MEMO

To:	Mohammad Sayemuzzaman, DEP
Cc:	Sara Davis, DEP Xueqing Gao, DEP Doug Gilbert, DEP
From:	Brian Watson, PE, PH, D.WRE, Tetra Tech Marcy Frick, REM, Tetra Tech Jim Greenfield, PE, Tetra Tech Nikolai Gurdian, Tetra Tech Erin Lincoln, PH, Tetra Tech Scott Wuitschick, AMEC
Date:	February 26, 2016
Subject:	Caloosahatchee River Basin Watershed Model Review and Calibration Refinement – Draft Task 1 Findings and Recommendations

1.0 INTRODUCTION

Tetra Tech and AMEC were contracted by the Florida Department of Environmental Protection (department) to address department and stakeholder issues regarding the set up and calibration of the current versions of the Caloosahatchee River and Estuary Hydrologic Simulation Program – Fortran (HSPF) and Environmental Fluid Dynamics Code (EFDC) models. These models will be used to develop total maximum daily loads (TMDLs) for impaired freshwater bodies within the Caloosahatchee River Basin and to refine the Caloosahatchee tidal estuary TMDLs that the department adopted in 2010. The department provided the model files, as well as a report on the models developed by Dynamic Solutions and CDM in 2009. Since 2009, the department has made modifications to these models, including extending the model simulation time and adjusting the delineation boundaries. The revised model files were provided for review in this project, as well.

The first task in this project is to review the existing HSPF and EFDC models, including the conceptual structure, watershed delineations and reach segmentation, model input data, mathematical stability, model parameterization, and comments raised by stakeholders, and to suggest to the department possible model revision and recalibration needs for use in TMDL development. This memo summarizes the findings from the model reviews, and provides recommendations on the most effective ways of revising and recalibrating these model applications to meet the goal of TMDL development. Throughout this memo, the Dynamic Solutions/CDM model will be referred to as the "2009 Model" and the department's updated version of the model will be referred to as the "2014 Model." The new model will be referred to as the "2017 Model," which is reflective of the project completion date in 2017.

In addition, Task 1 includes templates for the evaluation comparisons, memos, and reports that will be used during this project, as well as the model performance criteria that will be evaluated. This information is also included in this memo, but may change throughout the course of the project if new informational needs are identified.

2.0 HSPF MODEL REVIEW

2.1 CONCEPTUAL STRUCTURE

The conceptual structure of the HSPF watershed model was developed to simulate instream hydrology and water quality conditions for the Caloosahatchee River and its tributaries, which link Lake Okeechobee and San Carlos Bay. The 2009 Model was set up to simulate the time period of 1/1/1996–12/31/2005, which was later extended by the department in the 2014 Model to 12/31/2011. The 2009 Model was used to develop nutrient and dissolved oxygen (DO) TMDLs in the Caloosahatchee watershed.

The Caloosahatchee River is fed by outflows from Lake Okeechobee, and flows southwest before emptying into the San Carlos Bay. There are three major control structures along the river (Moorehaven Lock [S-77], Ortona Lock [S-78], and Franklin Lock and Dam [S-79]) that are operated to maintain the water level in the Caloosahatchee River and for navigational purposes (**Figure 1**). The Moorehaven Lock (S-77) is located at the interface between Lake Okeechobee and the Caloosahatchee River and defines the upstream boundary of the HSPF model.

The HSPF model includes a representation of the major tributaries in the watershed, which generally flow perpendicularly to the Caloosahatchee River mainstem. The modeled drainages of the tributaries follow the existing waterbody identification (WBID) boundaries with some additional segmentation to account for stream confluences and areas of focus, including monitoring on impaired streams. The Caloosahatchee HSPF model is set up for each stream to have a single downstream target, although this is not an inherent limitation of the HSPF model.

The watershed model is currently set up to simulate the following water quality constituents:

- Water temperature
- Total suspended solids (TSS)
- 5-day biochemical oxygen demand (BOD5) from ultimate carbonaceous BOD (BOD)
- Nitrogen; including total nitrogen (TN), total Kjeldahl nitrogen (TKN), nitrite + nitrate (NO_x), organic nitrogen (OrgN), ammonia/ammonium (NH_3/NH_4) as total ammonia (TAM)
- Phosphorus; including total phosphorus (TP), organic phosphorus (OrgP), and orthophosphate (PO_4)
- Phytoplankton (as chlorophyll-*a*)
- DO

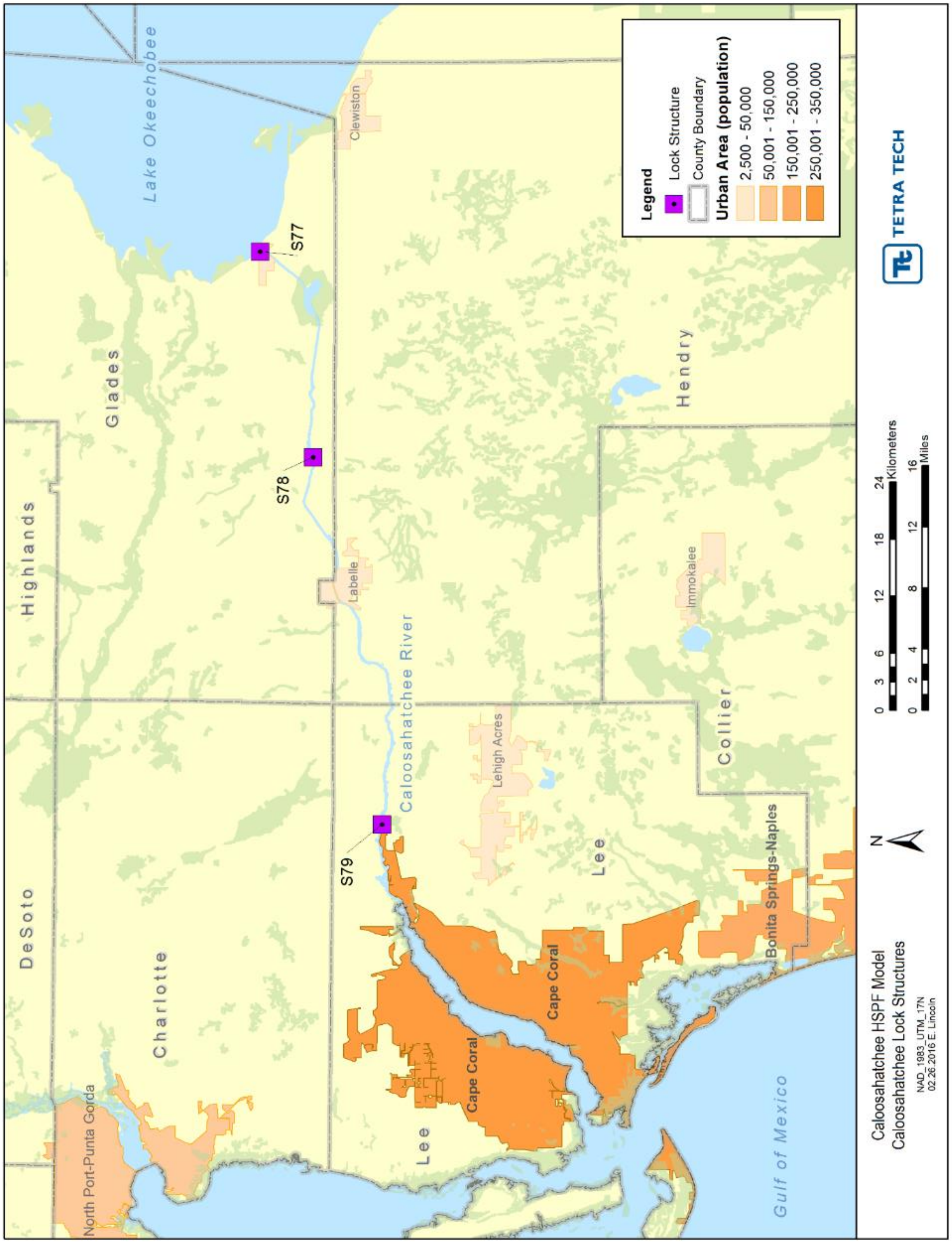

Figure 1: Location of major control structures on the Caloosahatchee River

Constituents simulated as originating from upland areas include TAM, NO_x, PO_4, refractory OrgN, and BOD. All land based loading are simulated using the HSPF model buildup and washoff parameters, as well as monthly concentrations specified for interflow and ground water outflows for pervious land segments. Wet deposition of nutrients, excluding BOD, is also represented on a monthly basis.

Upland loads are linked to instream water quality as shown in **Table 1**. Instream constituents include those from upland simulations. However, NO_x is split into its requisite components and refractory OrgN is used to determine OrgP and organic carbon species (based on available monitoring data at station CES01). The labile OrgN and OrgP are not explicitly represented as independent state variables in the HSPF model, but instead are represented implicitly as proportional to BOD based on the input specification of nitrogen to carbon and phosphorus to carbon ratios in input block CONV-VAL1. In the linkage from the land surface to the instream model, concentrations of refractory OrgN and OrgP are assigned based on ratios to BOD. These are in addition to the implicit labile OrgN and OrgP represented within BOD; both labile and refractory portions are tabulated together by the HSPF model as TORN (total organic nitrogen) and TORP (total organic phosphorus). The nutrient constituents are used to drive DO and phytoplankton simulations in the HSPF model.

Table 1: Upland instream constituent linkages

Upland GQUAL Pollutant	Multiplier	RQUAL Module	Instream RQUAL Pollutant
NO_x	0.5	NUIF	NO_3
	0.5		NO_2
TAM	1		TAM
PO_4	1		PO_4
OrgN	1	PKIF	TORN
	0.02		TORP
	5.7		ORC
BOD	1	OXIF	CBODU
Sediment	0.1	ISED	Sand
	0.6		Silt
	0.3		Clay

In addition, total sediments are modeled as loads from upland areas using the HSPF SEDMNT module for pervious lands, SOLIDS module for impervious land, and instream simulation of TSS including representation of sand, silt, and clay fractions. There is no sediment association for the upland nutrient simulation; however, the HSPF model is set up to use RQUAL (the more complex option for simulating nutrient fate and transport) and represent PO_4 and TAM as sediment-associated with partition coefficients in the instream module.

The initial model calibration and validation was done in sequence with watershed hydrology calibrated first, followed by water quality. The 2009 Model defined a hydrology calibration time period of 1/1/2001–12/31/2005 and a validation time period of 1/1/1997–12/31/1999. Water quality simulations were calibrated and validated for the time periods 1/1/2004–12/31/2005 and 1/1/2001–12/31/2003, respectively. The hydrology and water quality calibration period was later extended through 2011 in the 2014 Model.

The initial 2009 Model calibration/validation effort used four separate U.S. Geological Survey (USGS) monitoring locations. Two of the stations (USGS 02292480 and USGS 02292900), located on the Caloosahatchee River mainstem, were calibrated for both hydrology and water quality. The hydrology and water quality in the mainstem was predominately driven by the HSPF model Lake Okeechobee upstream boundary, and not by watershed tributary inputs. The department's 2014 Model extension assessed the modeled hydrology and water quality at additional calibration locations. The original and extended calibration locations are listed in **Table 2**.

Table 2: 2009 and 2014 HSPF Model calibration locations

Modeling Effort	Station Name	Hydrology Calibration	Water Quality Calibration	WBID
2009	Caloosahatchee Canal at the Ortona Lock (S-78), near La Belle	X	X	3237A
	Caloosahatchee River at the Franklin Lock and Dam (S-79), near Olga	X	X	3235A
	Whiskey Creek at Ft. Myers		X	3240H
	San Carlos Canal at Cape Coral	X		
2014	Jacks Branch	X	X	3235D
	Crawford Canal (Fast Creek)	X		3235B
	Whiskey Creek	X		3240H
	Telegraph Creek	X		3236A
	Popash Creek	X	X	3240Q
	Billy's Creek	X	X	3240J
	Orange River	X		3240K
	Townsend Canal		X	3235L
	Cypress Branch		X	3235G
	Cape Coral		X	3240A2
	Lake Hicpochee		X	3237C
	Caloosahatchee River between S-79 and S-78		X	3235B
	S-4 Canal (C-21)		X	3246
	Long Hammock Creek		X	3237B
	Nine Mile Canal		X	3237D
	Deep Lagoon Canal		X	3240A4

Multiple model performance metrics were used to assess the quality of both the hydrology and water quality simulations of the Caloosahatchee River HSPF watershed model. Nash-Sutcliffe coefficients of model fit efficiency and average annual flow volume error were the primary measures used to assess model fit. The coefficient of determination (R^2) was also calculated for the 2009 Model. The department expanded the calibration metrics to include the Pearson Correlation Coefficient (R), and Root Mean Square Error (RMSE) for the 2014 Model. The department noted that, in general, although there is a relatively small error over the entire 11-year period of record at locations S-78 and S-79, there are multiple years with extremely large errors (2001, 2007, and 2008). The department identified the following improvements that should be made to the model to improve calibration:

- Set up the model to simulate the control structure operations.
- Model the flow reversals for the C-43 reaches.
- Revise the representation of agricultural irrigation practices.

Water quality model performance metrics included the P-value for Wilcoxon Rank Sum Test and P-value for 2-Sided Kolmogorov-Smirnov Test, both of which were calculated for the entire simulation time period at the S-79 assessment location. Notes for the water quality calibration stated that "since watershed derived loads delivered at S-79 at the upstream boundary of the estuary accounted for 83% of total nitrogen (TN) and 77% of total phosphorus (TP) loads simulated with the HSPF model for the existing (2003-2005) calibration/validation case, the availability of observed nutrient data for comparison to HSPF model results at the S-79 location provides a good check on the credibility of the HSPF results as a tool for quantifying nutrient loading to the estuary." Thus, it was determined that a reasonable calibration performance at this location was sufficient to drive the downstream EFDC estuary model simulations.

Assessment of the water quality calibration at S-79 using the 2-sided Kolmogorov-Smirnov Test showed that the distributions of measured and modeled water temperature, TSS, DO, PO_4, TKN, and NO_x were all considered similar. Application of the Wilcoxon Rank Sum Test showed water temperature, TKN, and PO_4 to have statistically different means between the measured and modeled data, while TSS, DO, and NO_x show statistically similar means.

2.2 WATERSHED DELINEATIONS AND REACH SEGMENTATION

The Caloosahatchee River HSPF model divides the watershed into 102 subbasins with an associated stream network of 97 reaches (**Figure 2**). Of the represented stream reaches, six are not associated with any land segment and represent nodes where two reaches come together. Thus, only 91 of the model subbasins include a reach segment, while the remaining 11 reflect land areas that drain directly to the Caloosahatchee River Estuary. Delineation of the model subbasins used existing WBID boundaries, topographic data (Composite Topography for Southwest Florida, 100-ft), and the High Resolution National Hydrography Dataset distributed by USGS. One F-Table (a depth-discharge relationship or rating curve) was developed for each reach using an equivalent trapezoidal cross-section. A previous effort by the South Florida Water Management District (SFWMD) developed a MIKE-SHE model of the Caloosahatchee River watershed, compiled the stream cross-section data from various sources, and estimated reach characteristics using equivalent trapezoidal cross-sections. According to the Dynamic Solutions 2009 report, SFWMD provided the cross-sections for parts of C-43, Jacks Branch, County Line Ditch, Canal 1, Canal 2, C-19, 42-foot canal, and Hilliard Canal. The cross-sections for other stream segments were estimated from the topographic data.

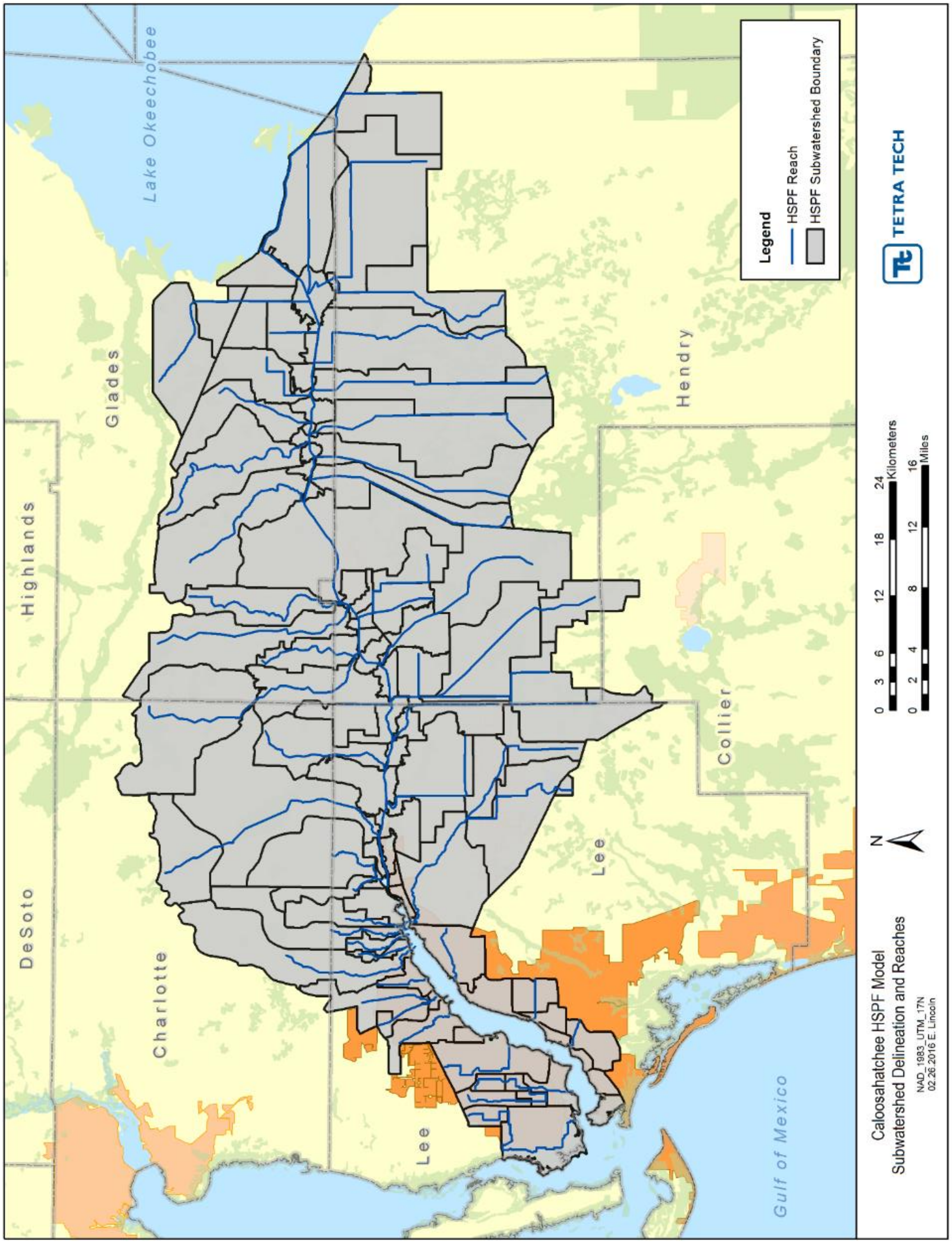

Figure 2: HSPF model subbasin delineation and reaches

The setup of the model segmentation and hydraulics seems reasonable in terms of the F-Table representation of reaches and lakes where simulated outflows, as reported by Dynamic Solutions (2009), are generally representative of observed conditions. In addition, reaches 46 and 18 are associated with river locks S-78 and S-79, respectively, and have F-Tables that generally capture the impoundment effects of these structures. Select areas in the watershed have been identified by the department as having complex hydraulics that are not fully represented by the current reach and F-Table setup. These locations include the City of Cape Coral canal networks and Deep Lagoon Canal, and representation may require additional delineation of the existing HSPF subbasins to properly capture hydrologic conditions. Additional delineation may also be necessary to generate model output at the locations of select water quality monitoring locations.

