparisons between observed and predicted TSS concentrations at different locations of the Caloosahatchee River and Estuary are presented from **Figure 136** through **Figure 139**, **Table 27** and **Appendix D**. The concentrations of TSS were highly variable in the estuary with observed mean concentrations ranging from 5 to 20 mg/L, minimum concentrations ranging from 0.6 mg/L to 3 mg/L, and maximum concentrations ranging from 6 m/L to 34 mg/L (**Table 140)**. In stations located in the tributaries and main stem, the model was able to reproduce the general trends, means, and ranges of variability of TSS. Despite some temporal under and overestimations, the model predictions captured well the observations, particularly at stations located in the tributaries, such as 21FLEECO23-5GR, 21FLEECODEEPGR10, 21FLEECO29-8GR, 21FLFTM-CALUSA0023FTM, and 21FLEECOBILLGR20.

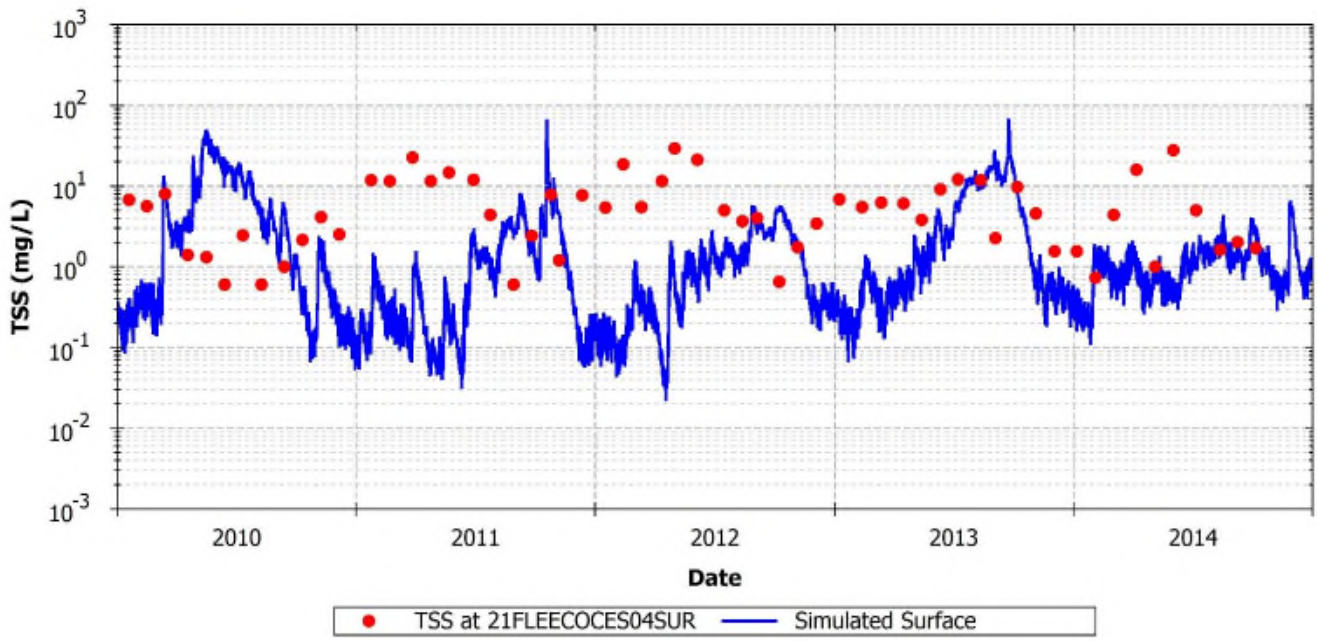

FIGURE 136: SIMULATED AND OBSERVED TSS AT 21FLEECOCES04SUR (LOG SCALE)

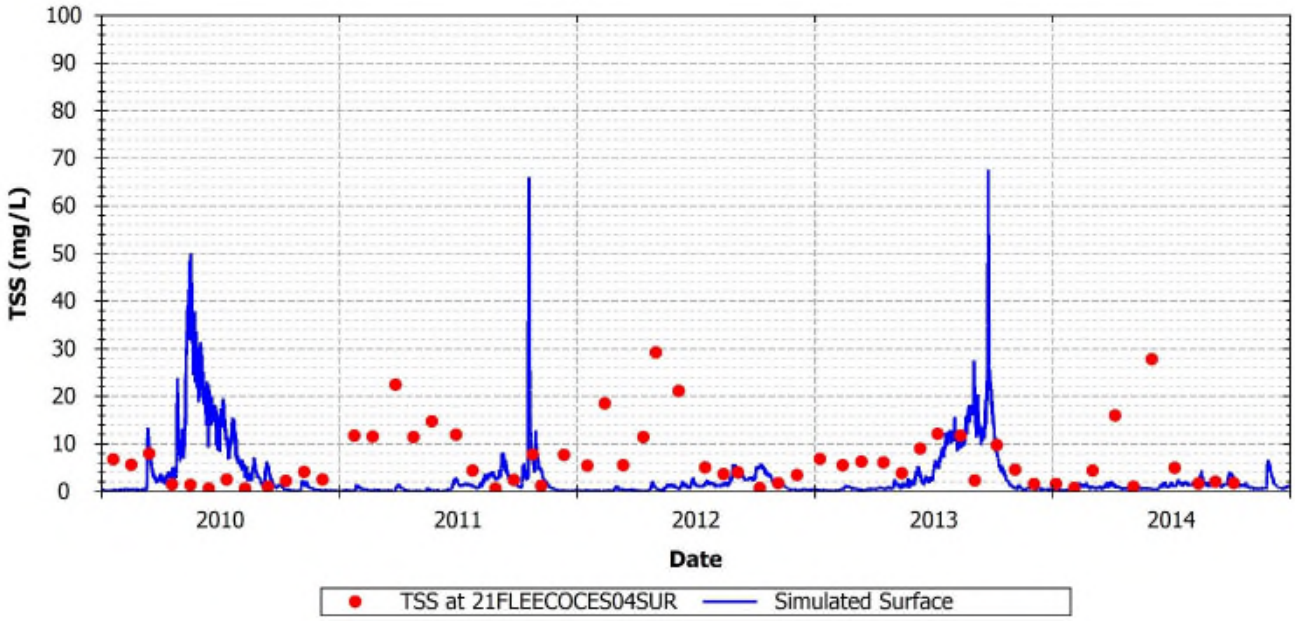

FIGURE 137: SIMULATED AND OBSERVED TSS AT 21FLEECOCES04SUR (LINEAR SCALE)

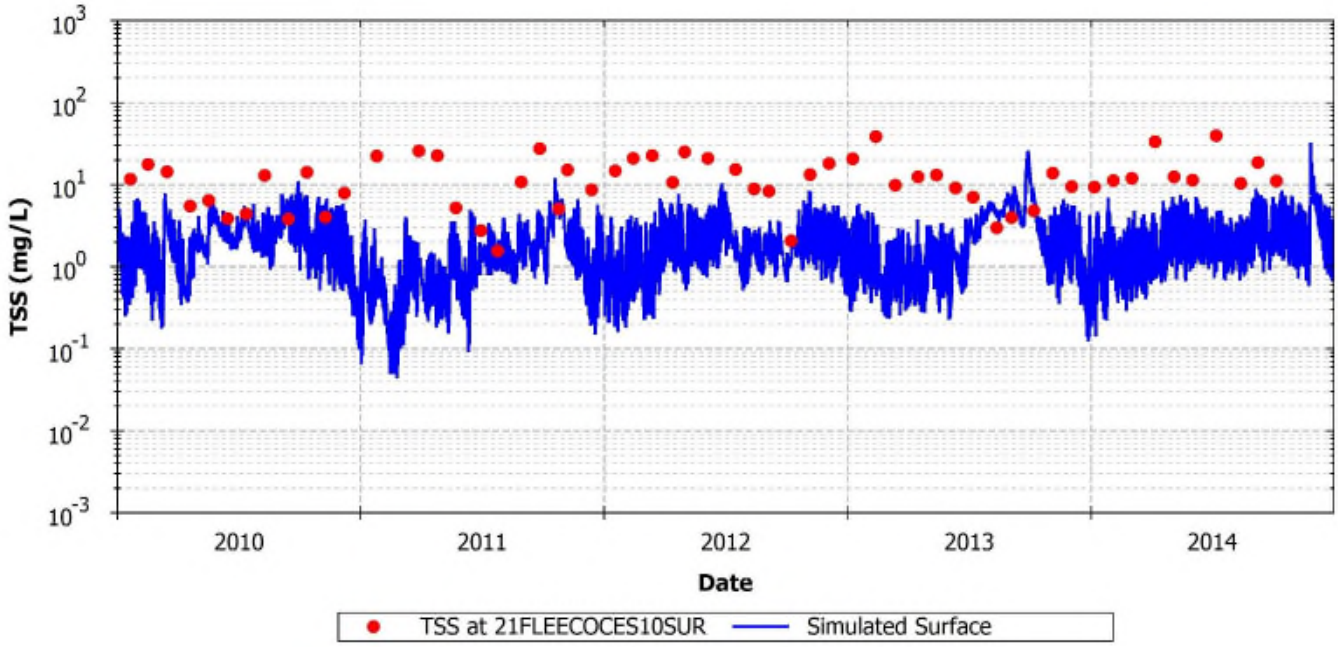

FIGURE 138: SIMULATED AND OBSERVED TSS AT 21FLEECOCES10SUR (LOG SCALE)

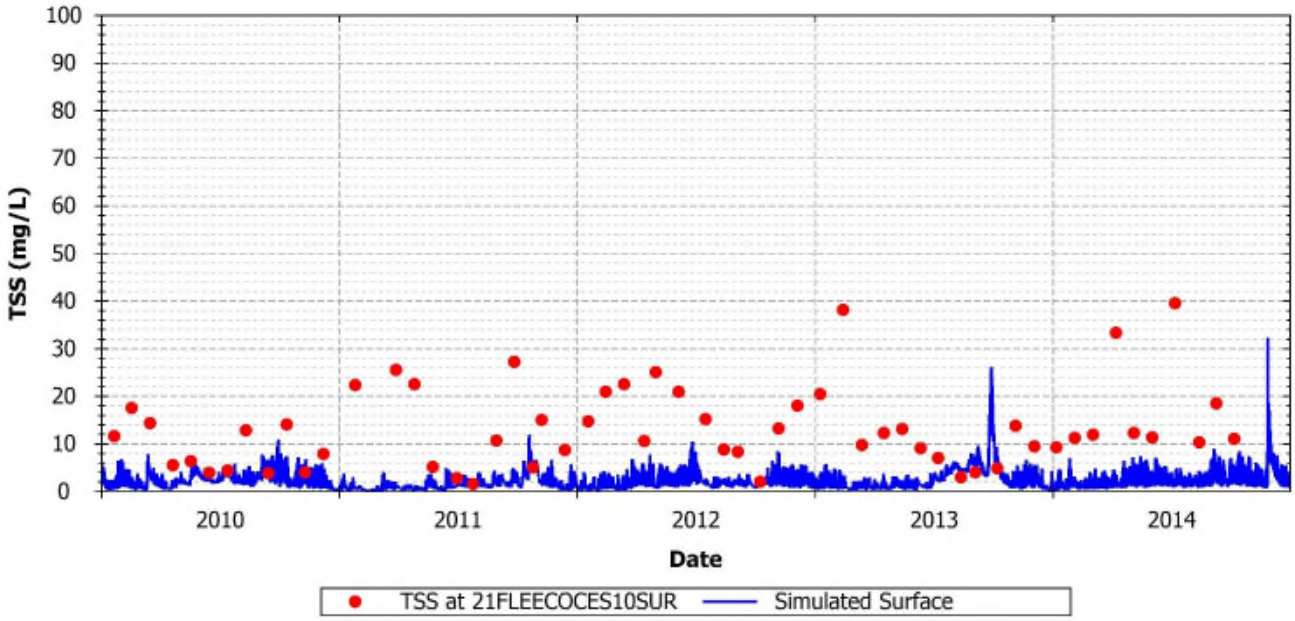

FIGURE 139: SIMULATED AND OBSERVED TSS AT 21FLEECOCES10SUR (LINEAR SCALE)

TABLE 140: CALIBRATION STATISTICS FOR TSS

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLEECO23-5GR	5.74	5.05	0.98	15.75	5.48	1.93	0.50	22.30	0.00	7.33	21.65	4.03	0.04	-4.5%
21FLEECO29-8GR	5.18	2.58	0.60	27.30	4.13	2.19	0.38	21.24	0.00	5.57	11.92	2.77	0.11	-20.2%
21FLEECOBILLGR20	6.59	4.17	0.75	19.38	9.01	4.63	1.09	33.48	0.00	9.35	13.73	1.72	0.38	36.7%
21FLEECOCES04SUR	6.71	5.35	0.60	22.40	3.53	1.29	0.08	18.81	0.04	7.10	11.01	2.95	0.10	-47.4%
21FLEECOCES10SUR	13.08	12.26	2.68	33.78	2.10	1.70	0.39	5.43	0.04	11.17	14.16	2.84	0.09	-83.9%
21FLEECODEEPGR10	6.81	5.24	0.65	17.23	14.50	5.45	0.31	71.43	0.02	15.16	28.80	3.58	0.24	112.9%
21FLEECOPI-03	17.63	15.66	9.78	31.55	2.33	0.85	0.11	10.05	0.04	15.31	17.64	2.50	0.28	-86.8%
21FLFTM CALUSA0023FTM	3.52	4.00	2.00	6.55	4.68	2.31	0.62	24.03	0.03	3.97	6.90	1.78	0.18	32.9%

3.5.8 Light Attenuation

The ultimate purpose of representing the levels of light attenuation currently observed in the Caloosahatchee Estuary was to be able to use the model to determine the nutrient reductions necessary to achieve light levels that allow the development of a healthy community of seagrass meadow at the mouth of the Caloosahatchee Estuary (San Carlos Bay) and other critical locations mid-estuary. In the EFDC model, one of the factors controlling the vertical distribution of light in the water column is the extinction coefficient K_e (1/m), which reflects the attenuation of the incident light due to algae shading and particulate organic matter concentration. The equation used to compute K_e, is given as:

$$Ke = ke_b + ke_{TSS}(TSS) + ke_{Chla}(Chla) + ke_{POC}(RPOC + LPOC) + ke_{DOC}(DOC)$$

In this equation, ke_{TSS}, ke_{Chla}, ke_{DOC}, and ke_{POC} are calibration coefficients. The light extinction coefficient, K_e, is computed in the EFDC model as a linear function of the concentrations of TSS, chlorophyll-*a* (Chla), DOC, and POC, specifically RPOC plus LPOC. Light distribution in the water column is simulated using the Beer-Lambert model, which uses the calibrated extinction coefficient (K_e):

$$I(z) = I_o e^{-K_e z}$$

In the Beer-Lambert model, $I(z)$ is the light intensity at a specific depth (z) from the water surface, I_o is the light intensity at the water surface, and K_e is the light attenuation coefficient (units of distance^{-1}). The impacts of light on phytoplankton production (represented as chlorophyll-*a*) are included in the EFDC model by assuming that production is directly proportional to the levels of light available in the water column. The general equation for phytoplankton production included in the EFDC model is expressed as:

$$P = P_{Max} * f_1 * f_2 * f_3$$

In the equation, P_{Max} is the maximum rate of phytoplankton production under optimal conditions of nutrients, light, and temperature; f_1, f_2, and f_3 ($0 \leq f_* \leq 1$) are dimensionless limiting factors for phytoplankton growth due to nutrients, light, and temperature, respectively; and P is the resulting rate of phytoplankton production. The computational details of f_1 and f_3 are presented in Tetra Tech (2007). The limiting factor for light is computed in EFDC for each vertical layer using the Steele (1962) model:

$$f_2 = \frac{2.718 * FD}{K_e(Z_b - Z_T)}\left(e^{-\varphi e^{-K_e Z_b}} - e^{-\varphi e^{-K_e Z_T}}\right)$$

In the Steele (1962) model, $\varphi = I_o/I_s$ where I_s is the optimal light intensity for phytoplankton production, Z_b and Z_T are the depths of the bottom and top boundaries of a layer, and FD the fraction of day with light. An adequate representation of the levels of light available for phytoplankton growth is important to correctly capture the available energy for growth. If solar radiation is low in the water column, phytoplankton communities can have insufficient energy to fixate carbon and nutrients and to increase biomass. However, if the levels of solar radiation are too high, phytoplankton can suffer photo-inhibition, which can also impair algae growth.

As part of the calibration of the light extinction coefficient Ke, the coefficients ke_{TSS}, ke_{Chla}, ke_{DOC}, and ke_{POC} were varied and refined in order to match observations of the K_e coefficient. In the Caloosahatchee River EFDC model, the K_e is defined as:

$$Ke = ke_b + ke_{TSS}(TSS) + ke_{Chla}(Chla) + ke_{POC}(RPOC + LPOC) + ke_{DOC}(DOC)$$

Available measurements of Ke collected during 2000-2002 and 2011-2014 indicate that the levels of light extinction in the system can vary between 0.1 (1/m) and 1.5 (1/m) with an average of 0.5 (1/m). To reproduce these values, a background light extinction coefficient of 0.05 (1/m) was prescribed in the model, and the coefficients related to algae concentration and organic matter concentration were adjusted during calibration.

A list of the values currently included in the EFDC model is presented in **Table 141**. These values were defined based upon the values included in the 2009 EFDC Model (Department 2009), and refined and calibrated based on comparisons between predicted and observed extinction coefficients available during the period 2000-2002 and 2011-2014 at different locations of the estuary (**Figure 140**).

TABLE 141: CALIBRATED PARAMETERS OF THE LIGHT EXTINCTION MODEL K_e

Parameter	2017 Model Value	2009 Model Value
ke_b	0.050	N/A
ke_{TSS}	0.140	0.052
ke_{Chla}	0.040	0.031
ke_{DOC}	0.090	0.014
ke_{POC}	0.070	0.078

The level of agreement achieved during calibration between the observed and predicted light extinction coefficients is presented in **Figure 141** through **Figure 153**, and in **Table 142**. The results indicate that the model was generally able to capture the magnitudes and range of variability of light extinction observed in the system. The comparison between the model predictions and observations of light extinction indicated that the model was able to simulate the average levels of light extinction in the system with values between 0.6 (1/m) and 2.0 (1/m). The simulations were also able to capture the trends and variability of the observations.

An evaluation of the factors impacting the light extinction coefficient in the offshore area and San Carlos Bay suggests that inorganic suspended solids can explain up to 70% of the variability of the light extinction coefficients followed by DOC (16%), chlorophyll-*a* (8%), and POC (5%). To identify and quantify the factors impacting light, the EFDC light extinction coefficient Ke for each evaluated grid cell was divided by the extinction coefficients $ke_{TSS}, ke_{Chla}, ke_{DOC},$ and ke_{POC}. The average percent contribution for each factor was calculated for the calibration period at stations 21FLSWMROOK474 and 21FLSWMROOK473, which are the closest to the San Carlos Bay. These values are in good agreement with the values reported in previous investigations of the Caloosahatchee River. The department (2009), citing studies in Charlotte Harbor (the major watershed north of the Caloosahatchee River) and other regions of the Caloosahatchee River, indicated that non-chlorophyll-*a* matter, consisting mainly of detritus (POC) as well as minerals (TSS), accounted for approximately 72% of the light extinction in the water column, while color in the form of DOC accounted for 21% and chlorophyll-*a* for 4% (see also McPherson and Miller 1987). Other studies indicate that detritus and minerals can represent between 30% and 72% of the light extinction in the estuary, dissolved organic matter between 13% and 66%, and chlorophyll-*a* between 4% and 18% (McPherson and Miller 1994; Dixon and Kirkpatrick 1999).

