Final Report

Dissolved Oxygen TMDLs for the S-4 Basin, C-19 Canal, Lake Hicpochee, Long Hammock Creek, and Townsend Canal (WBIDs 3246, 3237E, 3237C, 3237B, and 3235L)

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Executive Summary

This report presents the total maximum daily loads (TMDLs) developed to address the dissolved oxygen (DO) impairments of the S-4 Basin, C-19 Canal, Lake Hicpochee, Long Hammock Creek, and Townsend Canal, all of which are tributaries to the Caloosahatchee River, located in the Caloosahatchee Basin. The Caloosahatchee River originates as the C-43 Canal at Lake Okeechobee. The channelized river flows from the lake control structure (S-77) predominantly east to west before discharging into the Gulf of Mexico at San Carlos Bay.

The waterbodies addressed in this report were identified as impaired based on DO concentration (in milligrams per liter) and DO (percent saturation) and were added to the Verified List of impaired waters by Secretarial Order in June 2005, January 2010, and October 2016. TMDLs for DO have been developed in accordance with Section 303(d) of the Federal Clean Water Act and guidance developed by the U.S. Environmental Protection Agency. **Table EX-1** lists supporting information for the TMDLs.

Table EX-1. Summary of TMDL supporting information for the Caloosahatchee River Tributaries

Type of Information	Description
Waterbody name (WBID number)	S-4 Basin (3246), C-19 Canal (3237E), Lake Hicpochee (3237C), Long Hammock Creek (3237B), Townsend Canal (3235L)
Hydrologic Unit Code (HUC) 8	03090205
Use classification/ Waterbody designation	Class III Freshwater Streams
Targeted beneficial uses	Fish consumption, recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife
303(d) listing status	Verified List of impaired waters for the Group 3 basins (Caloosahatchee) adopted via Secretarial Order dated June 17, 2005; January 15, 2010; and October 21, 2016
TMDL pollutants	Total nitrogen (TN), total phosphorus (TP), and biochemical oxygen demand (BOD)
TMDLs	**TN (pounds per year [lbs/yr])** **S-4 Basin:** 430,844; **C-19 Canal:** 78,114; **Lake Hicpochee:** 4,175,743; **Long Hammock Creek:** 330,381; **Townsend Canal:** 300,564, expressed as a 7-year rolling average load not to be exceeded. **TP (lbs/yr)** **S-4 Basin:** 28,622; **C-19 Canal:** 5,167; **Lake Hicpochee:** 227,423; **Long Hammock Creek:** 25,384; **Townsend Canal:** 28,749, expressed as a 7-year rolling average load not to be exceeded. **BOD (lbs/yr)** **S-4 Basin:** 664,946; **C-19 Canal:** 186,354; **Lake Hicpochee:** 5,768,701; **Long Hammock Creek:** 773,946; **Townsend Canal:** 673,151, expressed as a 7-year rolling average load not to be exceeded.

Type of Information	Description
Load reductions required to meet the TMDLs (TMDL model period from 2008 to 2014)	**S-4 Canal:** A 23 % reduction in TN, a 27 % reduction in TP, and a 28 % reduction in BOD. **C-19 Canal:** A 48 % reduction in TN, a 48 % reduction in TP, and a 48 % reduction in BOD. **Lake Hicpochee:** A 2 % reduction in TN, a 2 % reduction in TP, and a 3 % BOD reduction in BOD. **Long Hammock Creek:** A 42 % reduction in TN, a 42 % reduction in TP, and a 42 % reduction in BOD. **Townsend Canal:** A 37 % reduction in TN, a 38 % reduction in TP, and a 37 % reduction in BOD.

Acknowledgments

This analysis was accomplished thanks to significant contributions from staff in the Florida Department of Environmental Protection (DEP) Division of Environmental Assessment and Restoration, specifically, the Office of Watershed Services, Watershed Assessment Section, Standards Development Section, Water Quality Restoration Program, South Regional Operations Center, and Watershed Evaluation and TMDL Section.

Special acknowledgment is due to Dr. Amie West, formerly at DEP, who was involved in the bulk of the TMDL modeling effort, and to the multiple contributors from Tetra Tech, who provided invaluable expertise in all stages of model development, calibration, and implementation.