2.3 PRIOIRTY REACHES WITH BIDIRECTIONAL FLOW

A preliminary analysis of available flow data show that there are a collection of streams throughout the watershed where bidirectional flow is occurring. The majority of these reaches are in the vicinity of a major control structure or located on a tributary to the estuary (typically a canal system) where tidal influences are present. There are only three reaches that have been identified as having bidirectional flow that are not located on the Caloosahatchee River between locks S-77 and S-78, not at a control structure of Lake Okeechobee, nor at or downstream of the S-79 lock, which marks the estuary boundary. These three reaches are Jacks Branch, Pollywog Creek, and Fast Creek. It is anticipated that bidirectional flow at all locations, except for the three identified above, will be simulated using an EFDC model due to the fundamental limitation of the HSPF model to only simulate unidirectional flow. For the remaining three reaches, F-Tables will be developed that represent net flow in the downstream direction toward the estuary.

2.4 MODEL INPUT DATA

The model input datasets used to develop the Caloosahatchee HSPF watershed model can generally be grouped into the following categories:

- Meteorological time series
- Land use classifications
- Boundary condition time series
- Point source time series
- Irrigation/withdrawal time series
- Best management practices (BMPs)

National Oceanic and Atmospheric Administration's (NOAA) Doppler satellite Next Generation Weather Radar (NEXRAD) network was the source for the hourly precipitation data developed for the Caloosahatchee River watershed model. The gridded data were aggregated into 15 area-weighted precipitation time series representing different parts of the watershed. A seasonal summary of the precipitation total for the 15 zones is presented in **Figure 3** and these areas are shown in **Figure 4**. Model evapotranspiration data were calculated from daily observed temperature data that were available from SFWMD at meteorological station S78W. The daily potential evaporation (PET) data were computed using the Hamon method (Hamon 1961) and the total annual PET was then compared with available evapotranspiration data at S78W and adjusted to ensure that the computed PET time series was representative of the Caloosahatchee River watershed.

The meteorological data appear reasonable based on a preliminary review. The model precipitation and PET data are consistent with protocols generally used to develop weather forcing data for HSPF model applications. Tetra Tech evaluated the HSPF model representation of annual rainfall and PET and found them to be consistent with independent local estimates of these variables available from National Climactic Data Center datasets available at the Fort Myers Airport (WBAN 12835). The department will extend the weather data from 2012 through 2014 using the same processing methodology used in the 2014 Model weather file development.

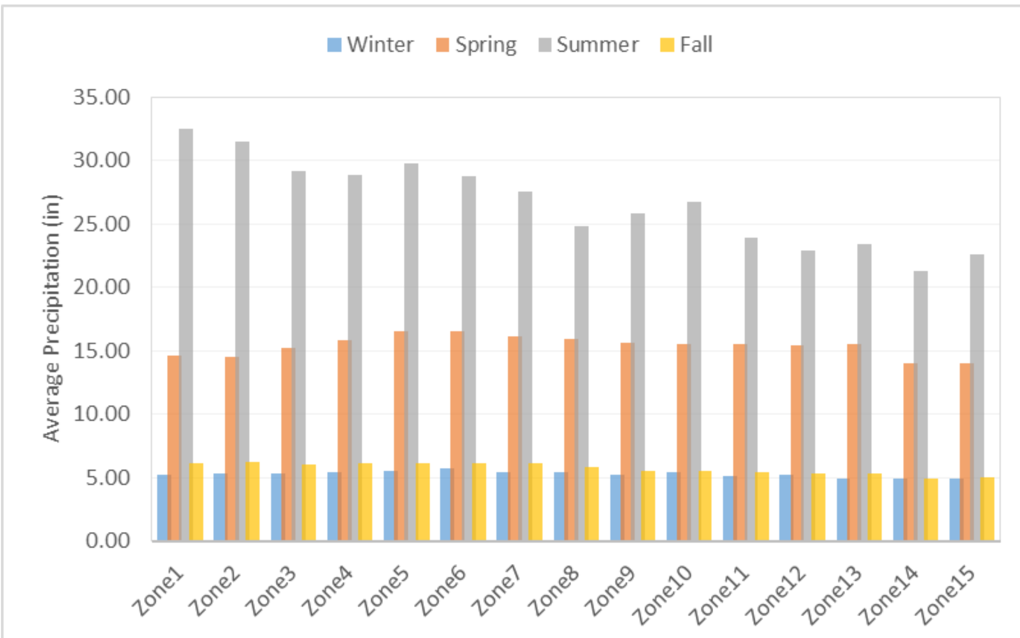

Figure 3: Average annual seasonal rainfall totals for the HSPF model

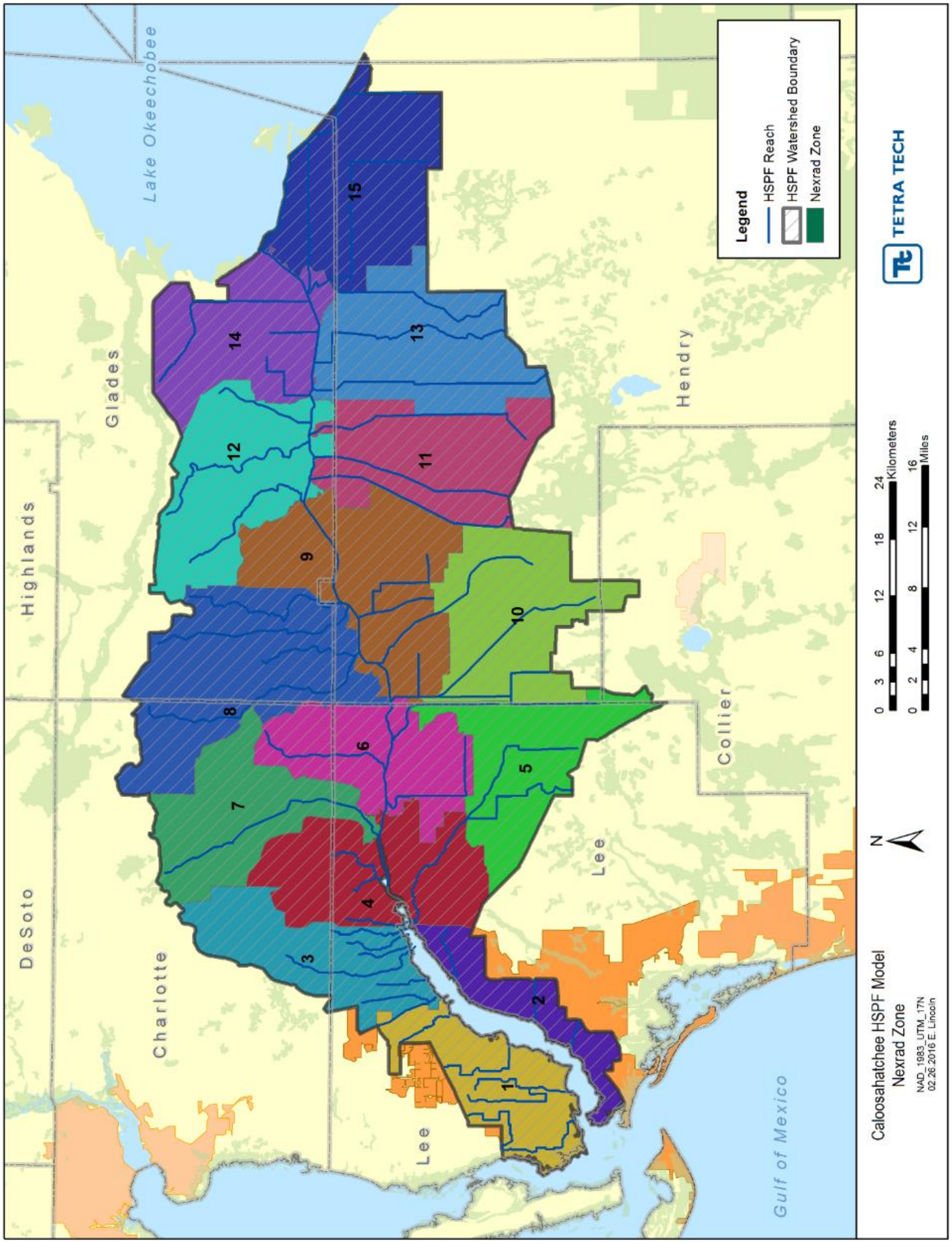

Figure 4: HSPF model NEXRAD zones

The final Caloosahatchee River HSPF modeling report (Dynamic Solutions 2009), states that a "seamless GIS coverage of a 2004 land use data provided by the SFWMD was considered appropriate for the development of the existing condition model." The seamless data were grouped into 10 land cover classifications for the model definition of PERLND and IMPLND land segments as shown in **Table 3** and **Figure 5**.

Table 3: Caloosahatchee model land use areas

Land Cover Class	PERLND Area (acres)	IMPLND Area (acres)
Citrus	97,635	986
Commercial/industrial	6,232	12,097
Cropland/improved pasture	272,889	2,756
High density residential	4,735	4,550
Low density residential	53,025	5,892
Medium density residential	25,014	8,789
Rangeland/open land	95,618	966
Unimproved pasture	51,028	515
Upland forests	72,473	732
Wetlands/water	164,077	--
Total	**842,727**	**37,283**

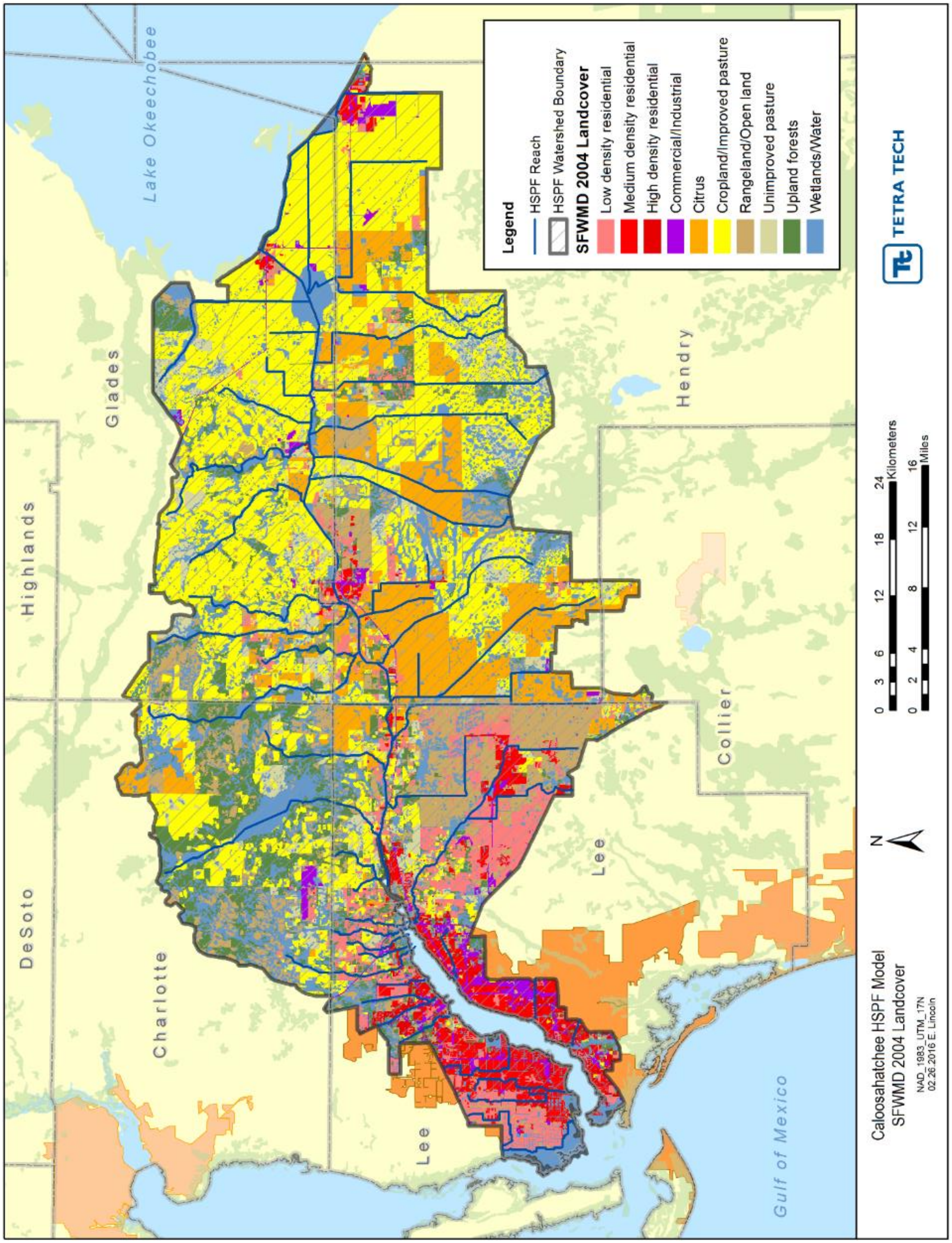

Figure 5: 2004 SFWMD land use coverage

Land use data sources and aggregation into model land use appears reasonable and is similar to the 2008 SFWMD coverage. For impervious land, assumptions of traditionally pervious land cover types (e.g. cropland, pasture, and forest) as having directly connected impervious area (DCIA) may not be appropriate. Although small, these areas could be causing the over-estimation of peak storm flows in some areas. Further evaluation of hydrologic conditions on impacted tributaries should be made to determine if this is the case. In the event that this indicates a need to refine the impervious area assignments, these assignments will need to be corrected to DCIA. If detailed local studies of the connected fraction are available, these will be preferable; otherwise, total impervious area can be converted to disconnected impervious areas using the methods described in Sutherland (1995).

Flow and ambient water quality measurements at S-77 were used to develop time series input data for the boundary condition. Discharge through Franklin Lock and Dam (S-79) and Ortona Lock (S-78) were computed using specific F-Tables and modeled flows in the upstream reaches. Daily mean flow data are available from two SFWMD gages, S77-S at Moorehaven Lock and S78-T at Ortona Lock.

The 2009 and 2014 models include nine connected point sources as shown in **Table 4**. There are a total of 44 point sources in the WDM file; however, these are not discharging to reaches in the current model set up. Model point sources include contributions of organic and inorganic nutrients, as well as BOD and sediments (sand, silt, and clay). Discussions with the department have indicated that the facilities assigned general permits (ID: FLA) should not be included in the model set up. Therefore, the currently connected general permits will be removed and replaced with the facilities assigned National Pollutant Discharge Elimination System (NPDES) permits that discharge to the HSPF model as identified in **Section 2.6**.

Table 4: Point sources included in the 2009 and 2014 Models

Facility ID	Facility Name	Design Flow (MGD)	UCI Reach
FL0040665	Clewiston, City of - WWTF	1.5	58
FLA014283	Labelle, City of		40
FLA014290	Port Labelle	0.25	41
FLA014548	North Fort Myers Utility	3.5	91
FLA014565	Lehigh Acres WWTP	2.48	10
FLA014676	River Trails Mobile Home Park	0.097	87
FL0039829	Lee County Utilities - Fiesta Village		4
FLA014563	Del Tura Country Club		91
FLA014658	Jamaica Bay West, Large		4

The Caloosahatchee HSPF model is currently configured to represent the application of irrigation water as a point source. The represented volumes are assumed to be completely sourced from ground water, although withdrawals from the modeled ground water storage are not simulated explicitly. Historic records of flow data were used to develop monthly average pumped volumes for the affected areas, which include 47 of the modeled reaches. The associated nutrient concentration of the irrigation water were assigned based on analysis of observed ground water concentrations. The simulated flows and pollutant loads from irrigation water are then input to the model as direct discharges to the nearest tributary. The simplifications used to represent irrigation in the current HSPF model set up will be improved to better capture the processes generally associated with cropland irrigation as described in **Section 2.6**.

The Caloosahatchee HSPF model also incorporates a representation of existing flow and pollutant load reductions provided by existing BMPs. These are applied to urban and agricultural areas and are represented as removal efficiencies that were determined through a data collection and analysis effort for the urban areas and as provided by the Florida Department of Agricultural and Consumer Services (FDACS) for the agricultural areas.

2.5 MODEL PARAMETERIZATION

The final set of HSPF model hydrologic parameters were checked against recommended ranges from the U.S. Environmental Protection Agency's (EPA) BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF, and most were found to be reasonable (USEPA 2000). The following parameters were found to be outside the recommended range:

- The recommended range for BASETP is 0 to 0.05 with a maximum possible value of 0.2. The Caloosahatchee River model uses a value of 0.99 for all land uses. BASETP represents the fraction of PET taken directly from baseflow and is, generally, attributable to riparian vegetation. It may be reasonable to have values toward the higher end of the possible range for natural vegetated land cover in areas with a dense stream network (e.g. canals). However, the current configuration appears to be well beyond that range and is applied to all land uses.
- The recommended range for AGWETP is 0 to 0.05 with a maximum possible value of 0.2. The Caloosahatchee River model uses a value of 0.5 for all land uses. 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. However, the current configuration appears to be well beyond that range and is applied to all land uses.
- The recommended range for CEPSC is 0.03 to 0.2 with a minimum possible value of 0.01. The Caloosahatchee River model uses a value of 0 for the wetlands/water land use. CEPSC is the interception storage capacity (in inches) of land cover. It is conceivable that an open water land use could have a value of 0, but a combined wetlands/water land use should have some interception capacity attributable to wetland vegetative cover.
- The recommended range for LZETP is 0.2 to 0.7 with a maximum possible value of 0.9. The Caloosahatchee River model uses a range of 0.25 to 1.49, with the highest values assigned to land uses occurring in precipitation zones 1–5. 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 HSPF model sediment parameters were also checked against recommended ranges from EPA's BASINS Technical Note 8: Sediment Parameter and Calibration Guidance for HSPF, and most were found to be reasonable (USEPA 2006). The following parameters were found to be outside the recommended range:

- The recommended range for KRER is 0.15 to 0.45 with a minimum possible value of 0.05. The Caloosahatchee River model uses a range of 0.001 to 0.25, with the lowest values assigned to the wetlands/water land use. KRER is the coefficient in the soil detachment equation and is analogous to the soil erodibility factor (K) in the Universal Soil Loss Equation (USLE).

- The recommended range for COVER is 0 to 0.9 with a maximum possible value of 0.98. The Caloosahatchee River model uses a range of 0.3 to 1, with the values of 1 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 KSER is 0.5 to 5 with a minimum possible value of 0.1. The Caloosahatchee River model uses a range of 0.001 to 0.34, with the values of 0.001 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 KEIM is 0.5 to 5 with a minimum possible value of 0.1. The Caloosahatchee River model uses a universal value of 0.075 for all land uses. 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.

A consistent set of instream sediment parameter values was applied to all model reaches, except for BEDWID. BEDWID, which represents the streambed width, was appropriately varied across the model reaches. Instream sediment parameters also appropriately represent the differences in behavior of the three sediment classes (sand, silt, and clay) and all values are within recommended ranges.