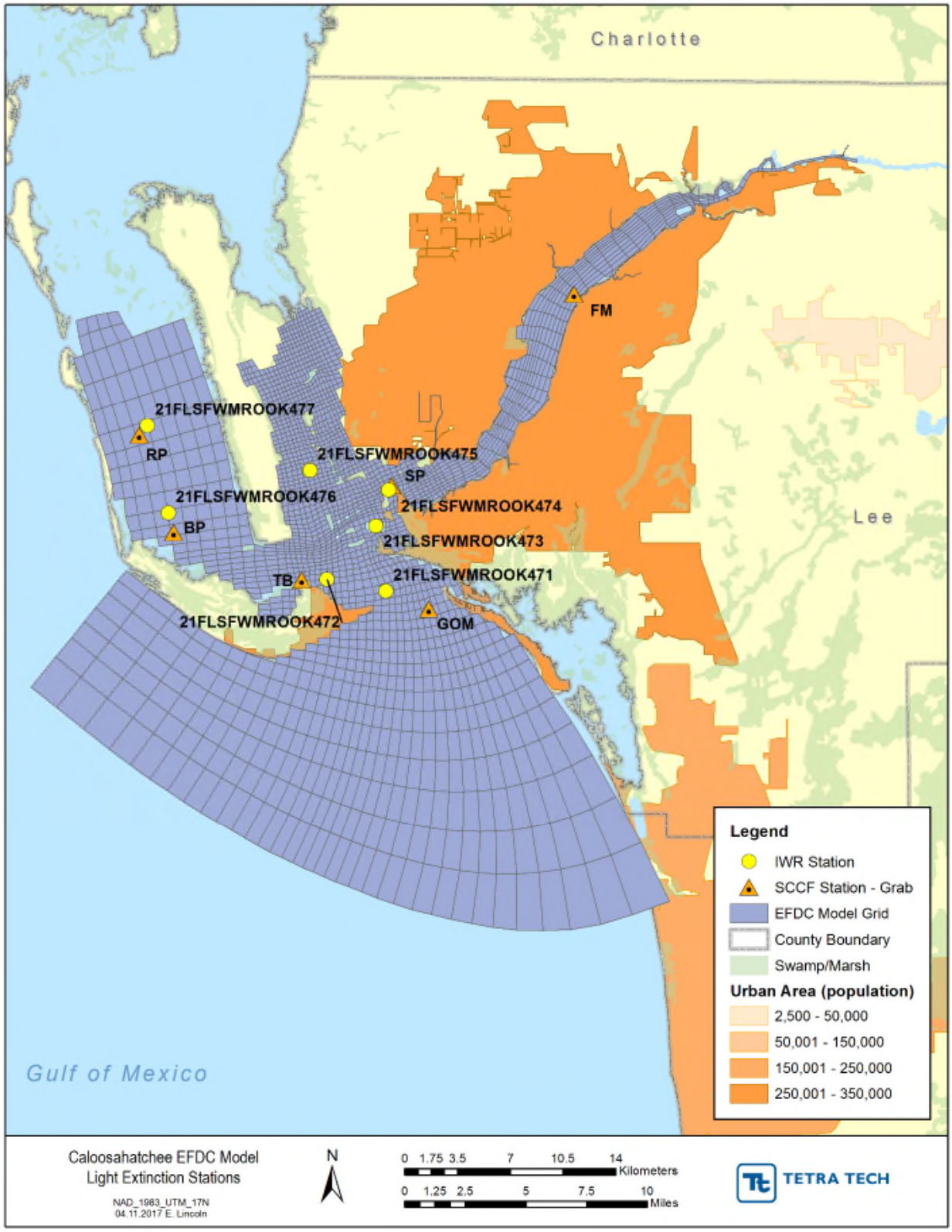

FIGURE 140: 2017 EFDC MODEL LIGHT EXTINCTION CALIBRATION COMPARISON STATION LOCATIONS

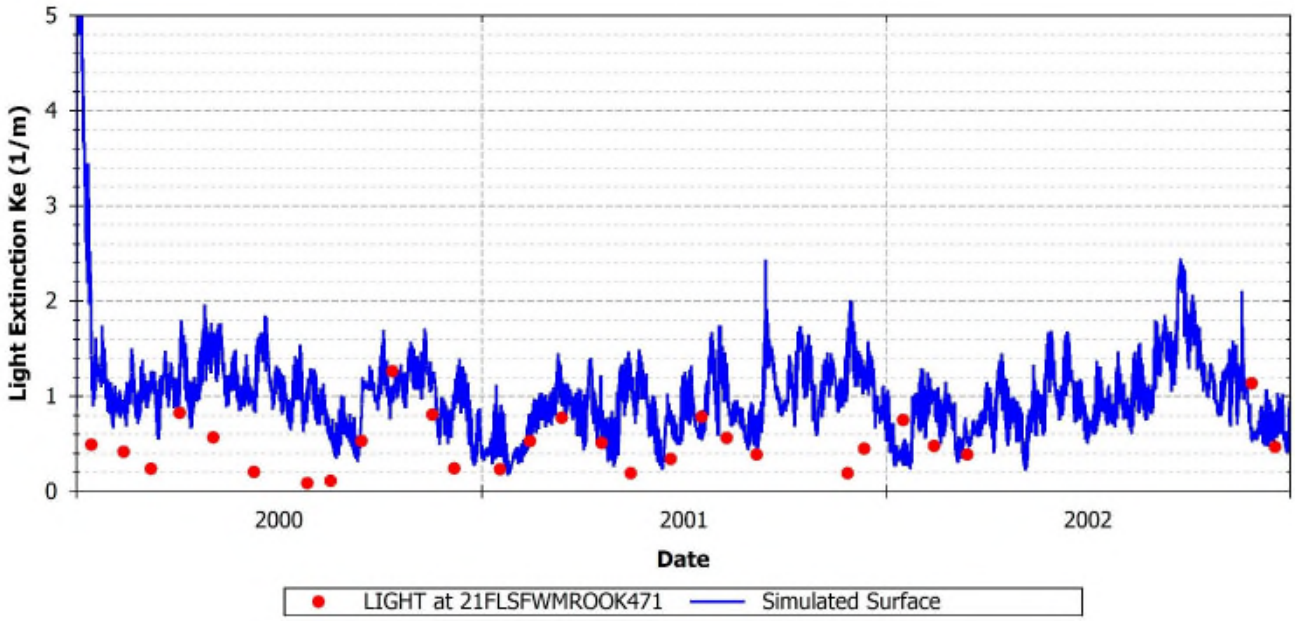

FIGURE 141: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT 21FLSWMROOK471

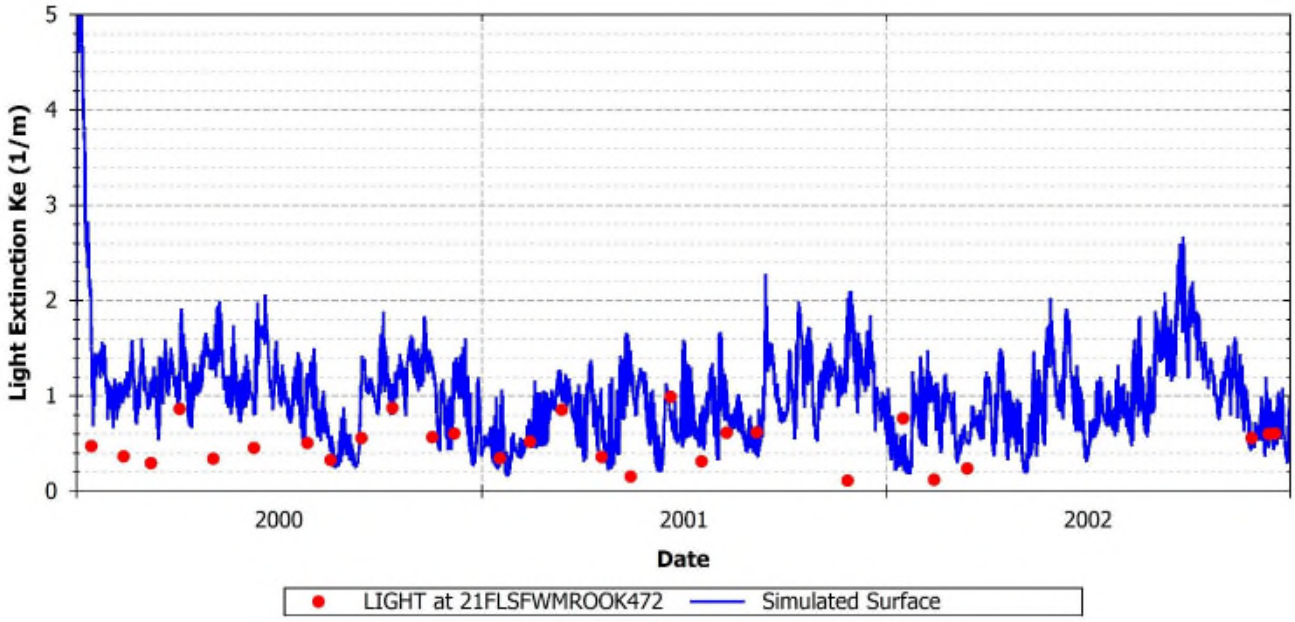

FIGURE 142: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT 21FLSWMROOK472

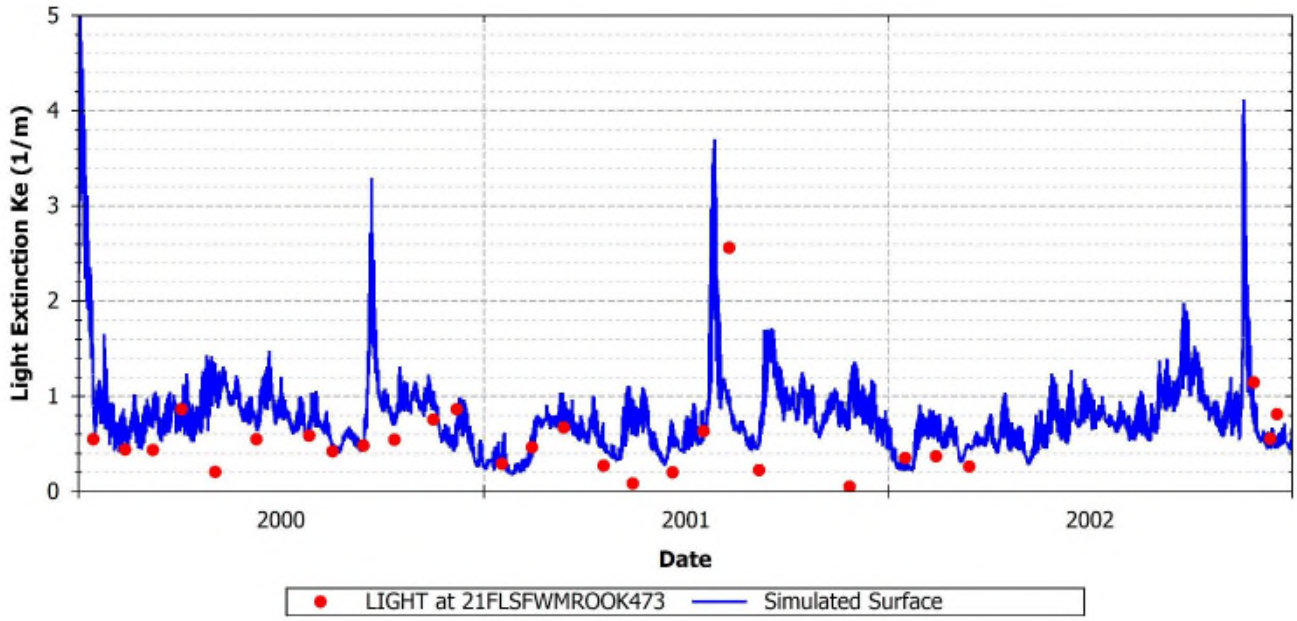

FIGURE 143: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT 21FLSWMROOK473

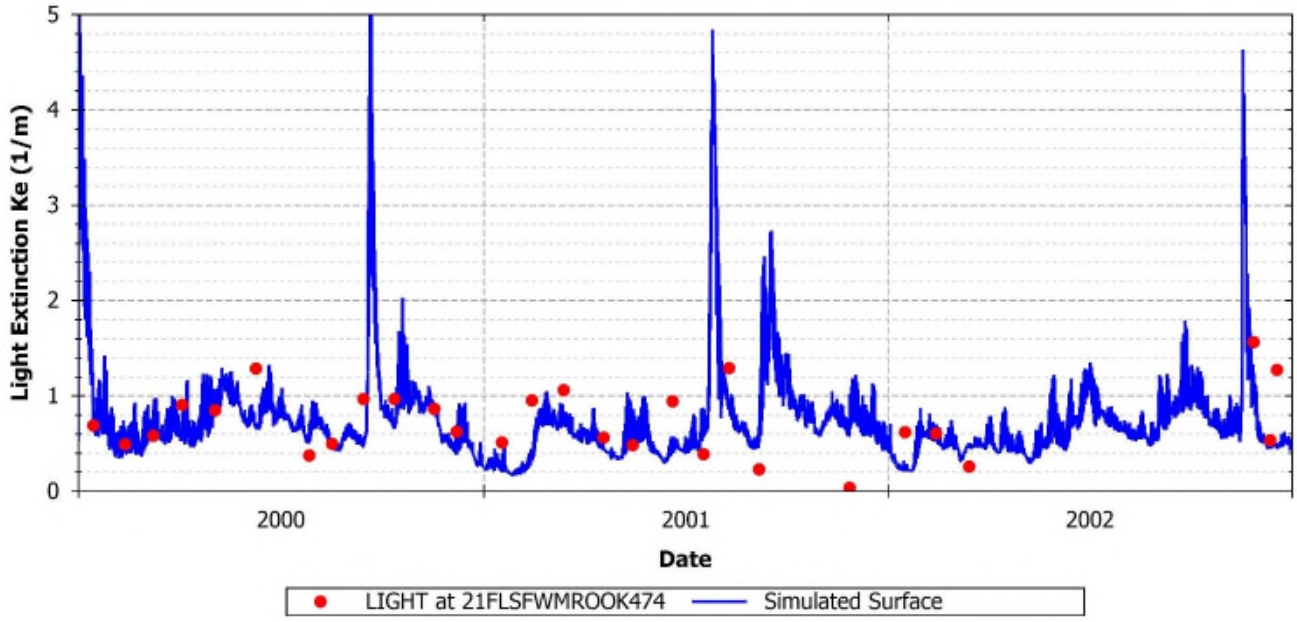

FIGURE 144: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT 21FLSWMROOK474

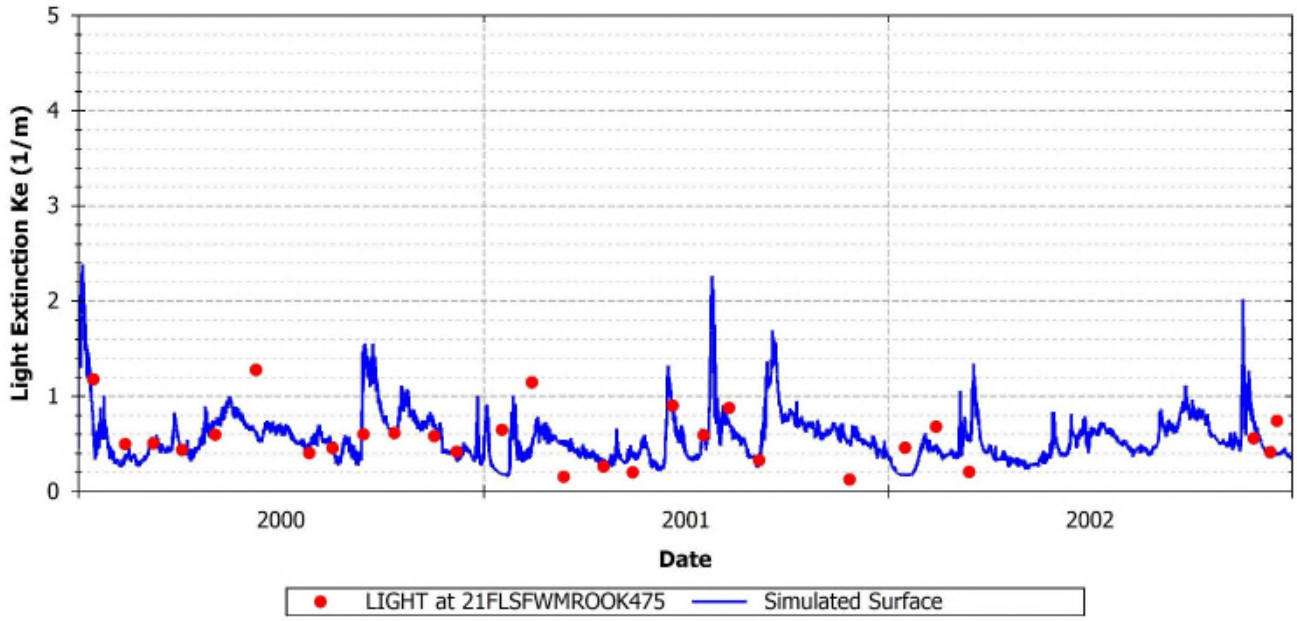

FIGURE 145: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT 21FLSWMROOK475

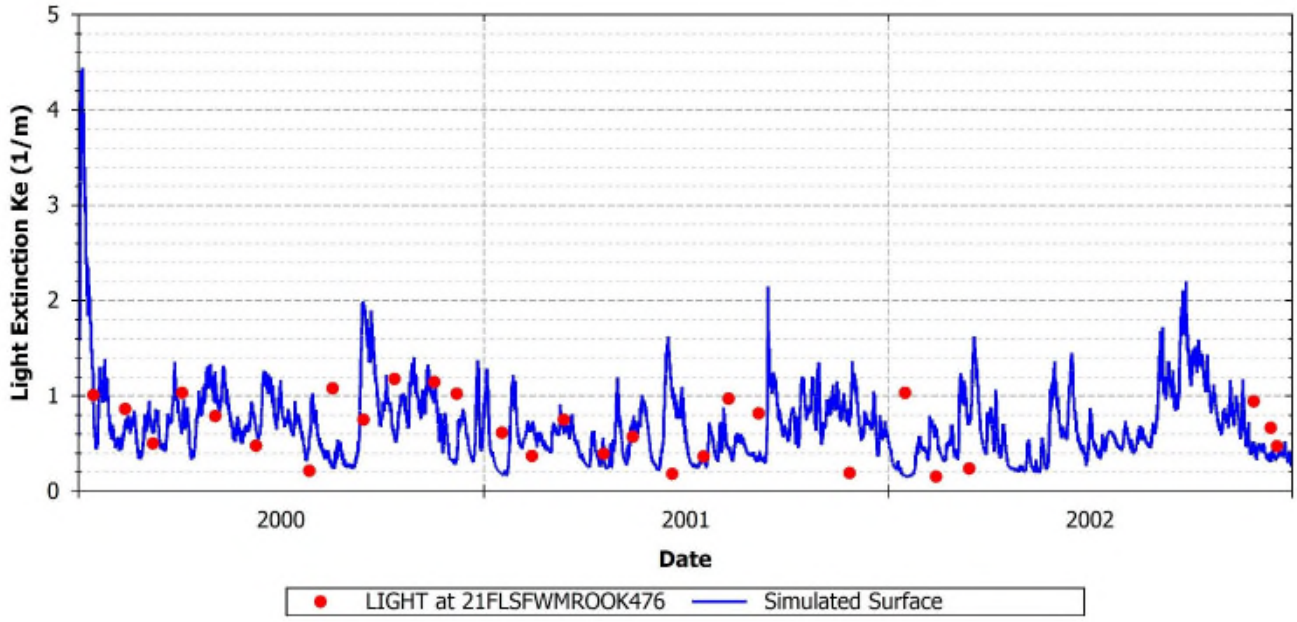

FIGURE 146: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT 21FLSWMROOK476

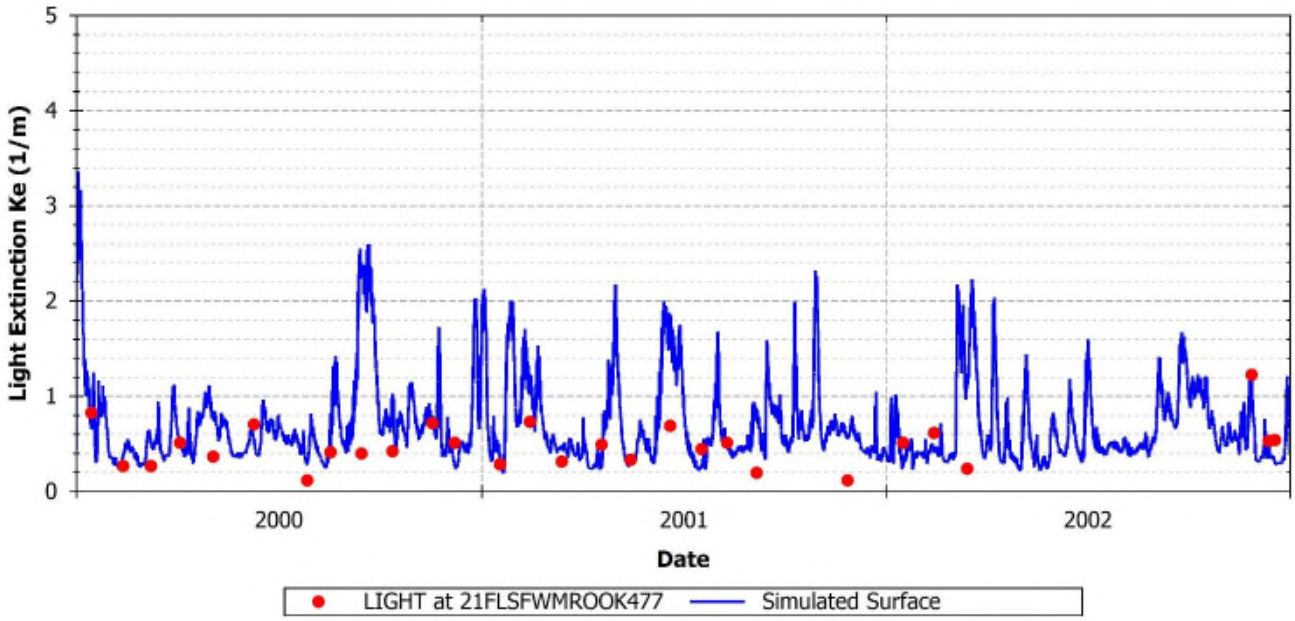

FIGURE 147: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT 21FLSWMROOK477

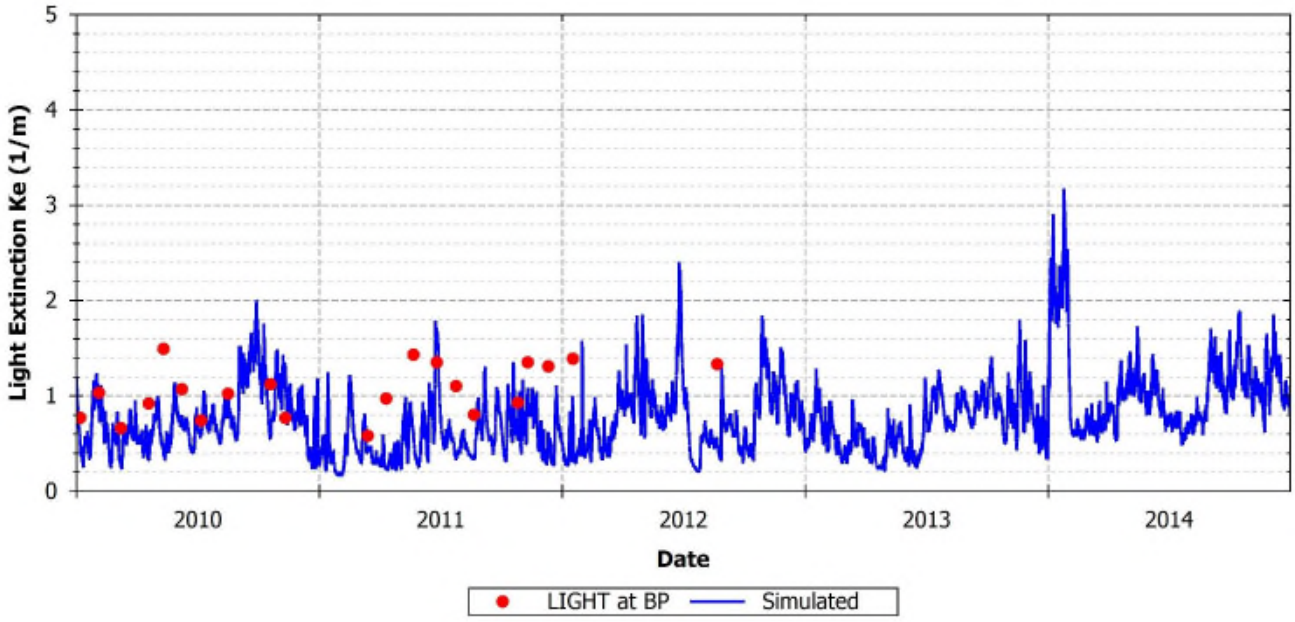

FIGURE 148: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT SCCF STATION BP

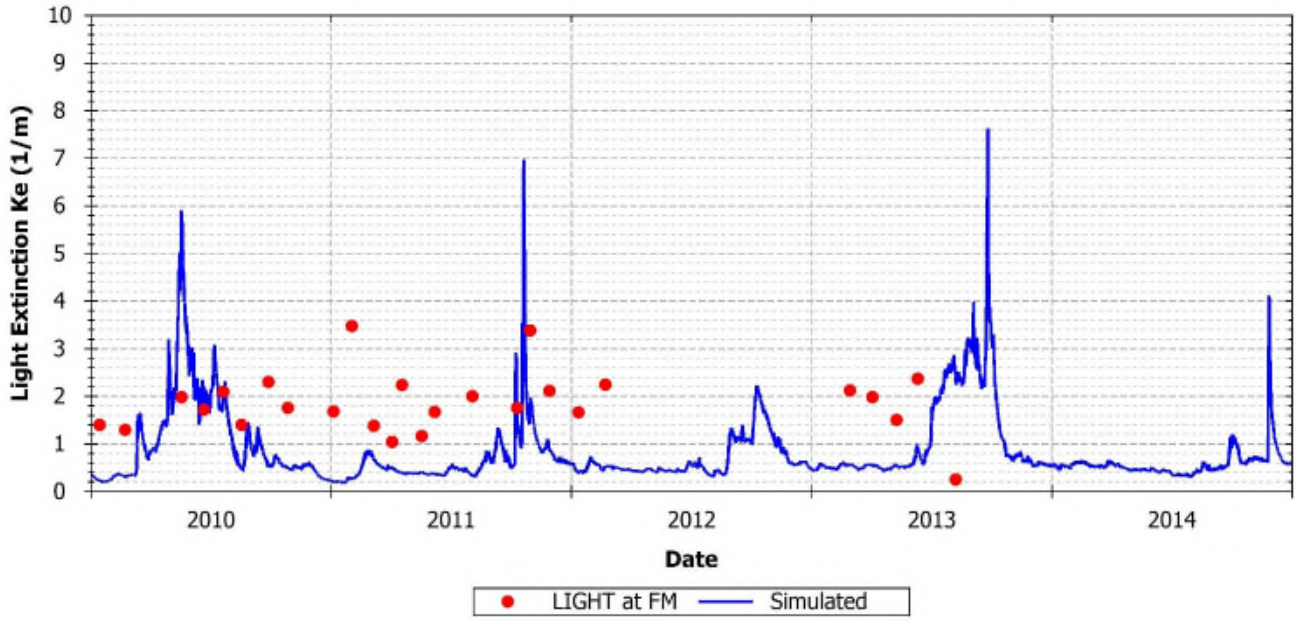

FIGURE 149: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT SCCF STATION FM

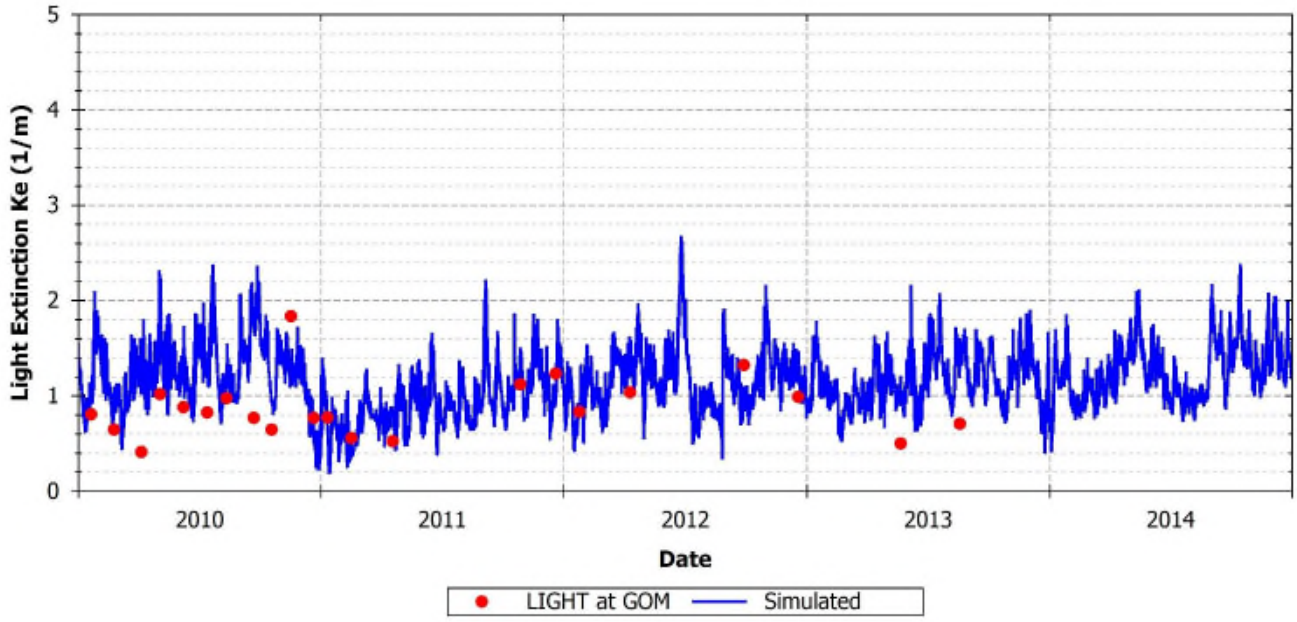

FIGURE 150: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT SCCF STATION GOM

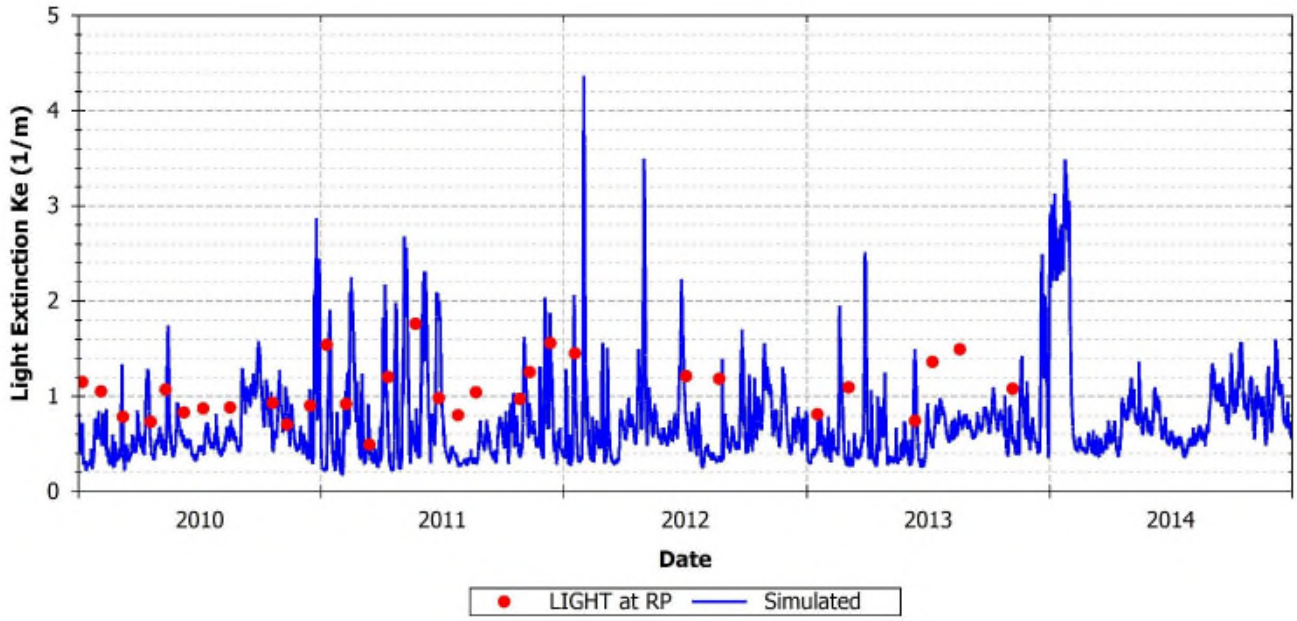

FIGURE 151: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT SCCF STATION RP

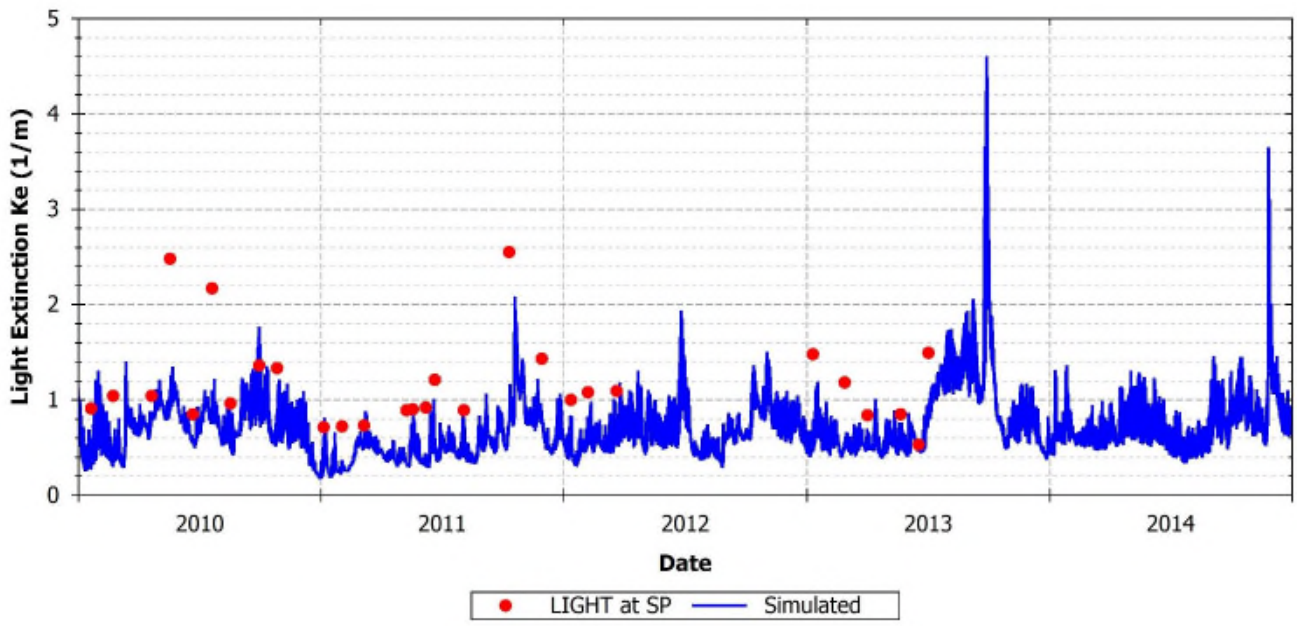

FIGURE 152: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT SCCF STATION SP

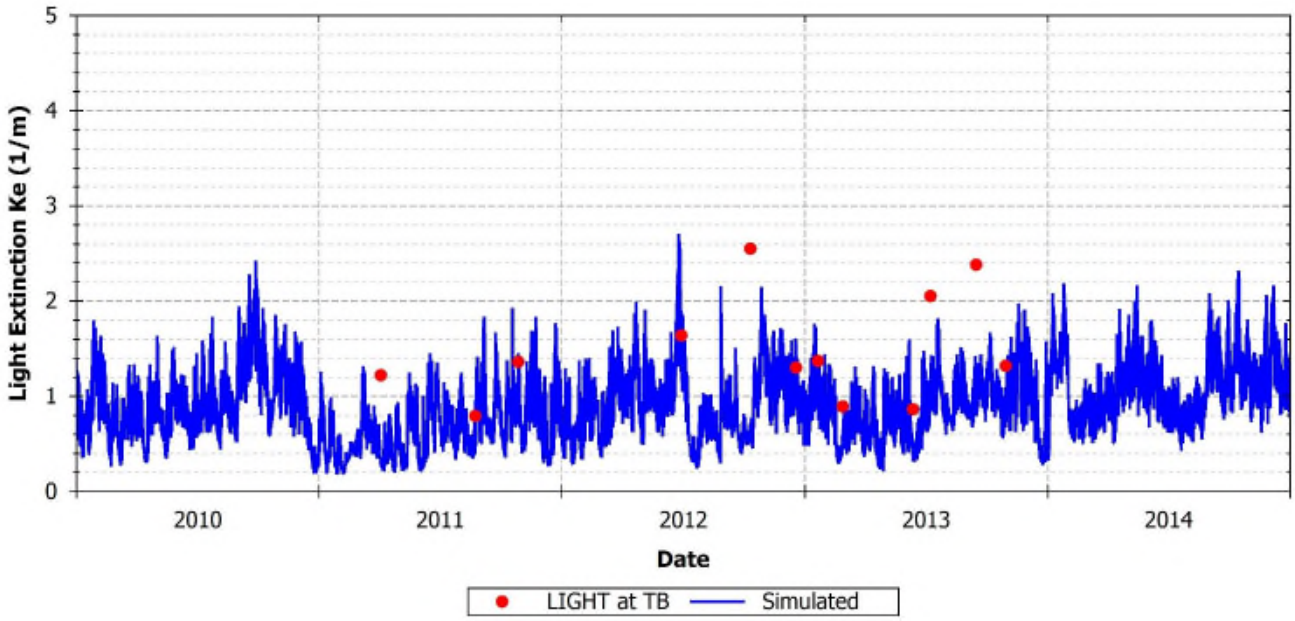

FIGURE 153: OBSERVED VERSUS PREDICTED LIGHT EXTINCTION AT SCCF STATION TB

TABLE 142: CALIBRATION STATISTICS FOR LIGHT EXTINCTION COEFFICIENTS

Station	Measured Mean (mg/L)	Measured Median (mg/L)	Measured 5th %tile (mg/L)	Measured 95th %tile (mg/L)	Simulated Mean (mg/L)	Simulated Median (mg/L)	Simulated 5th %tile (mg/L)	Simulated 95th %tile (mg/L)	R^2	MAE (mg/L)	RMSE (mg/L)	NRMSE	IA	Percent Diff. (%)
21FLSFWMCES04	2.70	3.08	0.00	0.00	1.68	1.98	0.00	0.00	1.00	1.02	1.06	0.44	0.82	-60.81
21FLSFWMROOK471	0.50	0.49	0.10	1.20	0.95	1.01	0.39	1.62	0.00	0.53	0.64	0.94	0.38	47.52
21FLSFWMROOK472	0.50	0.55	0.11	0.94	0.91	1.01	0.34	1.61	0.04	0.49	0.63	0.95	0.38	45.03
21FLSFWMROOK473	0.56	0.54	0.06	1.92	0.67	0.68	0.26	1.19	0.03	0.32	0.49	0.78	0.43	17.36
21FLSFWMROOK474	0.73	0.69	0.12	1.44	0.62	0.63	0.22	1.06	0.13	0.30	0.36	0.52	0.54	-18.21
21FLSFWMROOK475	0.56	0.58	0.14	1.23	0.52	0.52	0.18	1.05	0.11	0.23	0.30	0.54	0.52	-7.63
21FLSFWMROOK476	0.67	0.75	0.17	1.16	0.63	0.63	0.17	1.63	0.00	0.41	0.50	0.77	0.33	-6.18
21FLSFWMROOK477	0.47	0.51	0.11	1.04	0.66	0.50	0.25	2.13	0.05	0.33	0.52	0.90	0.44	28.01
BP	1.05	1.07	0.59	1.48	2.71	2.92	0.30	6.00	0.00	1.84	2.30	1.36	0.45	61.05
FM	1.84	1.95	0.53	3.44	5.46	6.37	0.26	15.84	0.00	4.35	5.86	1.87	0.45	66.28
GOM	0.87	0.83	0.42	1.76	1.21	1.28	0.29	3.08	0.00	0.73	0.91	0.88	0.40	28.19
RP	1.06	1.06	0.62	1.64	2.88	3.18	0.44	5.70	0.01	1.98	2.32	1.32	0.43	63.26
SP	1.17	1.04	0.61	2.52	3.61	3.52	0.34	11.58	0.01	2.79	4.07	2.03	0.41	67.69

3.5.9 Parameter Sensitivity Analysis

A sensitivity analysis of the Caloosahatchee River EFDC water quality model was conducted to identify the most important model parameters and input datasets affecting the predictions of the model. A sensitivity analysis is a process by which different aspects of a model such as parameter values, input time series, and model structure elements such grid resolution are perturbed and the results evaluated to identify the factors that cause the largest variability in the model predictions. The results of a sensitivity analysis can be used for multiple purposes. For example, they can be used to gain a better understanding of mechanistic relationships controlling specific physical, chemical, and biological processes (Perumal and Gunawan, 2011), or to identify the model parameters that have the largest impacts on the predictions in order to focus the calibration efforts only in the most critical parameters (Saltelli et al. 2000; White and Chaubey 2005).

When a sensitivity analysis of a model involves the evaluation of multiple parameters or inputs, each simulation can be performed by simultaneously perturbing all model parameters and inputs or, as performed in this project, by individually changing each parameter or input while keeping the other constant. The later approach is commonly known as one at a time sensitivity analysis (OAT-SA) and is a widely applied approach for sensitivity analyses (Saltelli et al. 2006; Loosvelt et al. 2013). One of the most important aspects of OAT-SA is that the impacts of each parameter or input variable on the model predictions can be isolated from the other aspects of the model, so it is easy to identify its relevance in the modeling effort. However, OAT-SA has the limitation that cannot be used to identify correlation between parameters.

A local sensitivity analysis based on OAT-SA model perturbation approach was performed for the Caloosahatchee River EFDC water quality model. The sensitivity analysis used the calibrated model parameters and input datasets as the baseline conditions for the analysis. The purpose of the sensitivity analysis was to inform the department of the most sensitive parameters and input variables of the model so future calibration efforts and model updates can focus on the most critical aspects of the model.

3.5.9.1 Model Parameters and Input Variables under Analysis

The sensitivity analysis was focused on some of the most relevant variables involved in problems of eutrophication given that the ultimate purpose of the 2017 EFDC Model is to be used to support management actions related to nutrient criteria and TMDL development. The output variables selected for the sensitivity analysis were phytoplankton chlorophyll-*a*, which is an indicator of biomass; inorganic nutrients including NH_4, NO_3, and PO_4, which are bioavailable nutrients for phytoplankton uptake; light extinction coefficient; and DO. The model parameters and input datasets perturbed during the sensitivity analysis included the loads from the S-79 model boundary; loads from the sub-watersheds; ratios used for the fractioning of the organic nutrients from the HSPF model into refractory, labile, and dissolved forms for the EFDC model; sediment oxygen demand; rates of phytoplankton growth and death; and linear extinction coefficients associated with TSS, POC, DOC, and chlorophyll-*a* (**Table 143**).

TABLE 143: SUMMARY OF PARAMETERS AND VARIABLES INCLUDED IN THE SENSITIVITY ANALYSIS

Category	Model component	Chlorophyll-*a*	DO	NH_4	NO_3	PO_4	Light
Input variable	Loads from S-79 boundary	x	x	x	x	x	x
Input variable	Watershed loads	x	x	x	x	x	x
Input variable	Fractioning of organic nutrients	x	x	x	x	x	x
Input variable	Sediment oxygen demand	x	x	x	x	x	x
Model parameter	Algae death	x	x	x	x	x	x
Model parameter	Algae growth	x	x	x	x	x	x
Model parameter	KeTSS	x	x	x	x	x	x
Model parameter	KePOC	x	x	x	x	x	x
Model parameter	KeDOC	x	x	x	x	x	x
Model parameter	KeChla	x	x	x	x	x	x

The sensitivity analysis was conducted for the simulation period 1/1/2013 – 12/31/2014 using as a baseline or reference condition the model setup and results of the calibrated model. **Table 144** describes the perturbations for the parameters and input variables of interest during the sensitivity analysis. In most cases, the perturbations corresponded to a 25% increment increase of the calibrated parameter values and input variables. This level of perturbation was selected to be able to identify with confidence non-sensitive aspects of the model while keeping the perturbations in a range comparable with similar studies (Cho et al. 2016). Generally, in most sensitivity studies, the perturbations induced in the model parameters or input variables range between 5% and 50%. However, the smaller the perturbation, the more difficult it is to conclude with confidence that a model parameter or input variable is insensitive if the perturbation causes no change in the model outputs. The reason for this is that the response surface of non-linear models (defined as the multidimensional space of model parameters versus model outputs) are typically characterized for having multiple local minima and maxima as well as multiple local valleys. In local valleys, in particular, the model is insensitive to changes in the parameters and input variables. The use of a relatively large perturbation of 25% is intended to cause a sufficient change in the model to evaluate the response outside local valleys in case one or more of the calibrated parameter values are located in one of these regions.

TABLE 144: SUMMARY OF MODEL PERTURBATIONS CONDUCTED DURING THE SENSITIVITY ANALYSIS

Input variable or model parameter	Perturbation scenario
Loads from S-79 boundary	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
Watershed loads	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
Splitting fractions for organic nutrients*	Splitting of organic carbon, nitrogen and phosphorus into refractory, labile and dissolved forms for all freshwater boundary loads. RPOC = 25%. Approximate baseline value RPOC = 30%. LPOC = 40%. Approximate baseline value LPOC = 10%. DOC = 35%. Approximate baseline value DOC = 60%. RPON = 30%. Approximate baseline value RPON = 30%. LPON = 35%. Approximate baseline value RPON = 10%. DON = 35%. Approximate baseline value DON = 60%. RPOP = 10%. Approximate baseline value RPOP = 30%. LPOP = 37%. Approximate baseline value LPOP = 15%. DOP = 53%. Approximate baseline value DOP = 55%.

Input variable or model parameter	Perturbation scenario
Sediment oxygen demand	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
Algae growth	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
Algae death	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
KeTSS	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
KePOC	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
KeDOC	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.
KeChla	25% increment from baseline condition while keeping all other parameters and inputs at the reference values.

* Approximate baseline values are presented for the 2017 Caloosahatchee River EFDC Model.

The splitting fractions for the organic nutrients from the HSPF model into refractory, labile, and dissolved forms for the EFDC model were perturbed slightly differently than the other parameters and input variables. The reason for this is that these ratios are not parameters of the EFDC model nor input variables. These ratios are used as a mechanism to convert the outputs of organic nutrients from the HSPF model into the organic nutrient forms simulated by the EFDC model. Because the approach to link the HSPF and EFDC models is slightly different in the 2017 Model compared to the approaches used in the 2009 Model and 2014 Model (department, personal communication), the perturbations of these fractions was intended to determine how sensitive the model outputs are to the approach used to link the HSPF and EFDC models. To investigate this, the ratios were set to the values used in the 2009 and 2014 Models, and the outputs were compared against the outputs obtained for baseline conditions. For the sensitivity analysis, RPOC was reduced by 16% (from 0.3 to 0.25), LPOC was increased by 400% (from 0.1 to 0.4) and DOC was reduced by 41% (from 0.6 to 0.35). RPON was not changed, LPON was increased by 350% (from 0.1 to 0.35) and DON was reduced by 41% (from 0.6 to 0.35). RPOP was reduced by 66% (from 0.3 to 0.1), LPOP was increased by 246% (from 0.15 to 0.37) and DOP was reduced by 3.6% (from 0.55 to 0.53).

3.5.9.2 Estimates of Model Sensitivity

Estimates of model sensitivity were obtained by computing the relative variation of the perturbed model predictions with respect to the baseline conditions. The analysis focused in identifying the sensitivity of the mean, 5th, and 95th percentiles of the model predictions by means of:

$$Relative\ change\ in\ mean = \frac{Mean\ perturbed\ condition - Mean\ baseline\ conditin}{Mean\ baseline\ condition}$$

$$Relative\ change\ in\ 5\%tile = \frac{5\%tile\ perturbed\ condition - 5\%tile\ baseline\ condition}{5\%tile\ baseline\ condition}$$

$$Relative\ change\ in\ 95\%tile = \frac{95\%tile\ perturbed\ condition - 95\%tile\ baseline\ condition}{95\%tile\ baseline\ condition}$$

The analysis was complemented with visual comparisons between the model predictions for baseline conditions and the model predictions under perturbed model parameters and input variables.

3.5.9.3 Stations Evaluated

The sensitivity analysis was performed at six stations distributed throughout the Caloosahatchee River model as shown in **Figure 154** and summarized in **Table 145**. Stations 1, 2, and 3 are located in the upstream, middle, and lower river portions of the model, respectively, while stations 4, 5, and 6 are located close to the Gulf of Mexico boundary, Matlacha Pass, and Pine Island, respectively. The results at these locations provide an overal estimate of how the model sensitivity varies with location.

TABLE 145: STATIONS USED FOR THE SENSITIVITY ANALYSIS

Station ID	Station Description	EFDC Cell Location I	EFDC Cell Location J
Station 1	Upstream river region	76	31
Station 2	Middle river region	59	31
Station 3	Lower river region	41	37
Station 4	Gulf of Mexico region	36	16
Station 5	Matlacha Pass region	23	48
Station 6	Pine Island region	6	39

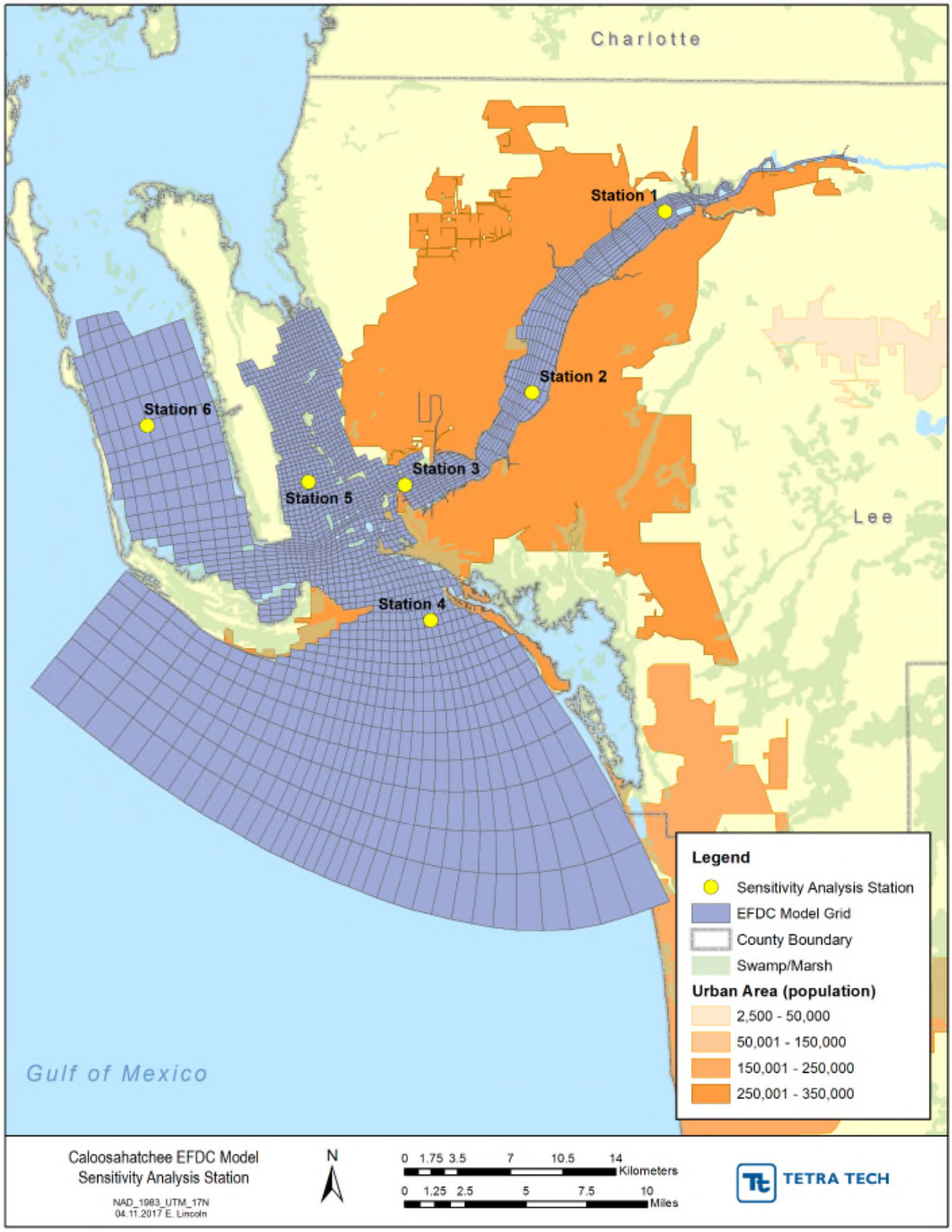

FIGURE 154: SELECTED LOCATIONS FOR THE SENSITIVITY ANALYSIS

3.5.9.4 DO Sensitivity Analysis Results

A summary of the sensitivity analysis results is presented for DO in **Table 146** and **Figure 155** through **Figure 160**. The predictions of DO were primarily sensitive to changes in the loads from the S-79 boundary and to changes in the splitting fractions of the organic nutrients. The predictions of DO exhibited a lower sensitivity to changes in other model parameters and input datasets (**Table 146**).

The load increase at the S-79 boundary caused a reduction of the DO concentrations particularly during the summer periods (Stations 1, 2, and 3, **Figure 155** through **Figure 160**). In the riverine portion of the system the 5th percentile concentrations (generally representative of summer periods) decreased between 3% and 14%, while the mean concentrations of DO decreased between 1% and 2% from the reference condition following the changes in loads at the S-79 boundary (**Table 146**). The changes in the highest (95th percentile) concentrations (typically occurring during winter) were negligible, as well as the changes in DO concentrations in stations located in the Gulf of Mexico, Matlacha Pass, and Pine Island. The results showed that the system does not respond linearly to the changes in the boundary loads. In this case, a 25% load increment causes less than a 14% reduction in the lowest DO concentrations and no changes in the highest concentrations. These results were reasonable given that other processes, such as reaeration, dispersion, and mixing of freshwater loads with salt water from the Gulf of Mexico, can impact the concentrations of DO in the estuary.

The changes in splitting the fractions of the organic nutrients had a positive impact on the simulations of DO. In the riverine portion of the system at Stations 1, 2, and 3, the modified splitting fractions caused an increase of DO particularly during the summer periods when the DO concentrations generally reached the minimum levels (**Figure 155** through **Figure 157**). The 95th percentile DO concentrations at Station 1 and Station 2 increased approximately 17% and 18%, respectively, while the increase at Station 3 was only about 5% with respect to the baseline condition. Finally, as noted in **Table 146**, the changes in splitting the fractions caused no relevant changes in the maximum DO concentrations nor changes in the DO concentrations at the stations located in the embayment region. The positive impact of the perturbations of splitting the fractions on DO was explained by the 40% reduction of the dissolved organic carbon and DON resulting from the use of the modified fractions. By reducing the dissolved carbon and dissolved nitrogen in the system, less carbon is available for oxidation and less nitrogen is available for hydrolysis and subsequent oxidation. As less oxygen is utilized for these processes, the DO concentrations in the system increase.

In addition, DO is affected by several processes such as DO loading, reaeration, BOD oxidation, sediment oxygen demand, nitrification, and phytoplankton production and respiration. All of these processes are non-linearly related to each other and simultaneously impact the pool of DO in the system. The low sensitivity of the DO simulations to the changes in the parameters and input variables evaluated suggests that none of these parameters is a dominant factor impacting DO in the Caloosahatchee River.