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Chapter 1: Introduction

1.1 Purpose of Report

This report presents the total maximum daily loads (TMDLs) developed to address the dissolved oxygen (DO) impairments of the S-4 Basin, C-19 Canal, Lake Hicpochee, Long Hammock Creek, and Townsend Canal, all located in the Caloosahatchee River Basin. Specifically, these are tributaries to the Caloosahatchee River, comprising the entirely freshwater portion of the river/C-43 Canal above the Franklin Lock (S-79), where the river then transitions to a tidal estuary. The waterbodies were verified as impaired for DO with nutrients as the causative pollutant, using the methodology in the Identification of Impaired Surface Waters Rule (IWR) (Chapter 62-303, Florida Administrative Code [F.A.C.]).

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody so that it can still meet water quality standards, identifies the sources of the pollutant, and provides water quality targets needed to achieve compliance with applicable water quality criteria based on the relationship between pollutant sources and water quality in the receiving waterbody. The TMDLs establish the allowable loadings to the S-4 Basin, C-19 Canal, Lake Hicpochee, Long Hammock Creek, and Townsend Canal that would restore these waterbodies so that they meet the applicable water quality criterion for DO.

1.2 Identification of Waterbodies

For assessment purposes, the Florida Department of Environmental Protection (DEP) divided the Caloosahatchee River Basin (Hydrologic Unit Code [HUC] 8: 03090205) into watershed assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or surface water segment. The S-4 Basin is WBID 3246, the C-19 Canal is WBID 3237E, Lake Hicpochee is WBID 3237C, Long Hammock Creek is WBID 3237B, and Townsend Canal is WBID 3235L. **Figure 1.1** shows the location of the WBIDs in the basin, and **Figure 1.2** provides a closer view of the WBIDs along with the major geopolitical and hydrologic features in the region.

The 70-mile-long Caloosahatchee River originates as the C-43 Canal at Lake Okeechobee. The channelized river flows from the lake control structure (S-77) predominantly east to west before discharging into the Gulf of Mexico at San Carlos Bay (**Figure 1.1**). With its primary channel 150 feet wide and 25 feet deep, the C-43 Canal was constructed to provide both a navigable shipping canal and drainage conveyance capacity.

The canal system is designed to maintain upstream water levels, with water flow in the Caloosahatchee River/C-43 Canal principally controlled by the U.S. Army Corps of Engineers (USACE) via three control structures: from Lake Okeechobee through the Moore Haven Lock (S-77), downstream though the Orton Lock (S-78), and finally entering the Lower

Caloosahatchee River through the Franklin Lock (S-79). **Figure 1.3** shows the location of these structures.

Segments of the Caloosahatchee River downstream of S-79 are tidally influenced, but all the waterbodies above S-79 are not. The WBIDs discussed in this report are freshwater tributaries to the Caloosahatchee River located upstream of the S-79 structure.

Moving from upstream to downstream along the Caloosahatchee River after its origin at the S-77 lock, the first major tributary of the Caloosahatchee/C-43 Canal are the canals draining the S-4 Basin (WBID 3246). Situated south of the Caloosahatchee River, the S-4 Basin consists of a series of irrigation and drainage canals that service farmland adjacent to the southwest corner of Lake Okeechobee. The large canals in the S-4 Basin include Disston Main Canal, Flaghole Canal, L-1 Canal, portions of Ninemile Canal, and the Industrial Canal that runs follows the perimeter of Lake Okeechobee. Water from the S-4 Basin enters the main Caloosahatchee/C-43 Canal above Lake Hicpochee. The flow of water in the S-4 Basin is actively managed through a complex series of gates and pump stations. Water from Lake Okeechobee can also enter the S-4 Basin through the Industrial Canal via the S-310 lock and through seepage under the levee.

The next downstream tributary is the C-19 Canal (WBID 3237E), which drains agricultural land on the western side of Lake Okeechobee north of the Caloosahatchee/C-43 Canal. This is the only tributary waterbody discussed in this report located on the north side of the Caloosahatchee.

Lake Hicpochee (WBID 3237C), a naturally occurring lake, was bisected by the dredging of the Gulf Coast Canal by the developer, Hamilton Disston, from 1881 to 1888. This massive drainage project connected the Caloosahatchee River with Lake Okeechobee and was followed by subsequent federal projects aimed at improving the navigability of the Caloosahatchee.

The creation of the C-43 Canal divided the lake into two marsh areas on either side of the canal. Historically, Hicpochee was a shallow lake, and its surrounding wetlands were the primary source of the Caloosahatchee River. Because of the large volume of through-flow and the relatively short retention time, DEP assesses Lake Hicpochee as a flowing stream rather than as a lake.