For the upland simulation of NO_x, TAM, OrgN, PO_4, and BOD, the pollutant accumulation rates and limits seemed to have been developed using a manual calibration for both pervious and impervious lands. The values vary across the modeled pervious land uses, but are consistent for the same land use category in different precipitation zones. This is 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 varies across land uses, but like the accumulation rates and limits, is consistent across precipitation zones. Atmospheric deposition of NO_x, TAM, OrgN, and PO_4 to surface waters is represented on a monthly basis. For the instream nutrient simulation using HSPF RQUAL, all parameters were fixed (generally to HSPF model defaults) except PHYSET, which is the phytoplankton settling rate. This parameter was generally assigned a value of 0.015 ft/hr, though smaller values were assigned to some reaches.

Tetra Tech recommends the following actions regarding these parameters:

- Check and re-evaluate the identified PET parameters (BASETP, AGWETP, LZETP) values.
- The parameter values identified as being out of range for CEPSC, KRER, COVER, and KSER are all applicable to the wetlands/water land use. The CEPSC value appears to have been selected to promote runoff from the land use, while the remaining sediment parameters are geared towards eliminating sediment contributions.
- Check KSER and KEIM values to ensure that the relative magnitude of sediment delivery rates among different land uses are consistent with literature.

When loads are transferred from the upland simulation to the reach simulation, assumptions are made for disaggregating upland parameters to instream constituents as shown in **Table 1**. The only disaggregation that is referenced, however, is the relation of ORP to ORN, which is described as being "based on [station] CES01 data" in the model UCI file notes. For the remainder of the modeled pollutants (sediment, organic carbon, and NO_x species) there is no documentation on how the splits were determined. Additional effort may be required to better characterize the disaggregation. It should be noted that BOD entering reaches also implicitly contains labile forms of OrgN, OrgP, and organic carbon determined by ratios set within the RQUAL module. These labile forms are converted to inorganic nitrogen, phosphorus, and carbon when BOD decays. A summary of the unit area pollutant loads from the 2014 Model by model land use are provided in **Figure 6** through **Figure 9**.

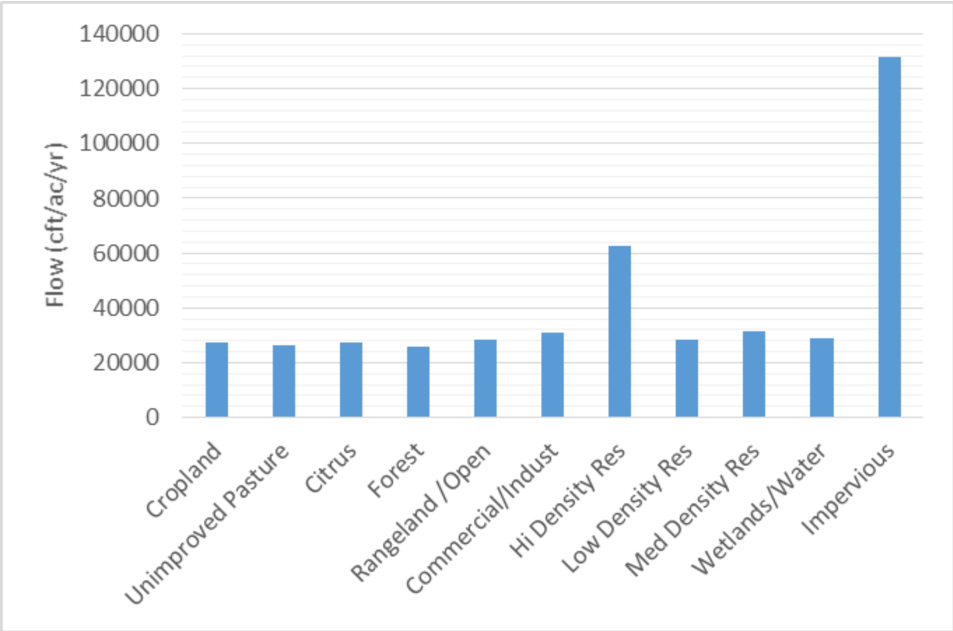

Figure 6: Unit area flows by land use

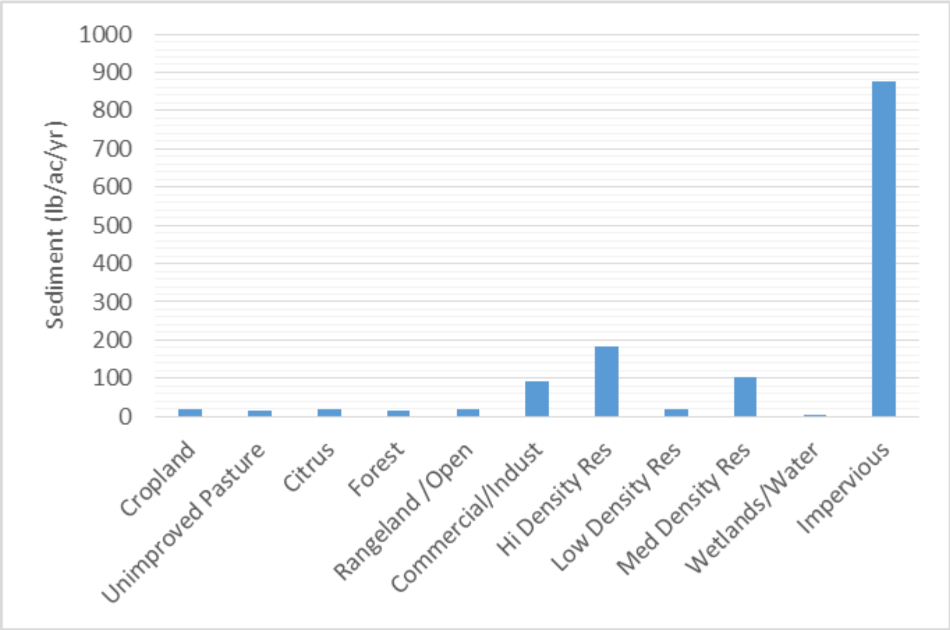

Figure 7: Unit area sediment loading by land use

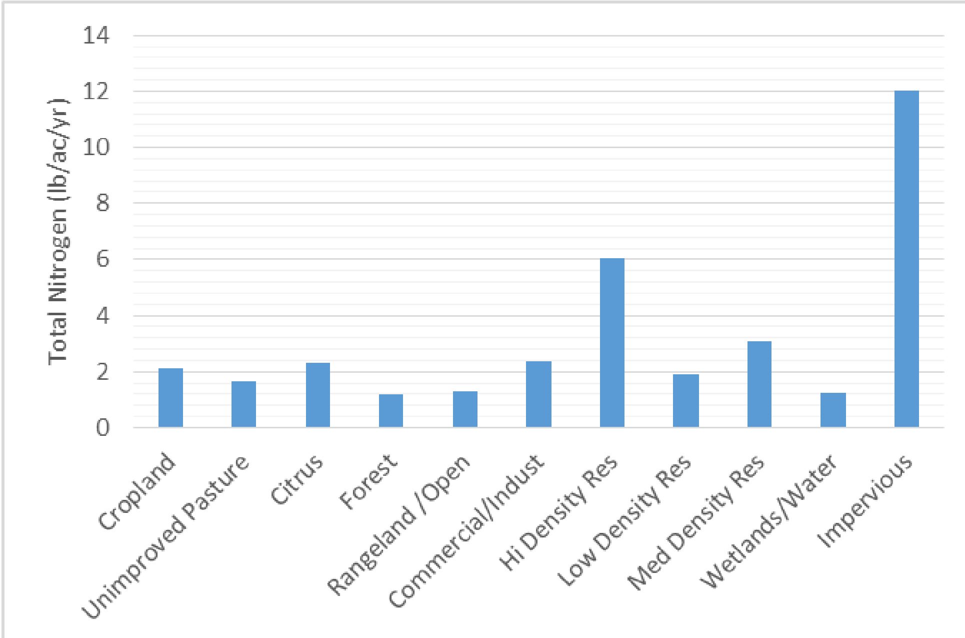

Figure 8: Unit area TN loading by land use

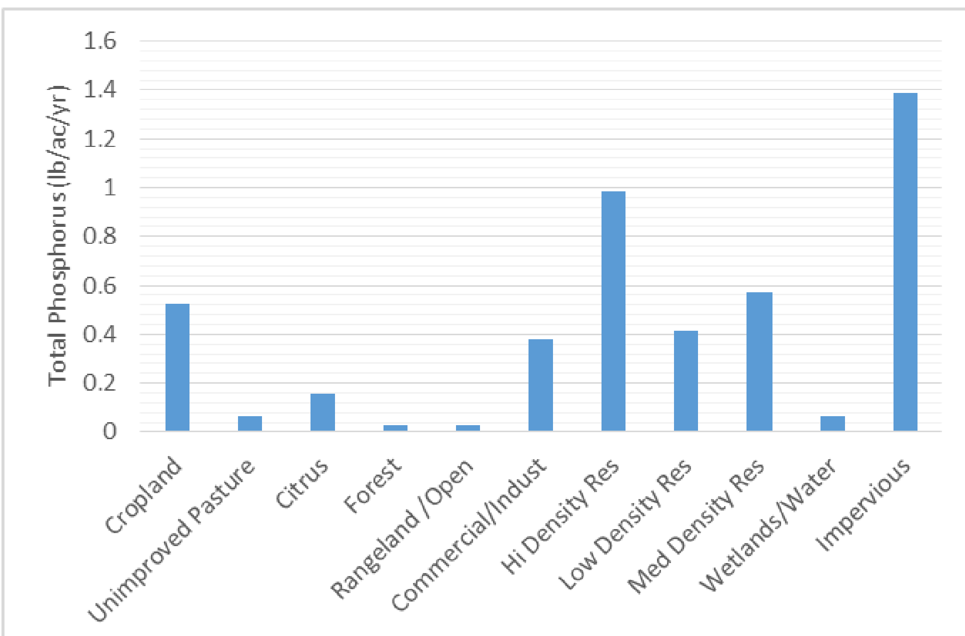

Figure 9: Unit area TP loading by land use

2.6 RECOMMENDATIONS

Based on our review and assessment, Tetra Tech has identified the following issues and recommendations for the HSPF model.

Issue #1: The current model simulation period ends in 2011.

> Recommendation: After discussions with the department, Tetra Tech will extend the current HSPF model time period from 2012 through 2014. The department will append the current model weather files for the simulation time period extension (2012-2014).

Issue #2: (*Stakeholder comment*) Model watershed delineations and reach segmentation may not correctly represent some watersheds, and are not delineated to some flow stations that will be used in the 2017 Model.

> Recommendation: Overall, the current model watershed delineations and reach segmentation were determined to be appropriate. Lee County provided the department with information on minor modifications to the southern boundary of the Deep Lagoon Canal watershed, and these changes will be incorporated in the model.
>
> Six of the 21 flow stations in the Caloosahatchee watershed were identified that are not located in close proximity to a subbasin outlet (**Table 5** and **Figure 10**). Two of the stations, 02292000 and 02292010, are located at the upstream boundary condition of the HSPF model at the beginning of the C-43. These stations will be used to verify the S-77 Lake Okeechobee boundary condition, but will not be used for HSPF model calibration. Station 02293214 is located on a small canal in Cape Coral, and redelineation is not recommended for this location. Tetra Tech recommends updating the HSPF model delineation so stations 264514080550700, 02293055, and Yellow Fever Creek are located at subbasin outlets to allow for model calibration or validation at these stations.

Table 5: Flow stations not located near an HSPF subbasin outlet

Station ID	Station Name	Agency	Recommend Redelineation
02292000	Caloosahatchee Canal at Moore Haven	USGS	No
02292010	Caloosahatchee Canal Downstream S-77	USGS	No
264514080550700	Industrial Canal at Clewiston	USGS	Yes
02293055	Orange River near Buckingham	USGS	Yes
Yellow Fever Creek	Yellow Fever Creek	DEP	Yes
02293214	Mead Canal at Cape Coral	USGS	No

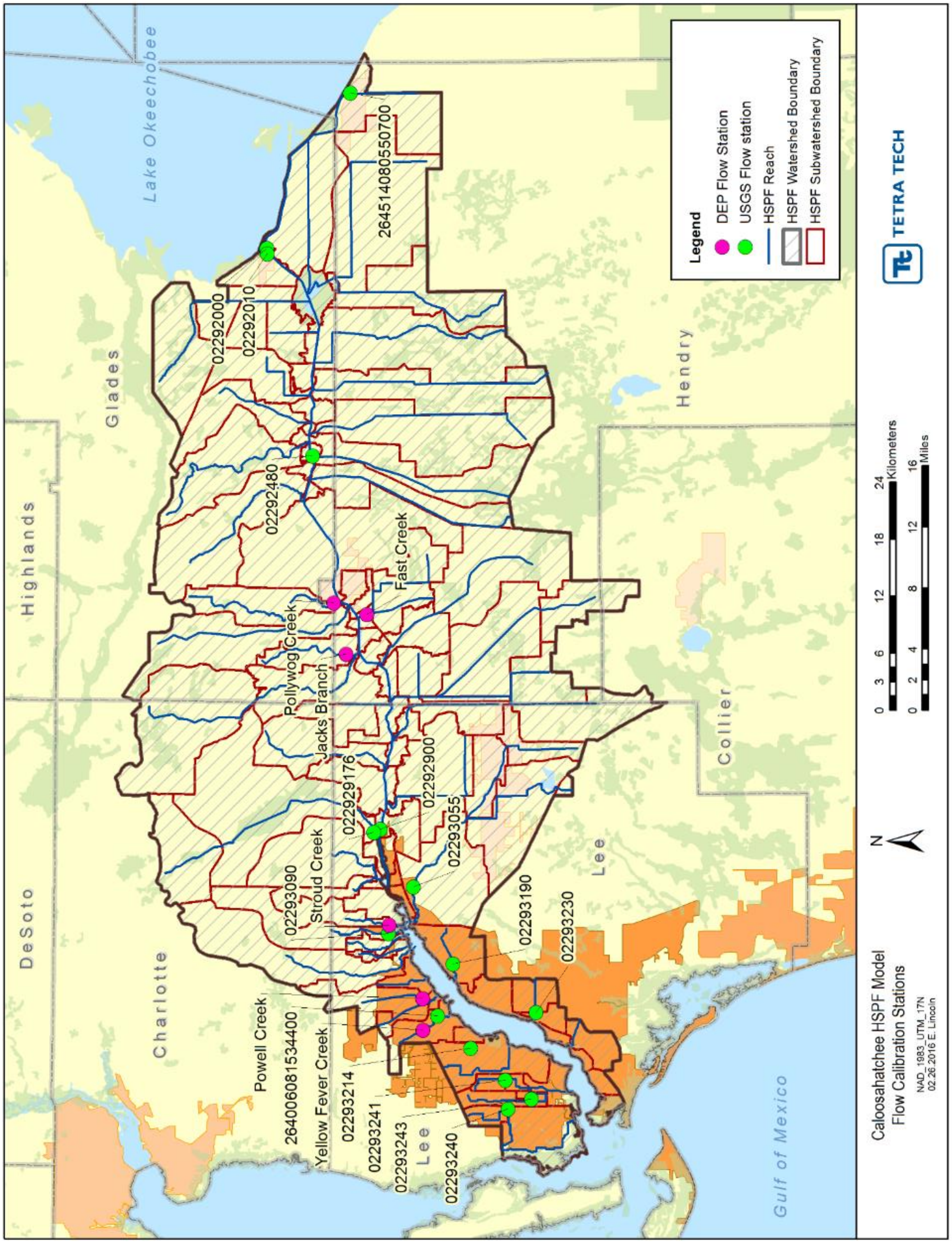

Figure 10: HSPF flow calibration stations

Issue #3: (*Stakeholder comment*) There are priority reaches within the Caloosahatchee Basin with bidirectional flow. The bidirectional flow was not adequately modeled in the 2009 and 2014 models.

Recommendation: There is an industrial canal near Lake Okeechobee where the lake outflows into the C-43, and the flows here reverse about 40% of the time. The Cape Coral canal system is not accurately represented in the current HSPF model and this representation will be updated as part of this project. Tetra Tech will simulate bidirectional flow in priority reaches (reaches with either a nutrient or DO impairment). Bidirectional flow is known to occur in the Caloosahatchee River between locks S-77 and S-78, at multiple locations at and downstream of lock S-79, and in three reaches in the middle of the watershed (Jacks Branch, Pollywog Creek, and Fast Creek). Tetra Tech will overlay a simplistic EFDC model over the HSPF model reaches that extend between locks S-77 and S-79 and include the industrial canal, Jacks Branch, Pollywog Creek, and Fast Creek. Tetra Tech will extend the current Caloosahatchee EFDC model grid to capture the bidirectional flows due to tidal influences that occur in priority reaches downstream of S-77, including Cape Coral canals, Billy's Creek, Orange River, and Yellow Creek.

Issue #4: The HSPF model needs to be calibrated to additional flow and water quality stations.

Recommendation: Tetra Tech will work with the department to identify approximately 20 calibration and 20 validation stations that will be used in the HSPF model.

Issue #5: There is no representation of onsite sewage treatment and disposal systems (septic systems).

Recommendation: The current version of the model does not include septic systems. Tetra Tech recommends adding septic systems to the model using Florida Department of Health and/or local county data on the locations of septic systems in the watershed. Both functioning and failing septic systems will be represented in the model.

The total number of septic systems in each subbasin will be estimated based on area weighting the total county estimates for residential land uses, not including residential land areas that are within sewered areas. For properly functioning systems, Tetra Tech will assume that each septic tank serves a household of 2.73 people, each person accounts for 70 gallons/day of water use, and 15% of the water used in the house is consumptive and does not reach the septic tank. Tetra Tech will also assume that it takes an average of 60 days for the septic flow to reach a body of water (unless the department has a better estimation of average travel time), so a first order decay rate will be applied to each constituent to determine the concentration after 60 days. **Table 6** presents the concentration of septic tank effluent, decay rates for each constituent, and the concentration after 60 days of decay. For phosphorus, it will also be assumed that 90% is sorbed to sediment; therefore only 10% of the effluent concentration will be used to calculate decay after 60-days. Non-failing septic systems loads will be developed into a direct input time-series, for each subbasin, and will be handled as a point source in the computational domain. The percentage of failing septic systems for each county will be estimated using available data, and if no data are available, Tetra Tech will assume a 15% fail rate. Because it is assumed that no decay occurs and raw effluent is directly applied to the land for these systems, Tetra Tech will adjust buildup and storage mass rates on residential land uses to account for these failing systems. Subbasins with greater numbers of failing systems will receive proportionally increased build-up and storage rates. Final rates will be adjusted during the calibration process.

Table 6: Proposed septic system effluent concentrations

Parameter	Effluent Concentration (mg/L)	Decay Rate (1/day)	Concentration at Stream (mg/L)**
BOD5	105	0.16	0.003
TN	70.258	0.1	0.1263
OrgN	0.458	0.1	0.0008
TAM	10.5	0.1	0.0189
NO_x	59.3	0.1	0.1066
TP*	0.3	0.014	0.1287
OrgP*	0.3	0.014	0.1287
PO_4*	0	0.014	0
TSS	10	0	10
DO	-	-	4

*Assumes that 90% of phosphorus is sorbed to sediment.
**Assumes septic flow takes an average of 60 days to reach stream.

Issue #6: The incorrect NPDES permitted point sources are represented.

Recommendation: There are nine wastewater treatment facilities in the watershed with permitted surface water discharges, although five are listed on the Environmental Protection Agency Permit Compliance System as directly discharging to the estuarine portion of the Caloosahatchee River (FL0021261, FL0021270, FL003007, FL0030325, and FL0039829) (**Figure 11)**. These five facilities, along with FL0001490, will be included in the EFDC model. A tenth facility, FL0591190 (S-4) was not active during the model time period and will not be included.