TABLE 146: PERCENT VARIATION OF DO MODEL PREDICTIONS RELATIVE TO BASELINE CONDITIONS FOR ALL SENSITIVITY ANALYSIS RUNS

Station	Baseline Mean	Baseline 5%tile	Baseline 95%tile	Loads from S-79 Mean	Loads from S-79 5%tile	Loads from S-79 95%tile	Watershed Loads Mean	Watershed Loads 5%tile	Watershed Loads 95%tile	Org. Nutrient Fraction Mean	Org. Nutrient Fraction 5%tile	Org. Nutrient Fraction 95%tile	Sediment Oxygen Demand Mean	Sediment Oxygen Demand 5%tile	Sediment Oxygen Demand 95%tile	Algae Death Mean	Algae Death 5%tile	Algae Death 95%tile	Algae Growth Mean	Algae Growth 5%tile	Algae Growth 95%tile	KeTSS Mean	KeTSS 5%tile	KeTSS 95%tile	KePOC Mean	KePOC 5%tile	KePOC 95%tile	KeDOC Mean	KeDOC 5%tile	KeDOC 95%tile	KeChla Mean	KeChla 5%tile	KeChla 95%tile
Station 1	5.48	2.58	7.63	1.9	3.2	0.7	-0.5	-2.5	-0.1	-4.3	-16.5	-0.7	1.2	0.7	0.8	1.3	0.4	1.1	-2.1	-0.5	-1.2	0.1	0.1	0.1	0.2	0.0	0.1	0.2	0.1	0.1	-0.1	0.0	-0.1
Station 2	6.67	3.16	8.34	1.5	13.7	0.1	0.2	0.5	0.1	-0.5	-18.3	0.3	0.8	1.6	0.6	0.3	0.5	0.1	-0.4	-1.3	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Station 3	6.27	4.11	7.75	1.1	9.8	0.1	0.2	1.2	0.0	-0.1	-5.2	0.2	1.2	2.2	0.8	0.4	0.4	0.1	-0.6	-1.4	-0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Station 4	5.17	3.53	6.88	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	3.1	1.4	0.4	0.3	0.3	-0.7	-0.7	-0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Station 5	6.52	5.43	7.66	0.6	2.8	0.0	0.1	0.2	0.0	0.1	-0.3	0.1	0.9	1.1	0.7	0.4	0.2	0.2	-0.6	-1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Station 6	6.02	4.89	7.18	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.8	2.5	1.1	0.4	0.1	0.3	-0.7	-0.2	-0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	***-***	***-***	***-***	***1.0***	***5.9***	***0.2***	***0.0***	***-0.1***	***0.0***	***-0.9***	***-8.1***	***0.0***	***1.3***	***1.8***	***0.9***	***0.6***	***0.4***	***0.4***	***-0.9***	***-1.1***	***-0.3***	***0.1***	***0.1***	***0.0***	***0.0***	***0.0***	***0.0***	***0.1***	***0.1***	***0.0***	***0.0***	***0.0***	***0.0***

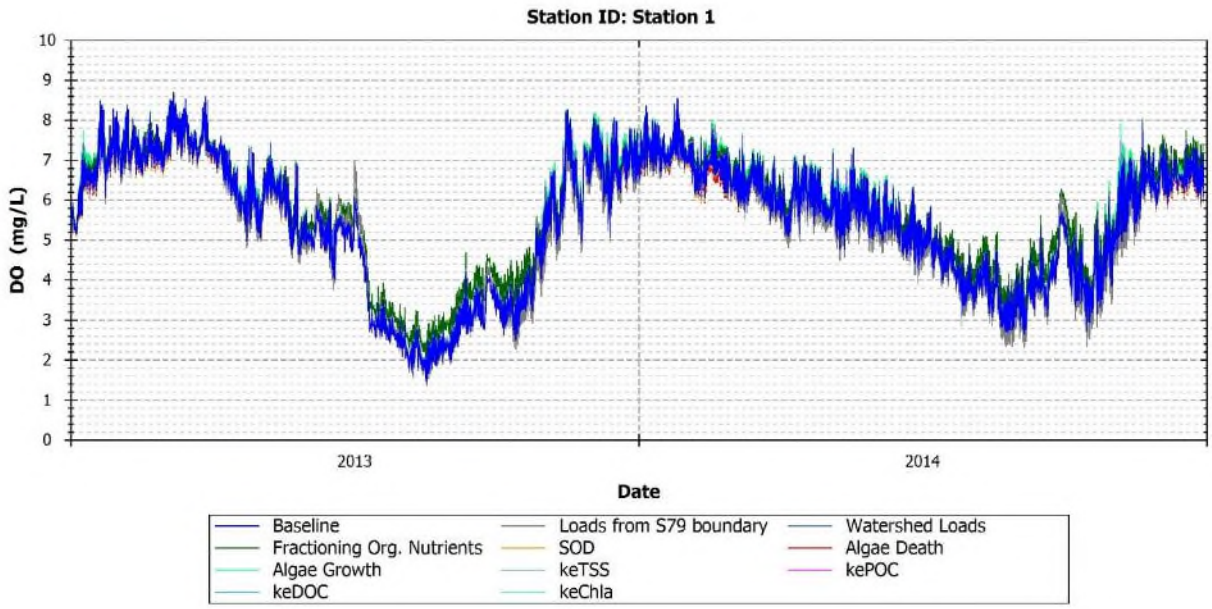

FIGURE 155: MODEL PREDICTIONS OF DO FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 1

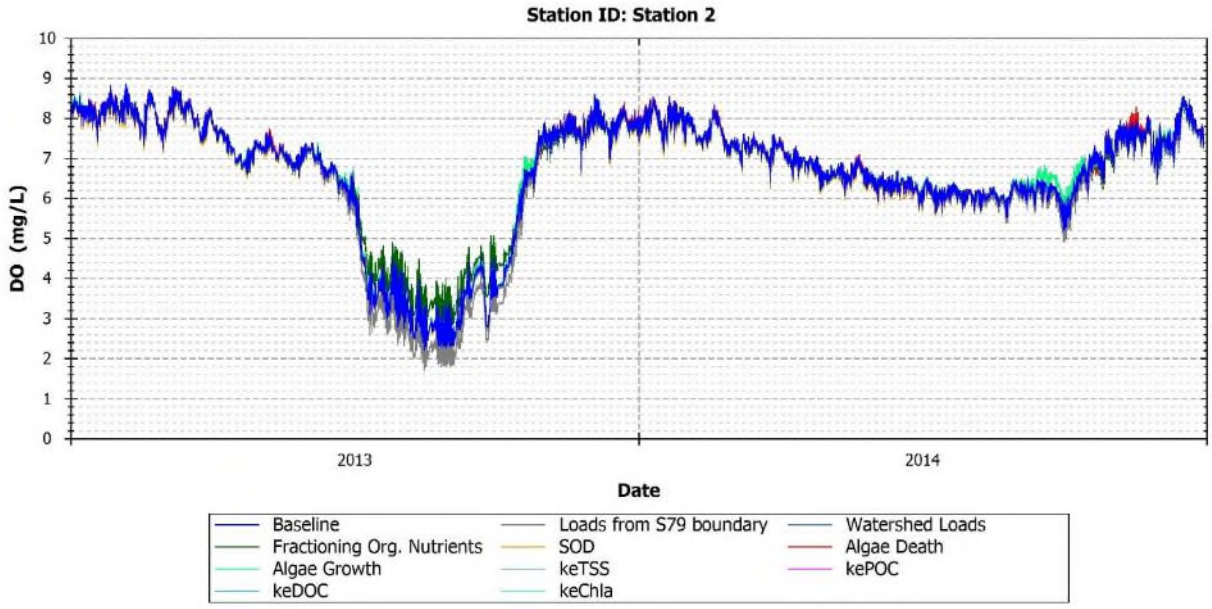

FIGURE 156: MODEL PREDICTIONS OF DO FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 2

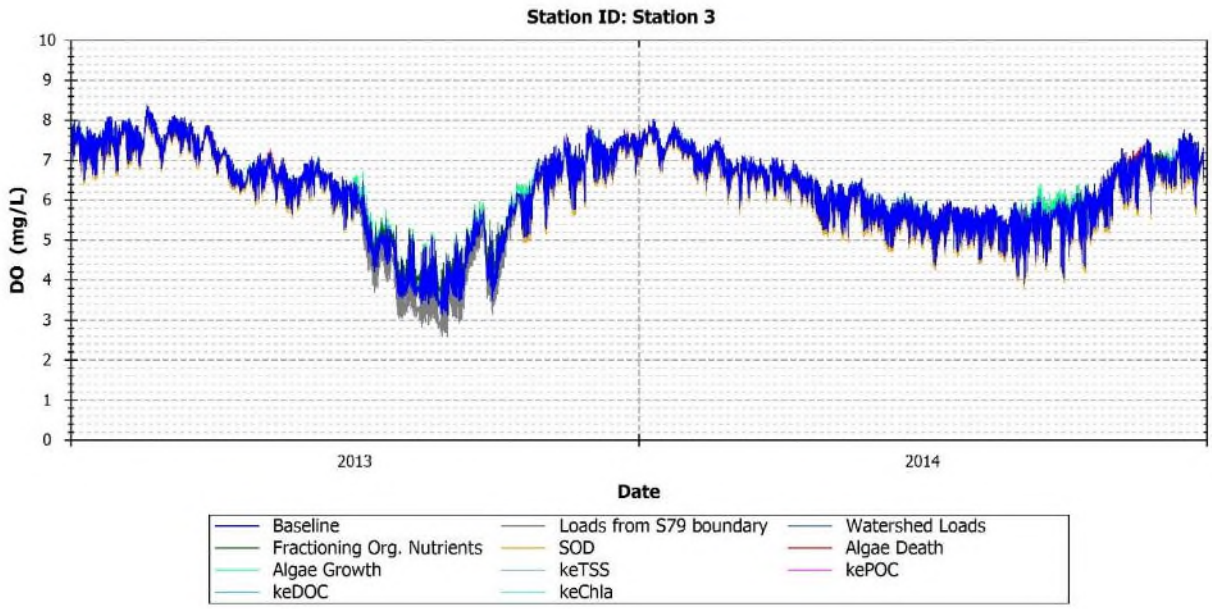

FIGURE 157: MODEL PREDICTIONS OF DO FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 3

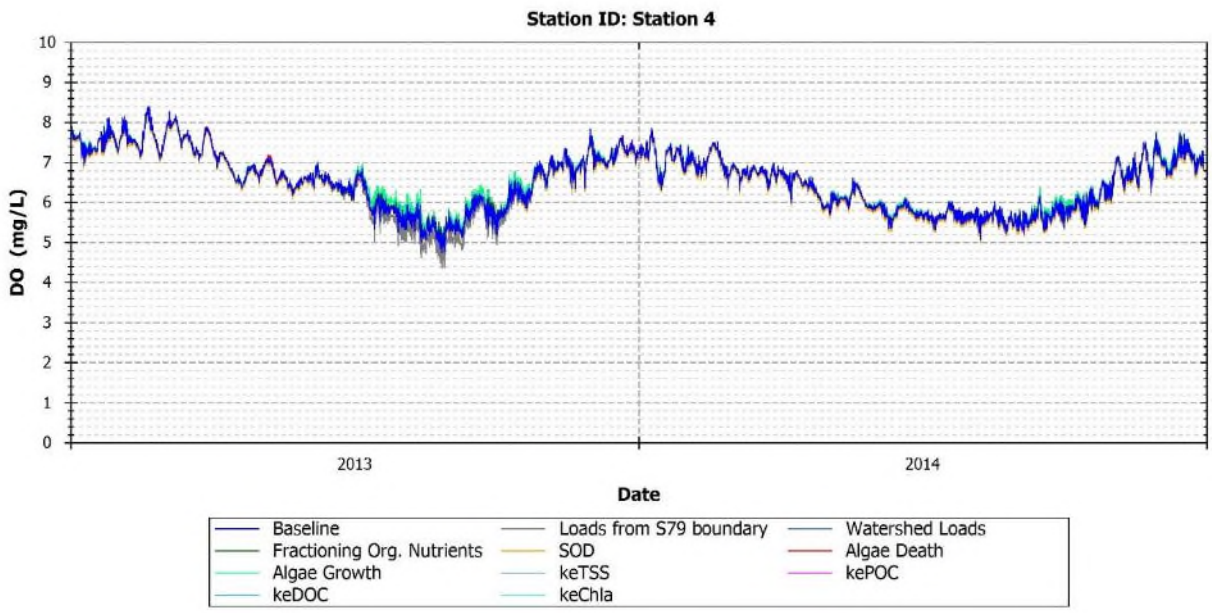

FIGURE 158: MODEL PREDICTIONS OF DO FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 4

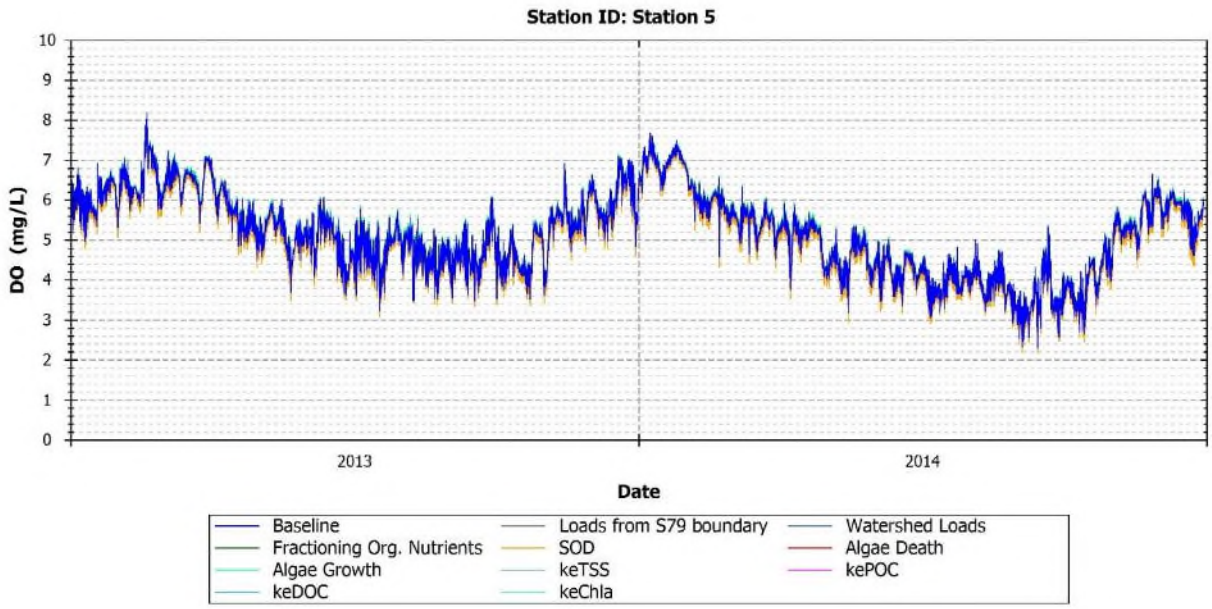

FIGURE 159: MODEL PREDICTIONS OF DO FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 5

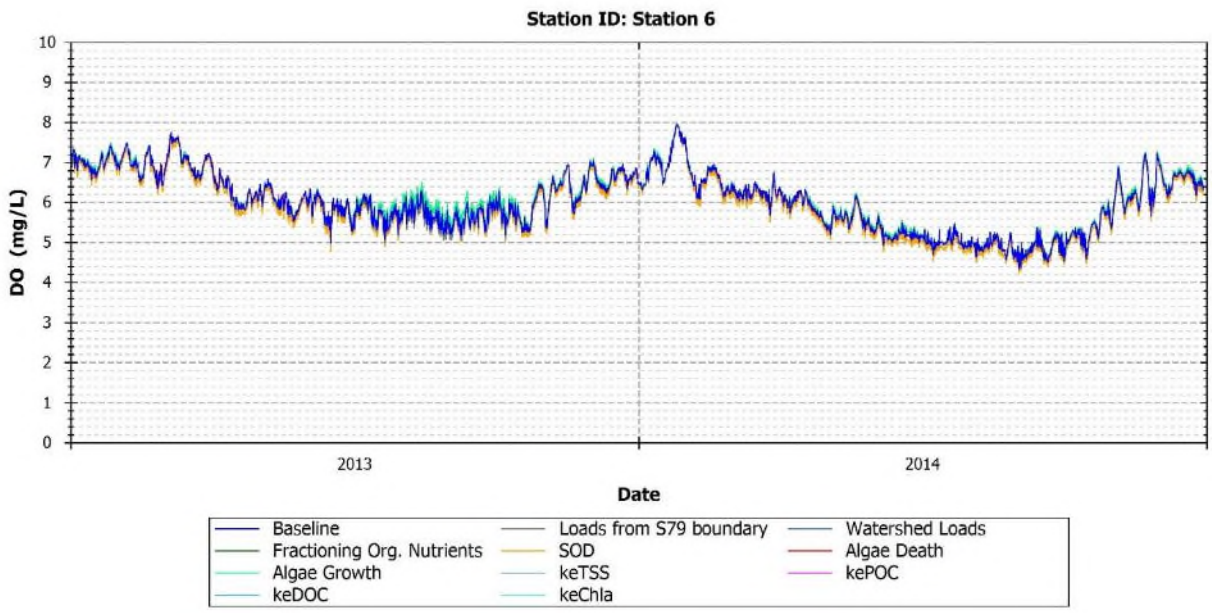

FIGURE 160: MODEL PREDICTIONS OF DO FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 6

3.5.9.5 Phytoplankton/Chlorophyll-*a* Sensitivity Analysis Results

A summary of the sensitivity analysis results for chlorophyll-*a* is presented in **Table 147** and **Figure 161** through **Figure 166**. Phytoplankton biomass was the most sensitive variable of all the output variables that were analyzed. In order of importance, phytoplankton biomass was most sensitive to perturbations in the rates of algae growth and death, the self-shading extinction coefficient (KeChla), and to a lesser extent to perturbations in the loads from the S-79 boundary and in the splitting fractions for the organic nutrients.

The results indicated that perturbations on the rates of algae growth and death are non-linearly propagated through the model and magnified to the predictions of chlorophyll-*a*. A 25% increase in the algae growth rate caused an approximately 40% increase in the mean chlorophyll-*a* concentration. Likewise, a 25% increase in the algae death rate caused an approximately 40% reduction in the mean chlorophyll-*a* concentration. The lowest chlorophyll-*a* concentrations were sensitive to changes in the rates of growth and death as the perturbations of these variables caused an average 170% increase and a 65% decrease of the 5th percentile concentrations of chlorophyll-*a*, respectively. The reason for this nonlinear response of the model to perturbations in the rates of growth and death is that these rates are internally corrected for temperature using exponential models to accelerate or slow down the rates when the ambient temperatures are inside or outside a given range of optimal temperatures for phytoplankton development.

The perturbations of the self-shading extinction coefficient KeChla also had an important and almost linear impact on the predictions of chlorophyll-*a*. In this case, a 25% increase of the extinction coefficient KeChla resulted in an approximately 20% reduction of the chlorophyll-*a* concentration. The impacts of the perturbations of KeChla on chlorophyll-*a* were highly homogeneous as the reduction in chlorophyll-*a* was approximately 20% for all the evaluated stations (**Table 147**). The high sensitivity of phytoplankton biomass to the self-shading coefficient could be explained by the fact that light is a limiting factor for phytoplankton development.

The perturbations in the loads from the S-79 boundary and in the splitting fractions of organic nutrients had a relatively lower impact on the predictions of chlorophyll-*a*. In the first case, a 25% increase of loads from the S-79 boundary resulted in an approximate 10% increase of chlorophyll-*a* in the riverine region (Stations 1 to 3, **Table 147**) in response to the increased availability of nutrients from the boundary. In the second case, the change in the splitting fractions of organic nutrients resulted in an approximately 10% reduction in the chlorophyll-*a* concentrations in the riverine region. This response was likely caused by the 25% reduction in DON resulting from the change in the splitting fraction of OrgN (**Table 144**).

TABLE 147: PERCENT VARIATION OF CHLOROPHYLL-*A* MODEL PREDICTIONS RELATIVE TO BASELINE CONDITIONS FOR ALL SENSITIVITY ANALYSIS RUNS

Station	Baseline Mean	Baseline 5%tile	Baseline 95%tile	Loads from S-79 Mean	Loads from S-79 5%tile	Loads from S-79 95%tile	Watershed Loads Mean	Watershed Loads 5%tile	Watershed Loads 95%tile	Org. Nutrient Fraction Mean	Org. Nutrient Fraction 5%tile	Org. Nutrient Fraction 95%tile	Sediment Oxygen Demand Mean	Sediment Oxygen Demand 5%tile	Sediment Oxygen Demand 95%tile	Algae Death Mean	Algae Death 5%tile	Algae Death 95%tile	Algae Growth Mean	Algae Growth 5%tile	Algae Growth 95%tile	KeTSS Mean	KeTSS 5%tile	KeTSS 95%tile	KePOC Mean	KePOC 5%tile	KePOC 95%tile	KeDOC Mean	KeDOC 5%tile	KeDOC 95%tile	KeChla Mean	KeChla 5%tile	KeChla 95%tile
Station 1	2.70	0.57	5.26	11.9	13.1	9.9	2.7	3.1	2.7	-10.1	-3.8	-10.8	-0.4	-0.4	-0.5	-47.6	-49.9	-49.5	52.5	43.6	58.3	-2.5	-2.7	-2.1	-3.6	-3.2	-3.6	-4.7	-3.9	-4.8	-18.4	-19.6	-18.2
Station 2	3.39	0.18	6.66	11.5	8.2	9.9	2.7	8.2	2.3	-14.8	-13.6	-15.9	-0.4	-0.6	-0.4	-33.8	-76.2	-26.7	17.1	326.7	6.5	-0.9	-6.0	-0.1	-0.8	-4.5	-0.2	-0.9	-4.8	-0.3	-19.7	-17.8	-19.5
Station 3	2.20	0.13	4.27	7.7	2.5	8.9	2.3	6.0	2.2	-10.6	-7.9	-10.0	-0.6	-0.7	-0.3	-39.6	-68.1	-24.4	31.6	195.8	15.3	-2.8	-10.5	-0.7	-1.0	-2.7	0.0	-1.6	-3.4	0.0	-19.5	-18.4	-19.7
Station 4	0.98	0.21	2.26	1.2	0.5	1.3	0.4	0.2	0.2	-1.6	-0.3	-2.1	-0.7	-0.3	-0.9	-42.8	-56.4	-39.5	52.1	67.5	33.4	-8.1	-9.8	-5.7	-0.7	-0.7	-0.5	-2.2	-2.3	-1.9	-19.3	-19.6	-19.2
Station 5	2.13	0.14	3.88	5.4	2.5	4.2	2.0	7.4	1.5	-8.0	-10.4	-6.2	-0.8	-0.6	-0.7	-42.8	-73.4	-26.3	40.2	218.3	23.4	-2.9	-9.9	-0.8	-1.0	-2.5	-0.2	-1.6	-3.3	-0.2	-19.6	-18.9	-19.7
Station 6	1.67	0.13	3.64	1.3	0.5	0.4	0.4	0.8	0.0	-2.3	-0.3	-0.5	-0.9	-0.3	-0.7	-42.0	-69.5	-19.8	49.9	145.3	27.0	-4.9	-10.9	-1.9	-0.7	-0.8	-0.2	-1.6	-2.7	-0.3	-19.6	-19.5	-19.8
Average	***-***	***-***	***-***	***7.5***	***5.3***	***6.8***	***2.0***	***5.0***	***1.8***	***-9.0***	***-7.2***	***-9.0***	***-0.6***	***-0.5***	***-0.5***	***-41.3***	***-64.8***	***-33.3***	***38.7***	***170.4***	***27.4***	***-3.4***	***-7.8***	***-1.9***	***-1.4***	***-2.7***	***-0.9***	***-2.2***	***-3.5***	***-1.4***	***-19.3***	***-18.9***	***-19.3***

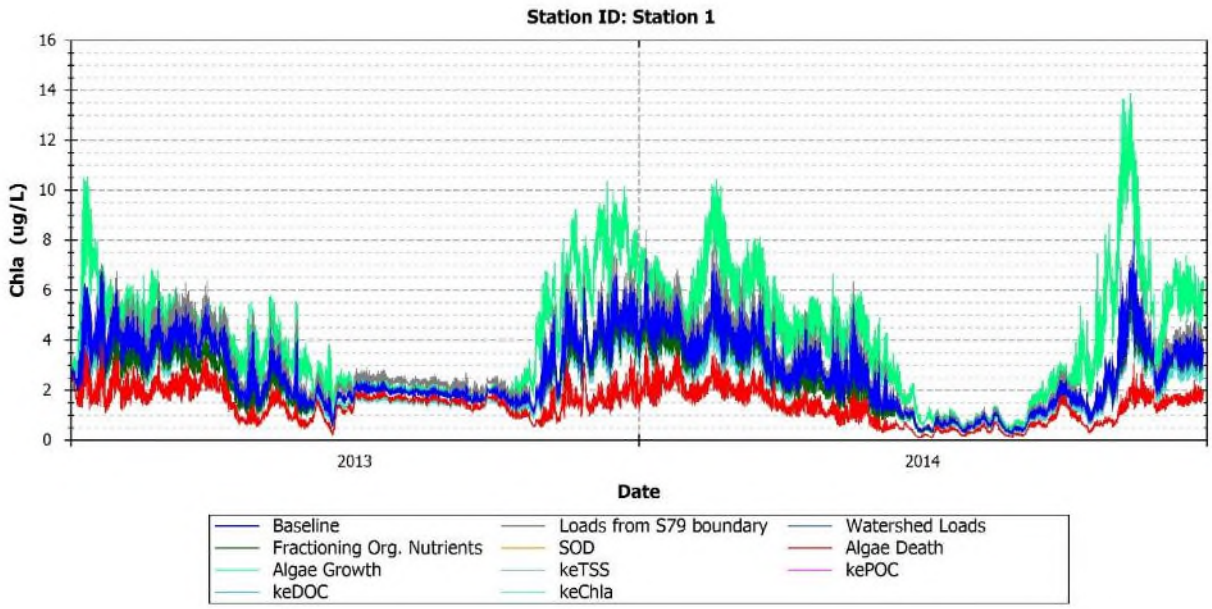

FIGURE 161: MODEL PREDICTIONS OF PHYTOPLANKTON BIOMASS FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 1

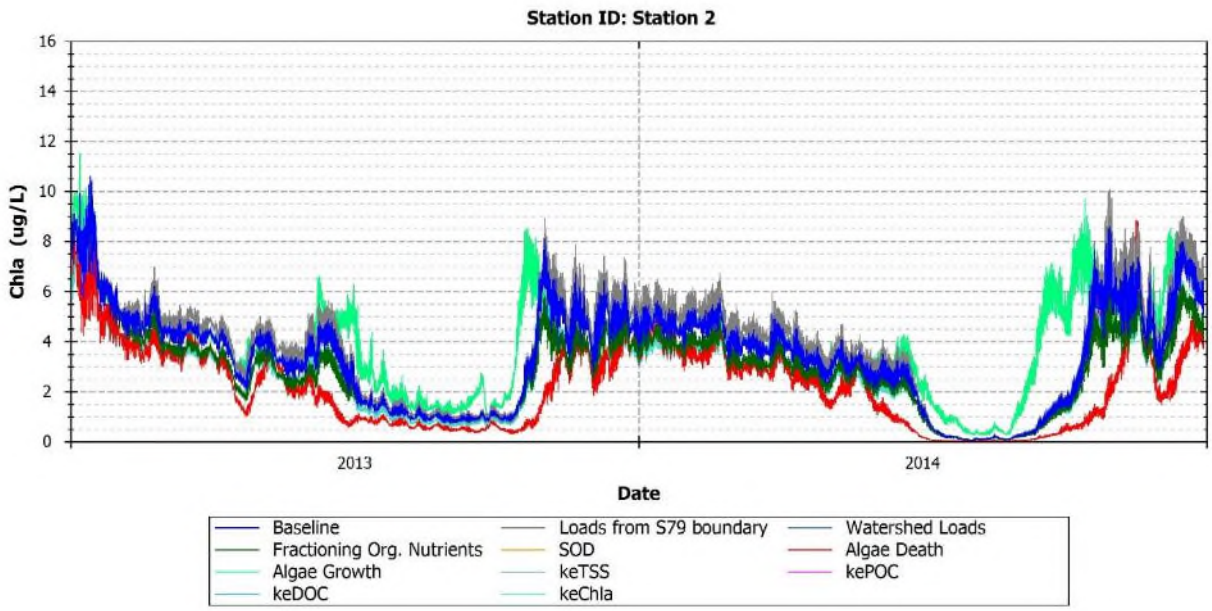

FIGURE 162: MODEL PREDICTIONS OF PHYTOPLANKTON BIOMASS FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 2

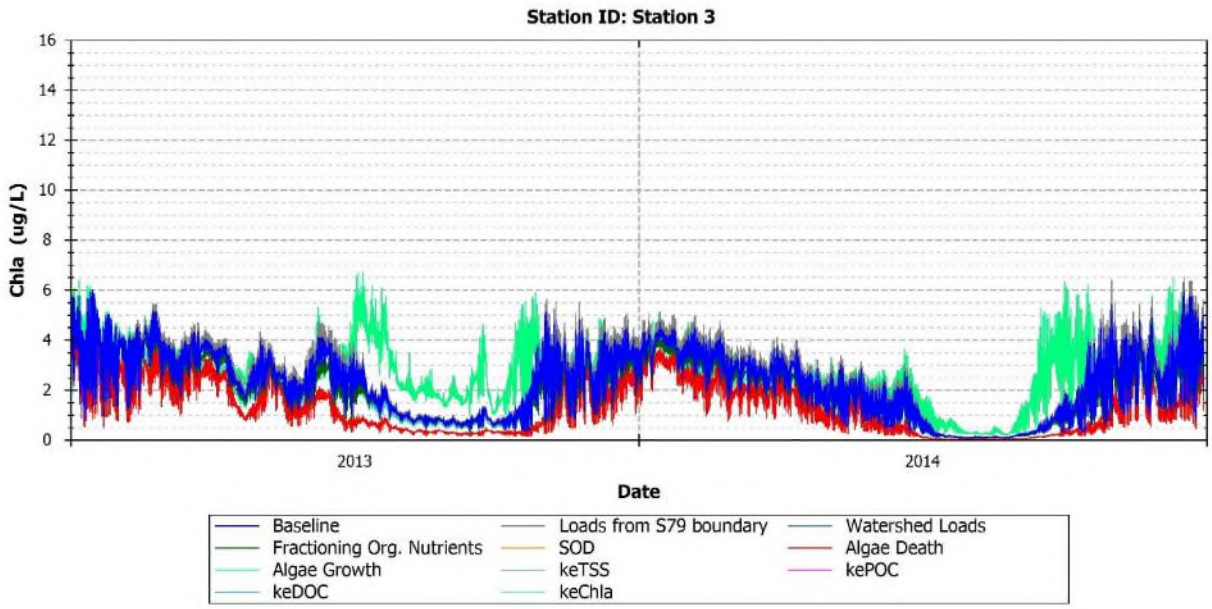

FIGURE 163: MODEL PREDICTIONS OF PHYTOPLANKTON BIOMASS FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 3

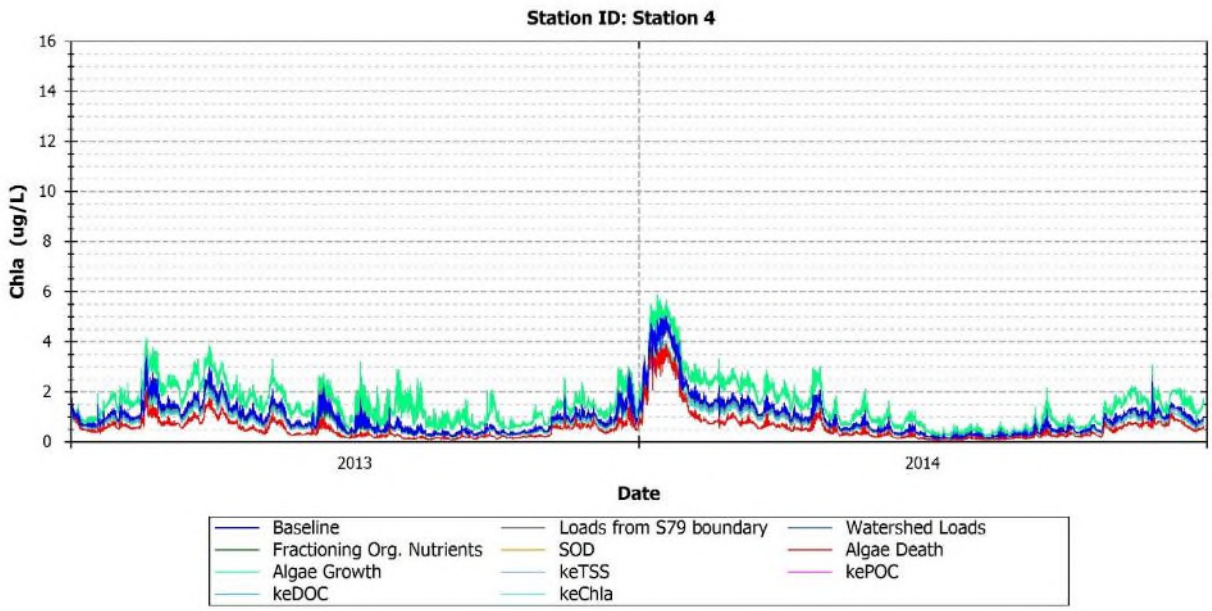

FIGURE 164: MODEL PREDICTIONS OF PHYTOPLANKTON BIOMASS FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 4

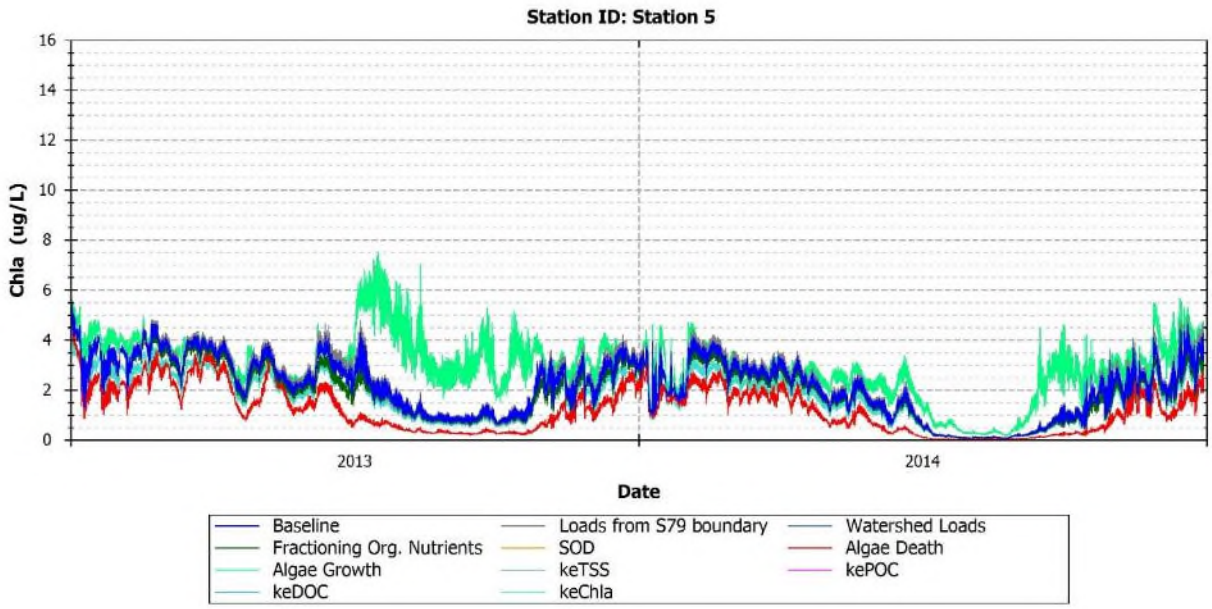

FIGURE 165: MODEL PREDICTIONS OF PHYTOPLANKTON BIOMASS FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 5

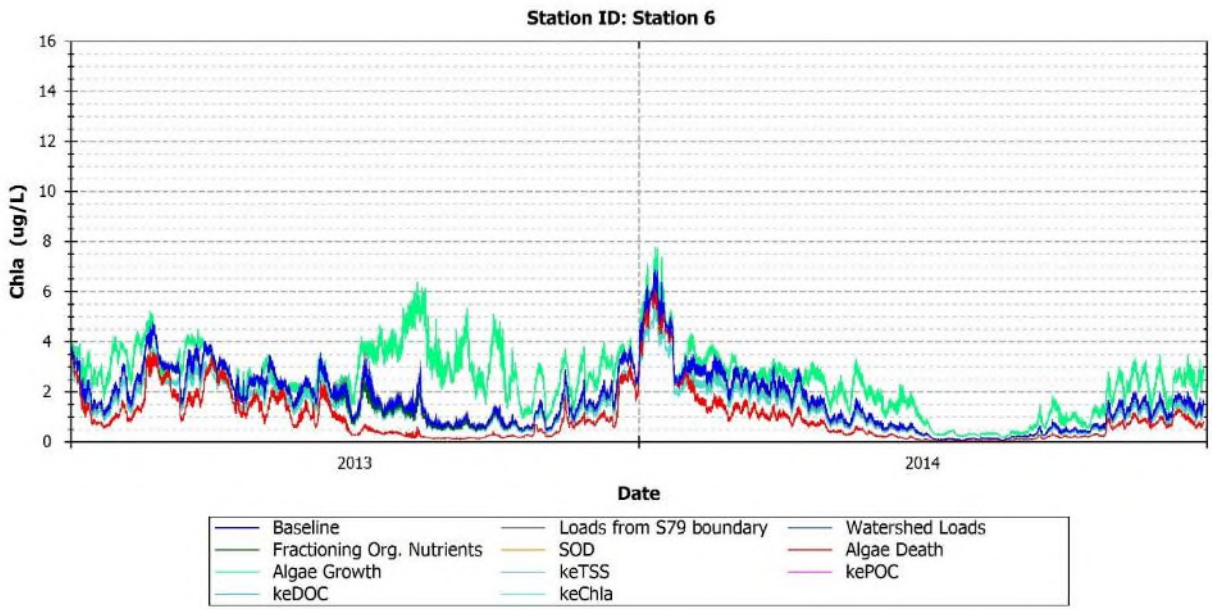

FIGURE 166: MODEL PREDICTIONS OF PHYTOPLANKTON BIOMASS FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 6

3.5.9.6 NH_4 and NOx

A summary of the sensitivity analysis results for bioavailable inorganic nitrogen (NH_4 and NOx) is presented in **Table 148** and **Table 149**, as well as **Figure 167** to **Figure 178**. Inorganic nitrogen was highly sensitive to the rates of phytoplankton growth and death, loads from the S-79 boundary, and splitting fractions of the organic nutrients.