The South Florida Water Management District (SFWMD) is currently completing Phase I of the Lake Hicpochee Shallow Storage and Hydrologic Enhancement Project, which will increase water storage, restore more natural peripheral wetland function, and provide hydrologic enhancement to further the goals of the Northern Everglades and Estuaries Protection Program (NEEPP). These modifications are expected to ultimately improve water quality both in Lake Hicpochee and in downstream waters. The first phase of the project entails the construction of a 6,500-foot-long spreader canal and the construction of a 670-acre flow equalization basin on the north side of Lake Hicpochee. Phase I is expected to be completed by spring 2019.

Long Hammock Creek (WBID 3237B) is a set of three primary canals (Canal 3, 42-foot Canal, and Hilliard Canal) that drains farmland and discharges into the Caloosahatchee River from the south. The canals discharge to the Caloosahatchee River/C-43 Canal immediately downstream of Lake Hicpochee.

Townsend Canal (WBID 3235L), the farthest downstream (farthest west) segment of the impaired waterbodies, flows north through agricultural land on the south side of the Caloosahatchee River and discharges downstream of the City of Labelle above the Franklin Lock (S-79).

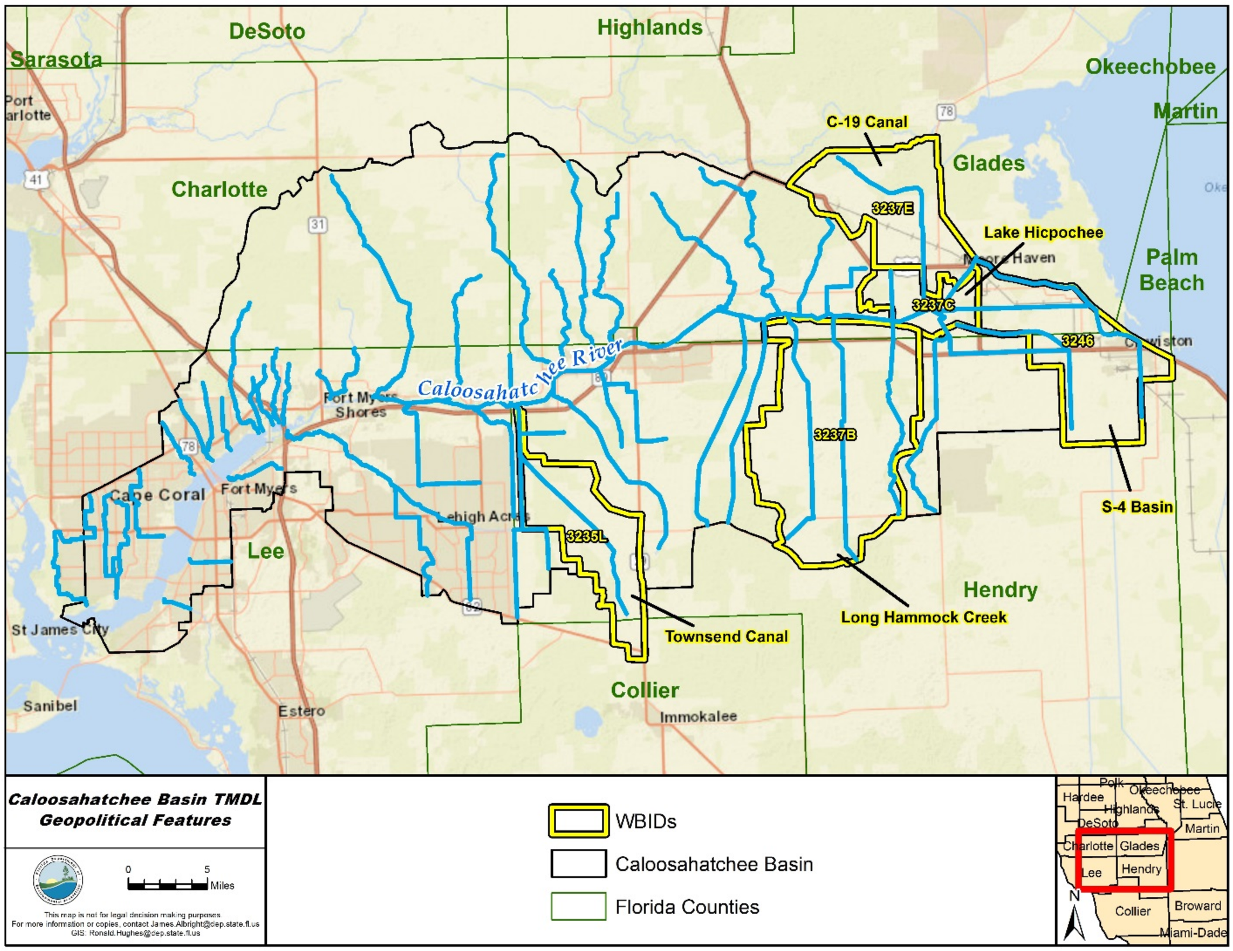

Figure 1.1. Overview map showing the location of the S-4 Basin (WBID 3246), C-19 Canal (WBID 3237E), Lake Hicpochee (WBID 3237C), Long Hammock Creek (WBID 3237B), and Townsend Canal (WBID 3235L) in the greater Caloosahatchee River Basin