Table 7 lists the three domestic wastewater (DW) and industrial wastewater (IW) treatment facilities that will be evaluated for inclusion in the HSPF model. The discharge monitoring report (DMR) data received by the department will be reviewed to determine how to best represent these facilities in the model. Tetra Tech will develop point source time series to include in the model.

Table 7: 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
FL0040088	Cape Coral, City of - RO WTP	IW	1.2
FL0040665	Clewiston, City of - WWTF	DW	1.5

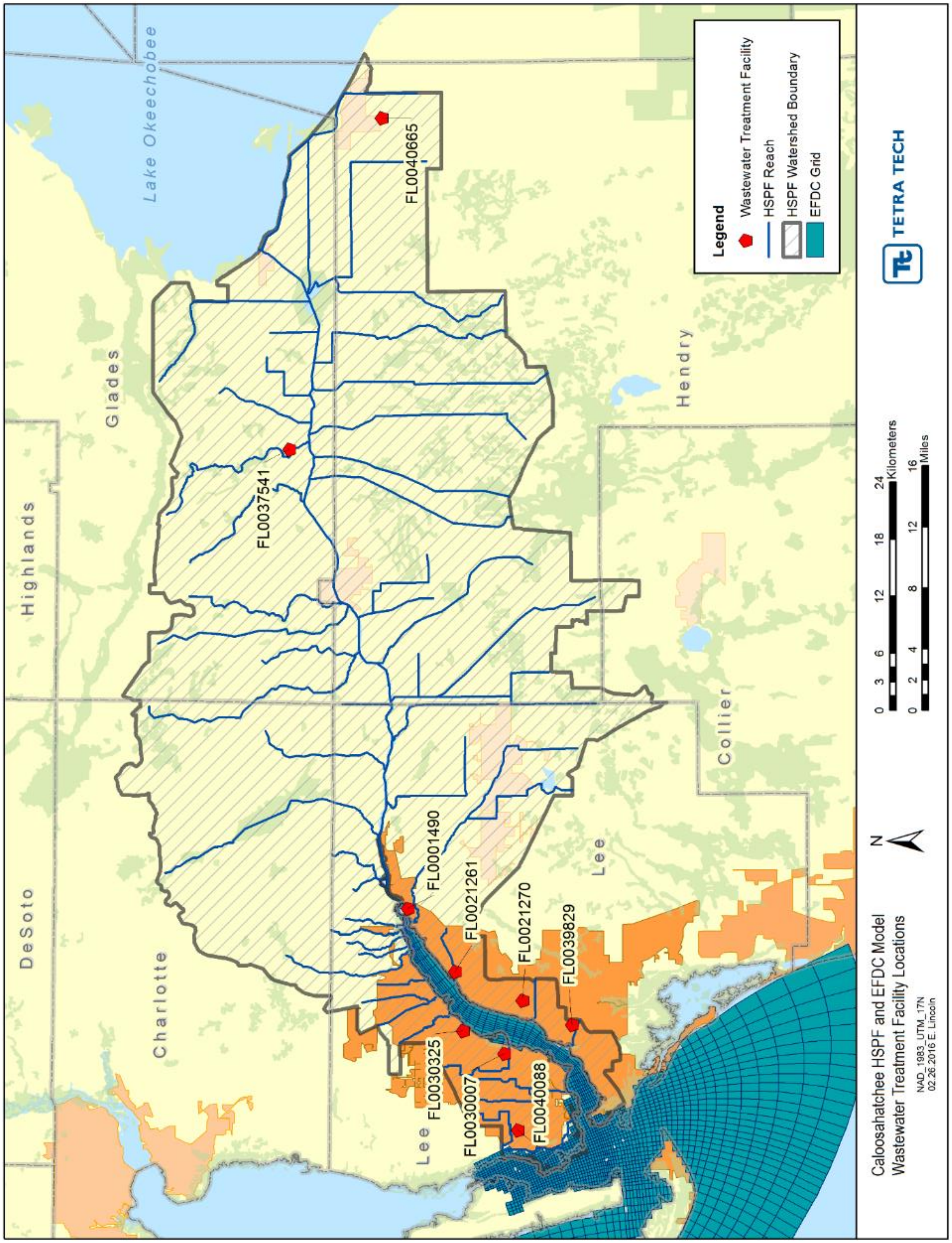

Figure 11: NPDES wastewater treatment facility locations

Issue #7: Representation of agricultural irrigation volumes and withdrawals may not properly represent withdrawal and demand.

Recommendation: The model currently represents agricultural irrigation as a point source that discharges directly to the HSPF model reaches, but the source of the water is not specified. Tetra Tech recommends that irrigation continue to be represented, but as a point source applied to the land. Information from the department on the source of the water (C-43, Lake Okeechobee, or ground water) will be used in the model (**Figure 12**). The irrigation will be represented in the model as a demand.

Tetra Tech recommends using the landscape coefficient method described in the WUCOLS III (Water Use Classifications of Landscape Species) manual in order to calculate the evapotranspiration (ET) demands within the Caloosahatchee River Basin. The equation to calculate ET Demand is:

$$\text{ET Demand} = \text{ETo} * \text{Kc}$$

Where ET Demand = Crop evapotranspiration demand (in.), ETo = Reference crop evapotranspiration (in.), and Kc = crop coefficient (dimensionless).

Tetra Tech will continue to research the best values to use for ETo and Kc. The proposed values for ETo are shown in **Table 8** and are based on University of Florida – Institute of Food and Agricultural Sciences recommended values. The proposed Kc values are shown in **Table 9**.

Table 8: Monthly reference crop evapotranspiration (ETo, in.)

Month	South Florida
January	0.9
February	1.1
March	1.4
April	1.1
May	2.5
June	3.9
July	3.6
August	3.1
September	2.8
October	1.8
November	0.7
December	0.8

Table 9: Crop irrigation coefficients (Kc)

Crop Type	Kc
Row crops	0.75
Orchards	0.70

Issue #8: The cropland/improved pasture reduced land cover representation should be broken out into at least two separate land covers. The SFWMD also has a more recent land coverage (2008-2009) than the 2004 land coverage used in the 2009 and 2014 Models.

Recommendation: Tetra Tech recommends using the SFWMD 2008-2009 land cover for the 2017 Model. The land cover will be reclassified using the same classifications as the 2009 and 2014

Models, although cropland and improved pasture will be represented as two separate land covers, for a total of 11 land cover classifications.

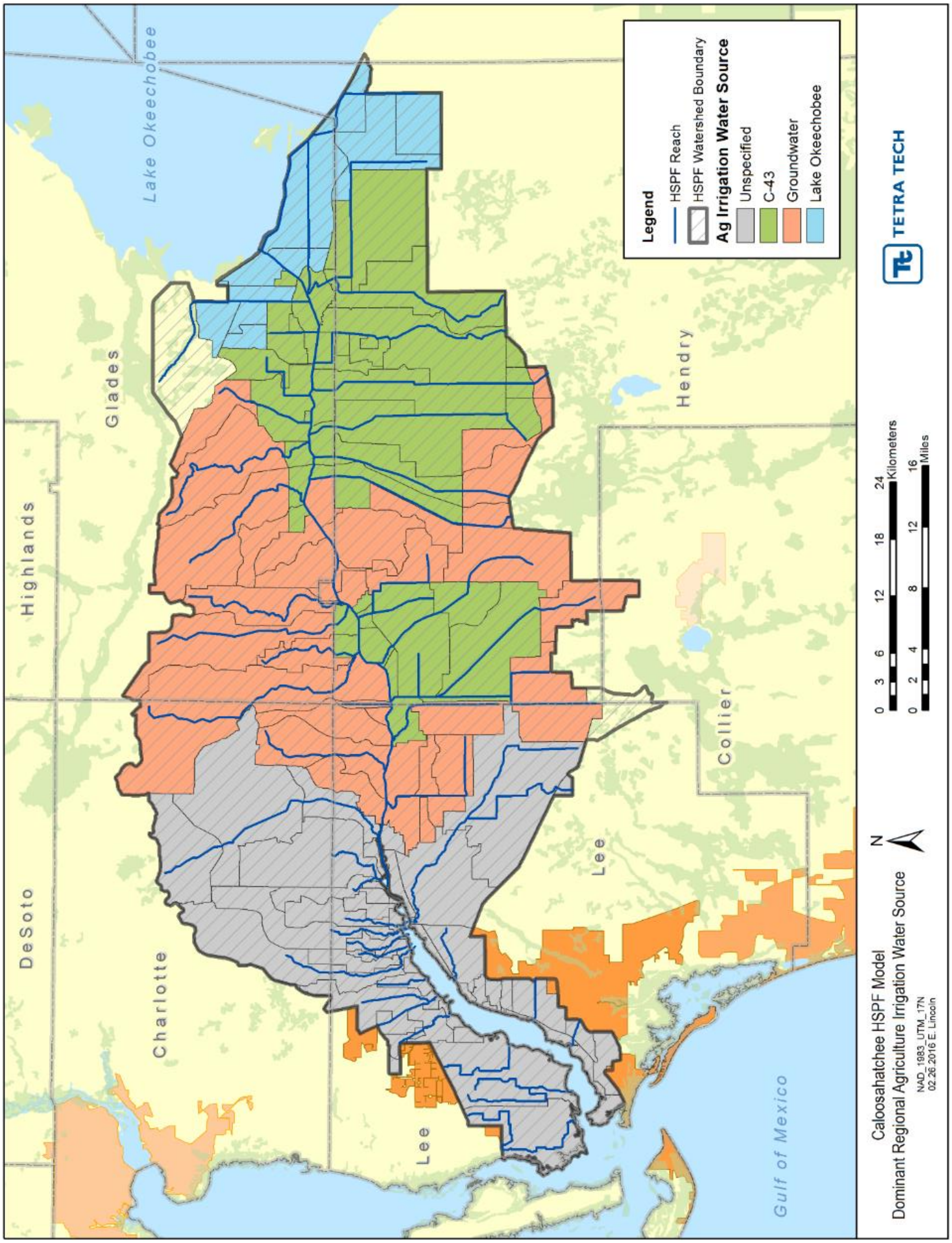

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Figure 12: Dominant agricultural irrigation water withdrawal source

3.0 EFDC MODEL REVIEW

3.1 CONCEPTUAL STRUCTURE

The 2009 Model is documented in the Dynamic Solutions 2009 report. The department and stakeholders identified additional model needs for the TMDLs. Therefore, the department expanded to the present 2014 Model grid. There is limited documentation for the 2014 Model set up and the following comments and recommendation are based on a detailed review of the 2014 Model input files.

The overall 2014 Caloosahatchee EFDC grid set up has a good spatial representation of the harbor and estuary areas. However, there are some issues with the implementation of this grid set up.

The 2009 and 2014 model grids included boundary tidal cells for both the main waterbody and shallow marsh areas that vary between wet and dry conditions. This is the case for both the Matlacha Pass and Pine Island Sound model areas (**Figure 13** and **Figure 14**). Applying tidal boundaries to cells that represent both wet and dry conditions can cause some instability in the model. Therefore, both of these tidal boundaries should be modified so that only the cells in the open water area are included.

Figure 13: Matlacha Pass model tidal boundary

Figure 14: Pine Island Sound model tidal boundary

The current model grid also does not represent the deep channels well. Some of the deep water model cells are not well connected to the channels due to large depth differences between adjacent cells, which could be causing issues with representing how the salinity wedge moves in these channels. The channel depths will be reviewed to ensure a well-connected channel is represented to move the salt wedge up and down the estuary.

A sigma grid of four layers is currently being used in the EFDC model, which results in cell depths ranging from 0.1 meters to 5 meters. The Caloosahatchee system may be better represented using the generalized vertical coordinate (GVC) multi-layer grid with variable cell layers and increasing the number of maximum layers to six, with an average cell depth of about 1 meter. This will increase the model's vertical resolution in the deeper areas and convert shallower, seagrass cells to one layer. In addition, this change should decrease the overall number of vertical cells and yield faster model run times without losing accuracy. In addition, thin bottom cells can have problems properly representing sediment oxygen demand (SOD) and DO. The SOD impacts are overstated due to the small cell volume and the resultant DO is much lower than expected. With less layers and larger cell volume, the SOD impacts are more realistically calculated.

The marsh areas, as represented in the current grid, are much deeper than the depths indicated on the NOAA nautical charts. Most likely, the routine used to set the various grid depths used the marsh channels' contour lines to assign depths for the entire marsh area, which resulted in marsh area depths of 1 to 2.5 meters. Tetra Tech recommends that the depths for the areas that are salt marshes be capped at a maximum depth of 0.5 meters, with the appropriate vegetation settings.

The original bathymetry appears to be from online NOAA depth data and should be adequate for this project. However, these data need to be checked against NOAA nautical charts to ensure the data are translated to the model grid correctly (**Figure 15**).

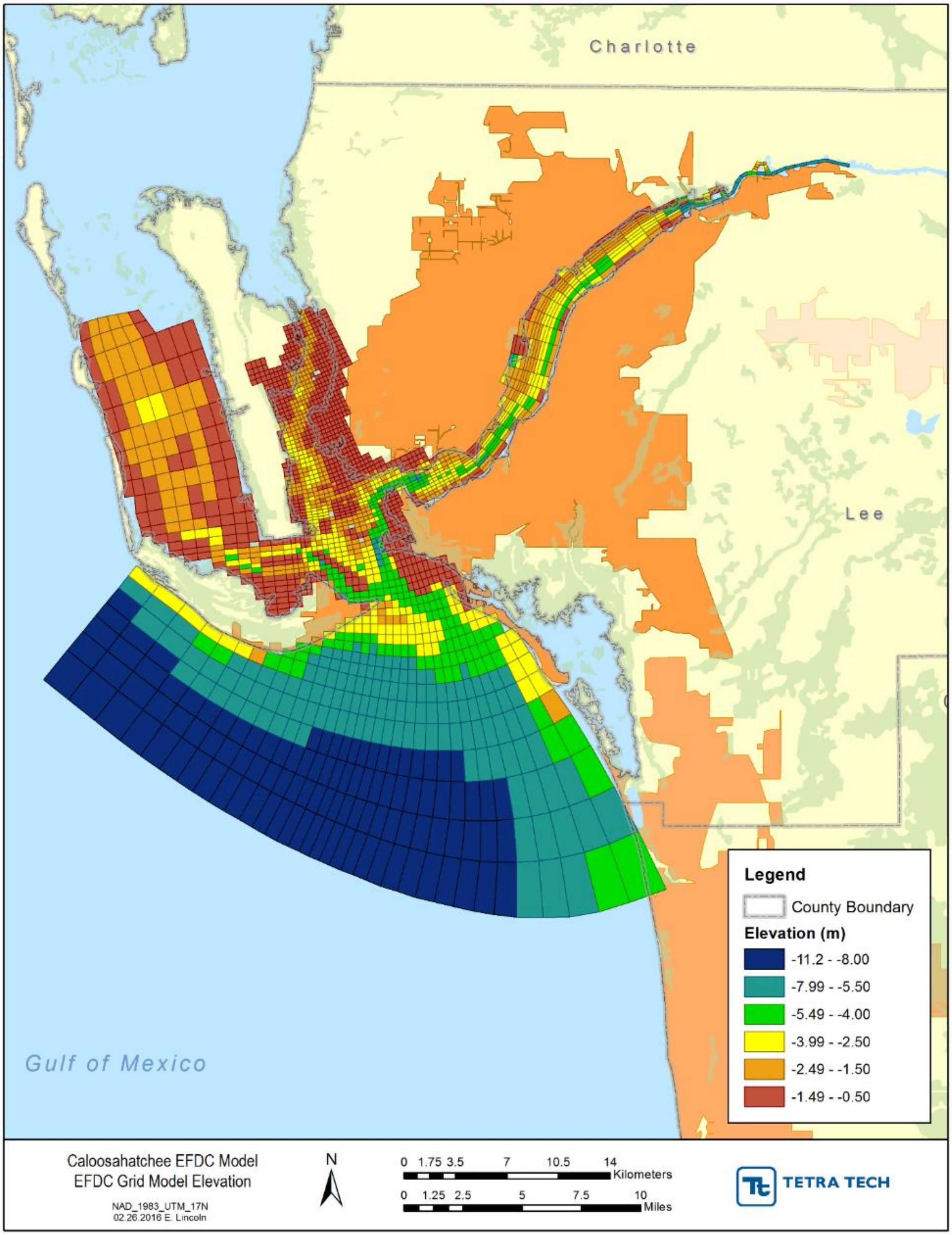

Figure 15: Caloosahatchee EFDC bottom elevations

The 2009 and 2014 EFDC models are linked to the HSPF model and all the linkages seem to be correct. **Table 10** and **Figure 16** show the HSPF model outputs and EFDC model cells where they are linked.

Table 10: HSPF Model outputs and linkages to EFDC Model cells

HSPF Model Segment	EFDC Model Cell I	EFDC Model Cell J
S-79 Structure	98	30
HSPF 02	97	30
HSPF 03	95	30
HSPF 04	94	30
HSPF 05	90	34
HSPF 06	89	30
HSPF 07	81	35
HSPF 08	81	30
HSPF 09	78	33
HSPF 10	79	30
HSPF 11	77	36
HSPF 12	76	36
HSPF 13	75	36
HSPF 14	74	37
HSPF 15	72	37
HSPF 16	71	29
HSPF 17	71	37
HSPF 18	68	37
HSPF 19	65	38
HSPF 20	62	29
HSPF 21	61	40
HSPF 22	59	29
HSPF 23	56	30
HSPF 24	54	29
HSPF 25	53	29
HSPF 26	49	39
HSPF 27	47	30
HSPF 28	42	30
HSPF 29	39	42

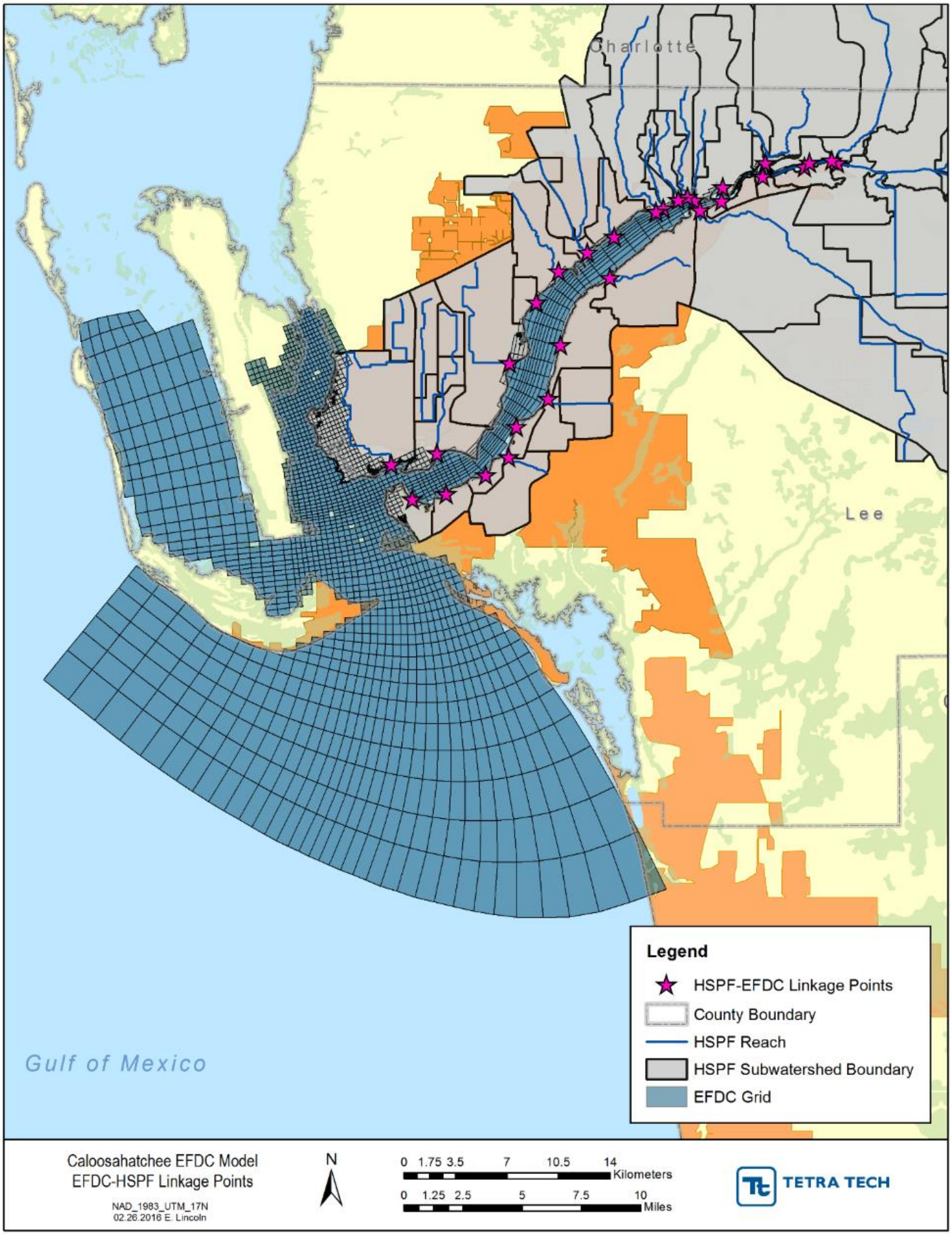

Figure 16: EFDC Model cell linkages to HSPF Model outputs

There were five point sources discharging directly to the 2007 and 2014 EFDC Models. **Table 11** lists these point sources and their EFDC cell location and the locations are shown in **Figure 11** (**Section 2.4**).