Table 148 and **Table 149** show that changes in the rates of algae growth and death had a large impact on the concentrations of inorganic nitrogen. A 25% increase in the algae growth rate caused an approximate reduction of 18% and 31% in the mean concentrations of NH_4 and NOx, respectively. The same perturbation caused a reduction of 28% and 62% in the lower 5th percentile concentrations of NH_4 and NOx respectively, and a reduction of approximately 18% and 15% in the highest 95th percentile concentrations of NH_4 and NOx, respectively. These results showed that the perturbations in the rates of algal growth had a nonlinear and magnified impact on the predictions of NH_4 and NOx. The reduction in the pool of inorganic nitrogen in response to higher rates of phytoplankton growth reflected the fact that the larger the populations of phytoplankton, the larger the uptake of nitrogen to sustain biomass.

A similar impact on the inorganic concentrations of nitrogen was observed by perturbing the rates of phytoplankton death, with an increase in the magnitude of the death rate resulting in less uptake of nitrogen from phytoplankton and, thus, the concentrations of NH_4 and NOx increased.

The concentrations of inorganic nitrogen were also impacted by changes in the loads from the S-79 boundary and by changes in the splitting fractions of the organic nutrients. A 25% increase of the loads from the S-79 boundary caused an increase of approximately 17% in the mean concentration of NH_4 and a 25% increase in the higher 95th percentile concentrations of NH_4. The change of the splitting fractions of OrgN caused an approximate 15% reduction of the mean NH_4 concentration and an approximate reduction of 27% of the highest 95th percentile NH_4 concentration.

TABLE 148: PERCENT VARIATION OF NH_4 MODEL PREDICTIONS RELATIVE TO BASELINE CONDITIONS FOR ALL SENSITIVITY ANALYSIS RUNS

Station	Baseline Mean	Baseline 5%tile	Baseline 95%tile	Loads from S-79 Mean	Loads from S-79 5%tile	Loads from S-79 95%tile	Watershed Loads Mean	Watershed Loads 5%tile	Watershed Loads 95%tile	Org. Nutrient Fraction Mean	Org. Nutrient Fraction 5%tile	Org. Nutrient Fraction 95%tile	Sediment Oxygen Demand Mean	Sediment Oxygen Demand 5%tile	Sediment Oxygen Demand 95%tile	Algae Death Mean	Algae Death 5%tile	Algae Death 95%tile	Algae Growth Mean	Algae Growth 5%tile	Algae Growth 95%tile	KeTSS Mean	KeTSS 5%tile	KeTSS 95%tile	KePOC Mean	KePOC 5%tile	KePOC 95%tile	KeDOC Mean	KeDOC 5%tile	KeDOC 95%tile	KeChla Mean	KeChla 5%tile	KeChla 95%tile
Station 1	0.040	0.011	0.110	26.2	9.1	28.2	2.8	0.0	3.6	-23.8	-27.3	-13.6	0.3	0.0	0.0	7.1	27.3	0.9	-10.6	-36.4	-2.4	0.5	0.0	0.0	0.7	0.0	0.0	0.9	0.0	0.0	-0.3	0.0	0.0
Station 2	0.028	0.006	0.105	26.3	0.0	26.6	3.1	0.0	5.7	-23.0	-6.7	-27.9	0.3	0.0	0.6	11.2	33.3	1.5	-16.1	-33.3	-3.8	0.7	0.0	0.6	0.7	0.0	0.6	0.9	0.0	0.6	-0.4	0.0	0.0
Station 3	0.021	0.006	0.091	24.5	16.7	35.2	3.4	0.0	5.5	-22.7	0.0	-36.3	0.5	0.0	0.0	9.0	33.3	4.4	-17.3	-16.7	-13.2	1.2	0.0	1.1	0.7	0.0	1.1	0.9	0.0	1.1	-0.3	0.0	0.0
Station 4	0.012	0.007	0.020	3.2	0.0	5.0	0.4	0.0	0.0	-3.2	0.0	-10.0	1.5	0.0	0.0	4.3	14.3	0.0	-8.7	-14.3	-10.0	1.1	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.0	-0.1	0.0	0.0
Station 5	0.018	0.006	0.076	22.6	0.0	36.1	3.1	0.0	6.6	-21.1	0.0	-39.5	0.5	0.0	0.0	11.0	16.7	5.8	-24.0	-33.3	-25.0	1.4	0.0	1.3	0.7	0.0	0.0	1.0	0.0	0.0	-0.3	0.0	-0.8
Station 6	0.011	0.005	0.025	6.9	0.0	24.0	0.7	0.0	1.6	-6.4	0.0	-20.0	1.0	0.0	0.0	11.1	20.0	16.0	-22.3	-40.0	-36.0	1.6	0.0	0.0	0.4	0.0	0.0	0.7	0.0	0.0	-0.2	0.0	0.0
Average	**-**	**-**	**-**	***20.6***	***5.2***	***26.2***	***2.6***	***0.0***	***4.3***	***-18.8***	***-6.8***	***-25.5***	***0.6***	***0.0***	***0.1***	***8.5***	***25.0***	***2.5***	***-15.4***	***-26.8***	***-10.9***	***1.0***	***0.0***	***0.6***	***0.6***	***0.0***	***0.3***	***0.8***	***0.0***	***0.3***	***-0.3***	***0.0***	***-0.2***

TABLE 149: PERCENT VARIATION OF NOX MODEL PREDICTIONS RELATIVE TO BASELINE CONDITIONS FOR ALL SENSITIVITY ANALYSIS RUNS

Station	Baseline Mean	Baseline 5%tile	Baseline 95%tile	Loads from S-79 Mean	Loads from S-79 5%tile	Loads from S-79 95%tile	Watershed Loads Mean	Watershed Loads 5%tile	Watershed Loads 95%tile	Org. Nutrient Fraction Mean	Org. Nutrient Fraction 5%tile	Org. Nutrient Fraction 95%tile	Sediment Oxygen Demand Mean	Sediment Oxygen Demand 5%tile	Sediment Oxygen Demand 95%tile	Algae Death Mean	Algae Death 5%tile	Algae Death 95%tile	Algae Growth Mean	Algae Growth 5%tile	Algae Growth 95%tile	KeTSS Mean	KeTSS 5%tile	KeTSS 95%tile	KePOC Mean	KePOC 5%tile	KePOC 95%tile	KeDOC Mean	KeDOC 5%tile	KeDOC 95%tile	KeChla Mean	KeChla 5%tile	KeChla 95%tile
Station 1	0.07	0.01	0.19	14.7	14.3	21.5	3.2	7.1	2.9	17.1	-14.3	23.1	-1.1	0.0	0.0	17.2	92.9	0.0	-22.0	-78.6	-0.5	1.1	7.1	0.0	1.6	7.1	0.0	2.1	14.3	0.0	-1.0	-7.1	0.0
Station 2	0.03	0.00	0.10	-1.4	0.0	3.9	1.4	0.0	1.9	14.1	0.0	27.2	-1.7	0.0	-1.9	55.2	150.0	10.7	-32.8	-50.0	-16.5	1.9	0.0	1.0	1.9	0.0	1.0	2.3	0.0	1.0	-1.2	0.0	0.0
Station 3	0.03	0.01	0.08	-2.6	-20.0	-1.2	0.2	-20.0	0.0	4.1	0.0	-6.0	-1.9	0.0	-2.4	42.2	120.0	8.4	-36.9	-60.0	-21.7	3.5	0.0	1.2	1.3	0.0	0.0	1.9	0.0	0.5	-1.0	-20.0	0.0
Station 4	0.03	0.02	0.04	-0.1	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	-2.6	-2.9	0.0	-2.6	14.0	22.2	5.3	-23.4	-50.0	-15.8	3.7	11.1	2.6	0.3	0.0	0.0	1.0	5.6	0.0	-0.4	0.0	0.0
Station 5	0.03	0.00	0.07	-1.8	-25.0	1.5	0.2	0.0	1.5	-0.9	0.0	-5.4	-1.7	0.0	-1.5	44.1	175.0	9.0	-42.8	-75.0	-17.9	4.0	0.0	1.5	1.2	0.0	0.0	1.9	0.0	0.0	-0.9	0.0	0.0
Station 6	0.02	0.00	0.05	0.9	0.0	5.9	0.0	0.0	2.0	-4.0	0.0	-17.6	-1.9	0.0	-2.0	32.1	175.0	13.7	-45.5	-75.0	-39.2	5.1	0.0	3.9	0.8	0.0	2.0	1.7	0.0	2.0	-0.6	-25.0	0.0
Average	**-**	**-**	**-**	***1.8***	***-6.1***	***5.1***	***1.0***	***-2.6***	***1.3***	***6.8***	***-2.9***	***7.3***	***-1.9***	***0.0***	***-1.7***	***34.5***	***112.0***	***6.7***	***-31.6***	***-62.7***	***-14.5***	***2.8***	***3.7***	***1.3***	***1.3***	***1.4***	***0.2***	***1.8***	***4.0***	***0.3***	***-0.9***	***-5.4***	***0.0***

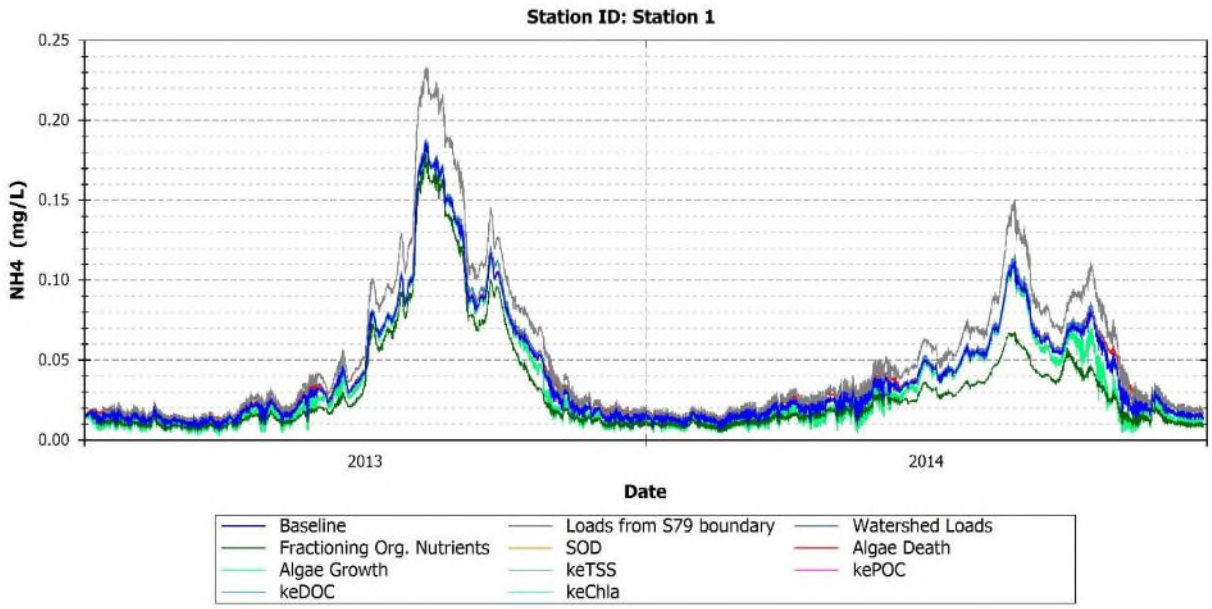

FIGURE 167: MODEL PREDICTIONS OF NH_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 1

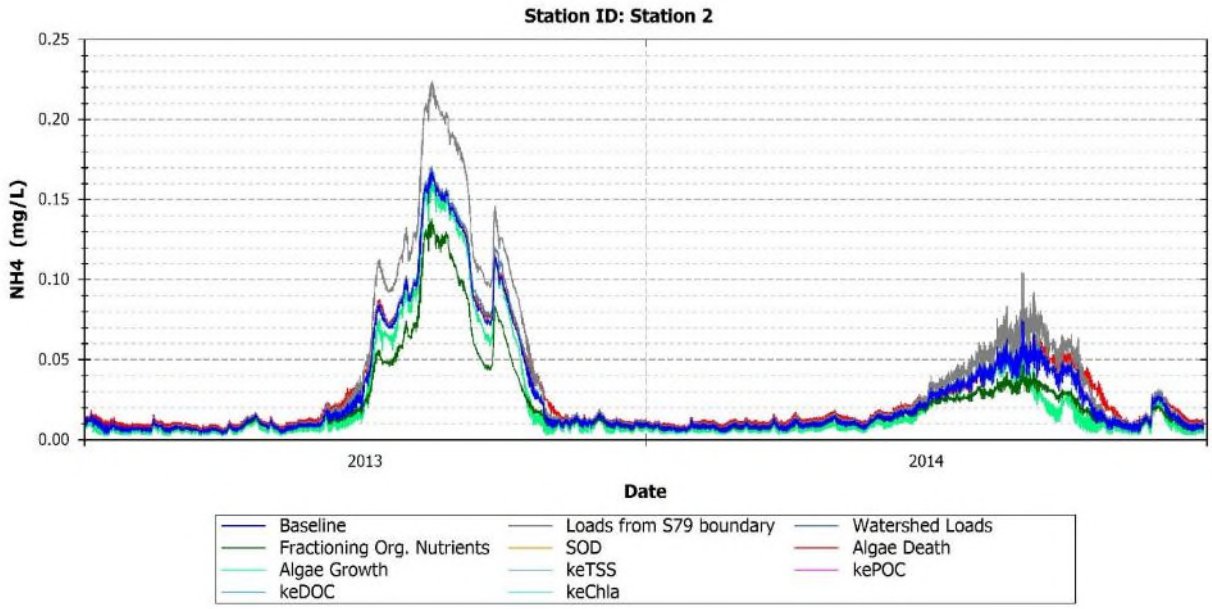

FIGURE 168: MODEL PREDICTIONS OF NH_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 2

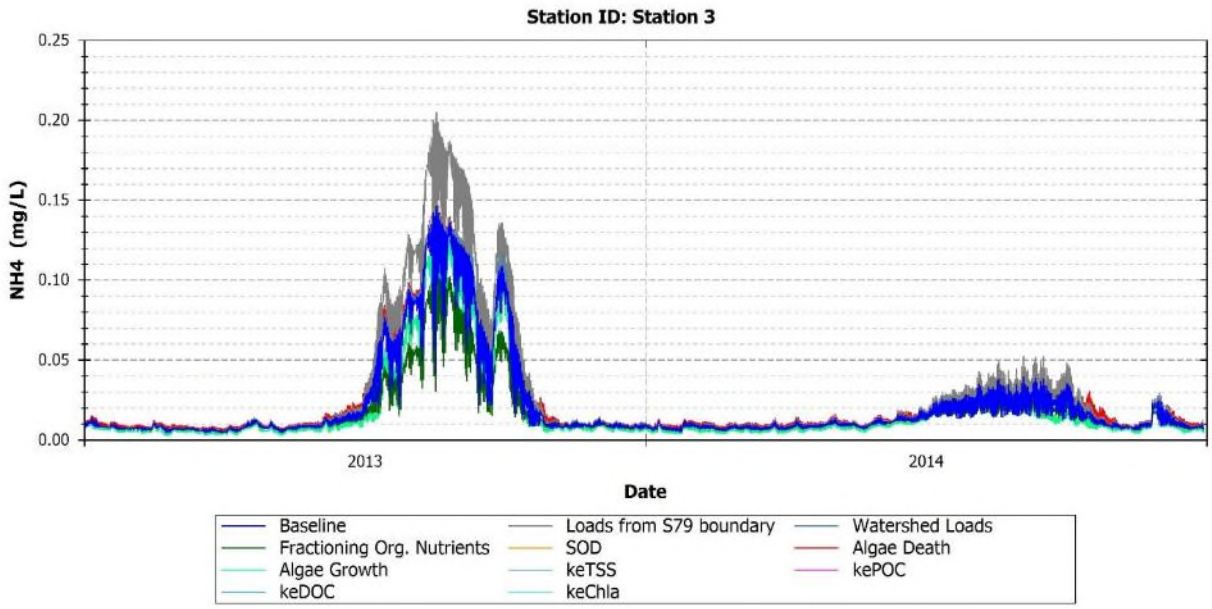

FIGURE 169: MODEL PREDICTIONS OF NH_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 3

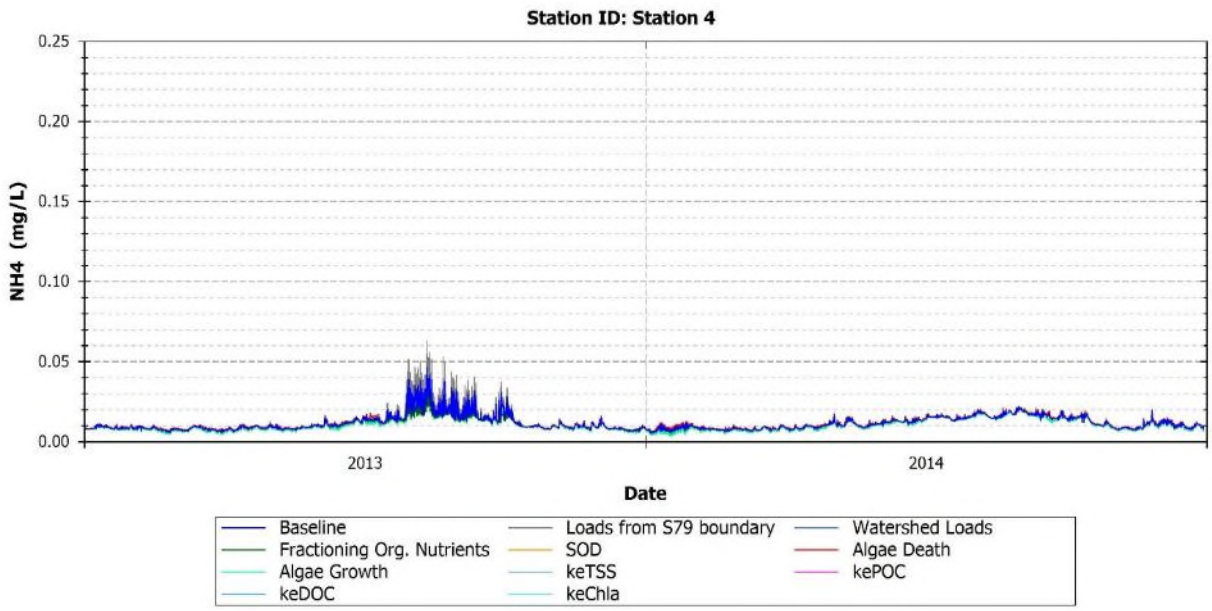

FIGURE 170: MODEL PREDICTIONS OF NH_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 4

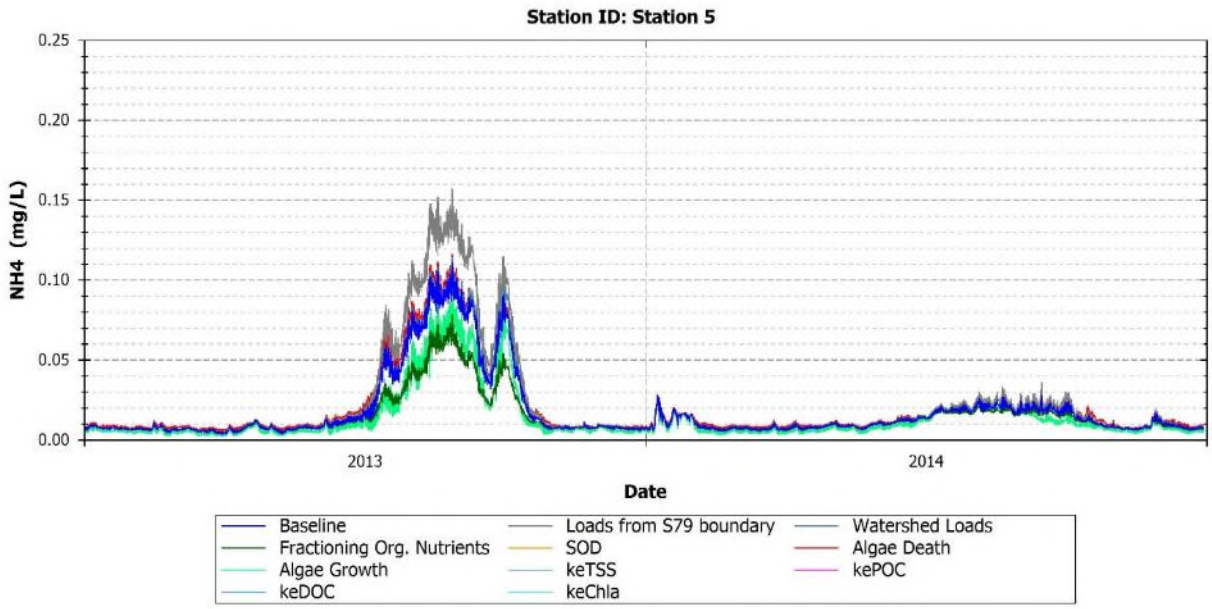

FIGURE 171: MODEL PREDICTIONS OF NH_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 5

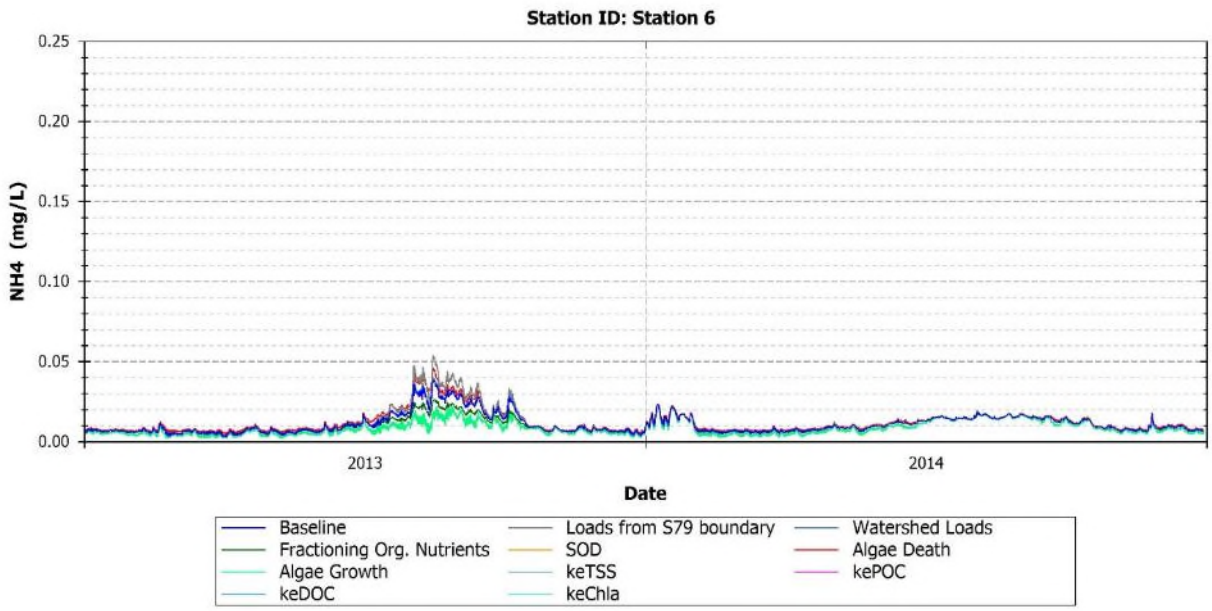

FIGURE 172: MODEL PREDICTIONS OF NH_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 6

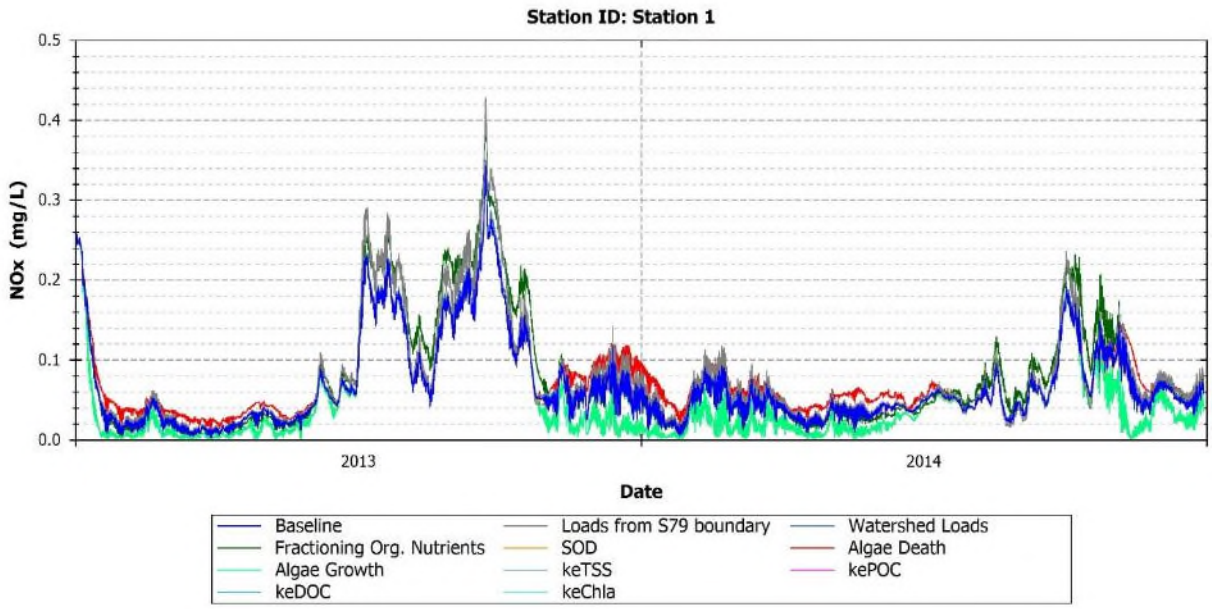

FIGURE 173: MODEL PREDICTIONS OF NOX FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 1

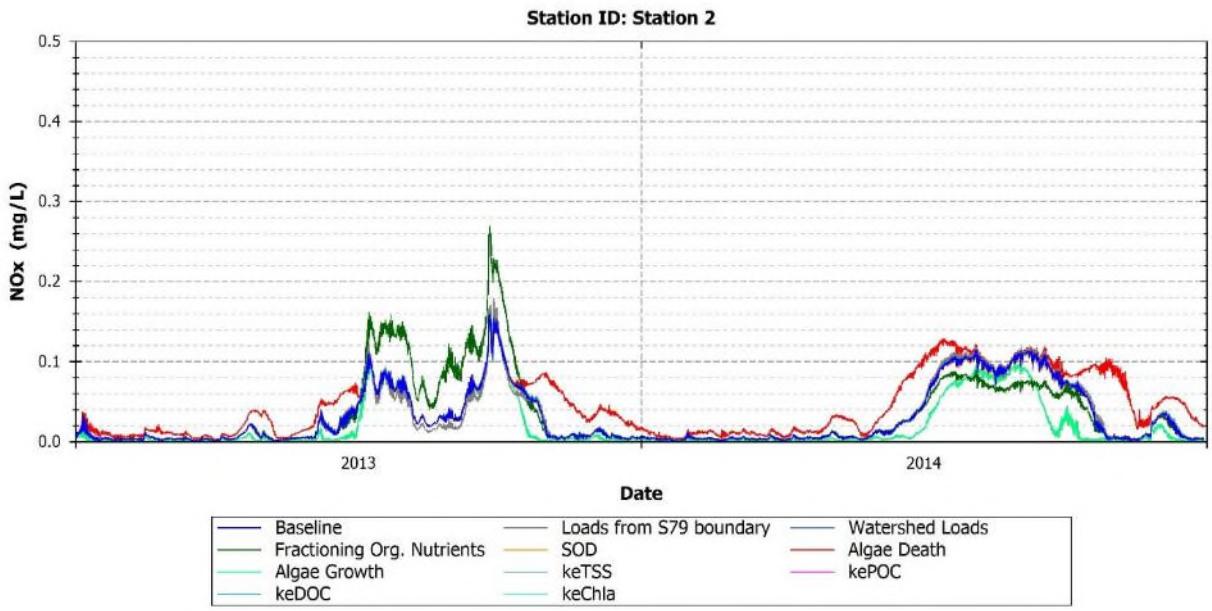

FIGURE 174: MODEL PREDICTIONS OF NOX FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 2

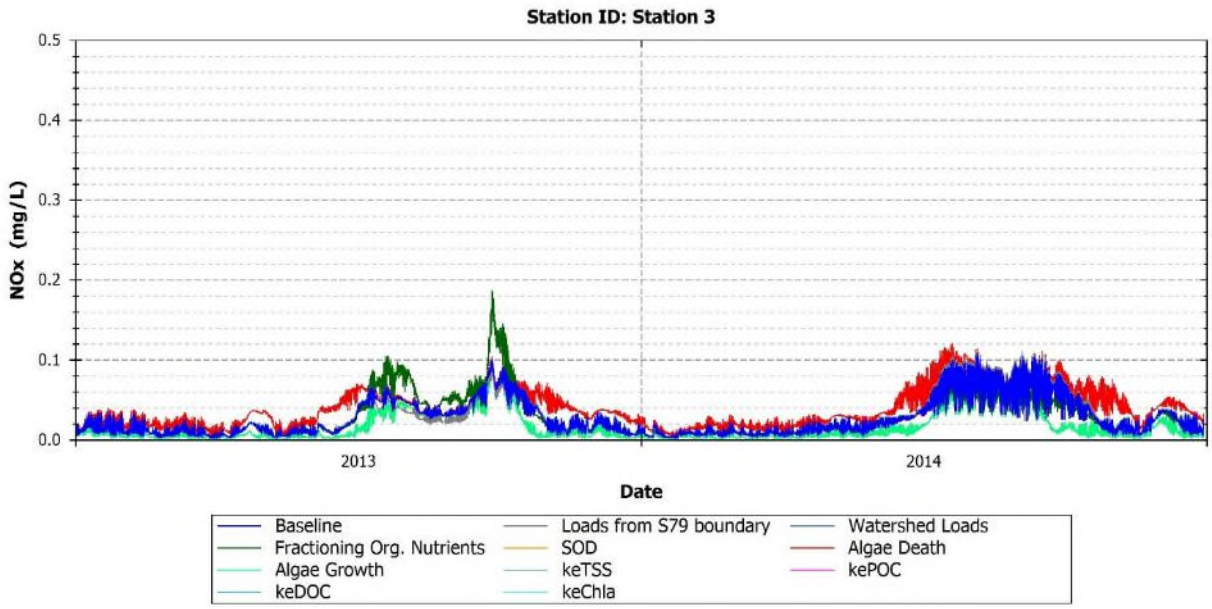

FIGURE 175: MODEL PREDICTIONS OF NOX FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 3

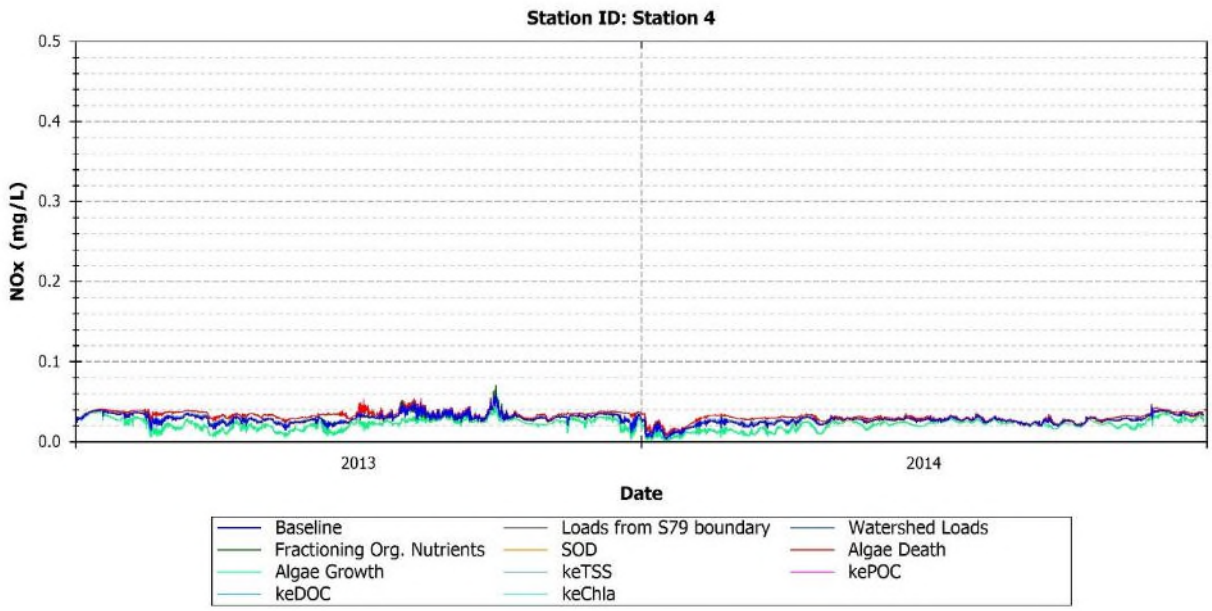

FIGURE 176: MODEL PREDICTIONS OF NOX FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 4

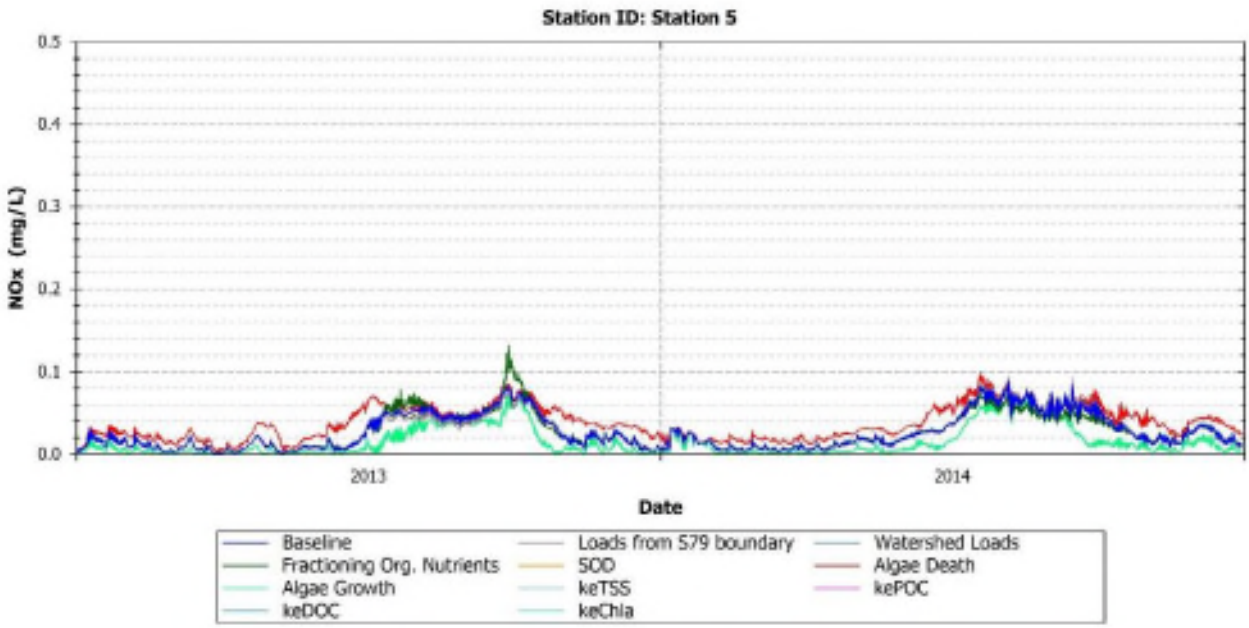

FIGURE 177: MODEL PREDICTIONS OF NOX FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 5

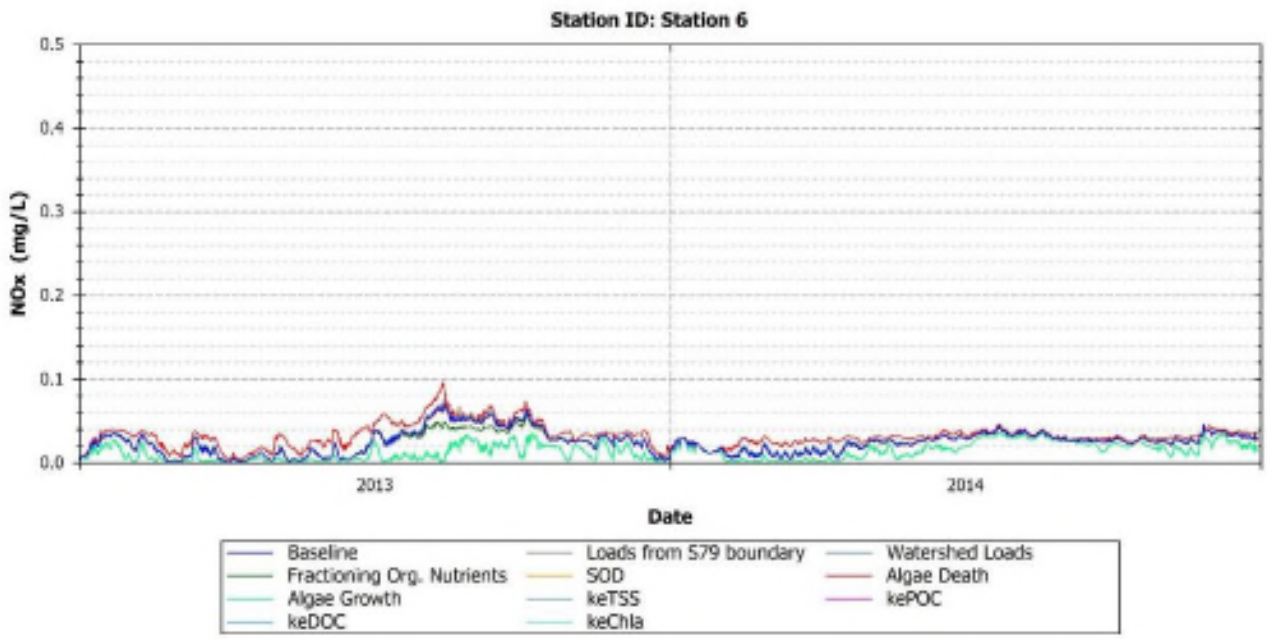

FIGURE 178: MODEL PREDICTIONS OF NOX FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 6

3.5.9.7 PO_4

A summary of the sensitivity analysis results for PO_4 is presented in **Table 150** and **Figure 179** through **Figure 184**. The predictions of PO_4 were mostly sensitive to changes in the loads from the S-79 boundary and to a lesser extent, to changes in the loads from the watershed boundaries, splitting fractions of organic nutrients, and rates of algae growth and death.

Perturbations in the loads from the S-79 boundary had a significant impact on the predictions of PO_4 particularly in the upper riverine portion of the model (Stations 1 and 2 in **Table 150**, **Figure 179**, and **Figure 180**). A 25% increase in the loads from the S-79 boundary resulted in an approximately 22% increase in the mean concentrations of PO_4 at Station 1, and in an approximately 14% increase in the mean concentrations of PO_4 at Station 2. The changes in the mean PO_4 concentration in the remaining stations were less than 10%. The load perturbations at S-79 had the largest impact on the highest 95th percentile PO_4 concentrations at all stations evaluated causing an approximately 15% increase in concentrations.

The changes in the splitting fractions of organic nutrients also had an impact on the predictions of PO_4 particularly in the riverine portion of the model. The change in the splitting ratios caused an increase of approximately 7% in the mean concentrations of PO_4 at Station 1 and an increase of approximately 10% at Station 2. At other stations, the increase in the mean PO_4 concentrations was approximately 5%. The lower 5th percentile concentrations of PO_4 also increased in response to the changes in the splitting ratios of organic nutrients. The increases were approximately 9%, 16%, and 10% at Stations 1, 2, and 5, respectively. The changes in the higher 95th percentile concentrations of PO_4 were less than 5%. The increase in PO_4 concentrations following the changes in the splitting ratios of organic nutrients is explained by the approximately 22% increase of the labile fraction of OrgP from the baseline condition (**Table 144**). This results in more OrgP available for dissolution and later for oxidation, ultimately increasing the concentrations of PO_4.

The perturbations in the rates of algae growth and death also impacted the predictions of PO_4. A 25% increase in the rates of algae growth caused an approximately 5% reduction in the mean and lower 5th percentile concentrations of PO_4. This result was explained by an increase in phosphorus uptake resulting from the increase in phytoplankton biomass. A 25% increase in the rates of algae death resulted in an increase of approximately 4% in the mean concentrations of PO_4 and of 7% in the lowest 5th percentile concentrations. This result was explained by a reduction in phosphorus uptake resulting from the reduction of phytoplankton biomass.

TABLE 150: PERCENT VARIATION OF PO_4 MODEL PREDICTIONS RELATIVE TO BASELINE CONDITIONS FOR ALL SENSITIVITY ANALYSIS RUNS

Station	Baseline Mean	Baseline 5%tile	Baseline 95%tile	Loads from S-79 Mean	Loads from S-79 5%tile	Loads from S-79 95%tile	Watershed Loads Mean	Watershed Loads 5%tile	Watershed Loads 95%tile	Org. Nutrient Fraction Mean	Org. Nutrient Fraction 5%tile	Org. Nutrient Fraction 95%tile	Sediment Oxygen Demand Mean	Sediment Oxygen Demand 5%tile	Sediment Oxygen Demand 95%tile	Algae Death Mean	Algae Death 5%tile	Algae Death 95%tile	Algae Growth Mean	Algae Growth 5%tile	Algae Growth 95%tile	KeTSS Mean	KeTSS 5%tile	KeTSS 95%tile	KePOC Mean	KePOC 5%tile	KePOC 95%tile	KeDOC Mean	KeDOC 5%tile	KeDOC 95%tile	KeChla Mean	KeChla 5%tile	KeChla 95%tile
Station 1	0.06	0.03	0.10	21.7	23.5	22.1	3.0	2.9	2.5	7.3	8.8	1.1	0.0	0.0	0.0	4.2	8.8	0.0	-6.0	-8.8	-0.6	0.3	0.0	0.0	0.4	2.9	0.0	0.6	2.9	0.0	-0.2	0.0	0.0
Station 2	0.07	0.04	0.14	14.1	10.5	16.0	6.5	2.6	10.9	9.7	15.8	3.5	0.1	0.0	0.0	5.1	7.9	1.8	-4.4	-2.6	-1.4	0.2	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.0	-0.1	0.0	0.0
Station 3	0.06	0.03	0.15	9.6	6.1	15.2	6.1	3.0	12.5	6.0	6.1	3.8	0.1	0.0	0.0	3.9	6.1	1.8	-4.2	-3.0	-2.3	0.4	3.0	0.4	0.2	0.0	0.0	0.2	1.8	0.0	-0.1	0.0	0.0
Station 4	0.04	0.03	0.05	1.3	0.0	4.9	0.7	0.0	2.0	0.7	0.0	2.0	0.0	0.0	0.0	2.1	3.6	0.0	-3.6	-7.1	-6.1	0.5	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-0.1	0.0	0.0
Station 5	0.05	0.03	0.13	8.2	7.1	15.0	5.5	3.6	9.8	4.8	10.7	3.8	0.1	0.0	0.0	4.1	10.7	1.5	-4.8	-3.6	-3.0	0.4	0.0	0.3	0.1	0.0	0.0	0.2	0.0	0.0	-0.1	0.0	0.0
Station 6	0.04	0.01	0.08	3.2	0.0	12.0	1.6	0.0	4.0	1.6	0.0	5.3	0.1	0.0	0.5	3.8	7.7	2.7	-5.8	-7.7	-9.3	0.6	0.0	1.3	0.1	0.0	1.3	0.2	0.0	1.3	-0.1	0.0	0.0
Average	**-**	**-**	**-**	***11.0***	***9.5***	***14.7***	***4.4***	***2.4***	***7.6***	***5.7***	***8.3***	***2.8***	***0.1***	***0.0***	***0.0***	***3.9***	***7.4***	***1.0***	***-4.6***	***-5.0***	***-2.7***	***0.4***	***0.6***	***0.1***	***0.2***	***0.6***	***0.0***	***0.3***	***1.0***	***0.0***	-0.1	0.0	0.0

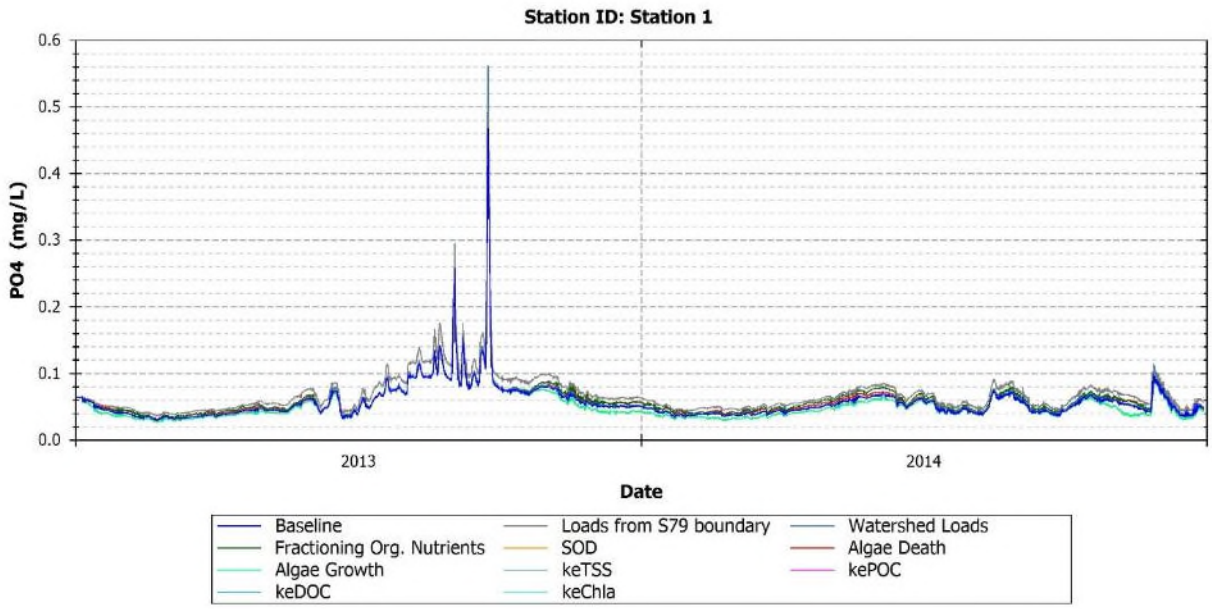

FIGURE 179: MODEL PREDICTIONS OF PO_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 1

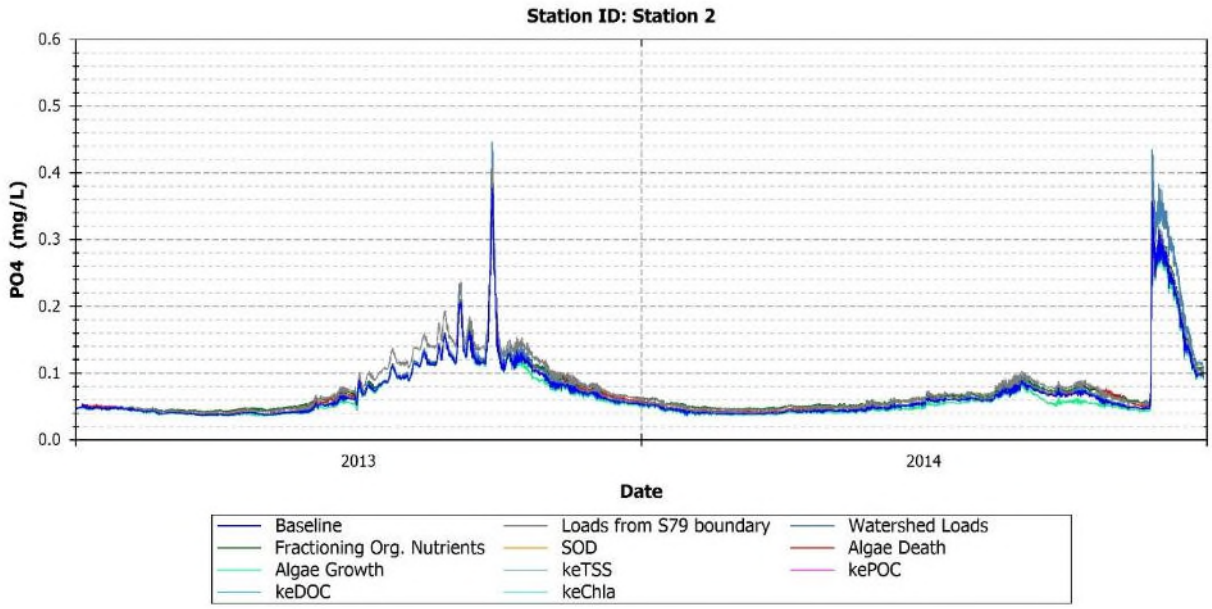

FIGURE 180: MODEL PREDICTIONS OF PO_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 2

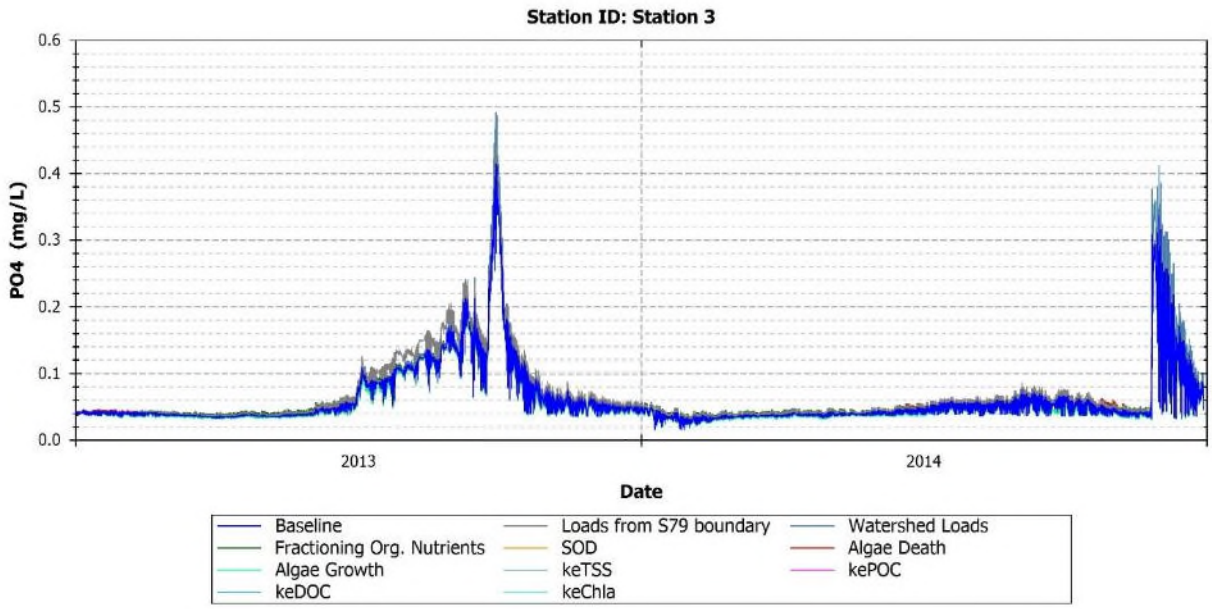

FIGURE 181: MODEL PREDICTIONS OF PO_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 3

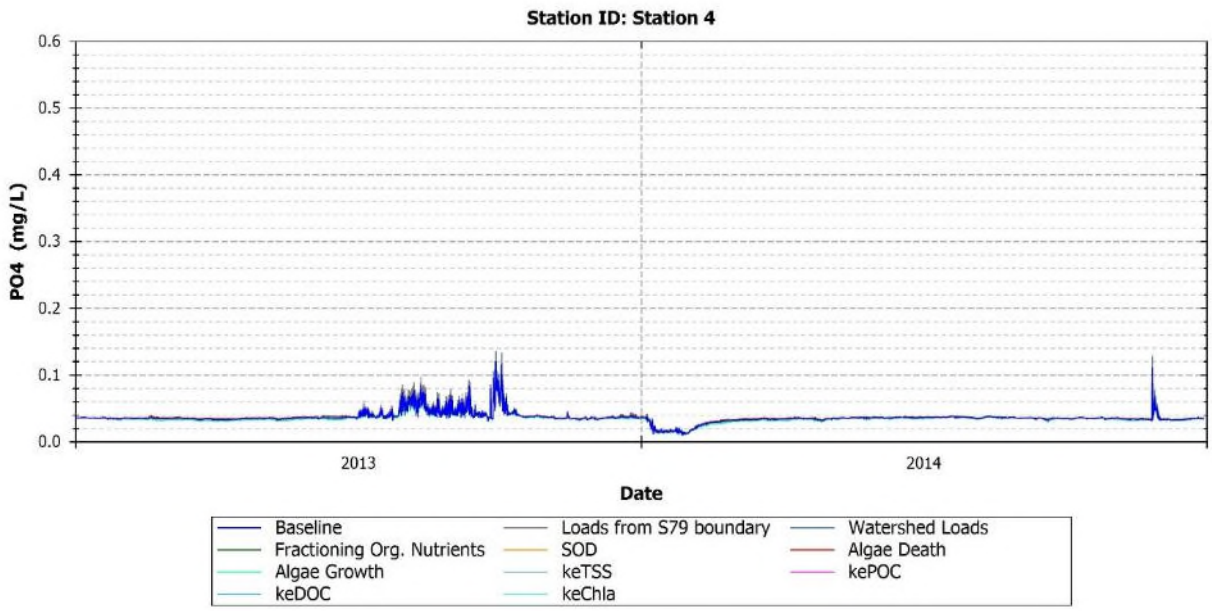

FIGURE 182: MODEL PREDICTIONS OF PO_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 4

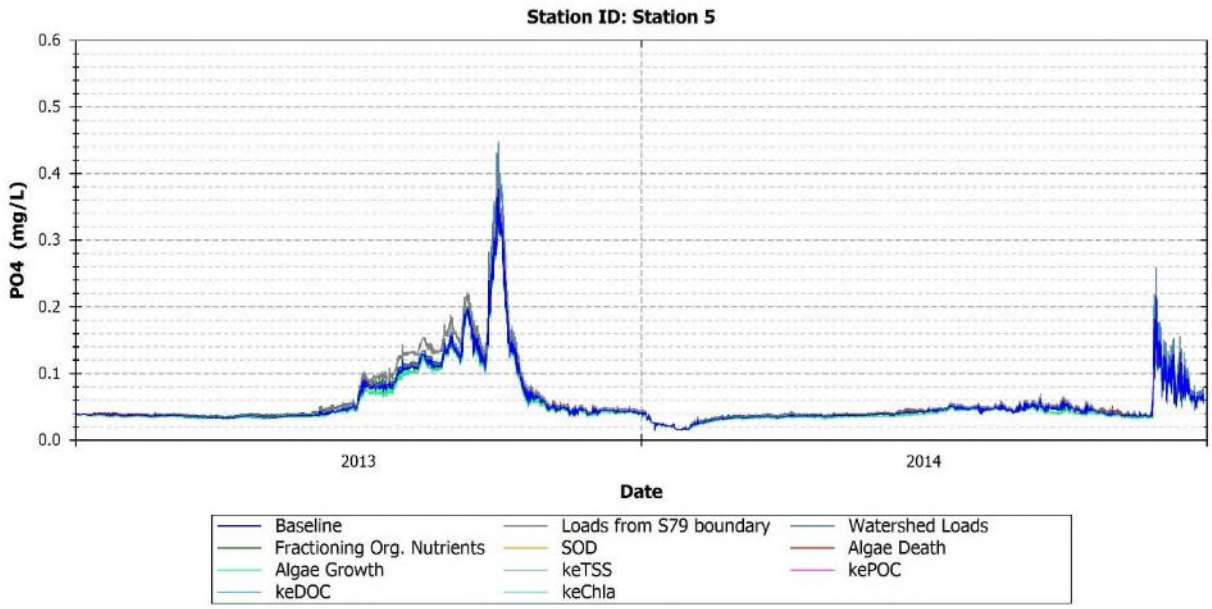

FIGURE 183: MODEL PREDICTIONS OF PO_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 5

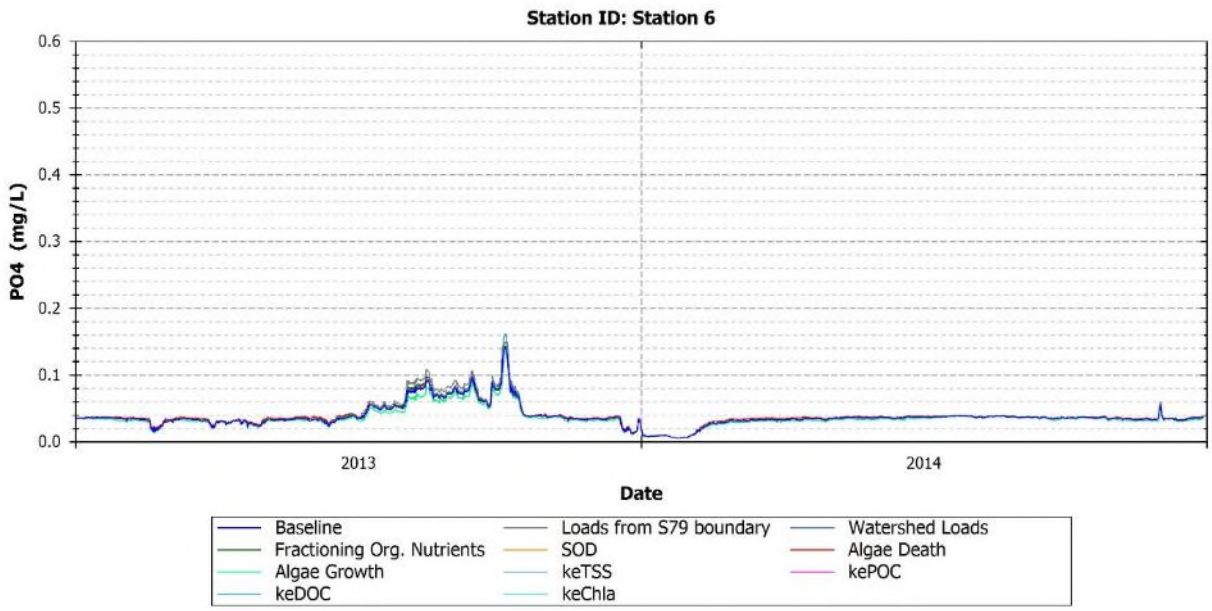

FIGURE 184: MODEL PREDICTIONS OF PO_4 FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 6

3.5.9.8 Light Extinction Coefficient (Ke)

A summary of the sensitivity analysis results for light extinction coefficient (Ke) is presented in **Table 151** and **Figure 185** through **Figure 190**. The light extinction coefficient was mostly sensitive to changes in the TSS and DOC light extinction coefficients (KeTSS and KeDOC) and the rates of phytoplankton growth and death.

A 25% increase in the TSS light extinction coefficient (KeTSS) caused an average increase of 10% in the Ke. A 25% increase in the DOC light extinction coefficient caused an average 5% increase in Ke. The perturbations in the rates of algae growth and death also impacted the predictions of Ke. A 25% increase in the rates of algae growth resulted in an approximately 5% increase in the mean predictions of Ke. This result was explained by the increase in self-shading from the increase in algae biomass. Conversely, a 25% increase in the rates of algae death resulted in a reduction of approximately 5% in the mean predictions of Ke. In this case, the results were explained by the reduction in self-shading resulting from the reduction in algae biomass.

3.5.9.9 Sensitivity Analysis Summary

A sensitivity analysis of the Caloosahatchee River 2017 EFDC model was conducted to identify the most important model parameters and input datasets affecting the predictions of the model. The sensitivity analysis was performed based on the analysis of model results at six stations distributed throughout the Caloosahatchee River. The results of sensitivity analysis revealed that:

- The simulations of DO were primarily sensitive to changes in the loads from the S-79 boundary and to changes in the splitting fractions of the organic nutrients. The predictions of DO exhibited a lower sensitivity to changes in other model parameters and input datasets from **Table 146**.
- The simulations of phytoplankton biomass were mostly sensitive to perturbations in the rates of algae growth and death, the self-shading extinction coefficient (KeChla), and to a lesser extent to perturbations in the loads from the S-79 boundary and in the splitting fractions for the organic nutrients.
- The simulations of inorganic nitrogen (NOx and NH_4) were highly sensitive to the rates of phytoplankton growth and death, loads from the S-79 boundary, and splitting fractions of the organic nutrients.
- The simulations of inorganic phosphorus (PO_4) were mostly sensitive to changes in the loads from the S-79 boundary and to a lesser extent, to changes in the loads from the watershed boundaries, splitting fractions of organic nutrients, and rates of algae growth and death.
- The simulations of the light extinction coefficient were mostly sensitive to changes in the TSS and DOC light extinction coefficients (KeTSS and KeDOC) and the rates of phytoplankton growth and death.

TABLE 151: PERCENT VARIATION OF LIGHT EXTINCTION (KE) MODEL PREDICTIONS RELATIVE TO BASELINE CONDITIONS FOR ALL SENSITIVITY ANALYSIS RUNS

Station	Baseline Mean	Baseline 5%tile	Baseline 95%tile	Loads from S-79 Mean	Loads from S-79 5%tile	Loads from S-79 95%tile	Watershed Loads Mean	Watershed Loads 5%tile	Watershed Loads 95%tile	Org. Nutrient Fraction Mean	Org. Nutrient Fraction 5%tile	Org. Nutrient Fraction 95%tile	Sediment Oxygen Demand Mean	Sediment Oxygen Demand 5%tile	Sediment Oxygen Demand 95%tile	Algae Death Mean	Algae Death 5%tile	Algae Death 95%tile	Algae Growth Mean	Algae Growth 5%tile	Algae Growth 95%tile	KeTSS Mean	KeTSS 5%tile	KeTSS 95%tile	KePOC Mean	KePOC 5%tile	KePOC 95%tile	KeDOC Mean	KeDOC 5%tile	KeDOC 95%tile	KeChla Mean	KeChla 5%tile	KeChla 95%tile
Station 1	0.668	0.341	1.522	13.3	13.8	11.5	1.4	0.9	1.1	1.3	-1.8	1.3	0.0	0.0	0.0	-6.3	-12.0	-0.6	6.1	10.0	0.3	6.1	3.4	10.7	5.4	5.6	4.7	7.0	5.5	7.1	-2.4	-3.3	-0.7
Station 2	0.440	0.197	1.152	9.8	8.4	11.9	1.9	1.5	1.8	-1.3	-1.0	3.1	0.0	0.0	0.0	-8.0	-12.2	-1.0	4.7	9.1	1.3	5.9	6.1	10.1	4.6	6.1	5.4	5.6	4.6	7.8	-3.9	-0.7	-0.5
Station 3	0.437	0.246	0.870	4.7	4.5	12.8	1.0	1.2	1.4	-0.3	-1.8	3.1	0.0	0.0	0.0	-6.0	-7.3	-1.6	5.4	5.3	3.4	10.2	7.7	10.0	2.8	3.1	5.5	4.8	4.5	7.7	-2.6	-2.8	-0.5
Station 4	0.591	0.404	0.802	0.2	0.8	0.0	0.0	0.1	0.0	0.0	-0.1	0.0	0.1	0.1	0.2	-2.2	-4.1	-0.9	2.7	4.6	0.7	16.7	13.7	19.1	1.0	1.3	0.7	3.4	4.1	3.1	-0.9	-1.4	-0.4
Station 5	0.377	0.208	0.711	4.4	3.1	8.6	1.1	0.7	1.1	-0.4	-1.4	2.0	-0.1	-0.3	-0.1	-7.9	-8.0	-2.3	7.8	6.0	6.6	8.3	7.9	10.3	2.8	2.6	4.1	5.1	4.0	6.9	-3.3	-2.7	-1.1
Station 6	0.418	0.227	0.816	0.9	0.7	0.0	0.2	0.3	0.0	-0.1	-0.4	0.0	0.0	0.0	0.0	-5.5	-11.0	-2.5	6.6	0.4	2.6	12.4	4.7	17.5	1.4	2.0	0.7	4.2	5.7	2.8	-2.4	-6.2	-2.0
Average	***-***	***-***	***-***	***6.5***	***6.1***	***9.0***	***1.1***	***0.9***	***1.1***	***-0.2***	***-1.2***	***1.9***	***0.0***	***0.0***	***0.0***	***-6.1***	***-8.7***	***-1.3***	***5.3***	***7.0***	***2.4***	***9.5***	***7.8***	***12.0***	***3.3***	***3.7***	***4.1***	***5.2***	***4.5***	***6.5***	-2.6	-2.2	-0.7

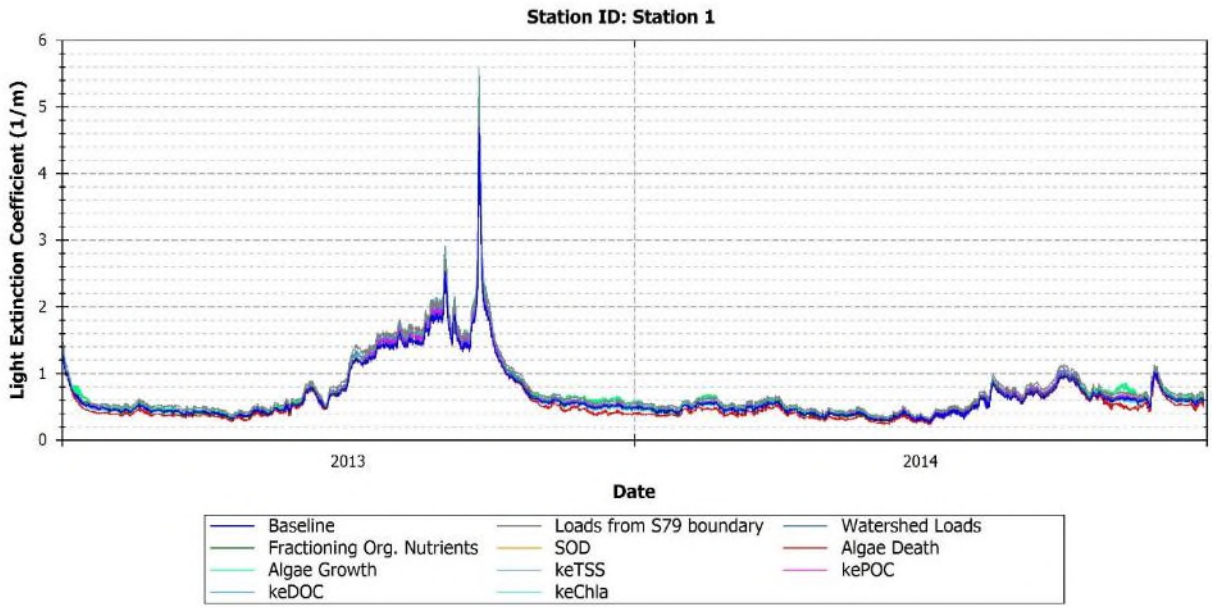

FIGURE 185: MODEL PREDICTIONS OF KE FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 1

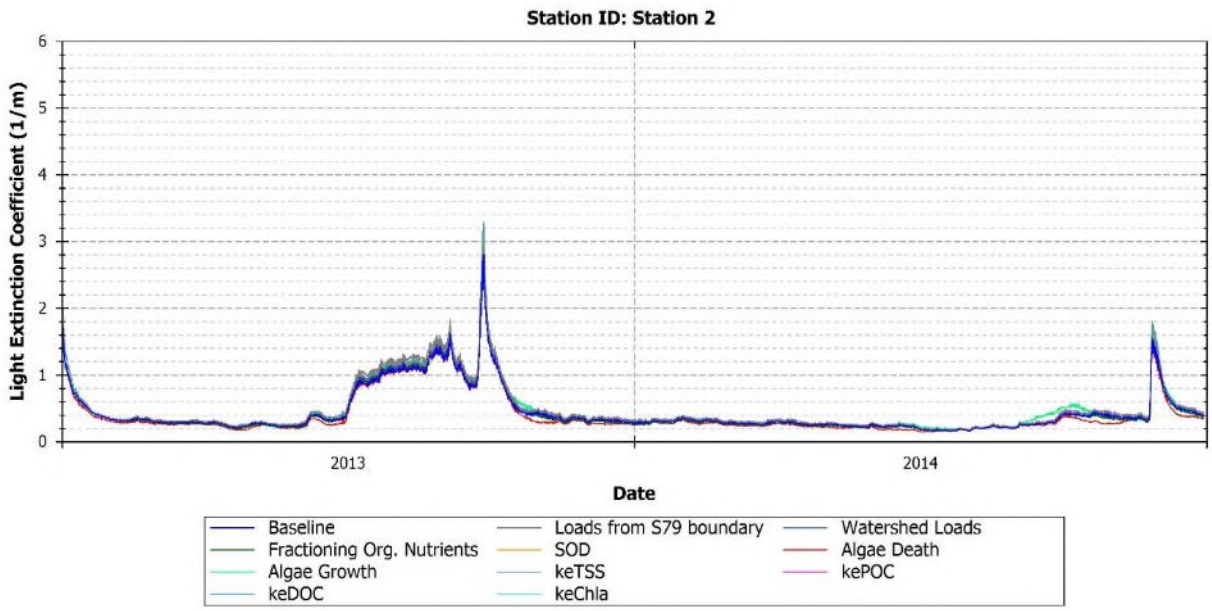

FIGURE 186: MODEL PREDICTIONS OF KE FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 2

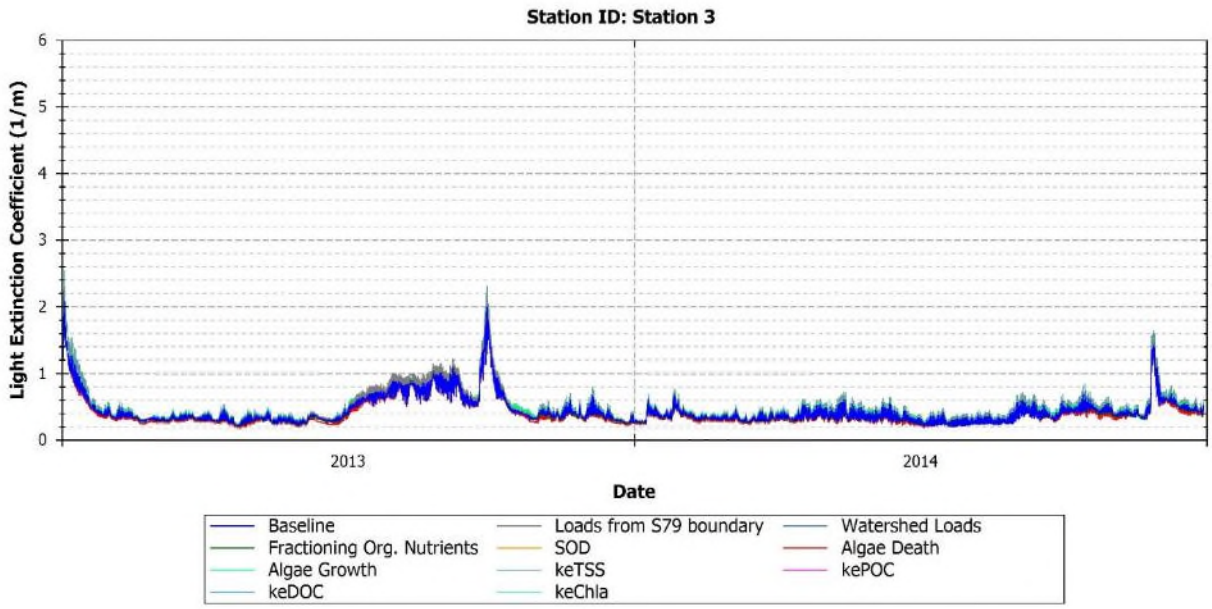

FIGURE 187: MODEL PREDICTIONS OF KE FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 3

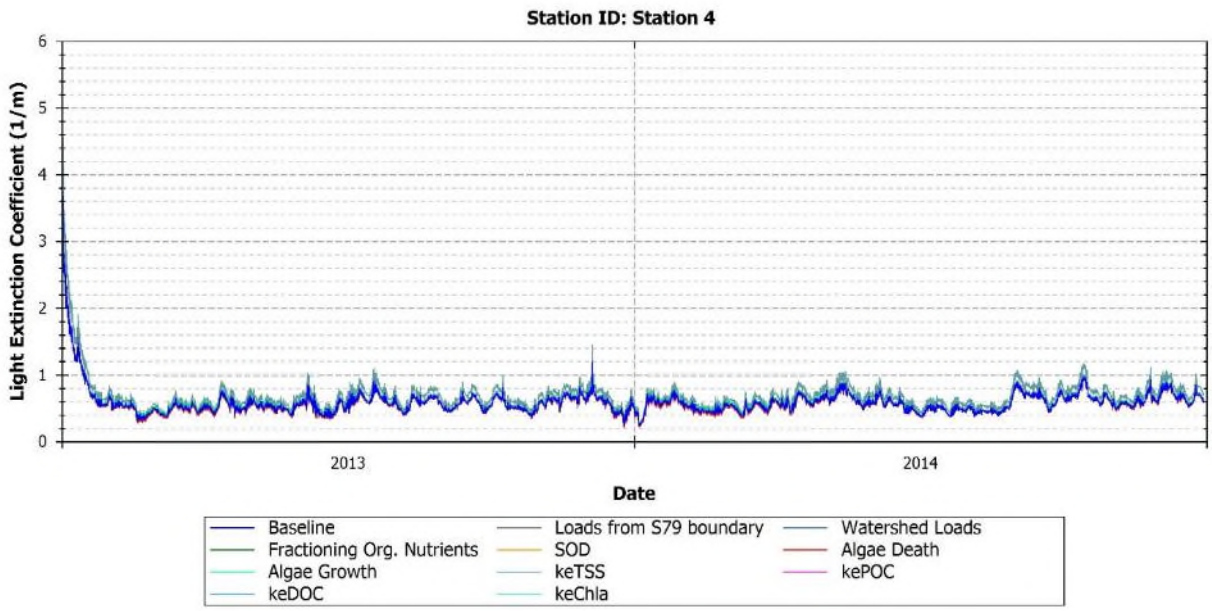

FIGURE 188: MODEL PREDICTIONS OF KE FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 4

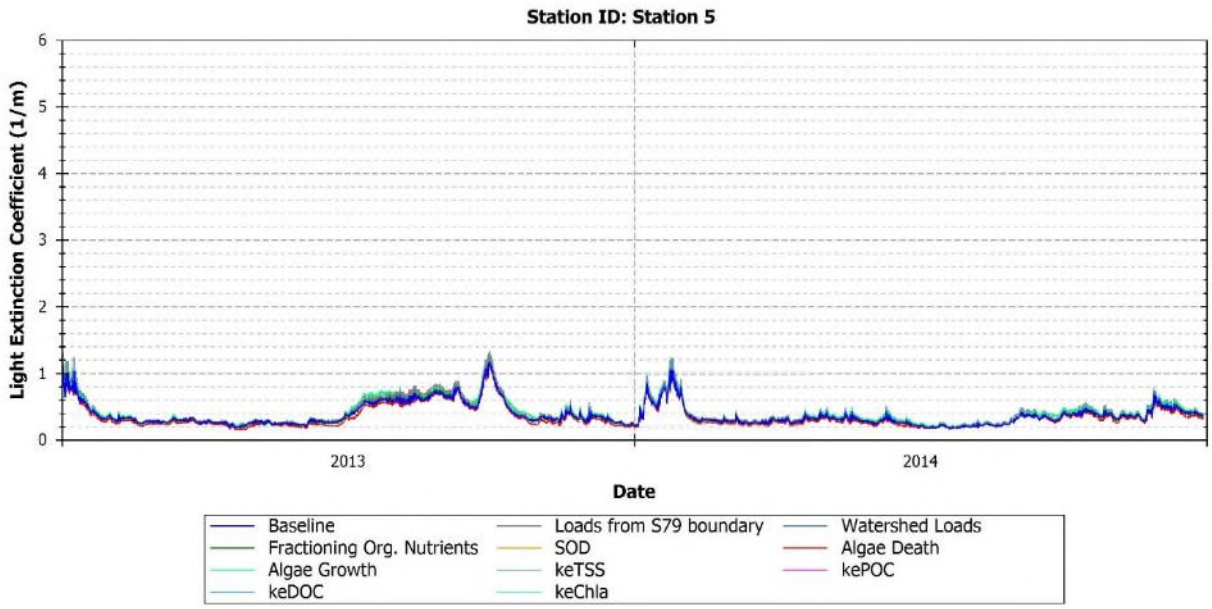

FIGURE 189: MODEL PREDICTIONS OF KE FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 5

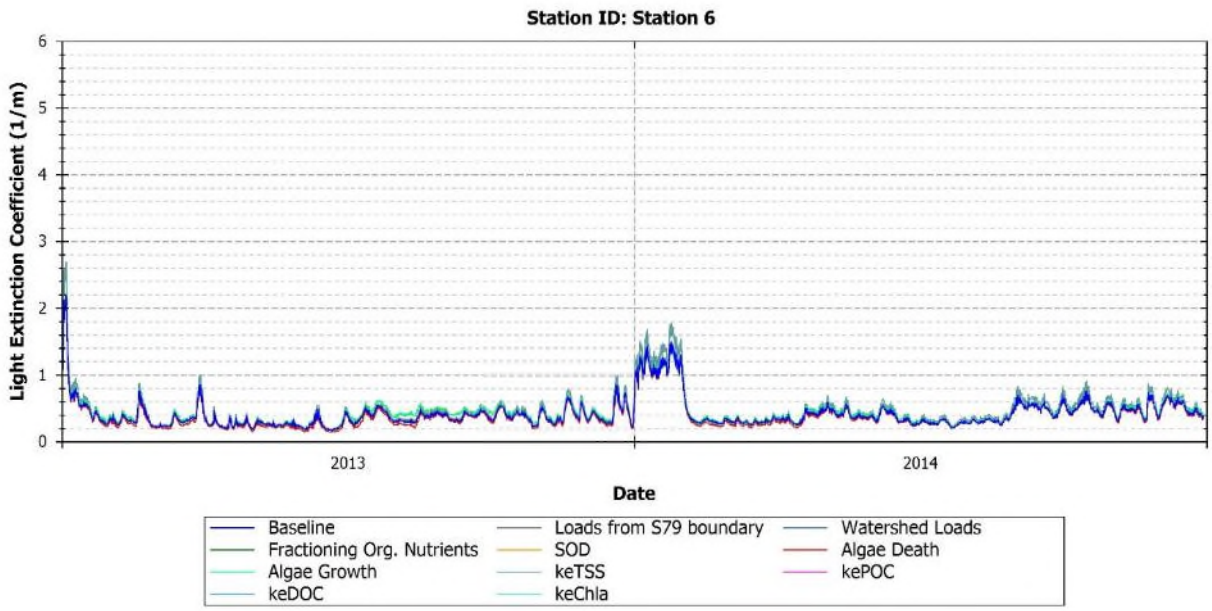

FIGURE 190: MODEL PREDICTIONS OF KE FOR BASELINE AND PERTURBED MODEL CONDITIONS - STATION 6

3.6 EFDC MODEL BACKGROUND SIMULATION

The background scenarios were simulated in EFDC by removing all point source loads directly discharging to the 2017 EFDC Model and by forcing the watershed boundaries with the loads computed by the 2017 HSPF Models background scenario models (**Section 2.5**). The scenarios evaluated included: (1) Background plus 1.2 (Caloosahatchee watershed natural background conditions and the Lake Okeechobee boundary at a TN concentration of 1.2 mg/L); (2) Background plus 1.4 (Caloosahatchee watershed natural background conditions and the Lake Okeechobee boundary at a TN concentration of 1.4 mg/L); and (3) Background plus 1.2 BENOD (Caloosahatchee watershed natural background conditions and the Lake Okeechobee at a TN concentration of 1.2 mg/L, plus reducing the sediment oxygen demand in the watershed reaches by 40%).