Table 11: Point sources 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	72	29
FL0021270	South AWWT Facility	DW	12	61	29
FL0030007	Cape Coral, City of - Everest WRF	DW	15.1	62	40
FL0030325	Waterway Estates	DW	5	64	38
FL0039829	Fiesta Village Advanced WWTF	DW	1.5	55	30

There is limited detail on how the 2009 or 2014 Model open boundary conditions were developed. These inputs will be reviewed and updated based on the available NOAA tide data and the measured salinity data. The meteorological data are from the Fort Myers Page Field records, which were supplemented with the Fort Myers Southwest Regional records. These data will be expanded to extend through 2014.

The water quality parameters are within expected normal ranges for southeastern estuaries. Only one algal group was used to represent the estuary's algal community; however, most southeast estuaries are represented using three algal groups.

3.2 MODEL INPUT FILES

Tetra Tech ran the EFDC model and examined the auxiliary input files. From this evaluation, the following was found:

- DXDY.inp: The depths and bottom elevation values do not match up, which is causing instability at the start of the model runs. The bottom roughness coefficient of 0.02 is in the appropriate range; however, Tetra Tech will examine the results using a higher roughness coefficient for the shallow marsh areas.
- VEGE.inp: This file factors aquatic vegetation impact in the model and provides more friction to the water movement. This can be accomplished by either: (1) increasing the bottom roughness coefficient, which only impacts the bottom layer; or (2) including an aquatic bottom fixed vegetation estimate for each cell. This file was used but may have been modified from the original EFDC model coding; however, there is no documentation for what changes were made, if any. If the 2009 Model used the original VEGE.inp file set up, a factor was included that zeroed out any vegetative resistance to water movement.
- SSER.inp: A freshwater salinity concentration of 0.5 ppt was used in the 2009 Model. Unless there is some evidence of minor saltwater intrusion, this value should be set to zero. An offshore constant salinity boundary of 35 ppt was used.
- TSER.inp: The temperature data in the input file appear reasonable; however, the 2009 Model is over predicting the summer temperature in 2003. The 2017 Model will need to be recalibrated to all available data.

- PSER.inp: The boundary elevations in this file seem reasonable. The 2009 Model report only includes one graph showing year 2003 at the NOAA tide station 8725520, with minimal statistics. Therefore, it is difficult to determine if the 2009 Model is predicting low and high tides correctly. During model recalibration, the water surface elevation will be recalibrated to all available data, including the USGS station located at S-79 and the USGS station at Whiskey Creek.
- ASER.inp: The meteorological data and coefficients in the input file appear reasonable; however, adjustments may need to be made to better calibrate temperature.
- WSER.inp: The data in the input file appears reasonable.
- QSER.inp: Flows in the QSER.inp file are two to three times the measured flow at the USGS gage and the HSPF model flows. For the S-79, the HSPF model flow is 1,200 cubic feet per second (cfs) and the USGS gage flow is 1,480 cfs. However, the EFDC QSER.inp flow is 3,561 cfs. In addition, at Whiskey Creek, the HSPF model flow is 13 cfs and the USGS gage flow is 10.3 cfs. However, the EFDC QSER.inp flow is 31 cfs. It appears that the conversion program used for inputting the HSPF model flows to the EFDC QSER.inp file calculated the flows incorrectly, and this will need to be corrected in the updated model.
- ALGALGRO.inp: This file provides the algal growth kinetics by zone. The 2009 and 2014 Models did not use this file; however, there is an undocumented WQALGG.inp file, which is hardwired into the 2009 and 2014 Models code. Tetra Tech recommends using the ALGALGRO.inp file and its documented parameters.

3.3 MODEL PARAMETERIZATION

Tetra Tech determined that the water quality and TSS kinetics and parameters for the water column are within normal ranges for southeastern estuaries. However, the water quality variables will be reevaluated in light of the more recent data that will be used in the 2017 Model. The main input file for the 2009 and 2014 models has various additions from the public domain version, suggesting changes have been made to the original code. These changes have not been documented and may cause an issue when comparing the outputs of the 2017 Model to the 2009 Model. Specific changes that will be made for the 2017 Model are noted in **Section 3.5**.

Tetra Tech could not determine how the sediment nitrogen and phosphorus water column fluxes were developed. The input files noted that a special modeling routine was used that is undocumented. Also, the SOD values were input as non-temperature varying, with no documentation on how or why this was done. Tetra Tech will use the EFDC model sediment diagenesis routines to develop appropriate sediment fluxes for this system.

3.4 MODEL STABILITY

Tetra Tech could not determine if the proprietary EFDC model was stable. Tetra Tech set up an initial public domain hydrodynamic EFDC model, which incorporated the changes recommended in this memo and checked stability. For the time period of May 2010 to October 2010, at a time step of 45 seconds, the model ran without instabilities.

3.5 RECOMMENDATIONS

Based on our review and assessment, Tetra Tech has identified the following issues and recommendations for the EFDC model.

Issue #1: The 2009 and 2014 Models use the Dynamic Solutions proprietary EFDC model.

> Recommendation: Tetra Tech will convert the current proprietary version of the EFDC model to the public domain application of the model. The model code will be supplied to the department.

Issue #2: (*Stakeholder comment*) The current model timeline ends in 2010 and does not allow model calibration to new datasets.

> Recommendation: After discussions with the department, Tetra Tech will extend the current EFDC model time period from 2011 through 2014. The department will append the weather files for the simulation time period extension (2012-2014).

Issue #3: (*Stakeholder comment*) An insufficient number of water quality stations were used for model calibration.

> Recommendation: Tetra Tech will work with the department to identify approximately 10 calibration and 10 validation stations that will be used in the EFDC model.

Issue #4: The original model grid included boundary tidal cells for the main waterbody and shallow marsh areas that vary between wet and dry conditions.

> Recommendations: Tetra Tech recommends that the Matlacha Pass and Pine Island Sound tidal boundaries only be applied to cells in the open water area to prevent model instability.

Issue #5: A sigma grid of four layers is currently being used in the model.

> Recommendations: Tetra Tech recommends changing the grid to a GVC multi-layer grid with variable cell layers. This will convert shallower cells to one layer, and decrease the overall number of vertical cells while yielding faster model run times without losing accuracy. Tetra Tech also recommends determining if changing the channel from four to six layers would improve the model calibration and performance; however, this may not be needed.

Issue #6: The deep channels are not well represented in the current model, which could be causing issues with representing how the salinity wedge moves in these channels.

> Recommendations: The channel depths will be reevaluated to ensure that the channels are appropriately represented and that there are no unintended blockages to the saltwater moving upstream.

Issue #7: The DXDY.inp file includes initial depths that did not match up with the bottom elevations, which is causing instability in the startup of the EFDC model runs.

> Recommendation: The initial depths should be revised to follow the bottom elevation.

Issue #8: The QSER.inp flow file has flows that are two to three times the measured flow at the USGS gage and the HSPF model flows.

> Recommendation: It appears that the conversion program used for inputting the HSPF model flows to the EFDC QSER.inp file was calculating the flows incorrectly, and this will be corrected in the updated model. The water quality input loads may also be an issue and will be corrected if needed.

Issue #9: The VEGE.INP file may not be set up correctly and is underestimating the vegetative resistance to water flow in the non-channel areas.

> Recommendation: Tetra Tech recommends setting up a VEGE.inp file with approximately five zones (the 2009 Model has two zones) that correspond to the various depths and aquatic plants in each area.

Issue #10: (*Stakeholder comment*) Algal representation may not be adequate.

> Recommendation: In the 2009 Model, the main water quality input file was changed to include an algae sub-model routine. However, there is no definition of what this sub-model does. In addition, only one algal class was activated. Tetra Tech recommends using three algal classes, which is typical for southern waterbodies. In addition, Tetra Tech recommends using the ALGALGRO.inp file, which provides the algal growth kinetics by zone, and its documented parameters.

Issue #11: (*Stakeholder comment*) Change light extinction in the public domain code.

> Recommendation: In the 2009 Model, light extinction is hardwired into the code of the main water quality input file, and Tetra Tech is unsure if the typical model equations are still available. Tetra Tech recommends including the light extinction equations in the public domain version of the model. This is part of Task 4 of this project.

Issue #12: (*Stakeholder comment*) Color can contribute up to 80% of the light attenuation in the Caloosahatchee River. It is critical to account for the temporal and spatial variation of color.

> Recommendation: Based on this comment, the 2014 Model was updated to include a new set of light extinction equations. These equations will be included in the public domain 2017 EFDC Model. The general equation to be incorporated in to the 2017 EFDC Model is:

$$K_e = K_{eback} + K_{eshd} + K_{esolid} + K_{eDOC}$$

> Tetra Tech will describe the approach to implement these equations in the 2017 EFDC Model and coordinate with the department to ensure the approach represents what the department and stakeholders intended. To account for the variations in color throughout the estuary and the relationship between color and salinity, the extinction coefficients will be varied by zone.

Issue #13: The SOD assumptions may be incorrect.

Recommendation: The 2009 Model included an extra variable in the code to ignore SOD temperature effects, and this is not a standard modeling assumption. Tetra Tech recommends that this be evaluated during model recalibration.

Issue #14: The representation of point sources inputs can be improved.

Recommendation: In the 2009 and 2014 models, point sources are input as loadings. Therefore, if the point source flows are wrong, the loadings are also incorrect. Tetra Tech recommends inputting tributary and point source parameters as concentrations, not loads, with the correct HSPF model calibrated flows. The benefit of this approach is that it is simple to assess the time series and verify that the concentrations are within expected ranges or if there are issues with the time series. The DMR data received by the department will be reviewed to determine how to best represent these facilities in the model. Tetra Tech will develop point source time series to include in the model.

FL0030325 and FL0039829 did not discharge for the entire 2017 Model simulation period, and their point source time series will be reflective of their active discharge dates. Tetra Tech will add the Florida Power & Light (FPL) Fort Myers power plant (FL0001490) to the EFDC model, as requested by FPL. This facility withdraws water from the Caloosahatchee River and discharges into Orange River.

Issue #15: Atmospheric deposition was not included in the model.

Recommendation: No wet or dry atmospheric deposition is currently included in the model. Tetra Tech recommends including atmospheric deposition from the nearest monitoring station.

4.0 PROJECT TEMPLATES

Tetra Tech has prepared this memorandum in the style and format that will be used for all future memorandums. The department should review the template and let Tetra Tech know if there are any changes needed to structure, format, and general content.

Tetra Tech has also prepared an outline of the HSPF and EFDC modeling report, and the outline is attached at the end of this memorandum. The report outline documents the expected sections and information that will be contained in the final report. The outline may be updated during the process of report writing as necessary to reflect additional information that may need to be provided.

Both the memorandum and modeling report contain a sample of map figures, calibration plots (temporal and depth profiles), general informational tables, and calibration statistical tables. These figures and tables display the general coloring schematic and formats that will be used throughout the memorandums and in the final report. The department should review the figures and tables and inform Tetra Tech if any formatting changes should be made.

5.0 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 for the model results to the measured data. These comparisons will be made through graphs, such as box and whisker plots, time series plots, and frequency distribution curves. In addition, summary statistics, such as relative error, root mean square error, Nash-Sutcliffe model efficiency, and Kolmogorov-Smirnov test will be used to evaluate the results.

To evaluate the statistical results, Tetra Tech recommends using the performance criteria in the tables below, which come from Donigian (2002) and McCutcheon et al. (1990).

Table 12: Donigian 2002 calibration/validation targets or tolerances for percent difference between modeled observed results for hydrologic parameters

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

Table 13: Donigian 2002 and McCutcheon et al. 1990 calibration/validation targets or tolerances for percent difference between modeled observed results for water quality parameters

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 14: Donigian 2002 R, R^2, Nash-Sutcliffe, and Index of Agreement ranges for model performance

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

These performance criteria will be only one line of evidence for evaluating the model results. While the goal will be to achieve results that fall into the “very good” and “good” categories, there may be locations in the river or watershed or certain parameters with results in the “fair” or “poor” categories. The other lines of evidence will then be evaluated to determine if overall model performance still meets the project objectives of providing the department with models that can be used to develop the TMDLs for the impaired freshwater bodies and to refine the Caloosahatchee tidal estuary TMDLs.

6.0 REFERENCES

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APPENDIX A: DRAFT HSPF AND EFDC MODELING REPORT TEMPLATE

Hydrology and Water Quality Modeling Report

for the

Caloosahatchee River, Florida

PREPARED BY:

Tetra Tech, Inc.
2110 Powers Ferry Rd. SE, Suite 202
Atlanta, Georgia 30339
Phone: (770) 850-0949

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PREPARED FOR:

Florida Department of Environmental Protection
2600 Blairstone Road
Tallahassee, Florida 32399-2400

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Task: 01

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BMAP	Basin Management Action Plan
Department	Florida Department of Environmental Protection
EFDC	Environmental Fluid Dynamics Code (model)
HSPF	Hydrologic Simulation Program – FORTRAN (model)
SJRWMD	St. Johns River Water Management District
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
WASP	Water Quality Analysis Simulation Program

1.0 INTRODUCTION

Project background, goal of the project, and description of the watershed

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Table 1-1: Placeholder

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Model calibration and validation overview – additional details in Appendix A

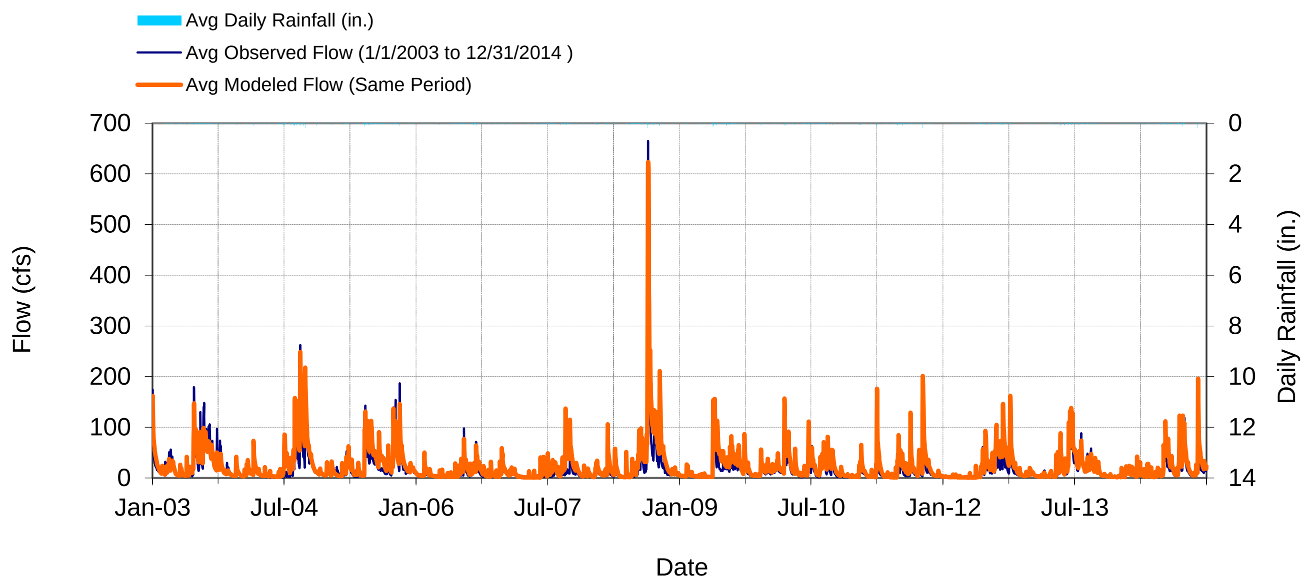


Figure 4-1 Time Series Comparison of Model Results to USGS Gage 02234400 (Gee Creek)

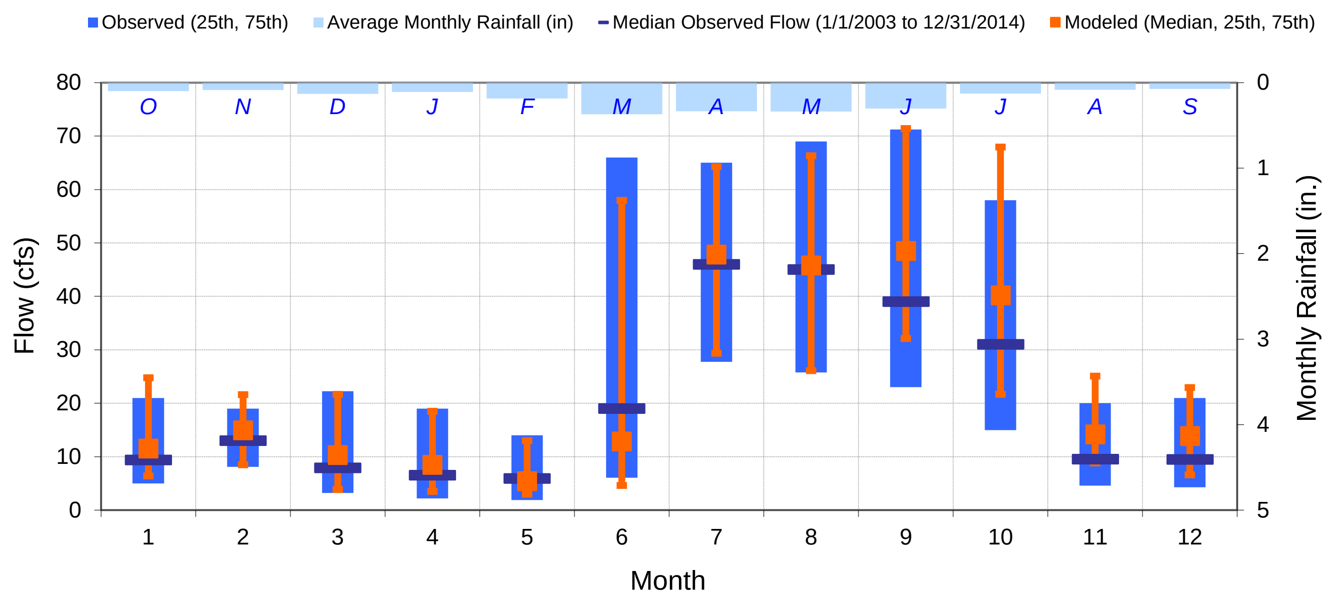


Figure 4-2 Box and whisker plots (observed and simulated monthly flows) for USGS Gage 02234324 (Howell Creek)