For the scenario runs, no changes were performed to the EFDC model open boundary conditions. The analysis of the scenario results were focus on evaluating the impacts of the nutrient load reductions on the light regimes within the San Carlos Bay area, and also on the regimes of DO, TN and TP at different locations of the estuary. The following section present the main conclusions of the natural scenario results.

3.6.1 Light Analysis

A set of 45 cells in the San Carlos Bay area were selected to evaluate the impacts of the load reductions scenarios in the light penetration regimes. The ultimate goal was to determine if the proposed nutrient load reductions were able to ensure that the bottom of the water column, in areas of 2.2 meters deep or less, could receive a minimum of 25% of the photosynthetically available radiation (PAR) received at the surface. The selected cells have a maximum depth of 2.2 meters and are presented in **Figure 191**.

To compute the fraction of light available at the bottom in San Carlos Bay region, the model predictions of light at the surface and bottom layers were output at a temporal resolution of 1 hour during the simulation period of 1/1/2008 through 12/31/2014. Then, at each cell, the daily average fraction of light (DAFL) reaching the bottom layer was computed. The DAFL was obtained by computing the average of the ratios of bottom light divided by the surface light from 10:00 am up to 2:00 pm. Once obtained, the DAFL values computed at each cell were spatially aggregated (averaged over the 45 cells under analysis) to obtain the total DAFL for the San Carlos Bay region. The results of this process are presented in **Figure 192** and **Table 152**.

The results suggested that under existing conditions the amount of light reaching the bottom in the San Carlos Bay varied seasonally. The minimum amount of light reaching the bottom was approximately 10% of the light reaching the surface and occurred during the periods between the end of spring and the end of fall (**Figure 192**). It is noted, however, that the frequency of the periods with low light regimes at the bottom was low and that 95% of the time the amount of light reaching the bottom was greater than 19.4% (**Table 152**). The maximum amount of light reaching the bottom represented up to 90% of the light at the surface and typically occurred during the winter period (**Figure 192**). The average light at the bottom represented approximately 45% of the light reaching the surface.

The scenario results showed a small change in the light regimes under natural or background conditions compared to the light regimes under existing conditions (**Table 152**). Under natural conditions, the amount of light reaching the bottom of the San Carlos Bay area only increased by approximately 1.5% from the 2017 EFDC Model. This is similar to the results from the 2009 Model, which appeared to show an increase

of approximately 2% in the natural condition run compared to the 2009 EFDC Model (Florida Department of Environmental Protection 2009).

No significant differences were found between the results of the different natural scenarios. This indicates that all the natural conditions evaluated have the same impact on the light regimes in the San Carlos Bay. A visual analysis of the change in light extinction in the Caloosahatchee Estuary for the scenarios is presented at select stations shown (**Figure 193** through **Figure 199**)

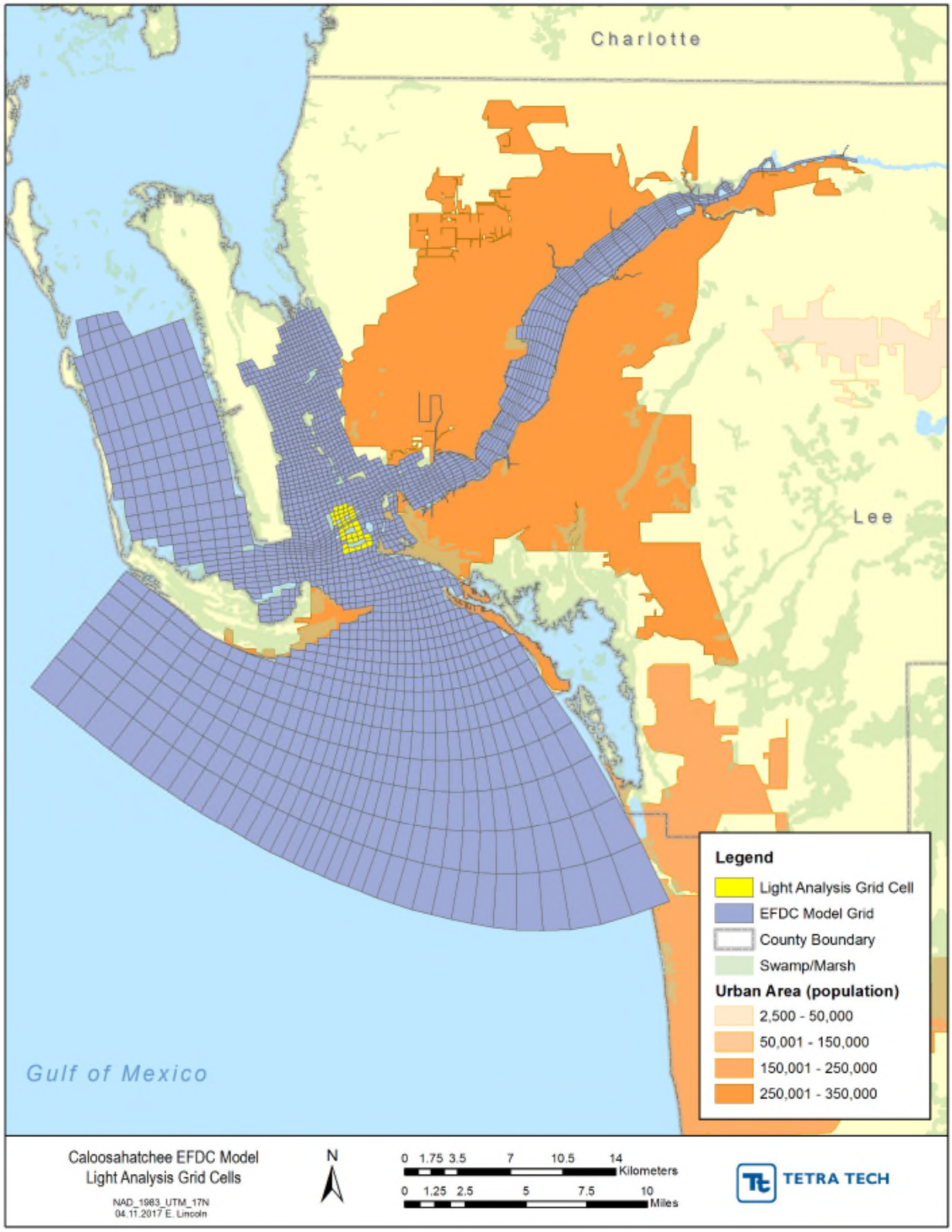

FIGURE 191: SAN CARLOS BAY SELECTED CELLS FOR LIGHT ANALYSIS THAT HAVE A MAXIMUM DEPTH OF 2.2 METERS

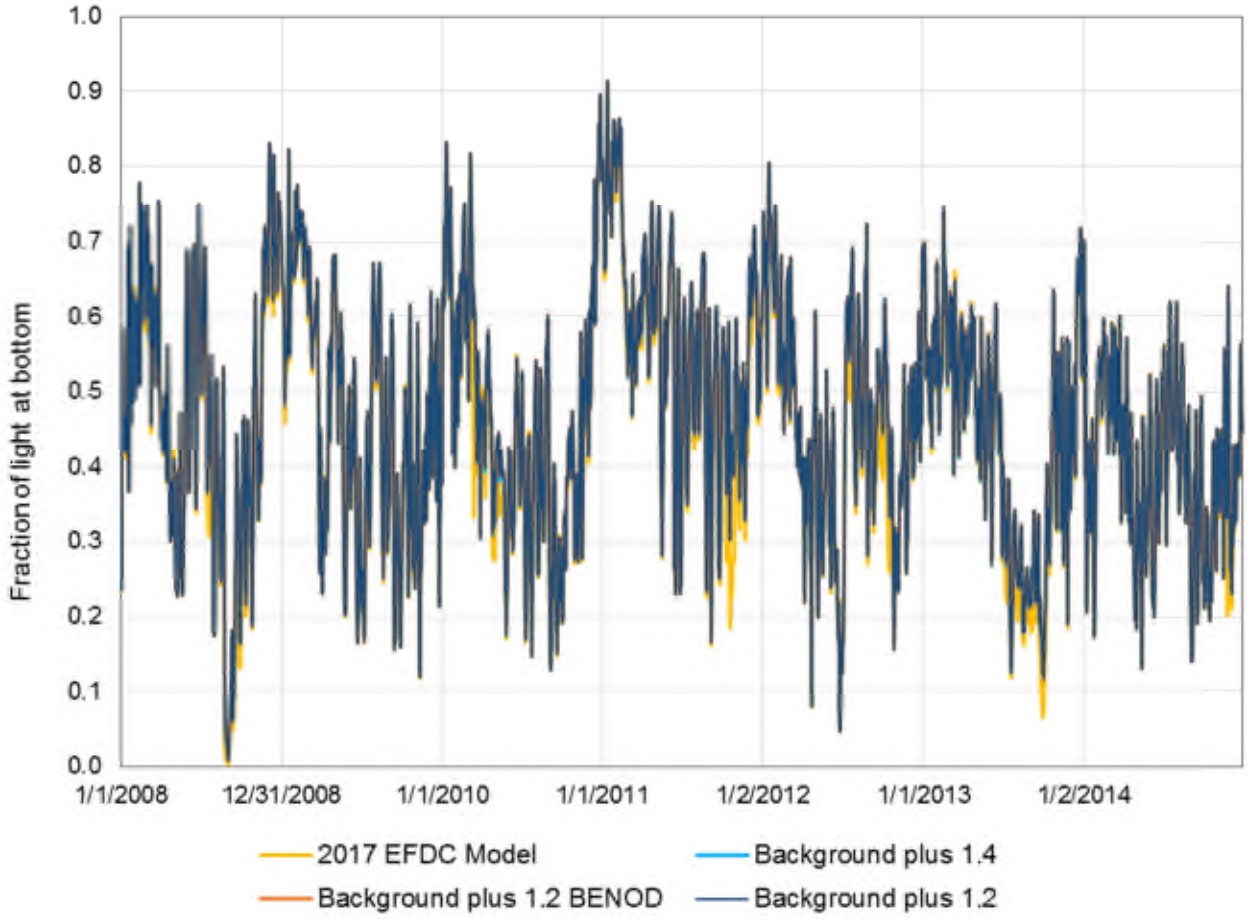

FIGURE 192: FRACTION OF LIGHT REACHING THE BOTTOM IN THE SAN CARLOS BAY REGION UNDER EXISTING CONDITIONS AND UNDER NATURAL CONDITIONS

TABLE 152: COMPARISON OF PERCENT OF LIGHT REACHING THE BOTTOM OF THE SAN CARLOS BAY AREA UNDER EXISTING CONDITIONS AND UNDER NATURAL CONDITIONS

Scenario	Average light at bottom (% from surface PAR)	5%tile light at bottom (% from surface PAR)*	95%tile light at bottom (% from surface PAR)**
2017 EFDC Model	45.32	19.43	72.00
Background Plus 1.4	46.66	21.14	72.09
Background Plus 1.2	46.74	21.16	72.19
Background Plus 1.2 BENOD	46.73	21.17	72.18

* 5% tile indicates that 95% of the time the amount of light at the bottom is greater than the value indicated in the table.
** 95% indicates that that 5% of the time the amount of light at the bottom is greater than the value indicated in the table.

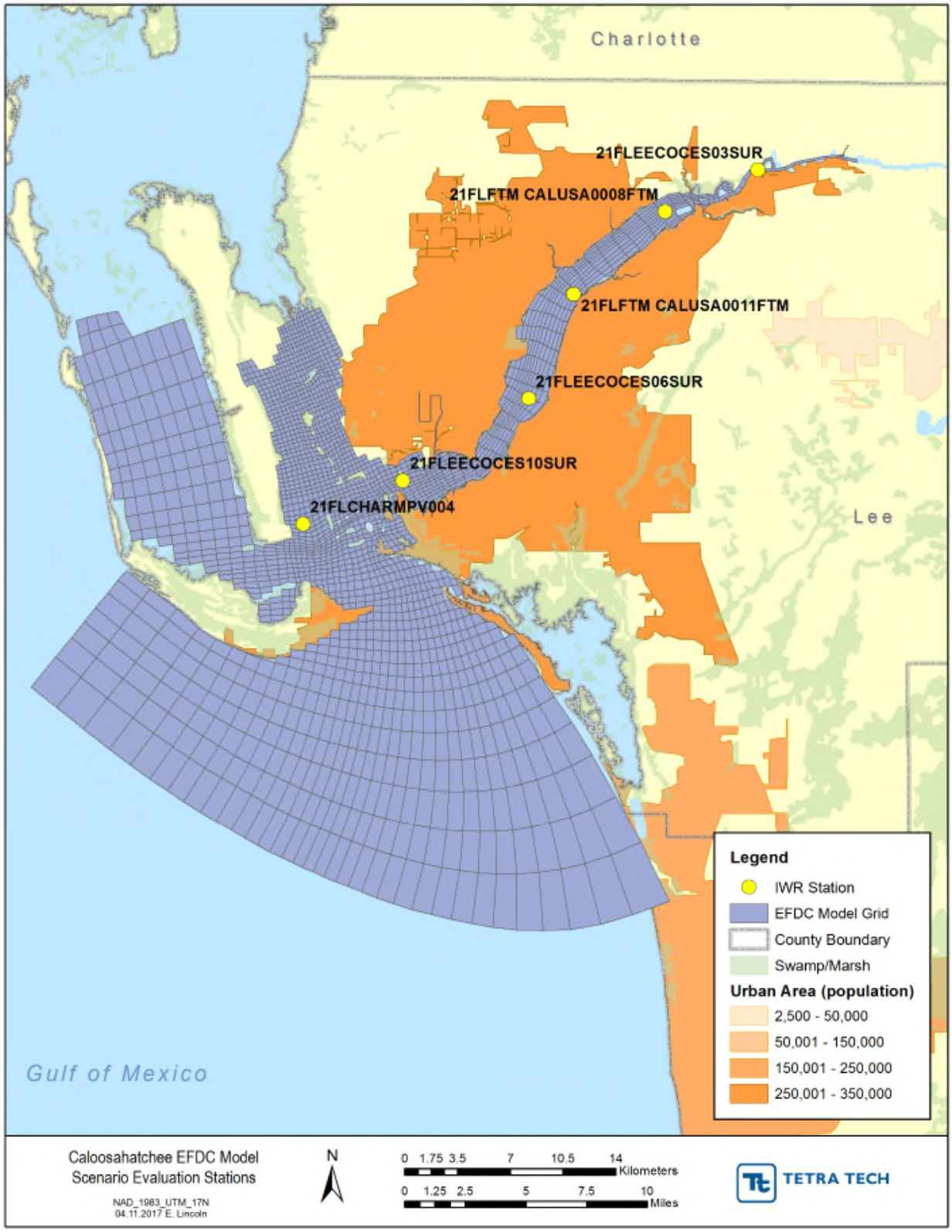

FIGURE 193: SELECTED CELLS FOR LIGHT, DO, AND NUTRIENT CONCENTRATION ANALYSES

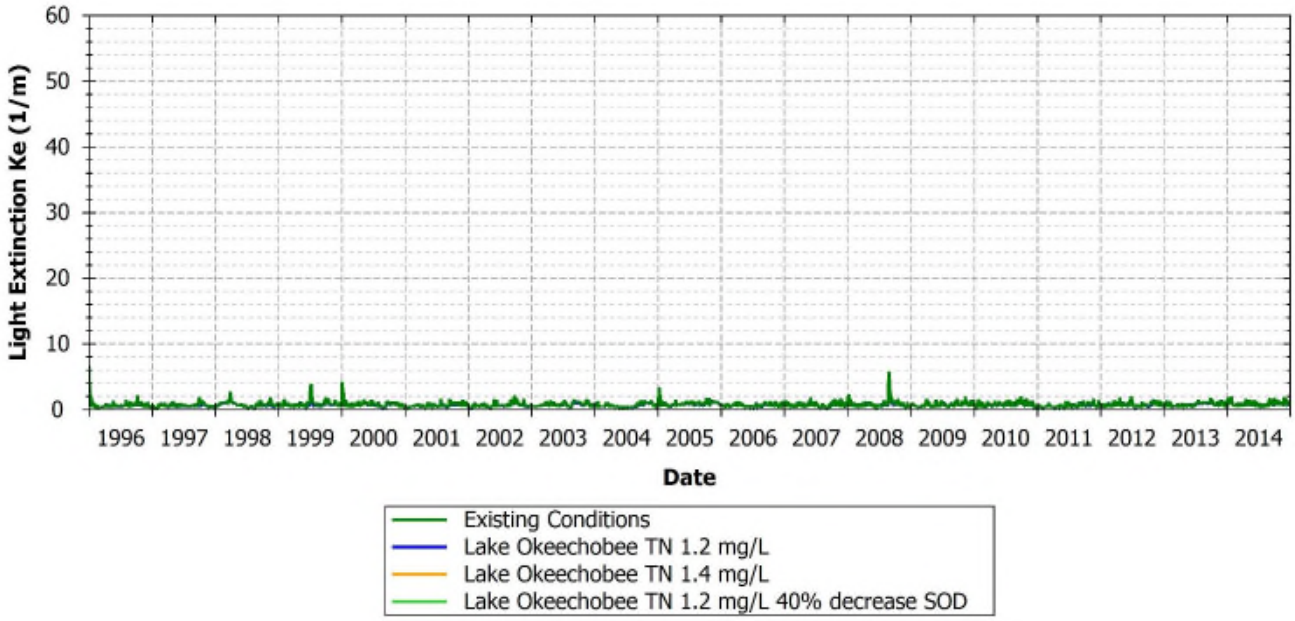

FIGURE 194: LIGHT EXTINCTION COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21CHARMPV004, MATLACHA PASS

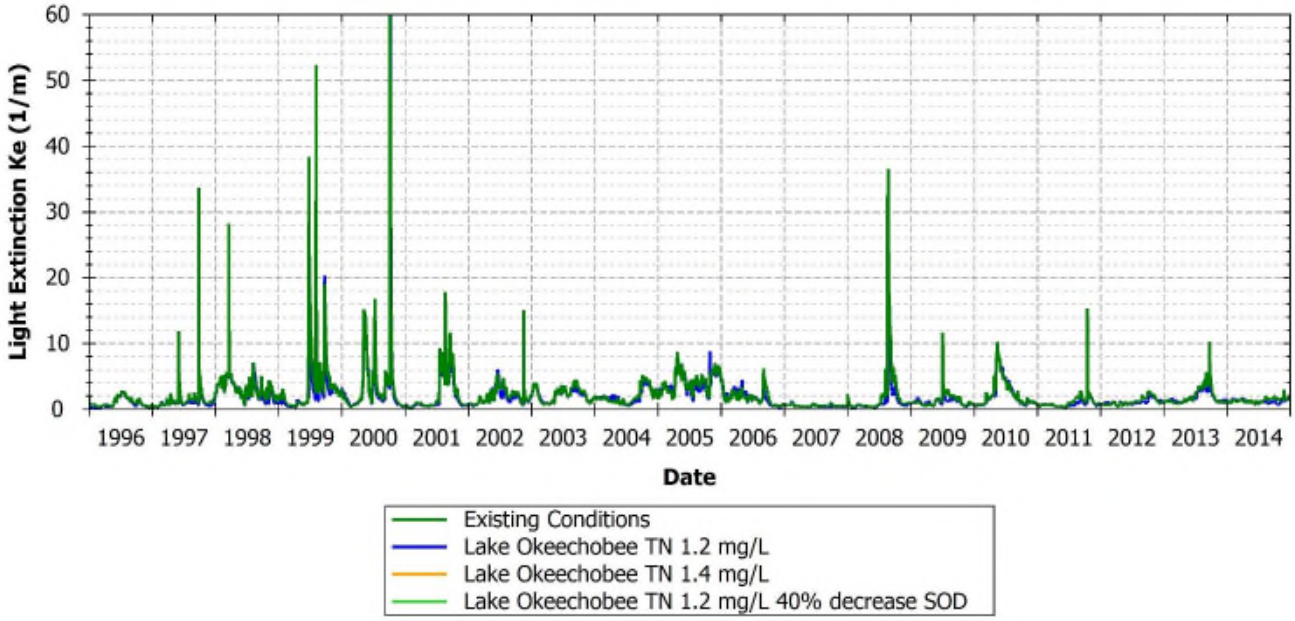

FIGURE 195: LIGHT EXTINCTION COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES03SUR, CALOOSAHATCHEE WATERWAY, ROUTE 31

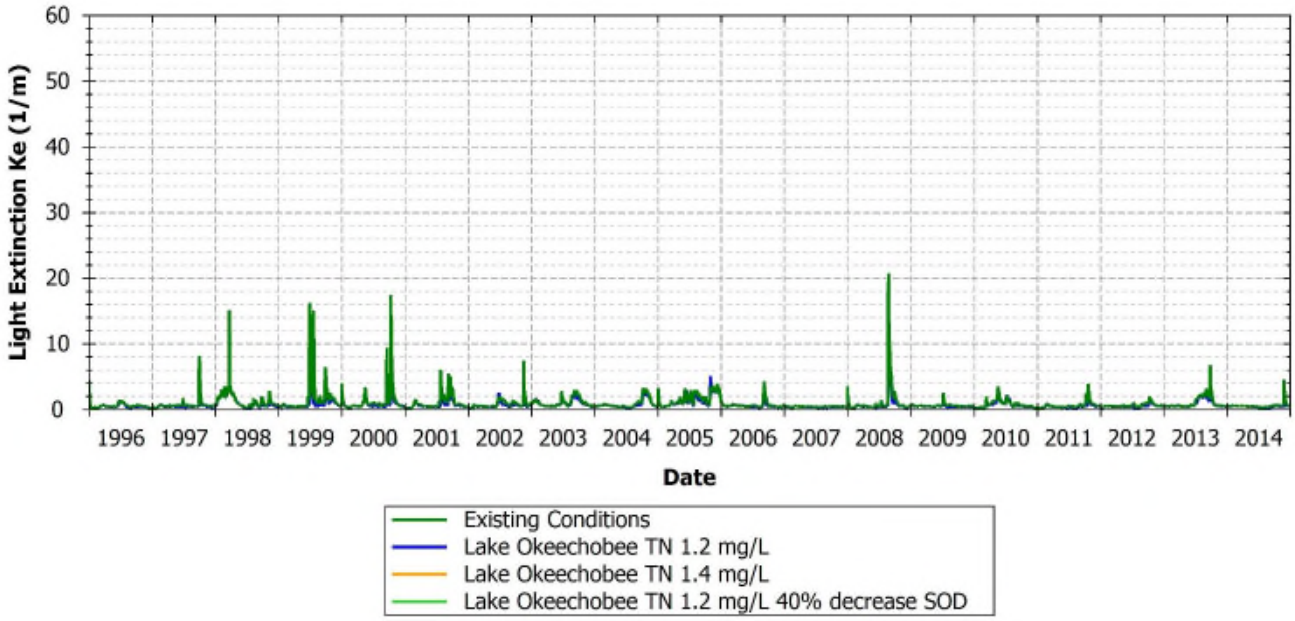

FIGURE 196: LIGHT EXTINCTION COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES06SUR, CALOOSAHATCHEE WATERWAY, MARKER 66

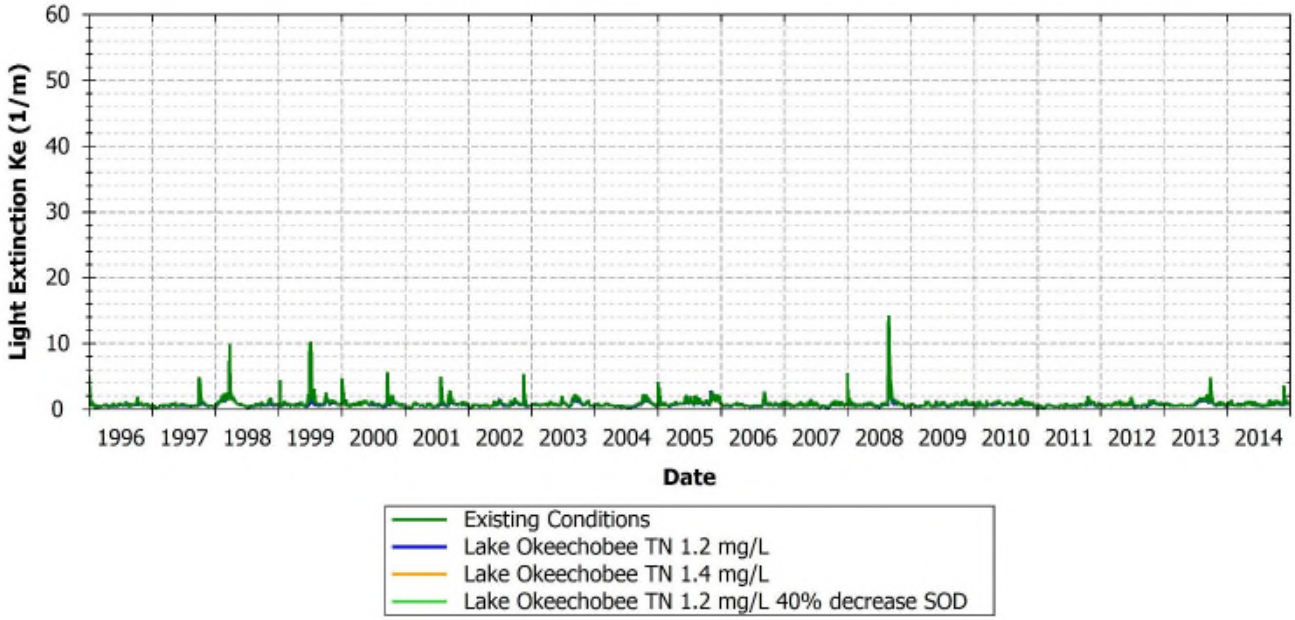

FIGURE 197: LIGHT EXTINCTION COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES10SUR, CALOOSAHATCHEE WATERWAY NEAR MOUTH

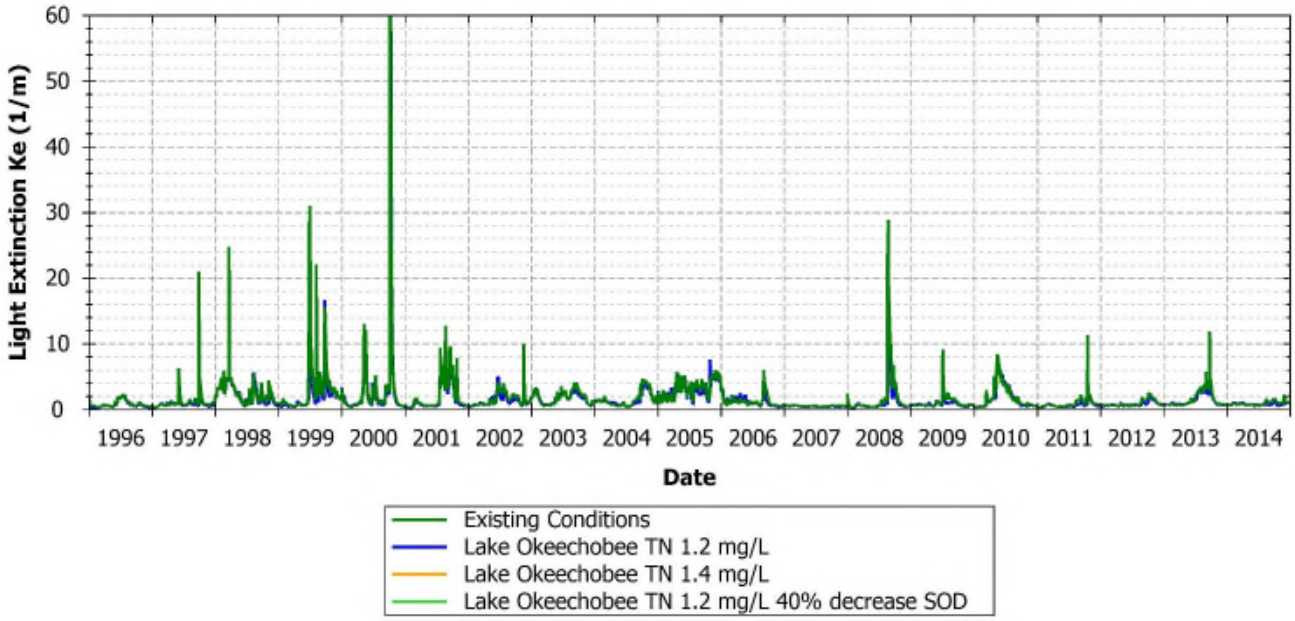

FIGURE 198: LIGHT EXTINCTION COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0008FTM, CALOOSAHATCHEE WATERWAY, MARKER 22

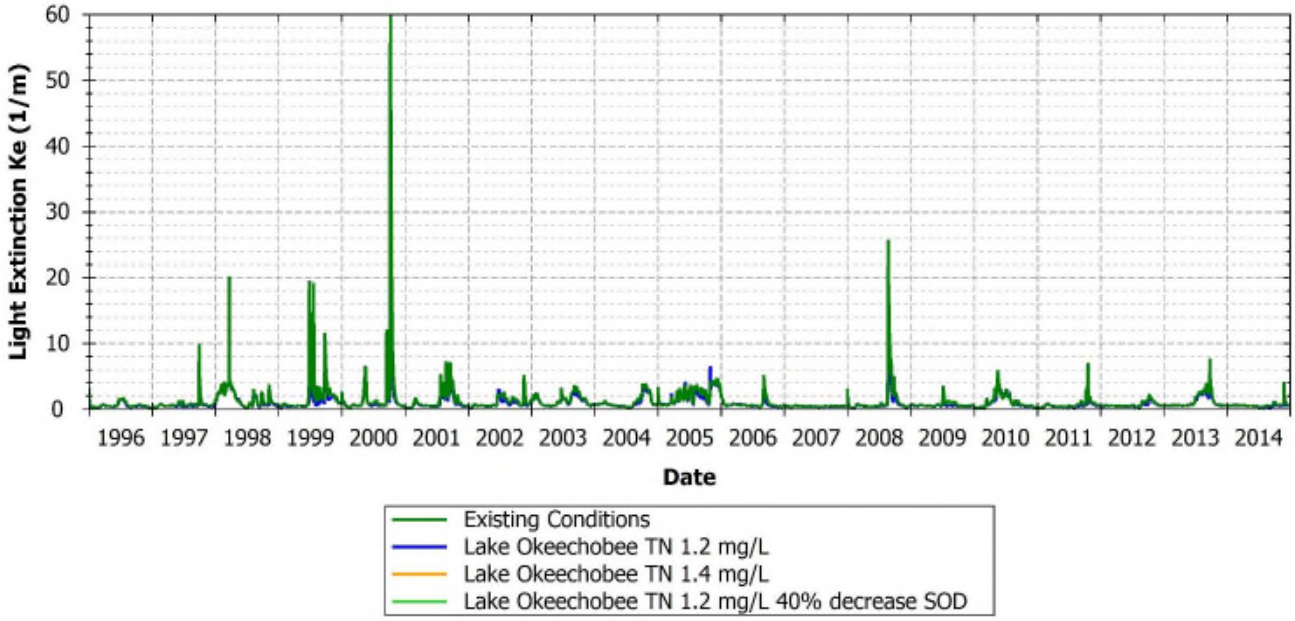

FIGURE 199: LIGHT EXTINCTION COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0011FTM, CALOOSAHATCHEE WATERWAY, MARKER 52

3.6.2 DO Analysis

Predictions of DO concentrations at selected stations (**Figure 193**) were used to evaluate the potential changes in DO under the different natural scenarios relative to the DO regimes observed under current conditions. The results of the analyses are summarized in **Table 153**, while the time series for DO concentrations for existing and scenario conditions are presented in **Figure 200** through **Figure 205**.

In natural condition scenarios, the levels of DO slightly increased relative to the existing conditions. In particular, the 5th percentile, mean, and 95th percentile DO concentrations increased by 10%, 5%, and 1% respectively (**Table 153**). The increases in DO were mostly observed in the middle and upper portions of the main Caloosahatchee River where at stations 21FLEECOCES03SUR, 21FLFTM CALUSA0008FTM, and 21FLFTM CALUSA0011FTM (**Table 153**) the mean, 5th percentile, and 95th percentile DO concentrations increased between 0.20 mg/L and 0.30 mg/L from the existing DO concentrations. The above increments represented between a 5% and a 10% increase of DO relative to the existing conditions. In the lower portions of the Caloosahatchee Estuary, the increases in DO levels generally varied between 0.1 mg/L and 0.2 mg/L.

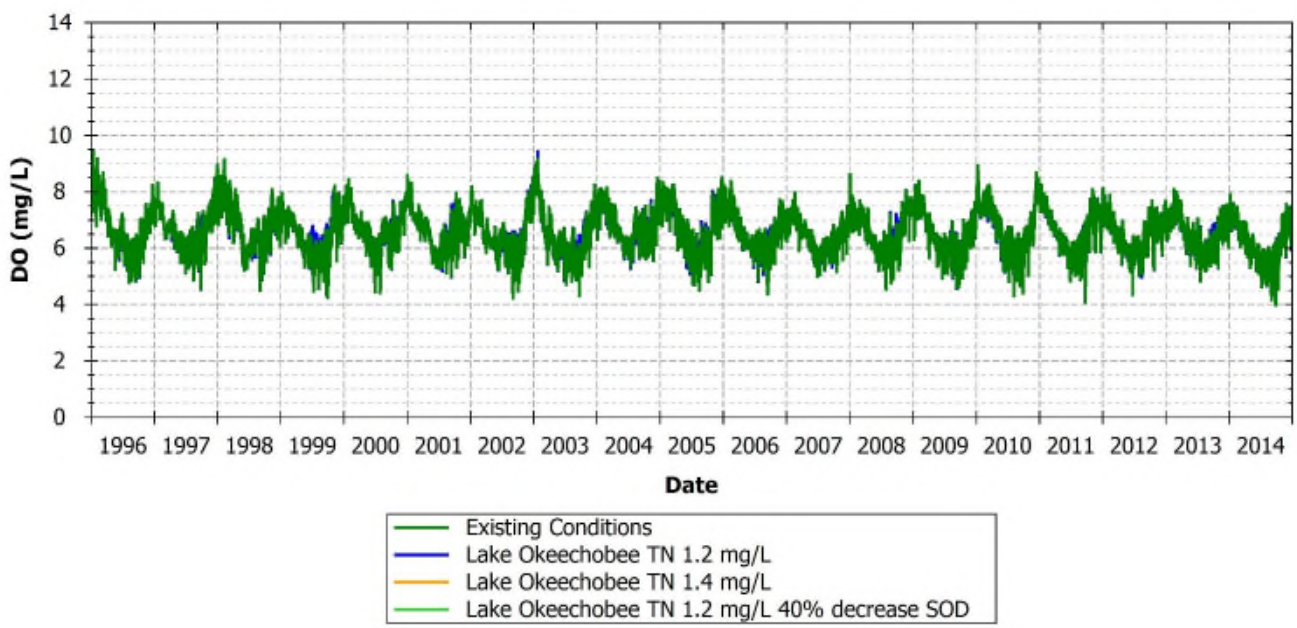

FIGURE 200: DO COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21CHARMPV004, MATLACHA PASS

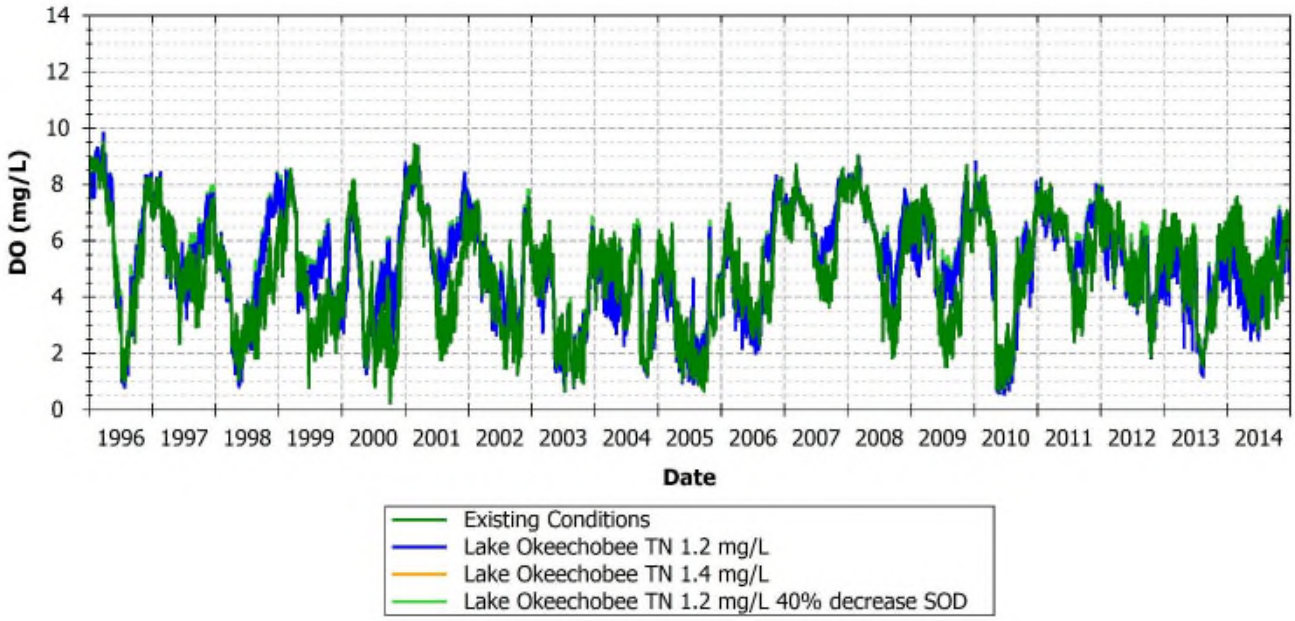

FIGURE 201: DO COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES03SUR, CALOOSAHATCHEE WATERWAY, ROUTE 31

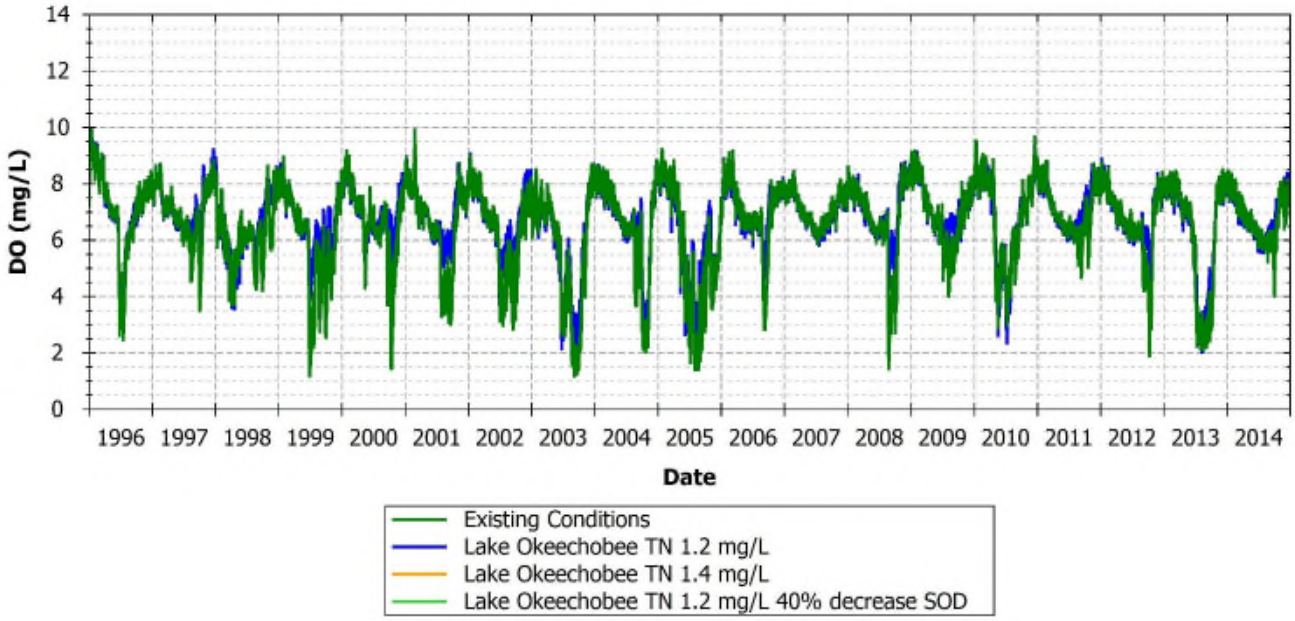

FIGURE 202: DO COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES06SUR, CALOOSAHATCHEE WATERWAY, MARKER 66

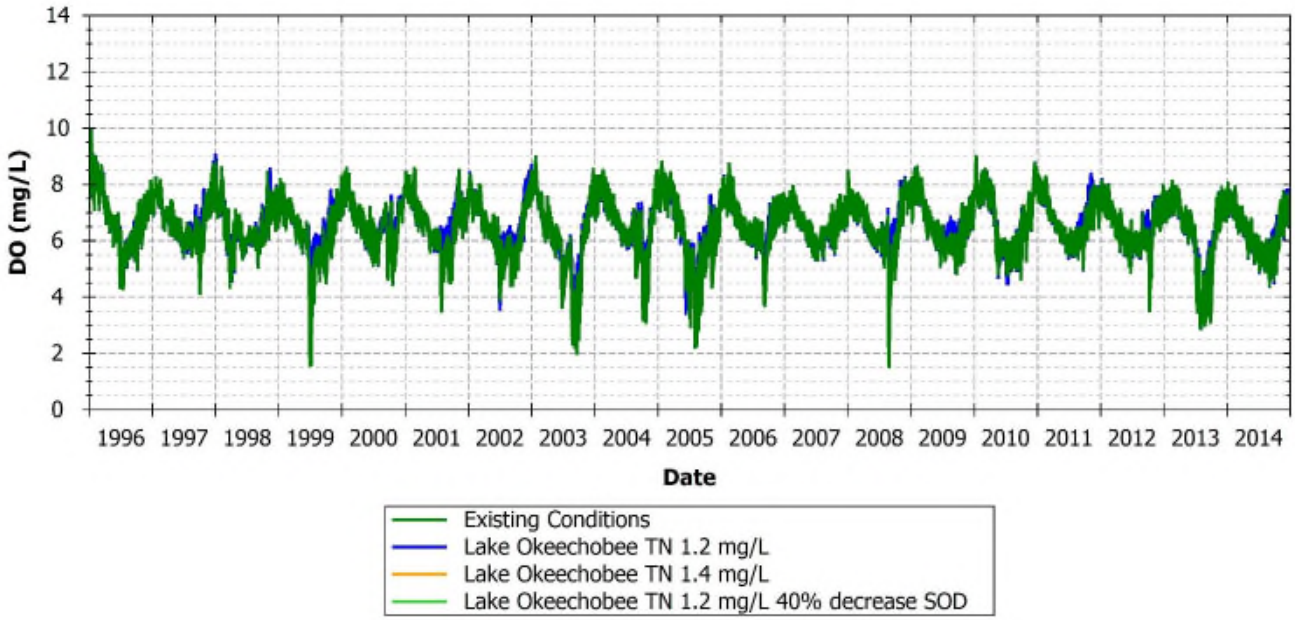

FIGURE 203: DO COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES10SUR, CALOOSAHATCHEE WATERWAY NEAR MOUTH

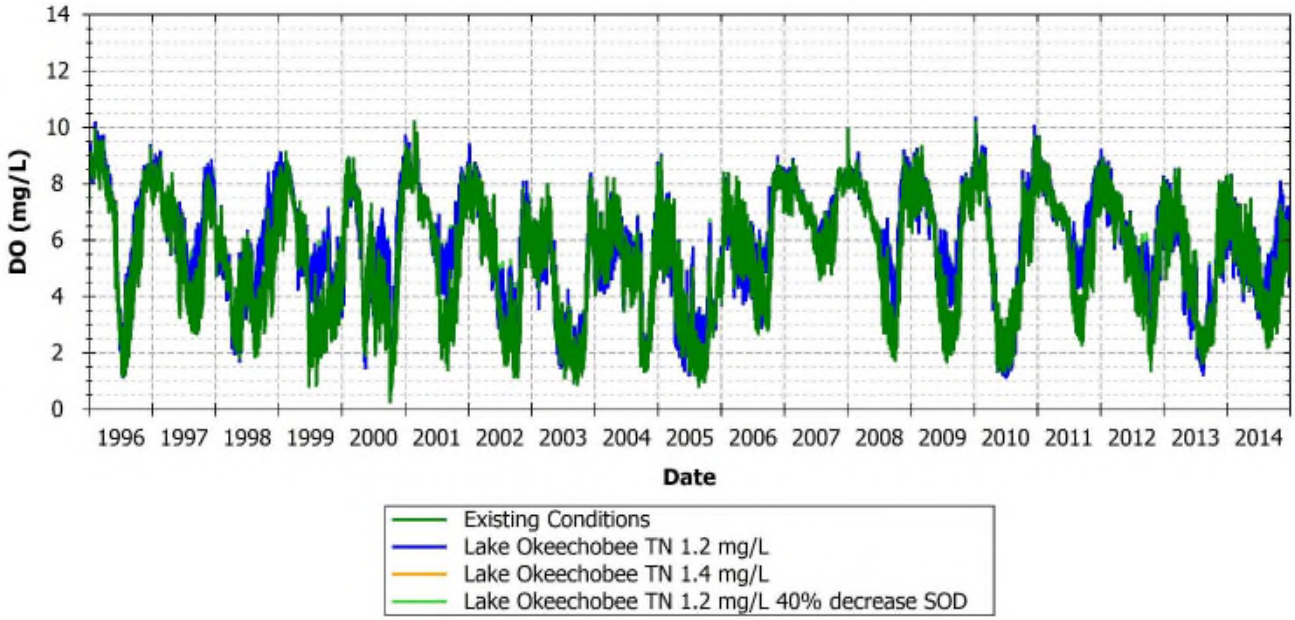

FIGURE 204: DO COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0008FTM, CALOOSAHATCHEE WATERWAY, MARKER 22

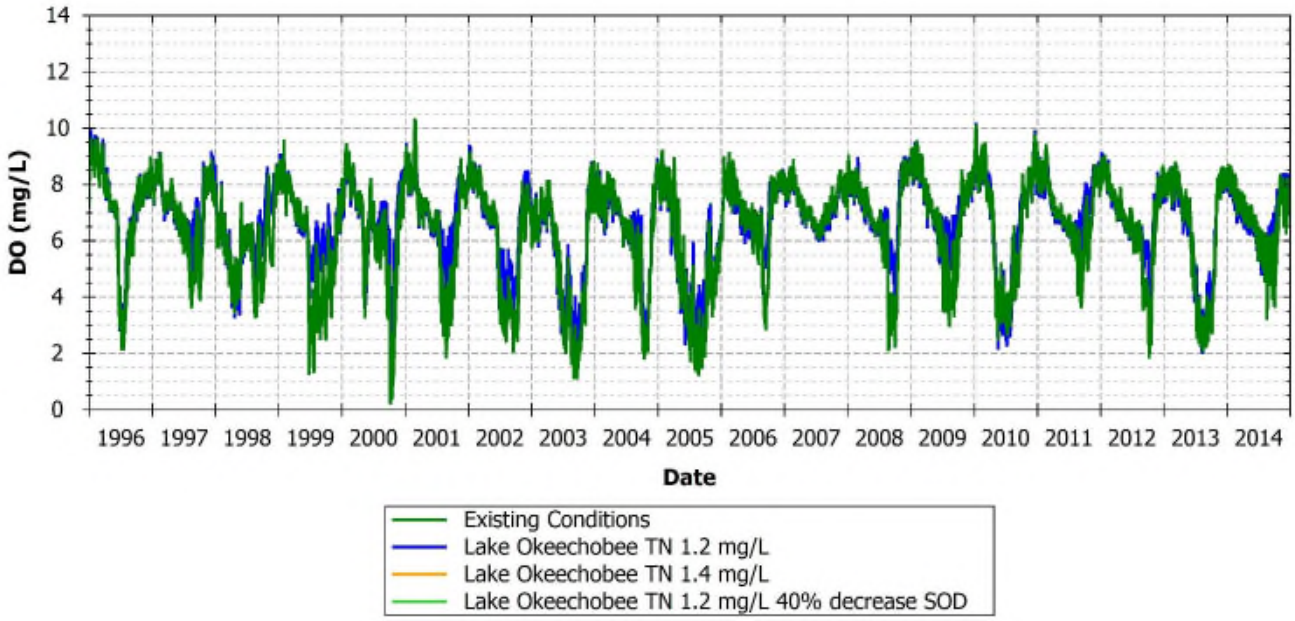

FIGURE 205: DO COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0011FTM, CALOOSAHATCHEE WATERWAY, MARKER 52

TABLE 153: COMPARISON OF DO CONCENTRATIONS AT SELECTED LOCATIONS UNDER EXISTING CONDITIONS AND UNDER NATURAL CONDITIONS

Station ID	Existing Mean (mg/L)	Background Plus 1.4 Mean (mg/L)	Background Plus 1.2 Mean (mg/L)	Background Plus 1.2 BENOD Mean (mg/L)	Existing 5th Percentile (mg/L)	Background Plus 1.4 5th Percentile (mg/L)	Background Plus 1.2 5th Percentile (mg/L)	Background Plus 1.2 BENOD 5th Percentile (mg/L)	Existing 95th Percentile (mg/L)	Background Plus 1.4 95th Percentile (mg/L)	Background Plus 1.2 95th Percentile (mg/L)	Background Plus 1.2 BENOD 95th Percentile (mg/L)
21FLCHARMPV004	6.66	6.65	6.65	6.65	5.53	5.58	5.58	5.58	7.90	7.87	7.87	7.87
21FLEECOCES03SUR	4.92	5.13	5.13	5.27	1.82	1.77	1.77	1.84	7.85	7.95	7.95	7.99
21FLEECOCES06SUR	6.57	6.76	6.76	6.76	3.24	4.07	4.08	4.09	8.40	8.39	8.39	8.39
21FLEECOCES10SUR	6.53	6.61	6.61	6.61	4.72	5.18	5.19	5.19	8.02	8.00	8.00	8.00
21FLFTM CALUSA0008FTM	5.38	5.82	5.82	5.88	2.01	2.21	2.21	2.25	8.28	8.50	8.50	8.52
21FLFTM CALUSA0011FTM	6.43	6.69	6.69	6.70	2.81	3.33	3.33	3.36	8.62	8.63	8.62	8.63

3.6.3 Nutrient Analysis

Predictions of TN and TP concentrations at selected stations (**Figure 193**) were used to evaluate the potential changes in TN and TP under the different natural scenarios relative to the nutrient regimes observed under current conditions. The results of the analyses are summarized in **Table 154** and **Table 155**, while the time series for TN and TP concentrations for existing and scenario conditions are presented in **Figure 206** through **Figure 217**.

In the natural conditions scenarios, the concentrations of TN and TP systematically decreased from the 2017 EFDC Model concentrations in all the evaluated stations. The most significant reductions occurred for the maximum nutrient concentrations. For nitrogen, the 5th percentile, mean, and 95th percentile concentrations of TN decreased in average by 8%, 22%, and 32%, respectively (**Table 154**). For phosphorus the 5th percentile, mean, and 95th percentile concentrations of TP decreased in average by 13%, 46%, and 65%, respectively (**Table 155**). The above results suggest that the proposed scenarios can cause important nutrient reductions throgout the system.

The largest reductions in TN occured in the upper regions of the Caloosahatchee Estuary at stations 21FLEECOCES03SUR and 21FLFTM CALUSA0008FTM, where the average TN concentrations decreased by up to 30% (**Table 154**), and the 95th percentile TN concentrations decreased by up to 40% under the natural background scenarios. In the lower portions of the estuary, the reductions in TN were lower compared to those in the upper areas, but also important. At station 21FLCHARMPV004 for example, the background load conditions resulted in a reduction of up to 15% in the mean TN concentration and in a reduction of up to 25% in the 95th percentile TN concentration. TN reductions were larger under the Background Plus 1.2 Scenario (**Table 154**).

The reductions in TP occurred in the upper regions of the Caloosahatchee Estuary (**Table 155**). At stations 21FLEECOCES03SUR and 21FLFTM CALUSA0008FTM, for example, the background scenarios resulted in a reduction of up to 50% of the average TP concentrations and of up to 60% of the 95th percentile TP concentrations. In lower portions of the estuary, the reductions of the TP concentrations were also important. At station 21FLCHARMPV004, for example, the background scenarios resulted in a reduction of up to 30% in the average TP concentration and in a reduction of up to 50% in the 95th percentile TP concentrations. The three natural background scenarios evaluated resulted in similar levels of TP attenuation.

The relative insensitivity to the TN and TP concentration reductions in the lower percentiles and lower flow periods may be due to several factors. First, the lowest nutrient loads and concentrations from Lake Okeechobee and the Caloosahatchee Watershed tend to occur during low flow periods. The relative change in nutrient loads and concentrations from these two sources were lower during these periods. Therefore, the relative response in the estuary in the lower percentiles would likely be less as well. Second, the boundary condition for Lake Okeechobee at S-77 to the 2017 HSPF Model was held constant under all flow conditions. Therefore, at times the TN and TP concentrations in the background scenarios were higher than the measured data, which would also contribute to the relative insensitivity.

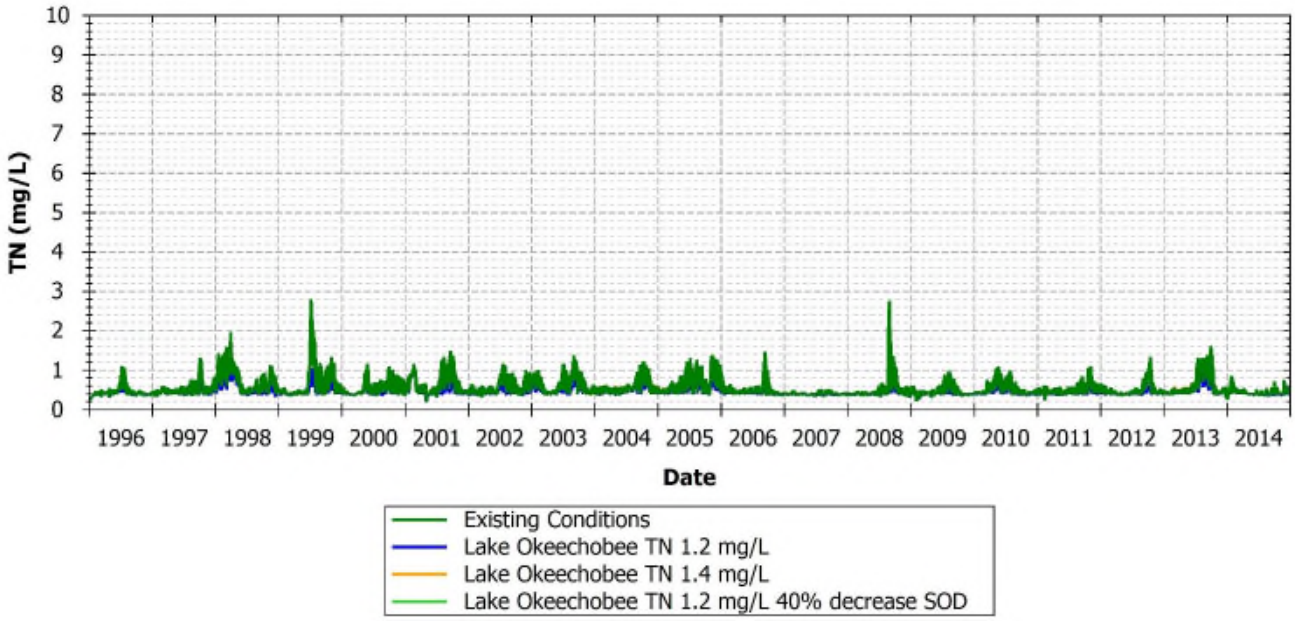

FIGURE 206: TN COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21CHARMPV004, MATLACHA PASS

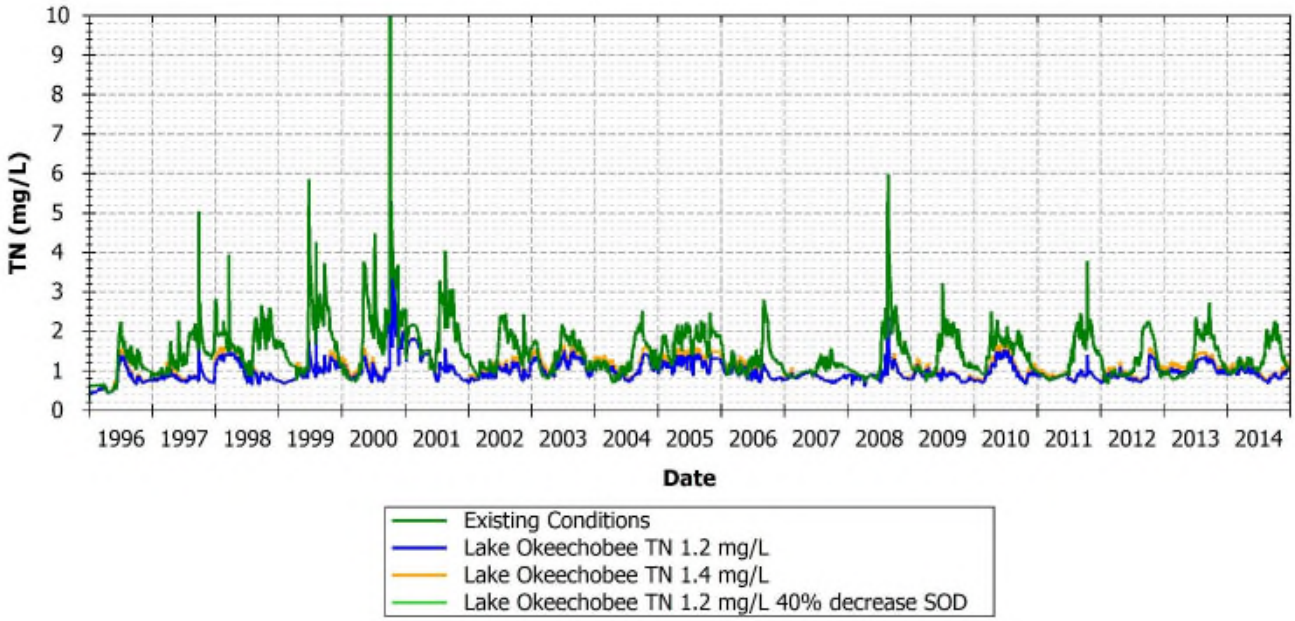

FIGURE 207: TN COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES03SUR, CALOOSAHATCHEE WATERWAY, ROUTE 31

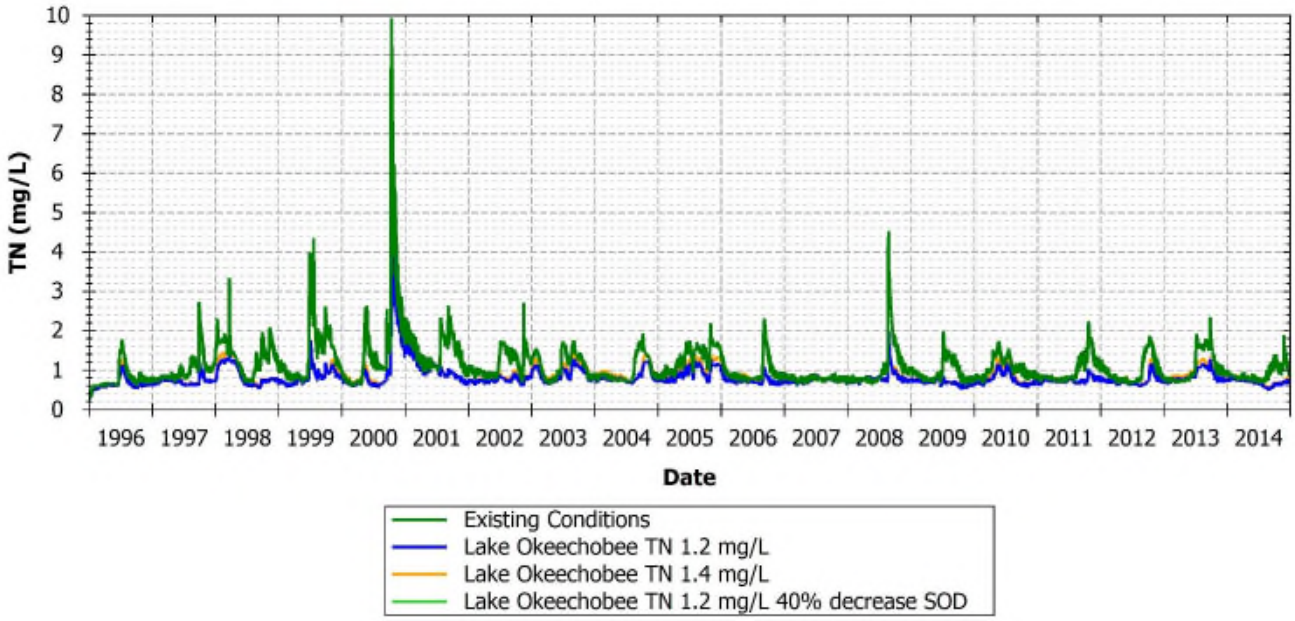

FIGURE 208: TN COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES06SUR, CALOOSAHATCHEE WATERWAY, MARKER 66

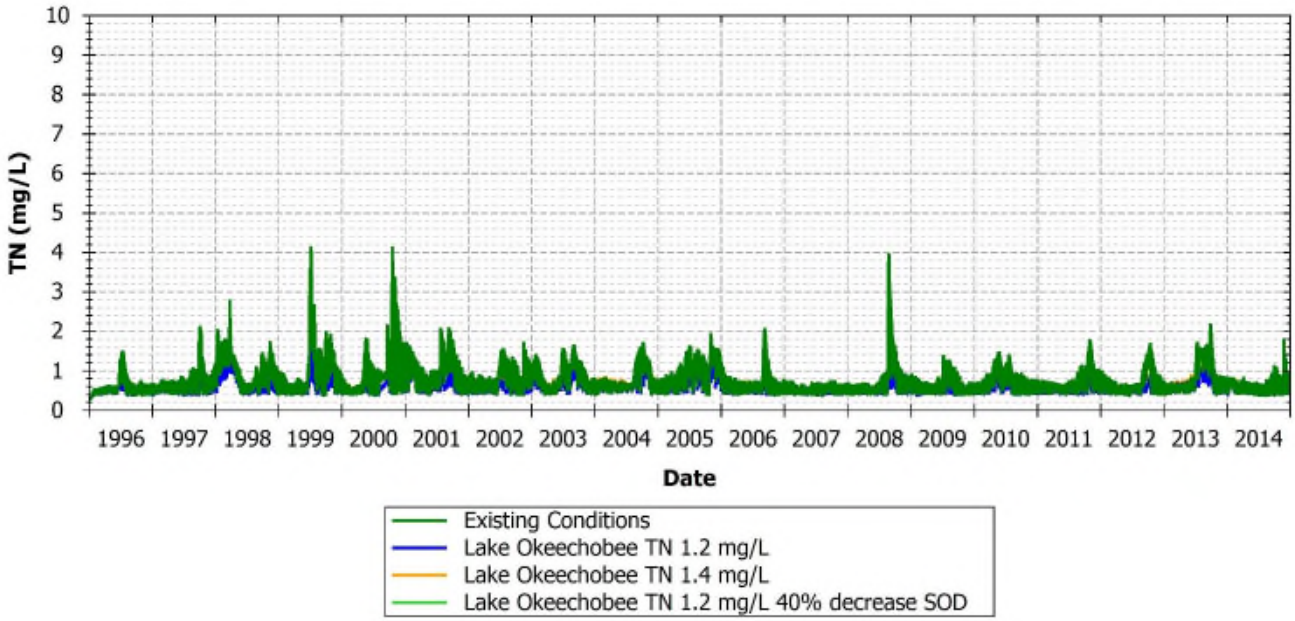

FIGURE 209: TN COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES10SUR, CALOOSAHATCHEE WATERWAY NEAR MOUTH

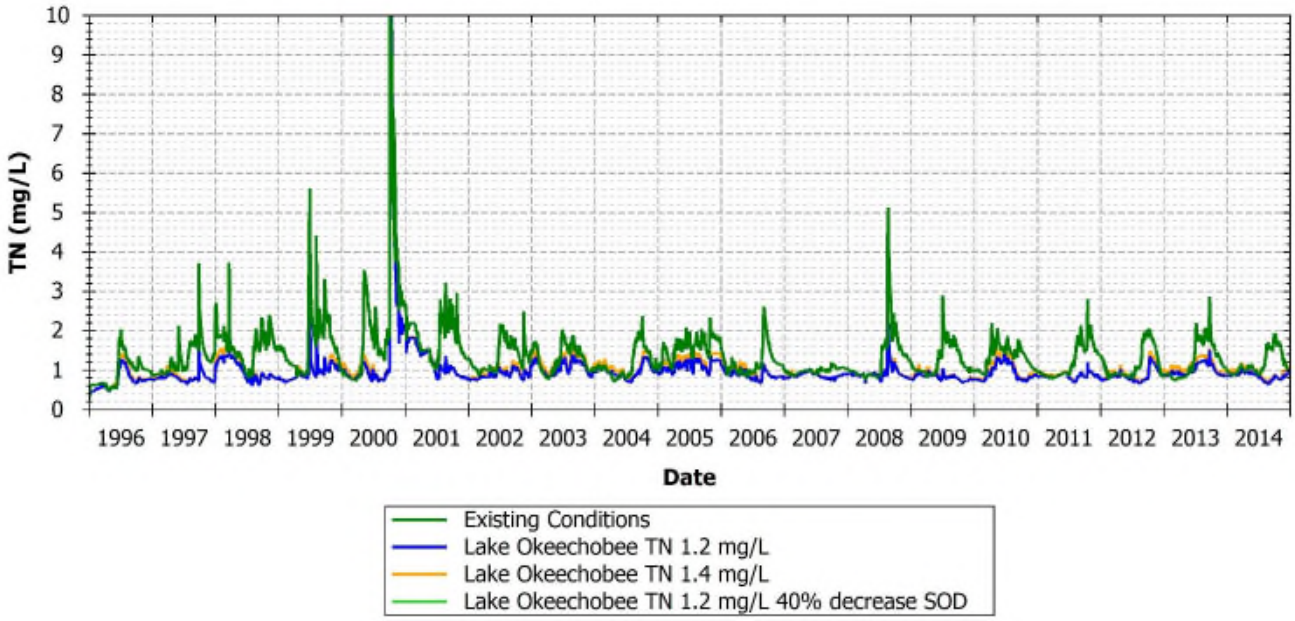

FIGURE 210: TN COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0008FTM, CALOOSAHATCHEE WATERWAY, MARKER 22

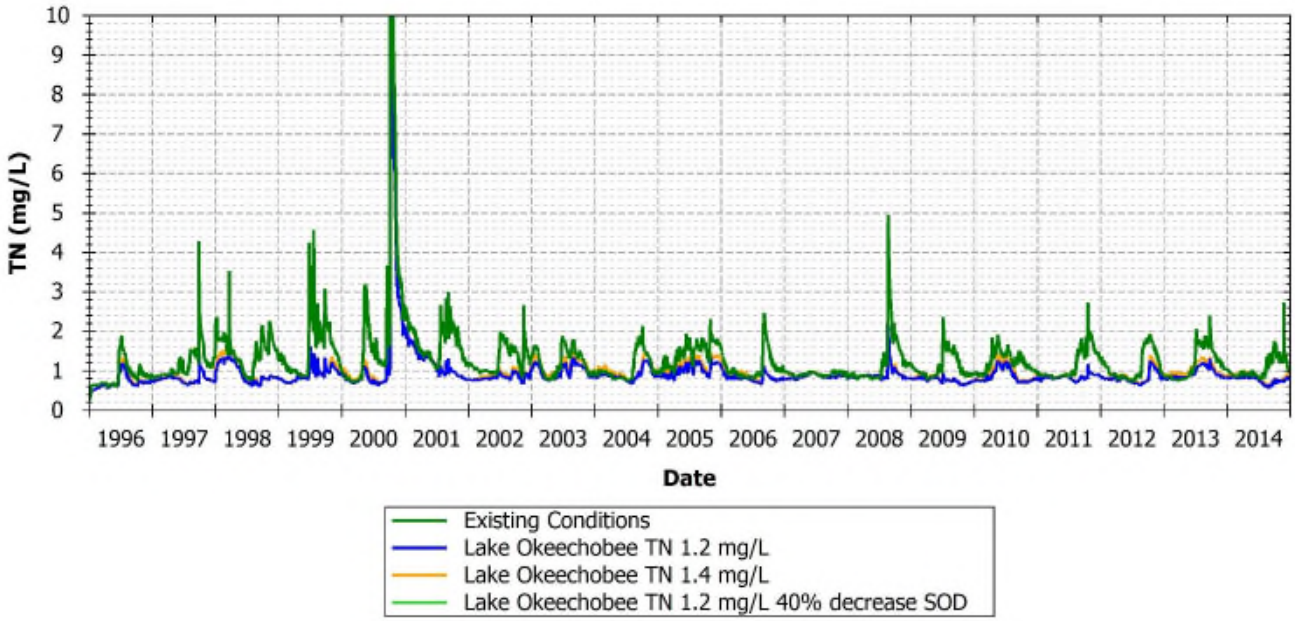

FIGURE 211: TN COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0011FTM, CALOOSAHATCHEE WATERWAY, MARKER 52

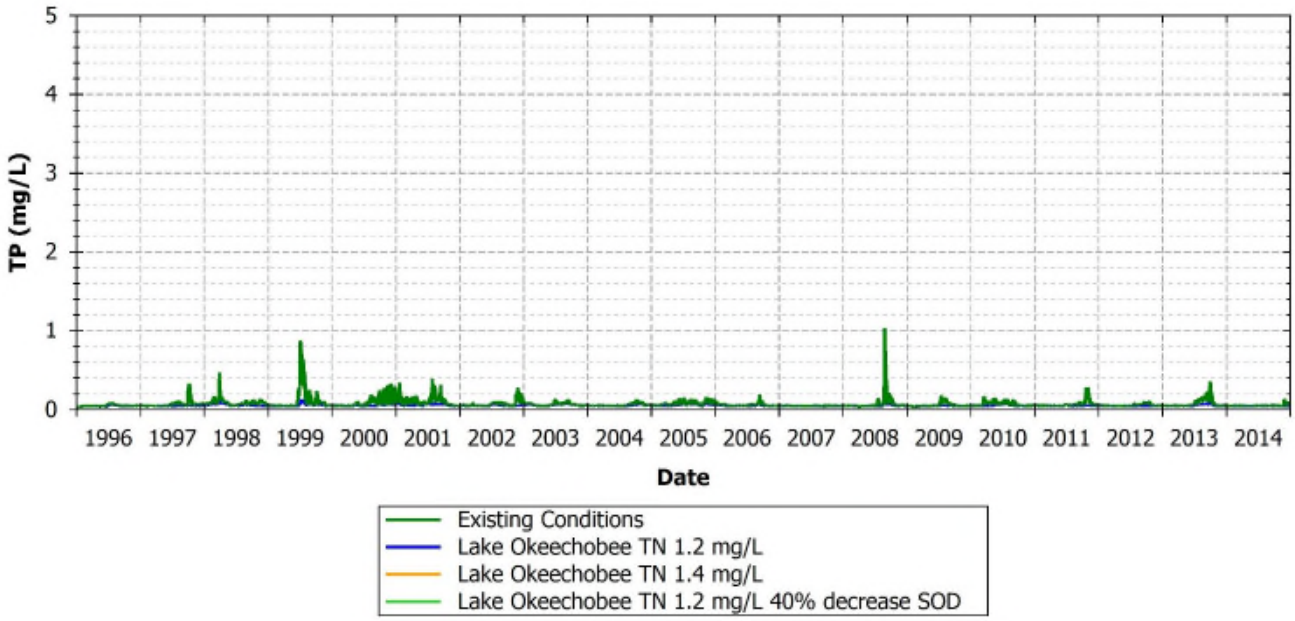

FIGURE 212: TP COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21CHARMPV004, MATLACHA PASS