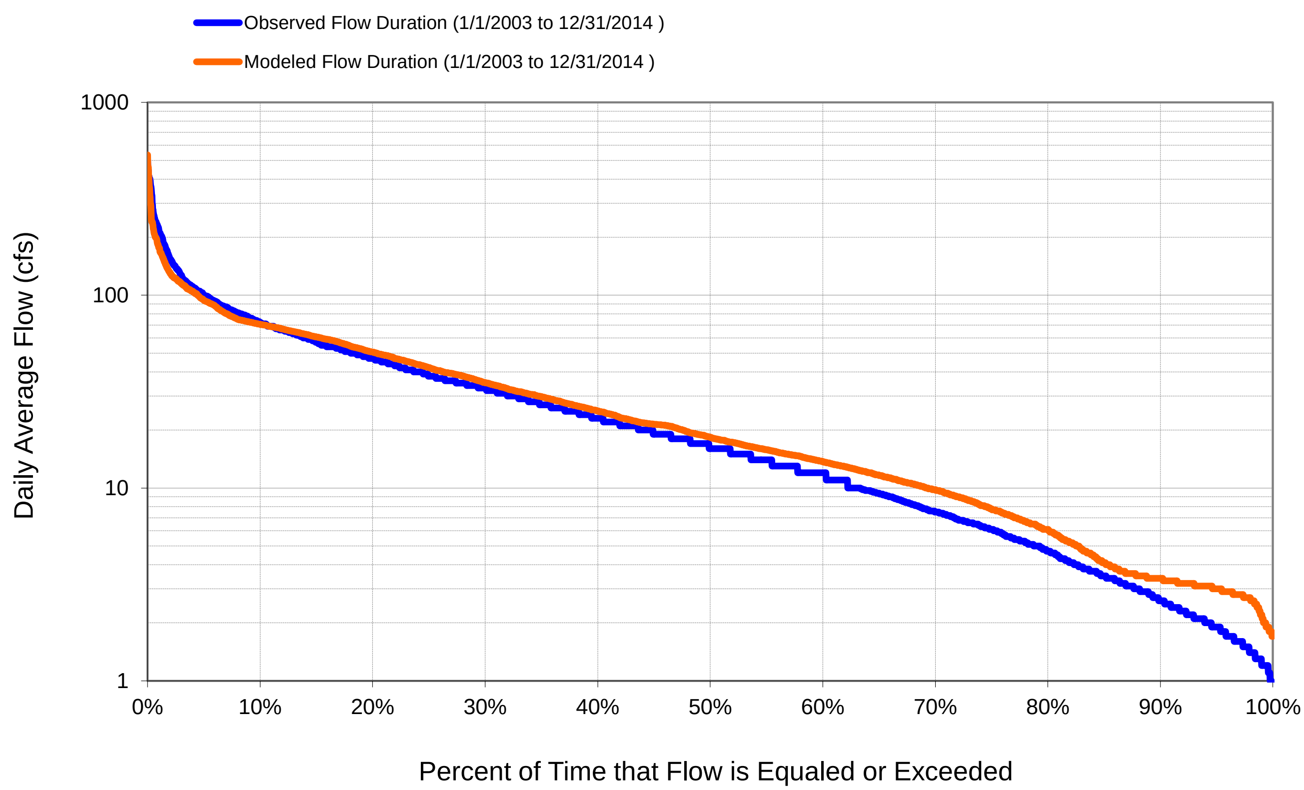


Figure 4-3 Frequency Distribution Curve (Observed and Simulated Daily Flows) for USGS Gage 02234324 (Howell Creek)

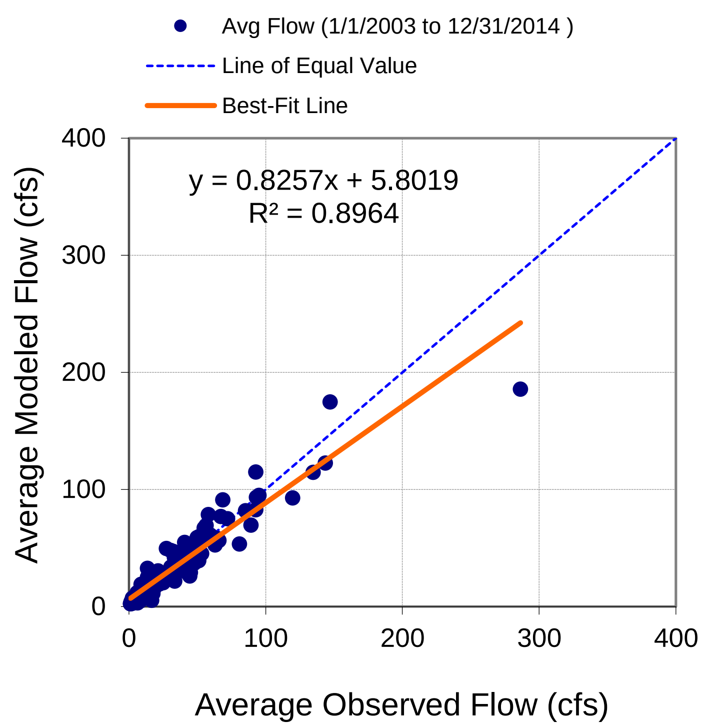


Figure 4-4 Scatter Plot (Observed and Simulated Monthly Flows) for USGS Gage 02234308 02234324 (Howell Creek)

Table 4-1 Error Statistics for USGS Gage 02234324 (Howell Creek)

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM SUBBASIN 45 12-Year Analysis Period: 1/1/2003 - 12/31/2014 Flow volumes are (inches/year) for upstream drainage area		USGS 02234324 HOWELL CREEK NEAR SLAVIA, FL Hydrologic Unit Code: 03080101 Drainage Area (sq-mi): 29.2	
Total Simulated In-stream Flow:	**10.06**	Total Observed In-stream Flow:	**9.91**
Total of simulated highest 10% flows:	**3.70**	Total of Observed highest 10% flows:	**4.14**
Total of Simulated lowest 50% flows:	**1.38**	Total of Observed Lowest 50% flows:	**1.12**
Simulated Summer Flow Volume (months 7-9):	**4.69**	Observed Summer Flow Volume (7-9):	**4.78**
Simulated Fall Flow Volume (months 10-12):	**2.38**	Observed Fall Flow Volume (10-12):	**2.10**
Simulated Winter Flow Volume (months 1-3):	**1.40**	Observed Winter Flow Volume (1-3):	**1.28**
Simulated Spring Flow Volume (months 4-6):	**1.59**	Observed Spring Flow Volume (4-6):	**1.75**
Total Simulated Storm Volume:	**1.17**	Total Observed Storm Volume:	**1.49**
Simulated Summer Storm Volume (7-9):	**0.55**	Observed Summer Storm Volume (7-9):	**0.72**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	1.53	10	
Error in 50% lowest flows:	22.51	10	
Error in 10% highest flows:	-10.55	15	
Seasonal volume error - Summer:	-2.06	30	
Seasonal volume error - Fall:	13.45	30	
Seasonal volume error - Winter:	9.51	30	
Seasonal volume error - Spring:	-8.77	30	
Error in storm volumes:	-21.28	20	
Error in summer storm volumes:	-24.25	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.850	Model accuracy increases as E or E' approaches 1.0	

4.4 HSPF WATER QUALITY CALIBRATION

4.4.1 *Calibration Methodology*

4.4.2 *Sediment*

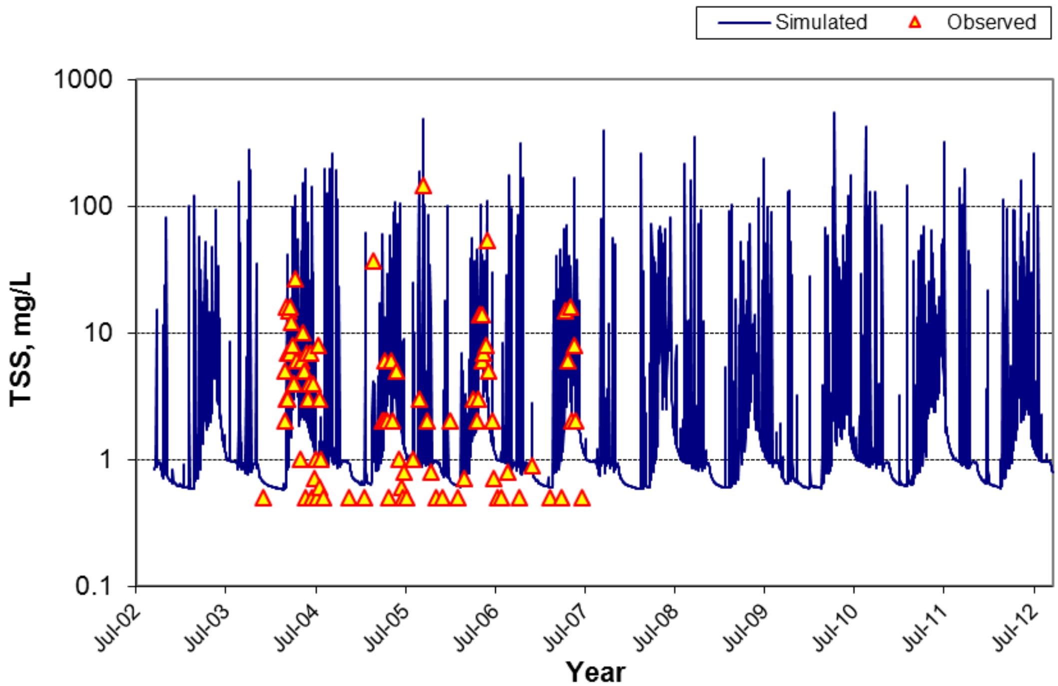


Figure 4-5 Comparison of modeled TSS and observed TSS concentrationsat station XXXX.

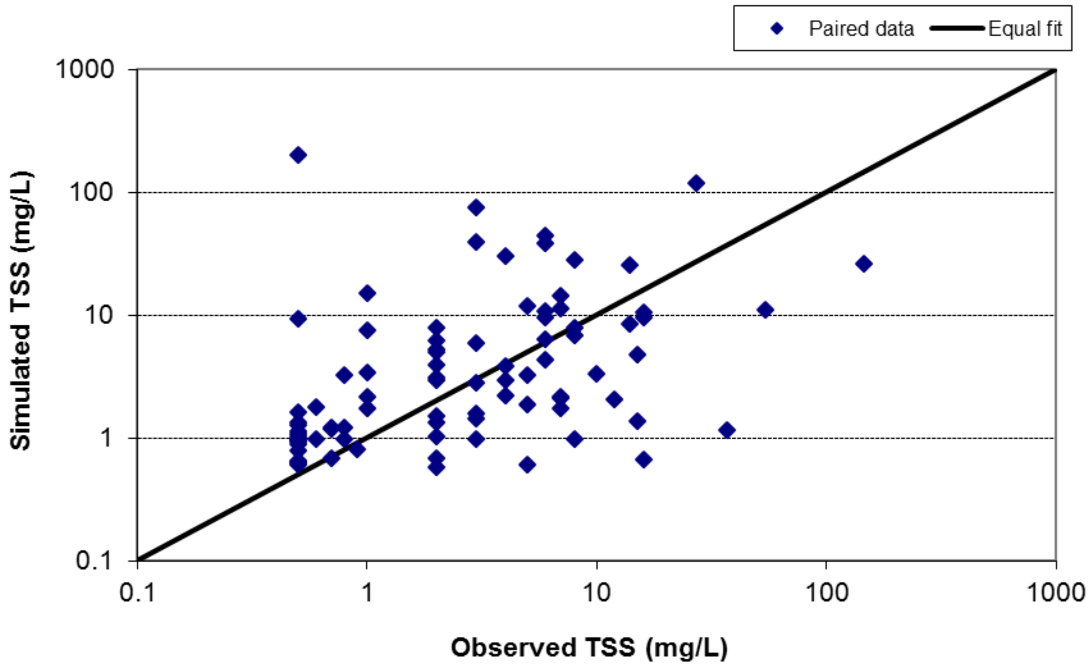


Figure 4-6 Linear regression of modeled TSS and observed TSS concentrations at station XXXX.

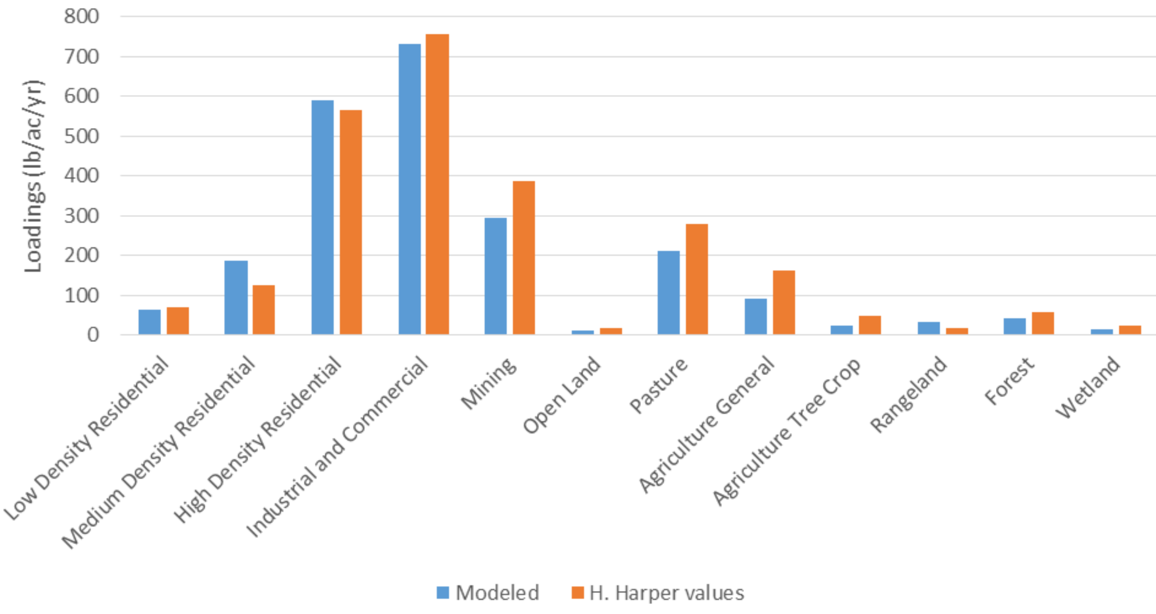
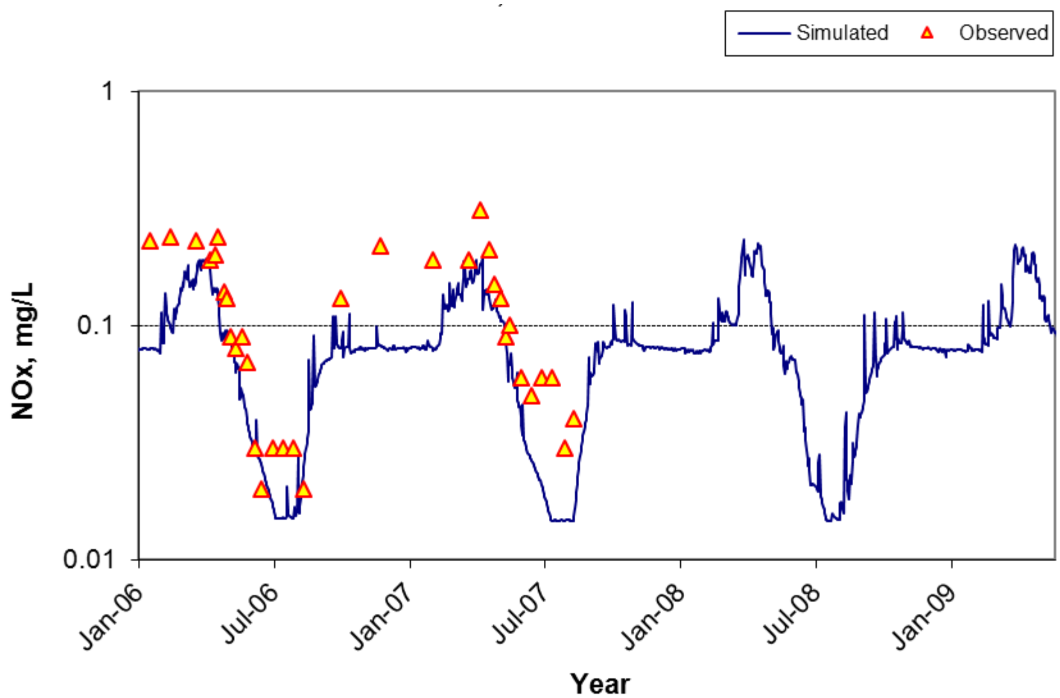


Figure 4-7 Comparison of modeled and literature values for annual sediment loading per acre by land use type

4.4.3 *BOD*

4.4.4 ***Nitrogen***



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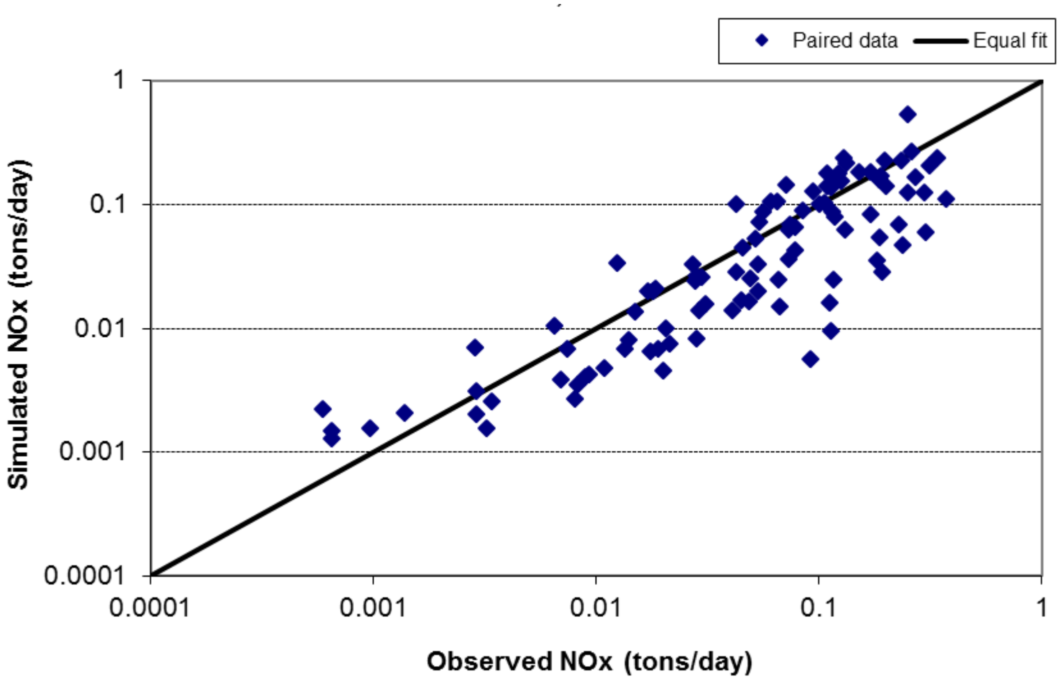

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5.3.4 *Layers*

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5.3.6 *Hydrodynamic Boundary Conditions*

5.3.7 *Meteorological Conditions*

5.3.8 *HSPF Linkage*

5.3.9 *Open Boundary Conditions*

5.4 EFDC Hydrodynamic Calibration

Model calibration and validation overview – additional details in Appendix B

5.4.1 *Calibration Methodology*

5.4.2 *Water Surface Elevation*

Table 5-1 Model water surface elevation calibration statistics from January 1, 2013 through April 30, 2014

Station ID	Measured (m MLLW)				Simulated (m MLLW)				R^2	MAE (m MLLW)	RMSE (m MLLW)	Norm RMSE	Index of Agrmt
	Mean	Median	5 %tile	95 %tile	Mean	Median	5 %tile	95 %tile					
XXXXXXX	1.89	2.17	0.60	2.86	1.80	1.94	0.56	3.04	0.92	0.20	0.25	0.13	0.97
XXXXXXX	1.45	1.74	-0.01	2.69	1.39	1.57	-0.05	2.85	0.97	0.15	0.19	0.11	0.99
XXXXXXX	1.60	1.88	0.14	2.84	1.40	1.57	0.03	2.84	0.97	0.21	0.25	0.14	0.98
XXXXXXX	1.21	1.40	0.00	2.36	1.26	1.44	0.00	2.47	0.99	0.07	0.09	0.06	1.00
XXXXXXX	1.40	1.66	-0.02	2.66	1.32	1.52	-0.09	2.72	0.98	0.12	0.15	0.09	0.99
XXXXXXX	1.57	1.84	0.17	2.73	1.38	1.51	0.08	2.79	0.95	0.22	0.27	0.16	0.98

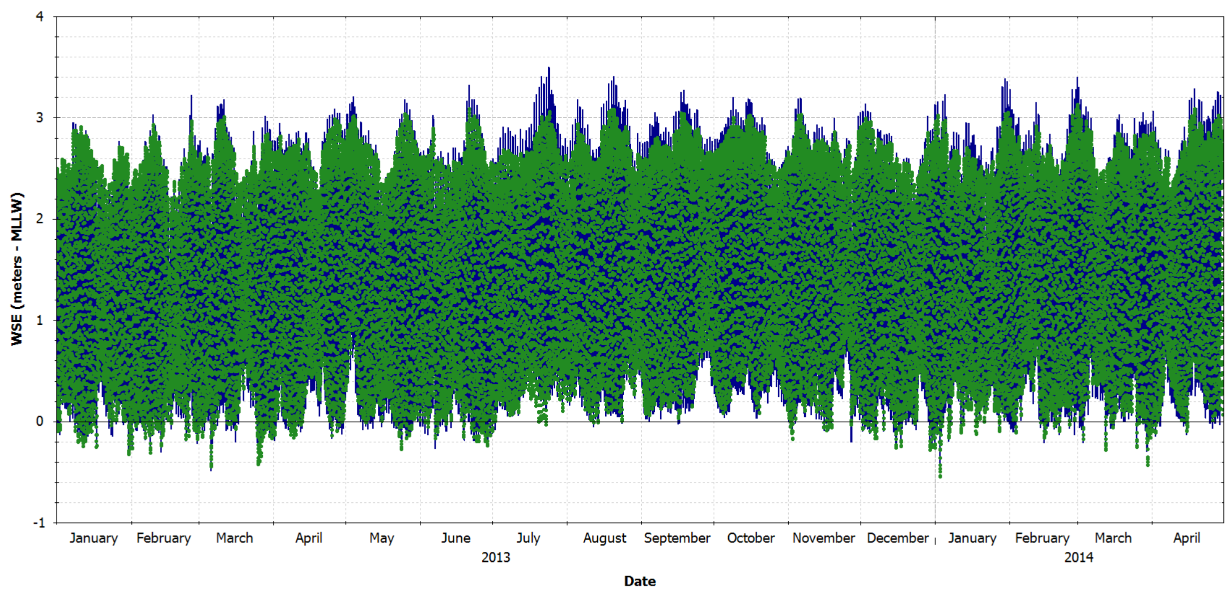

Figure 5-1 Water surface elevation comparison at USGS station XXXXXXX for the period 01/01/2013 – 04/30/2014

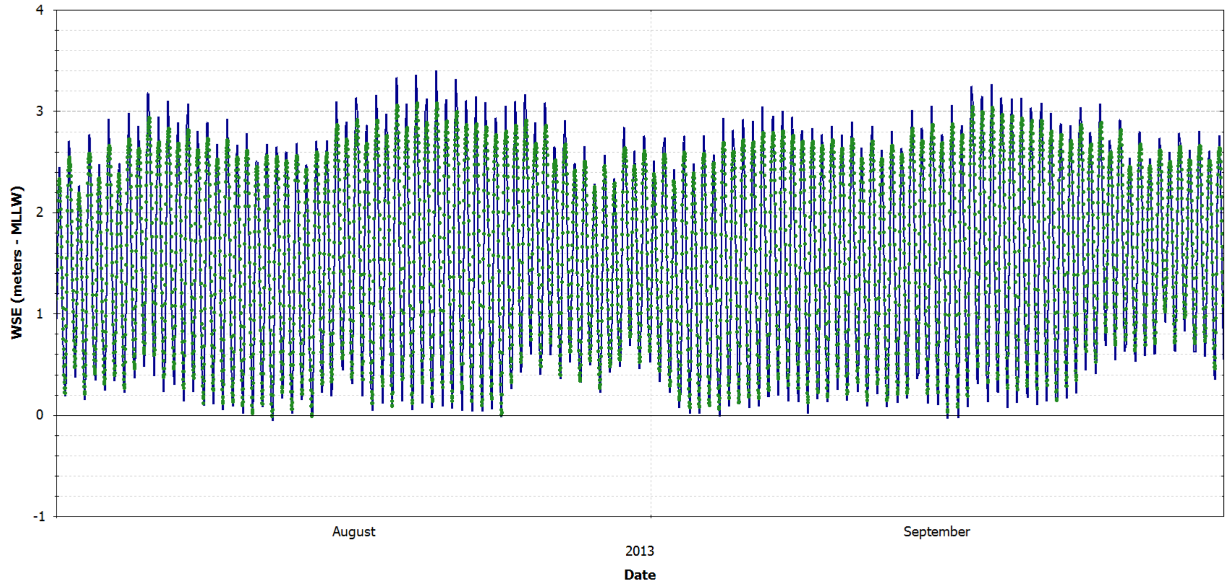

Figure 5-2 Water surface elevation comparison at USGS station XXXXXXX for the period 08/01/2013 – 09/30/2013

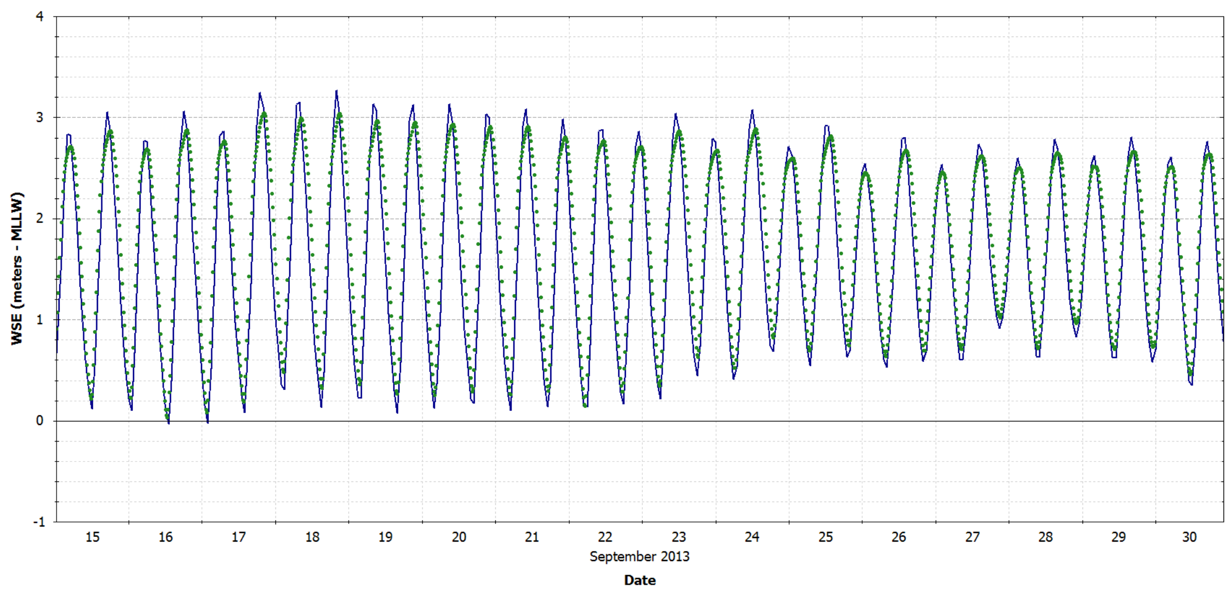

Figure 5-3 Water surface elevation comparison at USGS station XXXXXXX for the period 09/15/2013 – 09/30/2013

5.4.3 *Flows*

Table 5-2 Model flow calibration statistics from January 1, 2013 through April 30, 2014

Station ID	Measured (cms)				Simulated (cms)				R^2	MAE (cms)	RMSE (cms)	Norm RMSE	Index of Agrmt
	Mean	Median	5 %tile	95 %tile	Mean	Median	5 %tile	95 %tile					
XXXXXXX	-313.8	-195.3	-1,437.1	869.4	-299.8	-350.6	-1,265.5	1,052.4	0.88	225.1	283.7	0.34	0.97
XXXXXXX	-38.3	12.1	-402.1	317.9	-36.2	-60.4	-316.1	345.1	0.87	70.7	86.6	0.38	0.96
XXXXXXX	-721.4	148.0	-6,964.3	5,809.7	-294.6	321.3	-5,574.5	5,676.9	0.95	821.4	1048.5	0.25	0.98
XXXXXXX	-483.6	-199.1	-2,702.1	1,953.4	-341.1	-227.7	-2,429.5	2,256.7	0.93	373.2	462.7	0.28	0.98
XXXXXXX	-45.7	-22.8	-253.8	161.2	-49.8	-73.9	-203.8	152.0	0.67	62.3	82.0	0.65	0.89

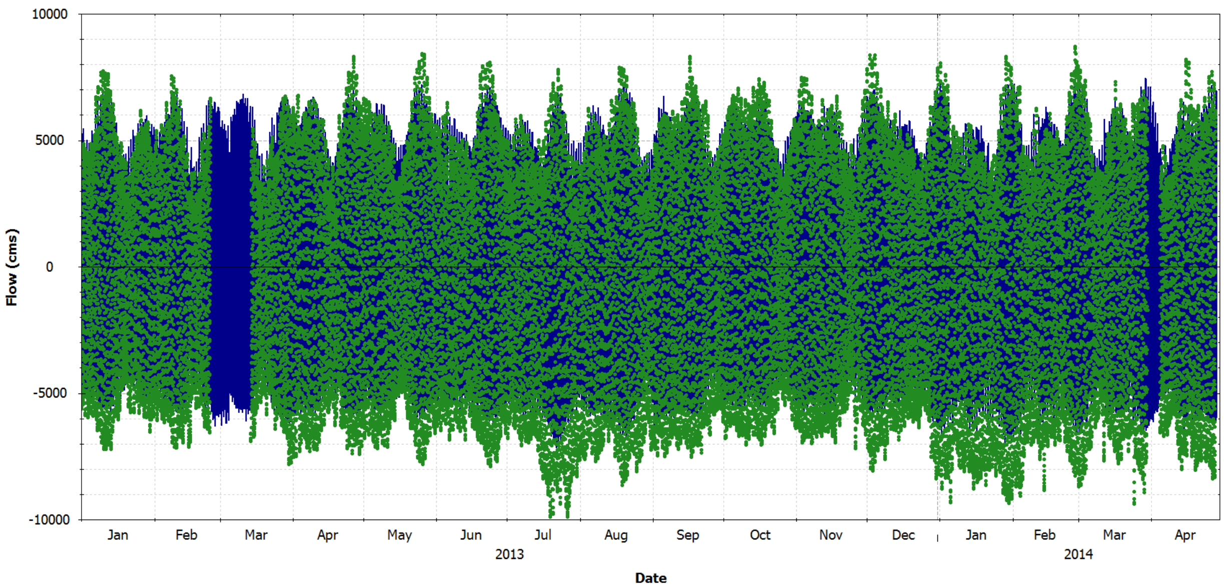

Figure 5-4 Flow comparison at USGS station XXXXXXX for the period 01/01/2013 – 04/30/2014

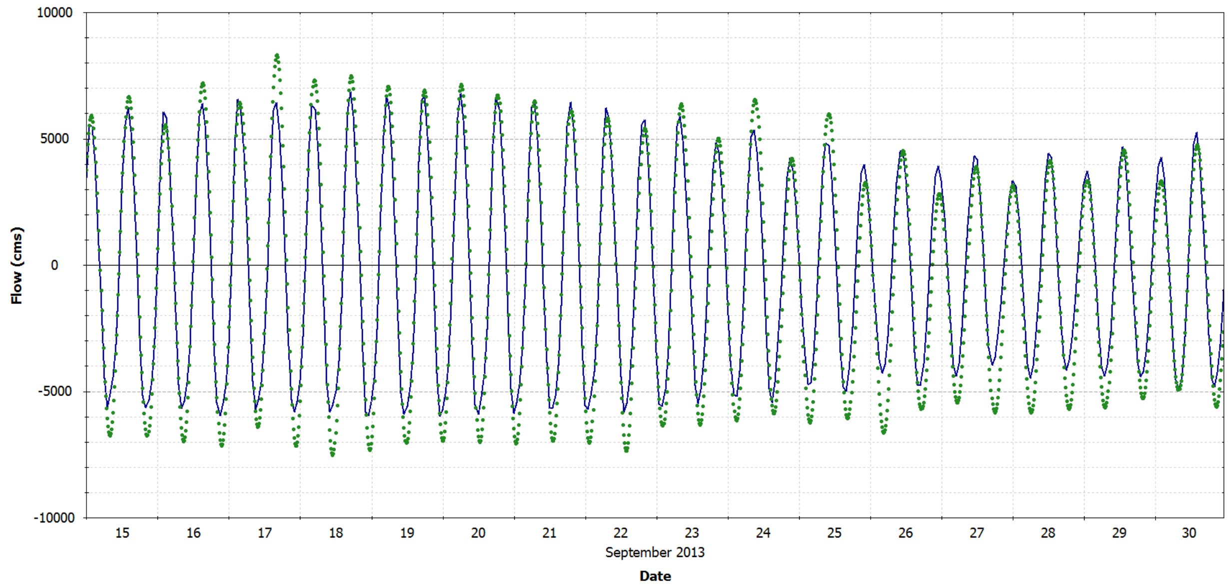

Figure 5-5 Flow comparison at USGS station XXXXXXX for the period 08/01/2013 – 09/30/2013

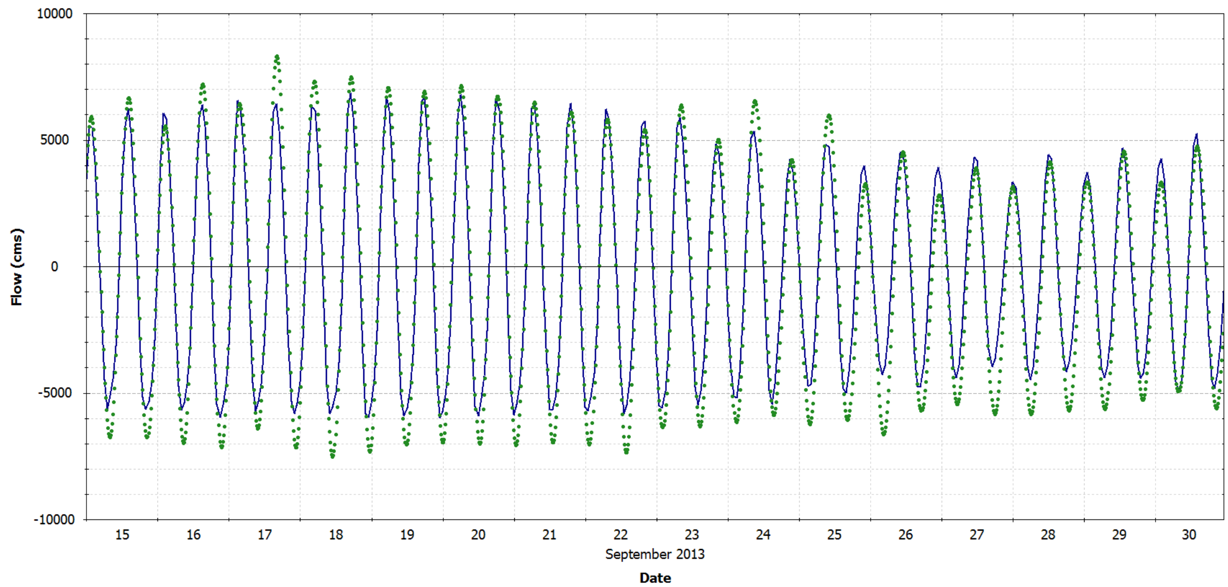

Figure 5-6 Flow comparison at USGS station 02198980 Savannah River at Fort Pulaski, GA for the period 09/15/2013 – 09/30/2013

5.4.4 *Water Temperature*

Table 5-3 Model water temperature calibration statistics from January 1, 2013 through April 30, 2014 for the USGS stations and August 15, 2013 through October 1, 2013 for the project stations

Station ID	Measured (°C)				Simulated (°C)				R^2	MAE (°C)	RMSE (°C)	Norm RMSE	Index of Agrmt
	Mean	Median	5 %tile	95 %tile	Mean	Median	5 %tile	95 %tile					
XXXXXXX	17.41	18.20	8.70	25.70	17.77	18.56	8.71	26.33	1.00	0.44	0.55	0.03	1.00
XXXXXXX	17.78	18.40	8.80	26.10	18.03	18.75	8.72	26.67	0.99	0.45	0.56	0.03	1.00
XXXXXXX	16.46	16.50	7.60	25.80	17.08	17.04	7.82	26.89	0.99	0.81	0.99	0.06	0.99
XXXXXXX	17.46	17.30	8.90	28.10	17.33	17.87	7.89	27.69	0.98	0.82	0.98	0.05	0.99
XXXXXXX	18.08	18.60	9.10	26.80	18.18	18.53	8.85	27.13	0.98	0.65	0.83	0.04	1.00
XXXXXXX	16.46	16.30	7.60	26.10	17.16	16.85	7.80	27.18	0.98	0.97	1.19	0.07	0.99
XXXX - Bottom	24.92	24.97	23.30	26.59	25.49	25.76	23.91	27.14	0.76	0.60	0.78	0.03	0.87
XXXX - Surface	24.87	24.95	23.03	26.59	25.37	25.46	23.78	27.09	0.87	0.52	0.64	0.03	0.92
XXXX - Bottom	26.54	26.92	24.42	27.92	26.55	26.69	24.62	27.62	0.36	0.73	0.87	0.03	0.76
XXXX - Surface	25.24	25.37	23.56	27.09	25.85	25.96	24.44	27.36	0.86	0.63	0.73	0.03	0.88
XXXX - Bottom	27.35	28.20	24.13	28.67	27.08	27.22	25.74	27.86	0.52	1.04	1.11	0.04	0.70
XXXX - Surface	26.90	27.38	24.16	28.65	27.11	27.46	25.54	28.30	0.66	0.72	0.88	0.03	0.84
XXXX - Bottom	24.54	24.60	22.68	26.16	25.00	25.00	23.24	26.69	0.94	0.46	0.53	0.02	0.94