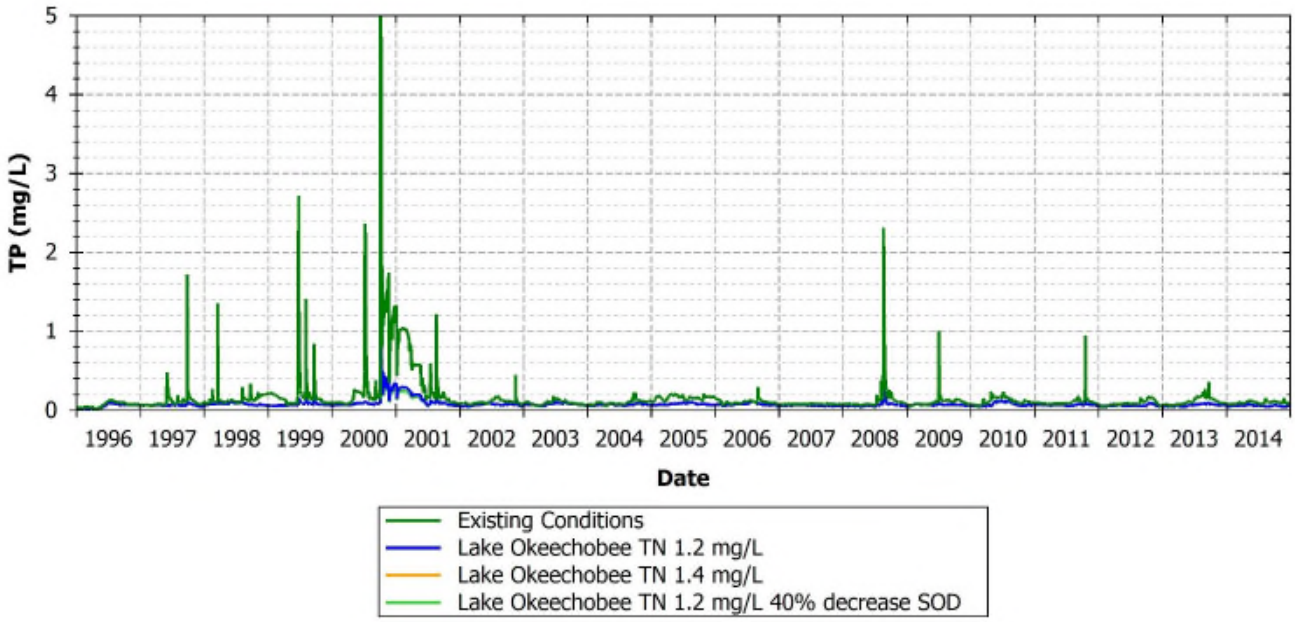

FIGURE 213: TP COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES03SUR, CALOOSAHATCHEE WATERWAY, ROUTE 31

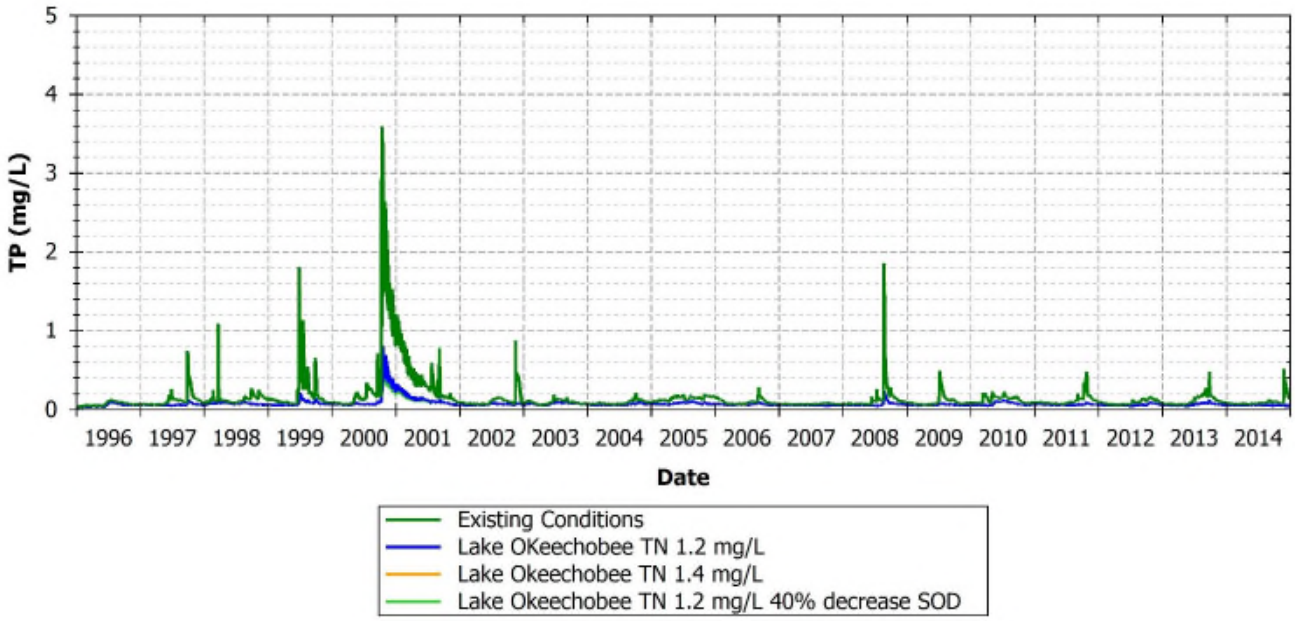

FIGURE 214: TP COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES06SUR, CALOOSAHATCHEE WATERWAY, MARKER 66

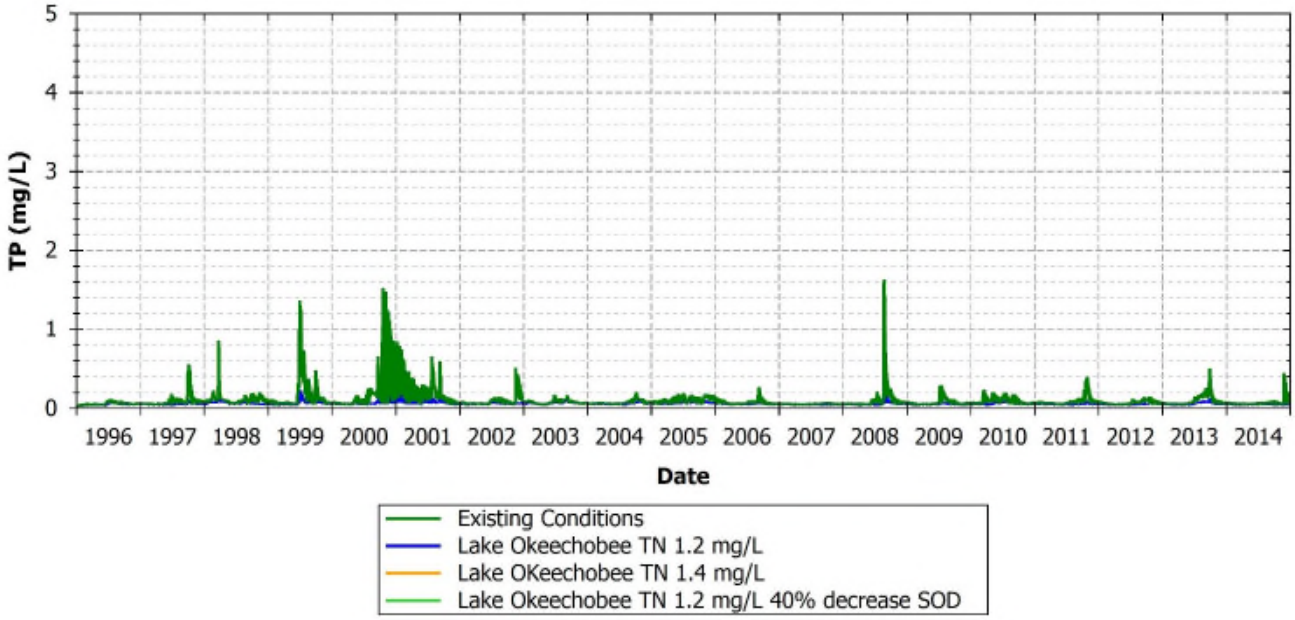

FIGURE 215: TP COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES10SUR, CALOOSAHATCHEE WATERWAY NEAR MOUTH

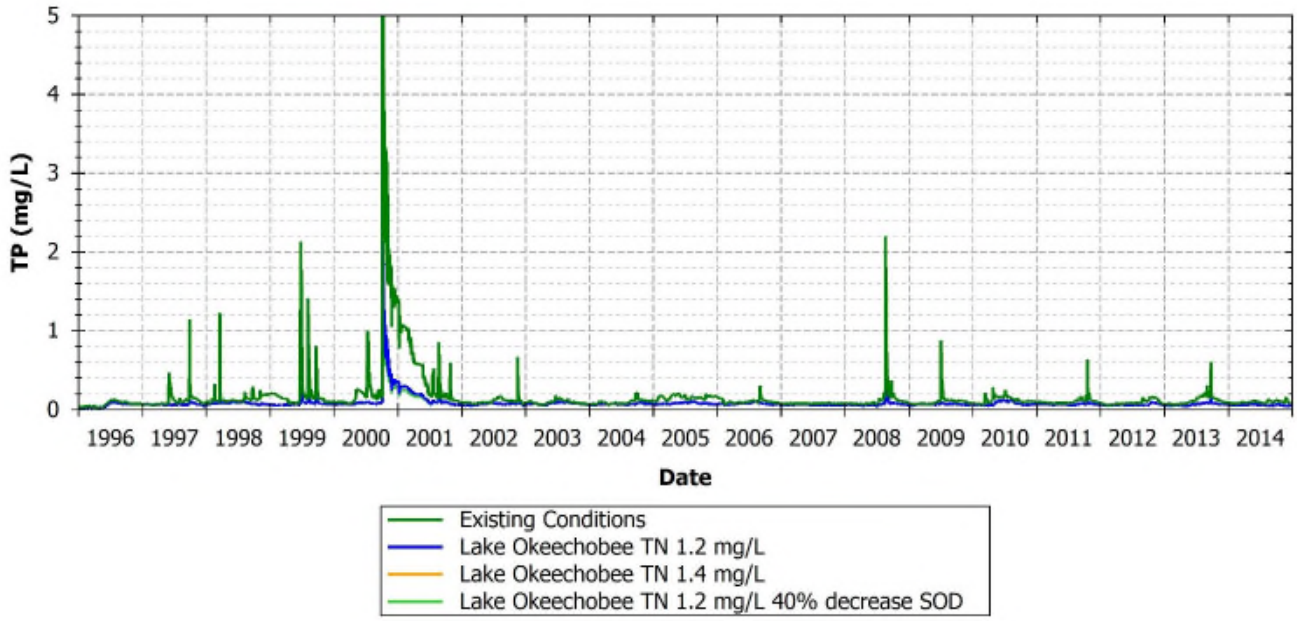

FIGURE 216: TP COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0008FTM, CALOOSAHATCHEE WATERWAY, MARKER 22

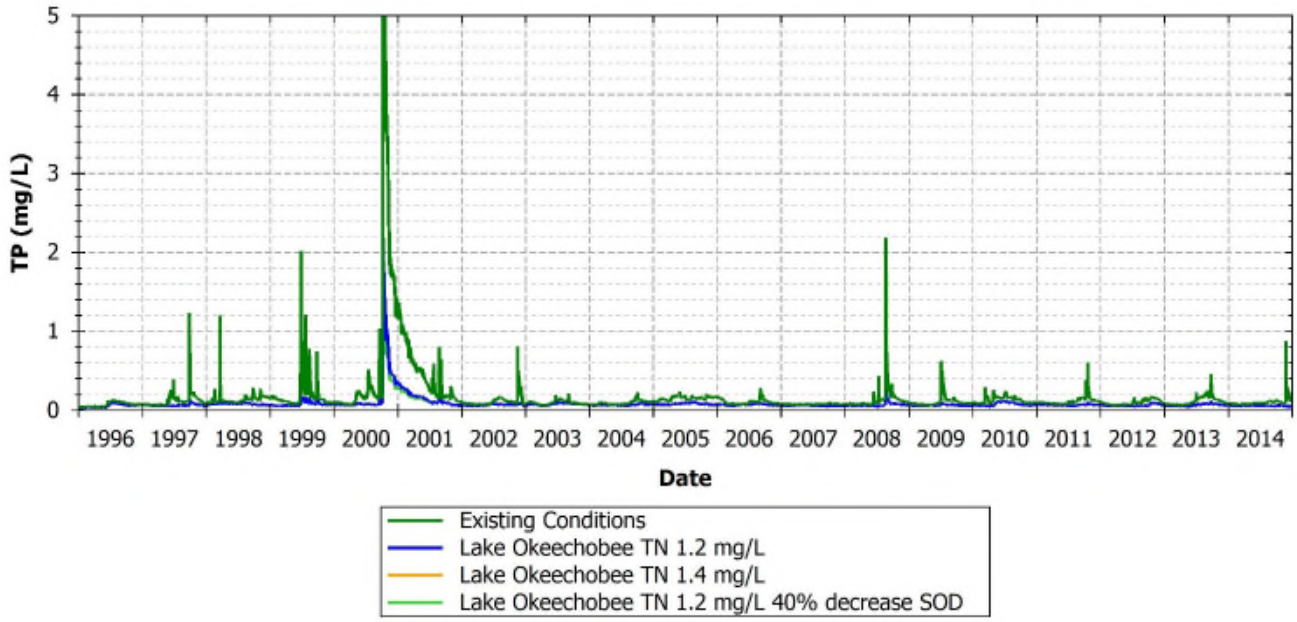

FIGURE 217: TP COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0011FTM, CALOOSAHATCHEE WATERWAY, MARKER 52

TABLE 154: COMPARISON OF TN CONCENTRATIONS AT SELECTED LOCATIONS UNDER EXISTING CONDITIONS AND UNDER NATURAL CONDITIONS

Station ID	Existing Mean (mg/L)	Background Plus 1.4 Mean (mg/L)	Background Plus 1.2 Mean (mg/L)	Background Plus 1.2 BENOD Mean (mg/L)	Existing 5th Percentile (mg/L)	Background Plus 1.4 5th Percentile (mg/L)	Background Plus 1.2 5th Percentile (mg/L)	Background Plus 1.2 BENOD 5th Percentile (mg/L)	Existing 95th Percentile (mg/L)	Background Plus 1.4 95th Percentile (mg/L)	Background Plus 1.2 95th Percentile (mg/L)	Background Plus 1.2 BENOD 95th Percentile (mg/L)
21FLCHARMPV004	0.56	0.48	0.47	0.47	0.37	0.36	0.36	0.36	1.06	0.79	0.74	0.74
21FLEECOCES03SUR	1.46	1.06	0.98	0.99	0.80	0.72	0.70	0.71	2.49	1.56	1.40	1.40
21FLEECOCES06SUR	1.11	0.85	0.81	0.81	0.69	0.61	0.59	0.59	1.88	1.30	1.18	1.18
21FLEECOCES10SUR	0.78	0.63	0.60	0.60	0.40	0.38	0.38	0.38	1.52	1.10	1.01	1.01
21FLFTM CALUSA0008FTM	1.36	1.03	0.96	0.96	0.79	0.72	0.69	0.69	2.24	1.46	1.33	1.33
21FLFTM CALUSA0011FTM	1.28	0.98	0.92	0.92	0.77	0.68	0.65	0.65	2.11	1.38	1.27	1.27

TABLE 155: COMPARISON OF TP CONCENTRATIONS AT SELECTED LOCATIONS UNDER EXISTING CONDITIONS AND UNDER NATURAL CONDITIONS

Station ID	Existing Mean (mg/L)	Background Plus 1.4 Mean (mg/L)	Background Plus 1.2 Mean (mg/L)	Background Plus 1.2 BENOD Mean (mg/L)	Existing 5th Percentile (mg/L)	Background Plus 1.4 5th Percentile (mg/L)	Background Plus 1.2 5th Percentile (mg/L)	Background Plus 1.2 BENOD 5th Percentile (mg/L)	Existing 95th Percentile (mg/L)	Background Plus 1.4 95th Percentile (mg/L)	Background Plus 1.2 95th Percentile (mg/L)	Background Plus 1.2 BENOD 95th Percentile (mg/L)
21FLCHARMPV004	0.07	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.15	0.07	0.07	0.07
21FLEECOCES03SUR	0.15	0.07	0.07	0.07	0.06	0.05	0.05	0.05	0.29	0.11	0.11	0.11
21FLEECOCES06SUR	0.14	0.07	0.07	0.07	0.06	0.05	0.05	0.05	0.37	0.11	0.11	0.11
21FLEECOCES10SUR	0.10	0.06	0.06	0.06	0.04	0.04	0.04	0.04	0.25	0.09	0.09	0.09
21FLFTM CALUSA0008FTM	0.16	0.08	0.08	0.07	0.06	0.05	0.05	0.05	0.33	0.11	0.11	0.11
21FLFTM CALUSA0011FTM	0.17	0.08	0.08	0.08	0.07	0.05	0.05	0.05	0.38	0.11	0.11	0.11

*3.6.4 Chlorophyll-*a *Analysis*

Predictions of chlorophyll-*a* concentrations at selected stations (**Figure 193**) were used to evaluate the potential changes in phytoplankton dynamics under the different natural scenarios relative to the dynamics observed under current conditions. The results of the analyses are summarized in **Table 156** while time series of chlorophyll-*a* concentrations for existing and scenario conditions are presented in **Figure 218** through **Figure 223**.

The simulation results indicate that the reductions in nutrient loads from the watershed result in small reductions of the phytoplankton concentrations in all the stations evaluated. At most stations, the average concentrations of chlorophyll-*a* were reduced up to 5% while the 95th percentile concentrations of chlorophyll-*a* had reductions of up to 15% (**Table 156**, stations 21FLCHARMPV004 and 21FLFTM CALUSA0011FTM). The 5th percentile concentrations of chlorophyll-*a* increased slightly for all the natural background scenarios evaluated. At station 21FLFTM CALUSA0008FTM for example, the 5th percentile chlorophyll-*a* concencentration increased from 0.45 µg/L to 0.69 µg/L (**Table 156**), possibly due to an increase in light availability. From the evaluated scenarios, the largest reductions in chlorophyll-*a* occurred in the Background Plus 1.2 scenario.

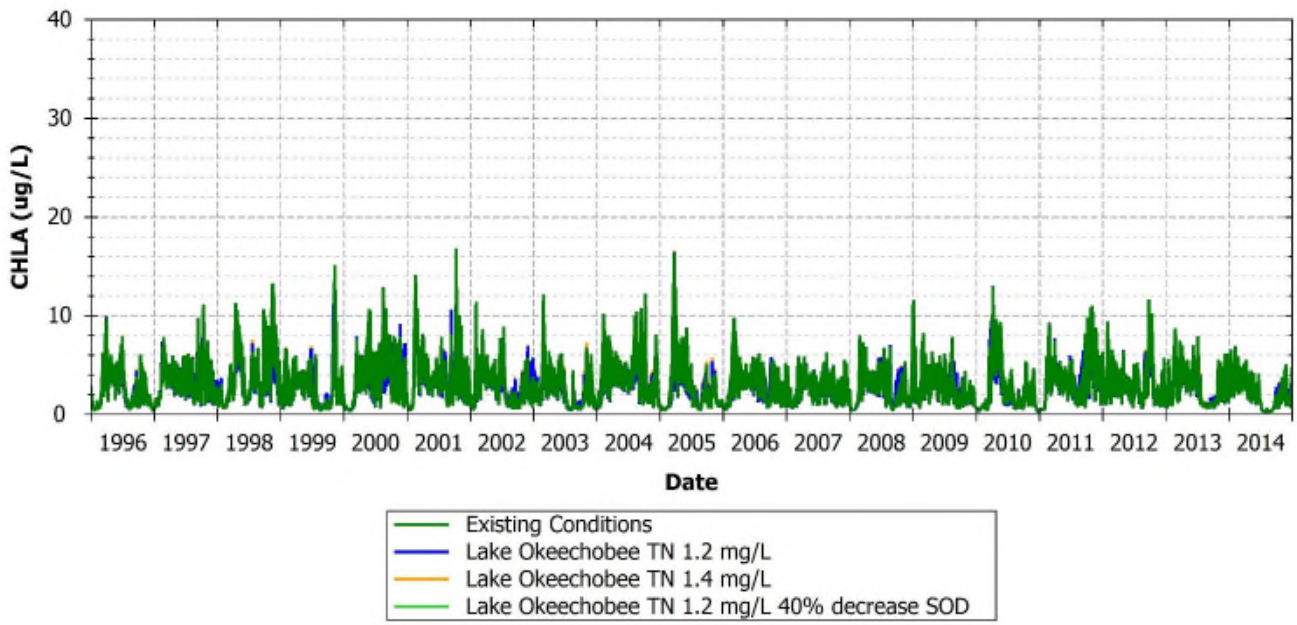

FIGURE 218: PHYTOPLANKTON BIOMASS COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21CHARMPV004, MATLACHA PASS

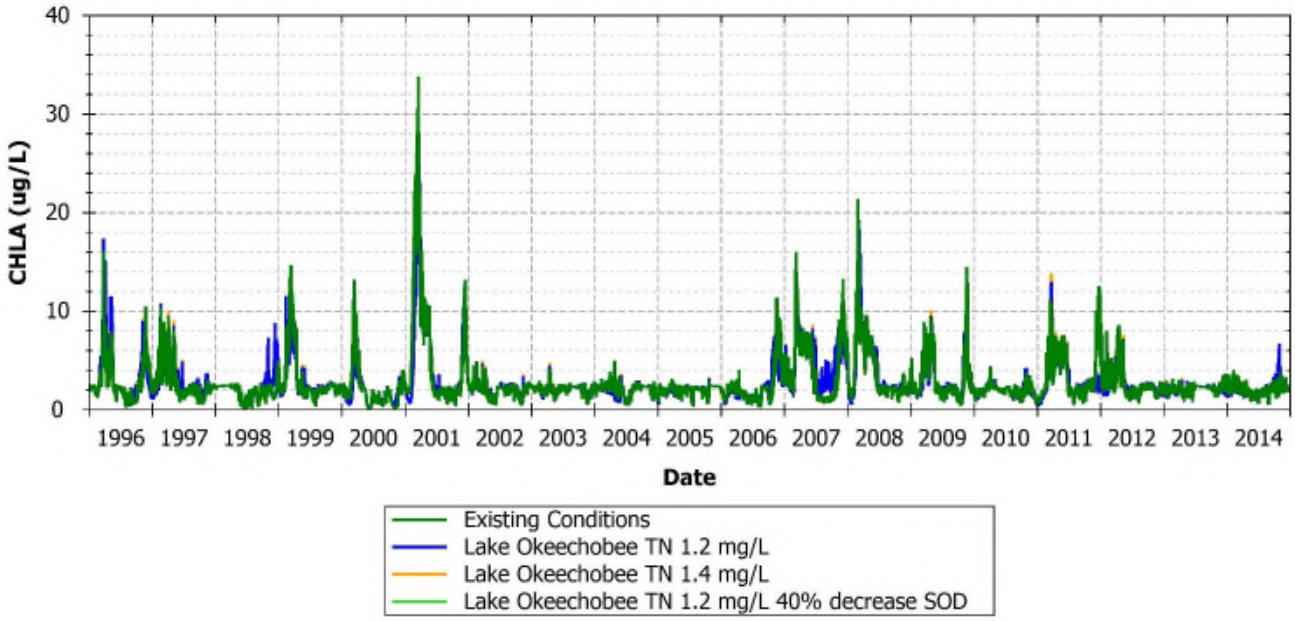

FIGURE 219: PHYTOPLANKTON BIOMASS COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES03SUR, CALOOSAHATCHEE WATERWAY, ROUTE 31

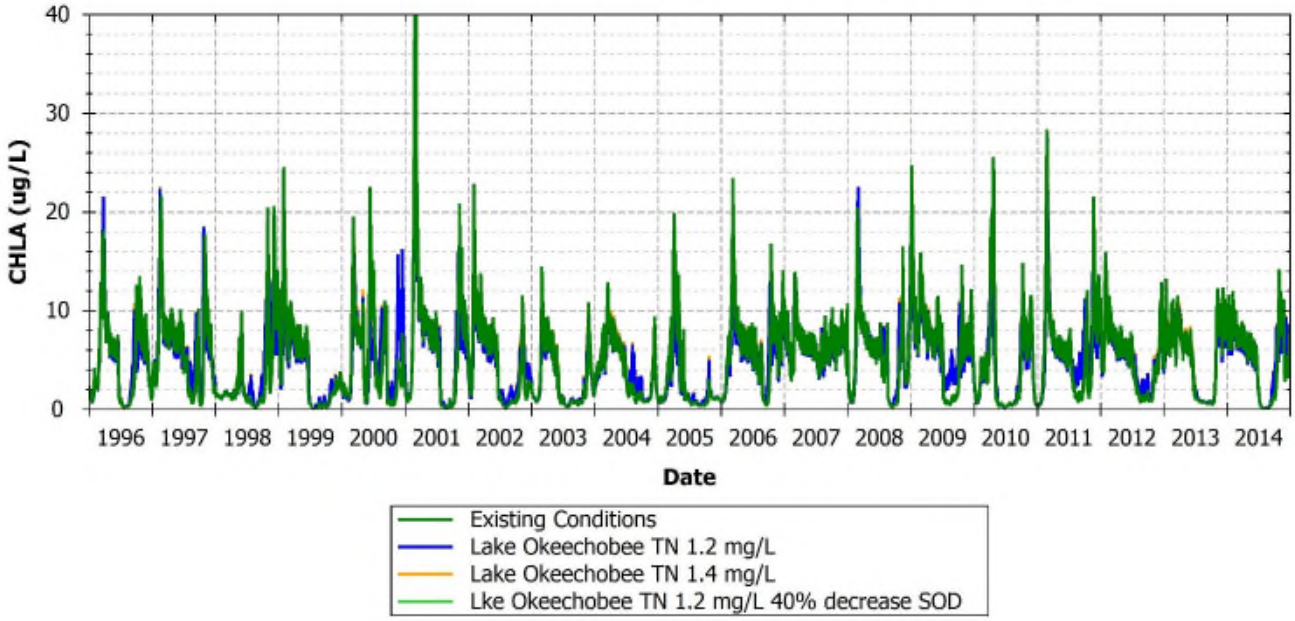

FIGURE 220: PHYTOPLANKTON BIOMASS COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES06SUR, CALOOSAHATCHEE WATERWAY, MARKER 66

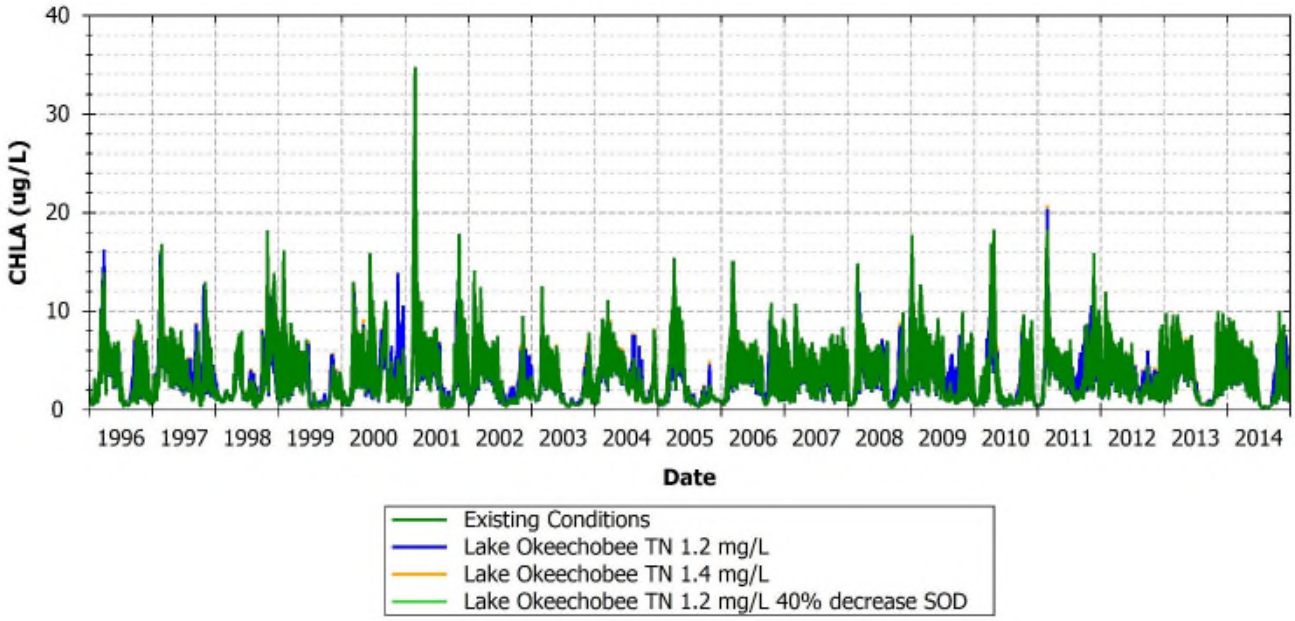

FIGURE 221: PHYTOPLANKTON BIOMASS COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLEECOCES10SUR, CALOOSAHATCHEE WATERWAY NEAR MOUTH

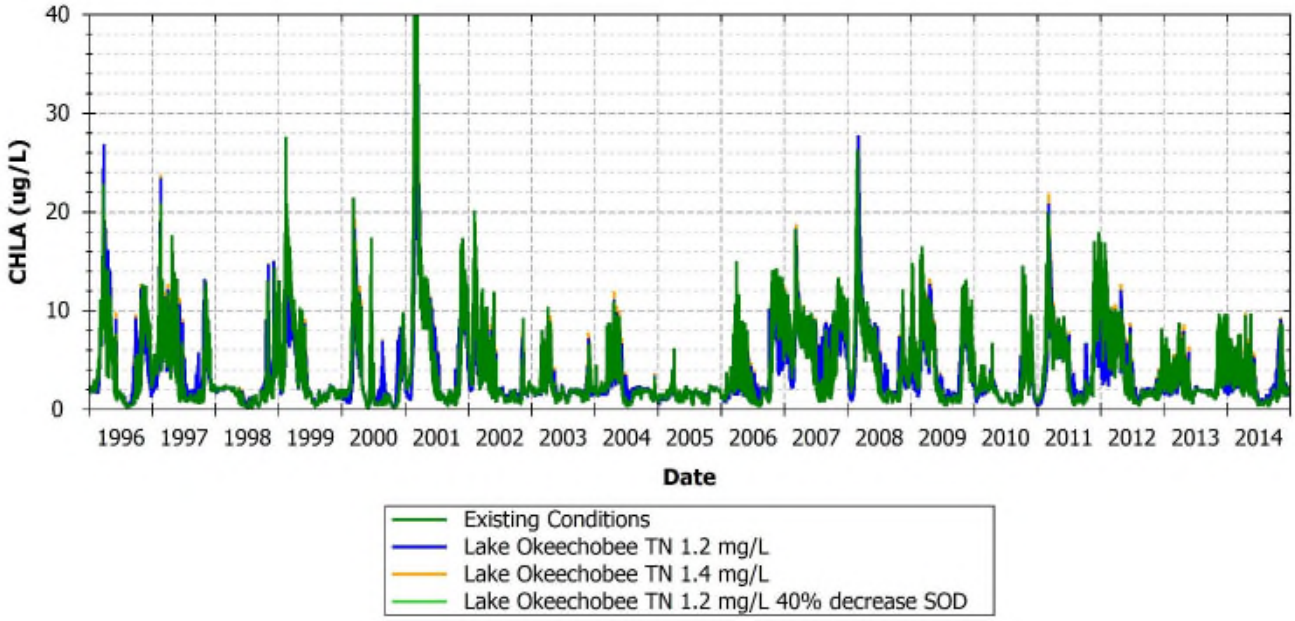

FIGURE 222: PHYTOPLANKTON BIOMASS COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0008FTM, CALOOSAHATCHEE WATERWAY, MARKER 22

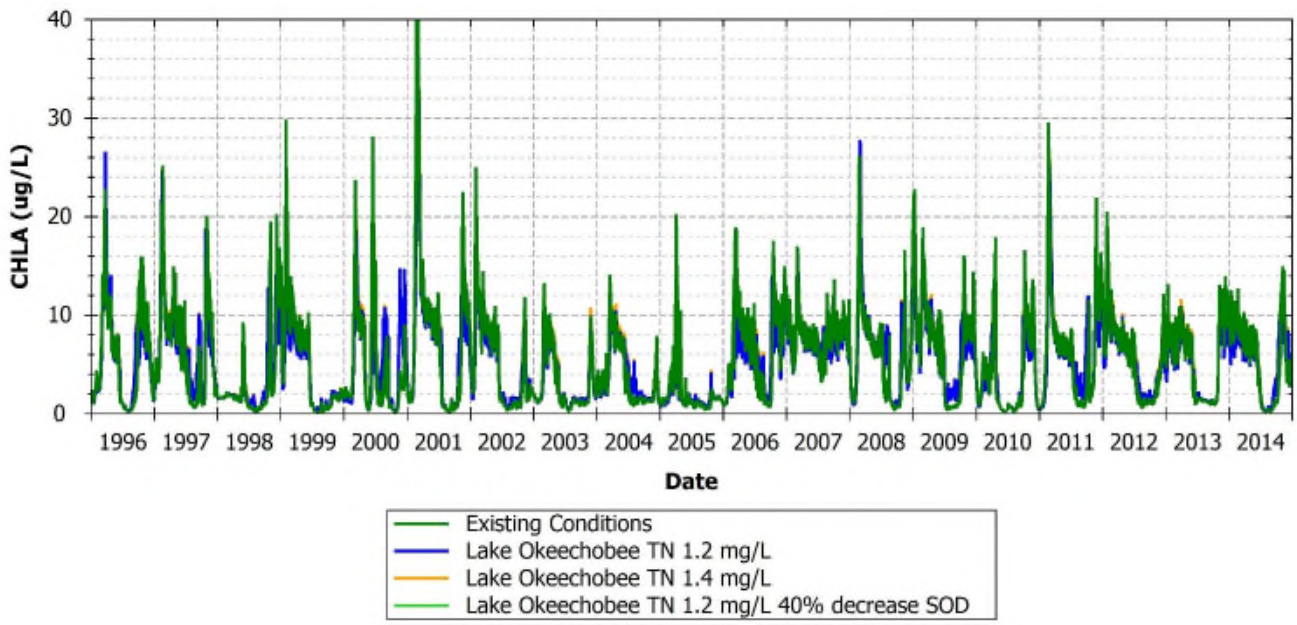

FIGURE 223: PHYTOPLANKTON BIOMASS COMPARISON BETWEEN EXISTING AND SCENARIOS AT 21FLFTM CALUSA0011FTM, CALOOSAHATCHEE WATERWAY, MARKER 52

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TABLE 156: COMPARISON OF CHLOROPHYLL-*A* CONCENTRATIONS AT SELECTED LOCATIONS UNDER EXISTING CONDITIONS AND UNDER NATURAL CONDITIONS

Station ID	Existing Mean (mg/L)	Background Plus 1.4 Mean (mg/L)	Background Plus 1.2 Mean (mg/L)	Background Plus 1.2 BENOD Mean (mg/L)	Existing 5th Percentile (mg/L)	Background Plus 1.4 5th Percentile (mg/L)	Background Plus 1.2 5th Percentile (mg/L)	Background Plus 1.2 BENOD 5th Percentile (mg/L)	Existing 95th Percentile (mg/L)	Background Plus 1.4 95th Percentile (mg/L)	Background Plus 1.2 95th Percentile (mg/L)	Background Plus 1.2 BENOD 95th Percentile (mg/L)
21FLCHARMPV004	3.00	2.85	2.80	2.80	0.50	0.52	0.51	0.51	6.72	5.96	5.81	5.82
21FLEECOCES03SUR	2.68	2.68	2.65	2.66	0.67	0.83	0.82	0.82	7.38	7.06	6.93	6.95
21FLEECOCES06SUR	5.01	4.95	4.83	4.84	0.28	0.39	0.38	0.38	11.98	10.43	10.24	10.26
21FLEECOCES10SUR	3.48	3.42	3.35	3.36	0.38	0.46	0.45	0.45	8.16	7.44	7.25	7.26
21FLFTM CALUSA0008FTM	3.67	3.68	3.60	3.62	0.45	0.70	0.69	0.69	10.93	9.95	9.78	9.82
21FLFTM CALUSA0011FTM	5.32	5.20	5.07	5.08	0.36	0.49	0.49	0.49	13.31	11.35	11.19	11.21

Section 4.0 SUMMARY AND CONCLUSIONS

Based on the above results, the 2017 HSPF Model does an acceptable job of simulating hydrology and water quality in the Caloosahatchee River Watershed. Mean and median upland loading rates of TSS, TN, and TP compare very favorably with the target loading rates, although minimum and maximum upland loading rates deviate from their targets. As stated previously, parameterization of upland loading rates was homogeneous across NEXRAD zones, and the deviation in loading rates was due to precipitation patterns and differences in each zone.

Overall, the HSPF model was able to represent the instream concentration for all water quality parameters. There are some biases, both high and low for various constituents, when comparing the simulated instream output to instream monitoring data. These are likely due to localized conditions (i.e. internal cycling and/or benthic releases of nutrients) that cannot be represented realistically in a one-dimensional large-scale watershed model. However, simulated output is generally in range with instream observations and compares very favorably to the measured data, especially when taking into account the complexities of the Caloosahatchee River Watershed.

The 2017 EFDC Model also successfully captures the trends and ranges of the hydrodynamics and water quality in the Caloosahatchee River and Estuary. The model performs very well in capturing the variability in DO, TN, and TP during the calibration period, as well as the timing and magnitude of important changes in concentrations.

The EFDC model is also generally able to capture the magnitudes and range of variability of light extinction observed in the system. The comparison between the model predictions and observations of light extinction indicate that the model is able to simulate the average levels of light extinction in the system and is also able to capture the trends and variability of the observations.

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