Figure 5-7 Water temperature time series comparison at Project station XXX and USGS station XXXXXXX for the period 01/01/2013 – 04/30/2014

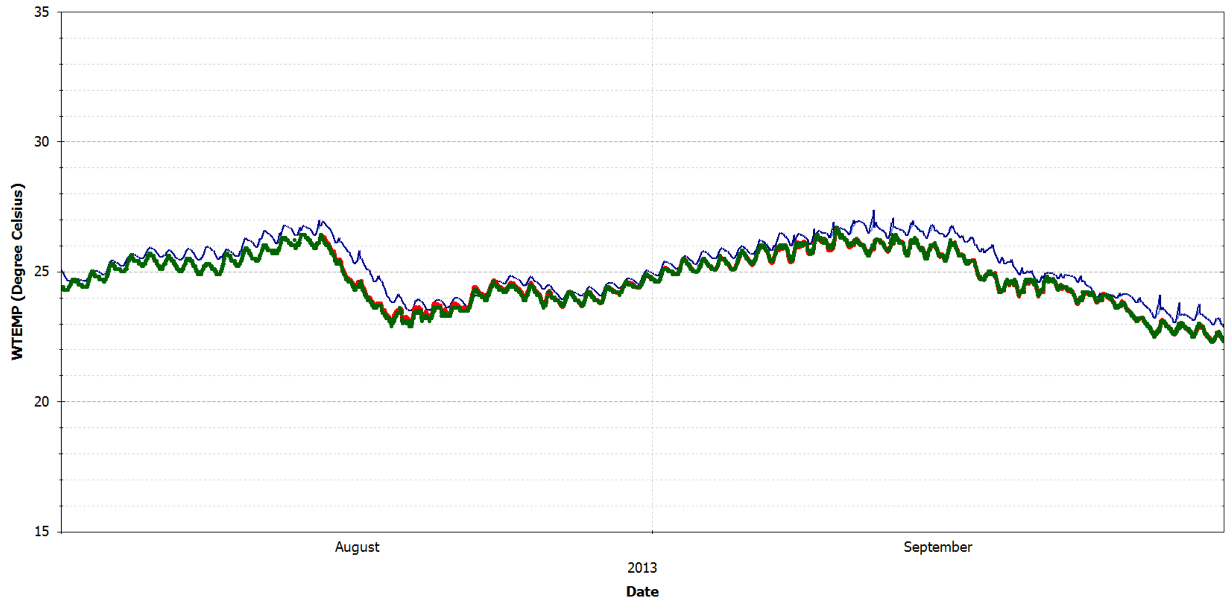

Figure 5-8 Water temperature time series comparison at Project station XXX and USGS station XXXXXXX for the period 08/01/2013 – 09/30/2013

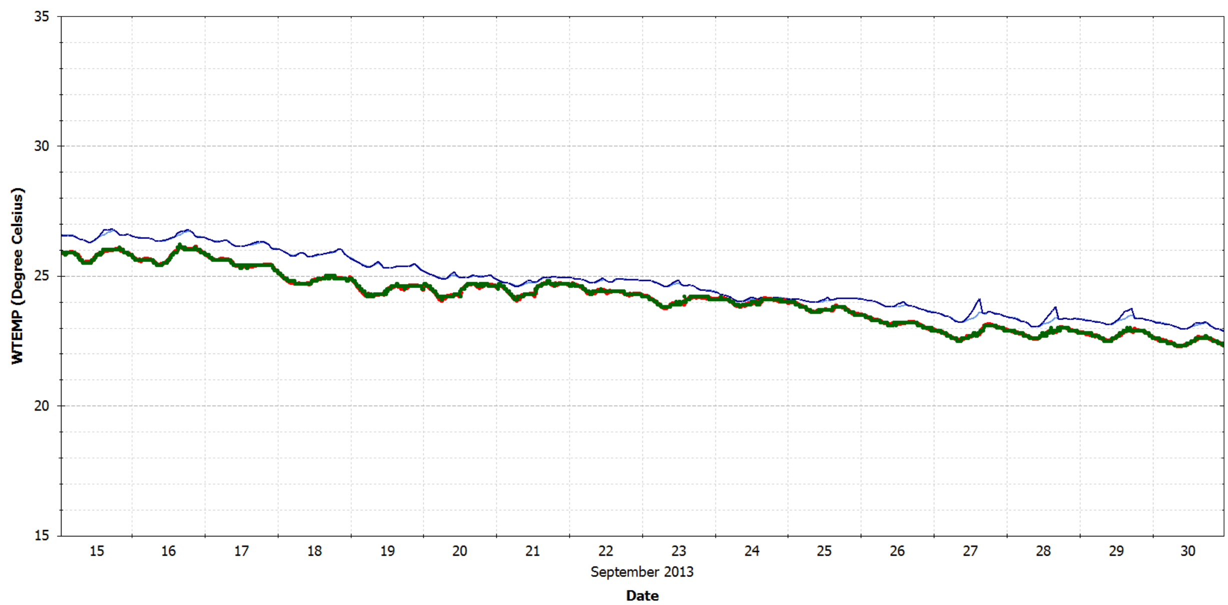

Figure 5-9 Water temperature time series comparison at Project station XXX and USGS station XXXXXXX for the period for the period 09/15/2013 – 09/30/2013

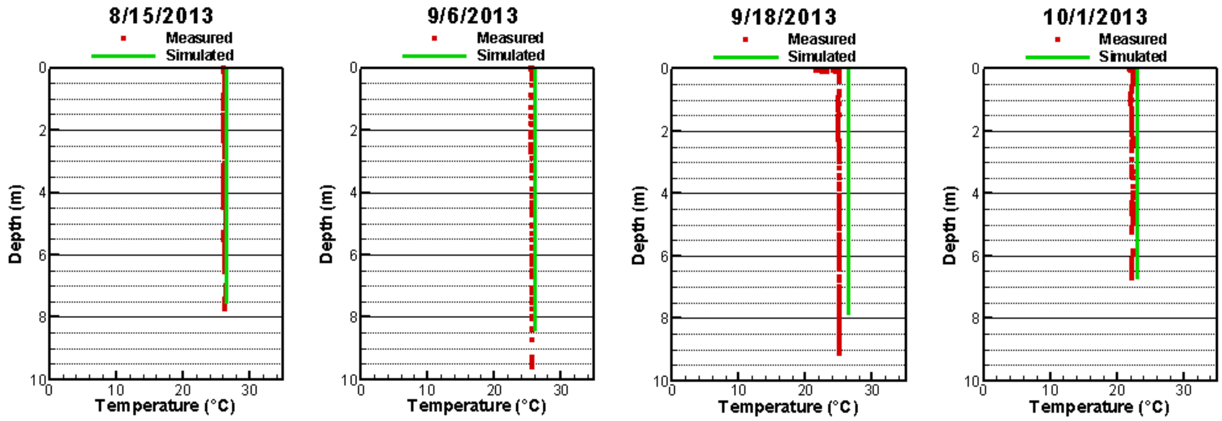

Figure 5-10 Water temperature vertical profiles comparison at Project station XXX

5.4.5 *Salinity*

Table 5-4 Model salinity calibration statistics from January 1, 2013 through April 30, 2014 for the USGS stations and August 15, 2013 through October 1, 2013 for the Project stations

Station ID	Measured (PSU)				Simulated (PSU)				R^2	MAE (PSU)	RMSE (PSU)	Norm RMSE	Index of Agrmt
	Mean	Median	5 %tile	95 %tile	Mean	Median	5 %tile	95 %tile					
XXXXXXX	0.05	0.05	0.04	0.06	0.01	0.00	0.00	0.05	0.54	0.04	0.05	1.80	0.48
XXXXXXX	2.69	1.32	0.04	10.30	2.36	2.01	0.07	6.69	0.83	1.12	1.78	0.48	0.90
XXXXXXX	6.27	6.41	0.67	13.50	9.88	10.91	0.82	17.16	0.71	3.70	4.46	0.50	0.79
XXXX - Bottom	1.12	0.06	0.03	8.23	1.77	0.19	0.00	10.53	0.57	1.13	2.29	0.76	0.86
XXXX - Surface	0.39	0.05	0.03	2.34	0.76	0.16	0.00	3.63	0.37	0.57	1.13	1.12	0.72
XXXX - Bottom	11.48	11.29	1.14	23.10	14.25	15.79	0.18	22.82	0.41	4.93	5.78	0.42	0.76
XXXX - Surface	4.34	4.52	0.61	8.10	4.74	5.11	0.98	8.69	0.69	1.13	1.44	0.29	0.90
XXXX - Bottom	27.31	28.63	20.19	32.38	29.65	30.66	22.86	32.25	0.44	2.82	3.65	0.13	0.70
XXXX - Surface	16.26	16.28	8.76	25.02	17.08	18.45	7.13	24.82	0.76	2.22	2.89	0.17	0.93
XXXX - Bottom	0.04	0.04	0.03	0.04	0.00	0.00	0.00	0.00	0.01	0.04	0.04	107.86	0.00

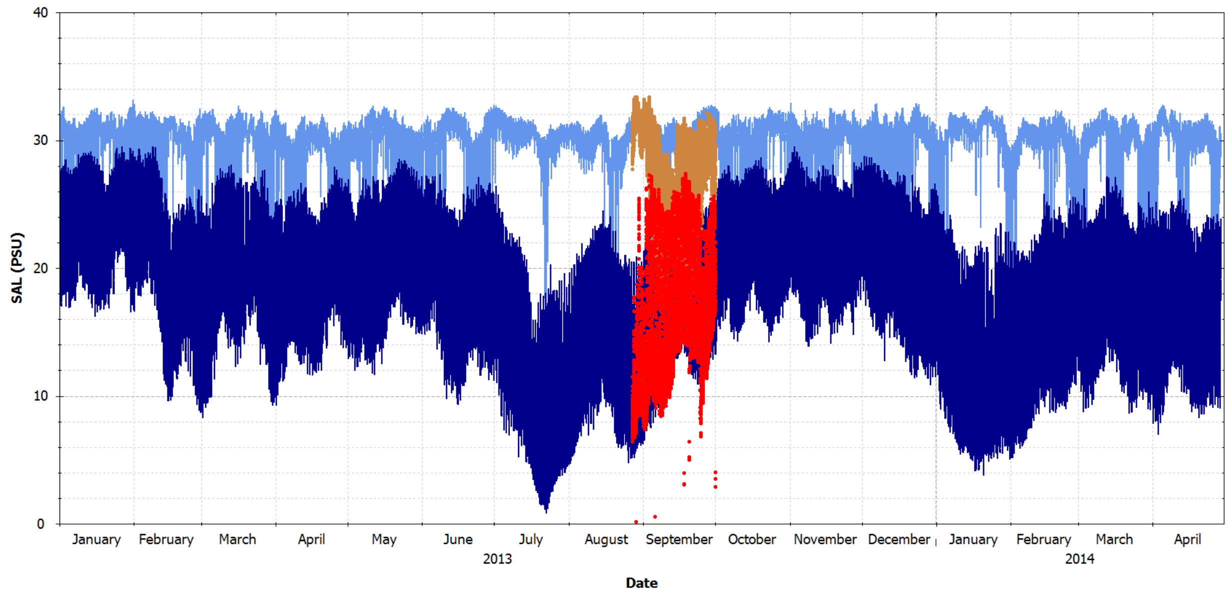

Figure 5-11 Salinity time series comparison at Project station XXX for the period 01/01/2013 – 04/30/2014

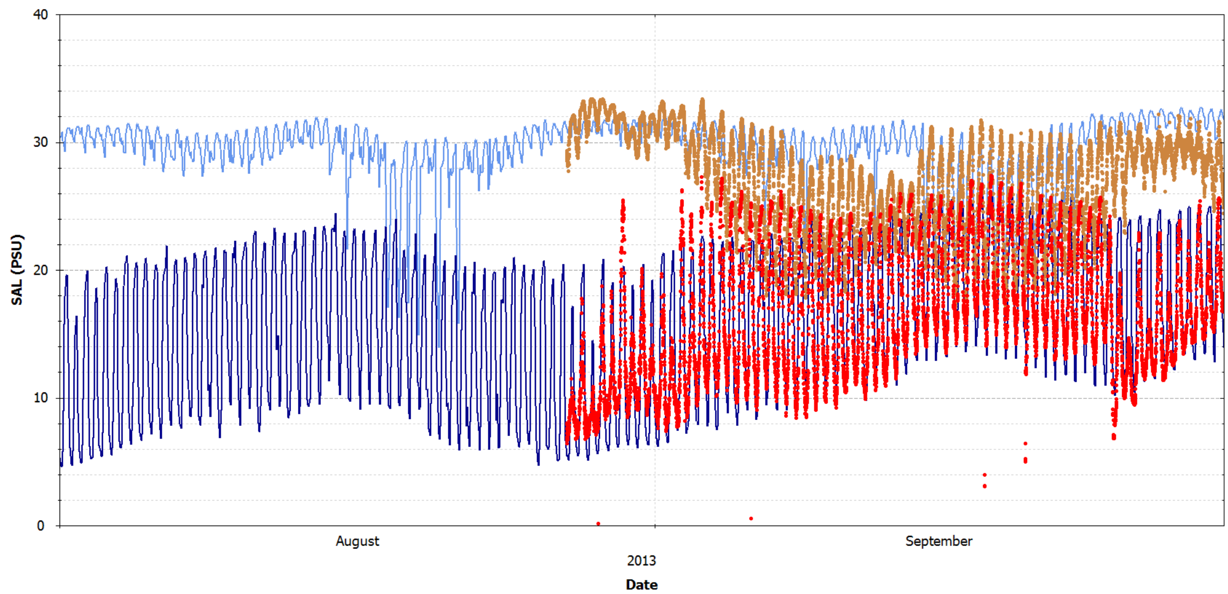

Figure 5-12 Salinity time series comparison at Project station XXX for the period 08/01/2013 – 09/30/2013

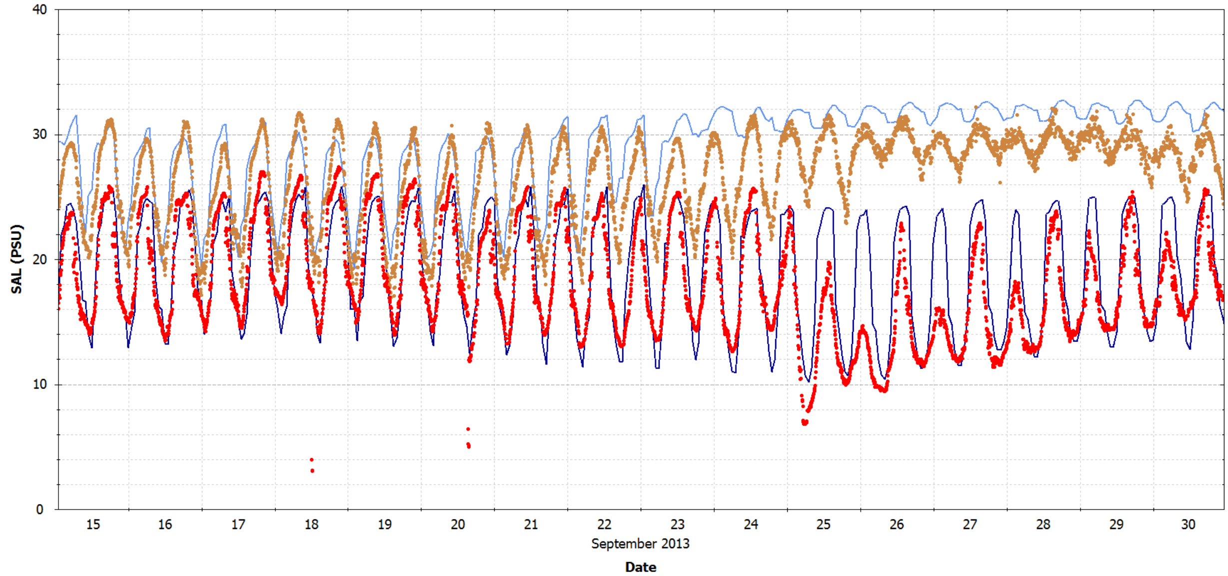

Figure 5-13 Salinity time series comparison at Project station XXX for the period 09/15/2013 – 09/30/2013

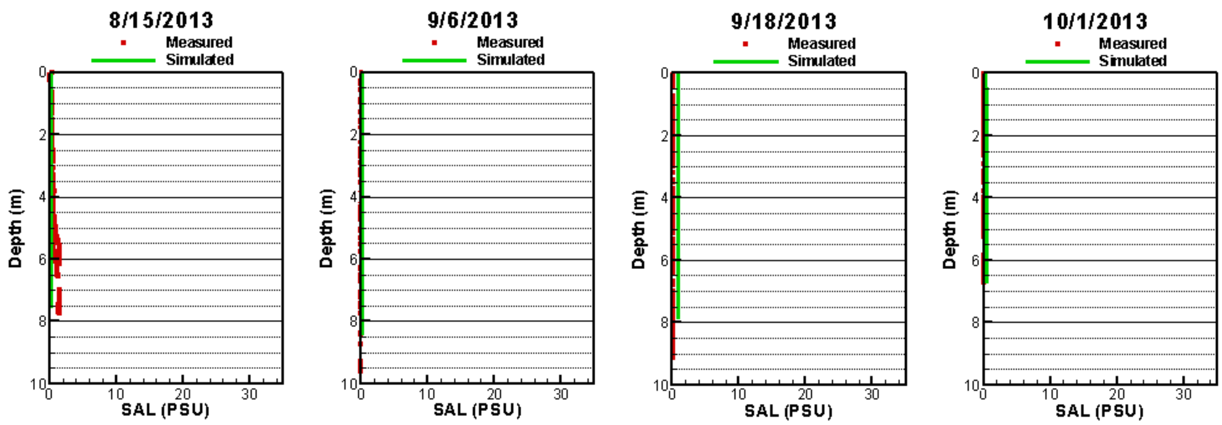

Figure 5-14 Salinity vertical profiles comparison at Project station XXX

5.5 EFDC Water Quality Calibration

5.5.1 *Calibration Methodology*

5.5.2 *BOD*

5.5.3 *Nitrogen*

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5.5.5 *Chlorophyll-a*

6.0 SUMMARY AND CONCLUSIONS

7.0 REFERENCES

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APPENDIX A: HSPF MODEL CALIBRATION RESULTS

APPENDIX B: EFDC MODEL CALIBRATION RESULTS