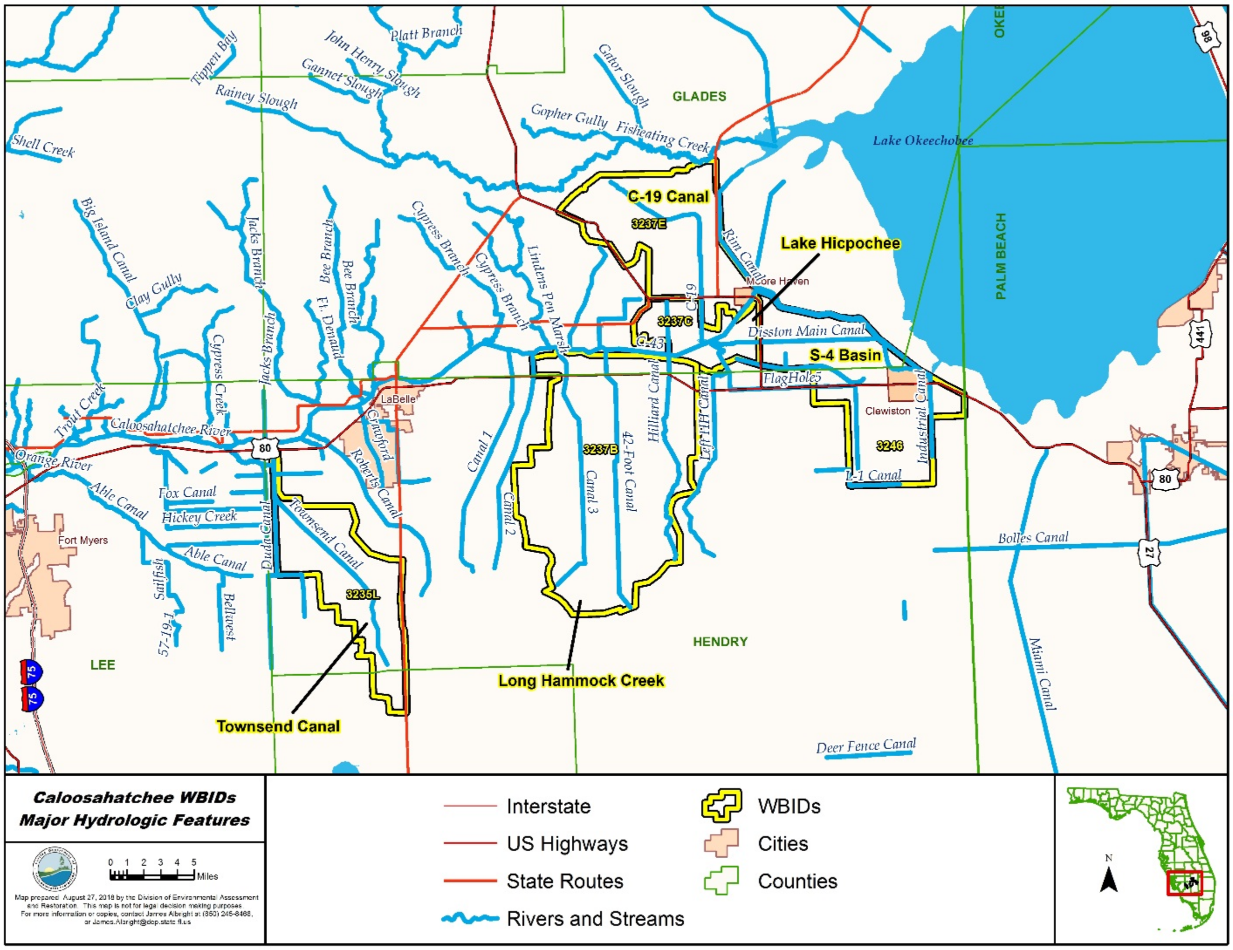

Figure 1.2. S-4 Basin (WBID 3246), C-19 Canal (WBID 3237E), Lake Hicpochee (WBID 3237C), Long Hammock Creek (WBID 3237B), and Townsend Canal (WBID 3235L) and major hydrologic and geopolitical features in the area

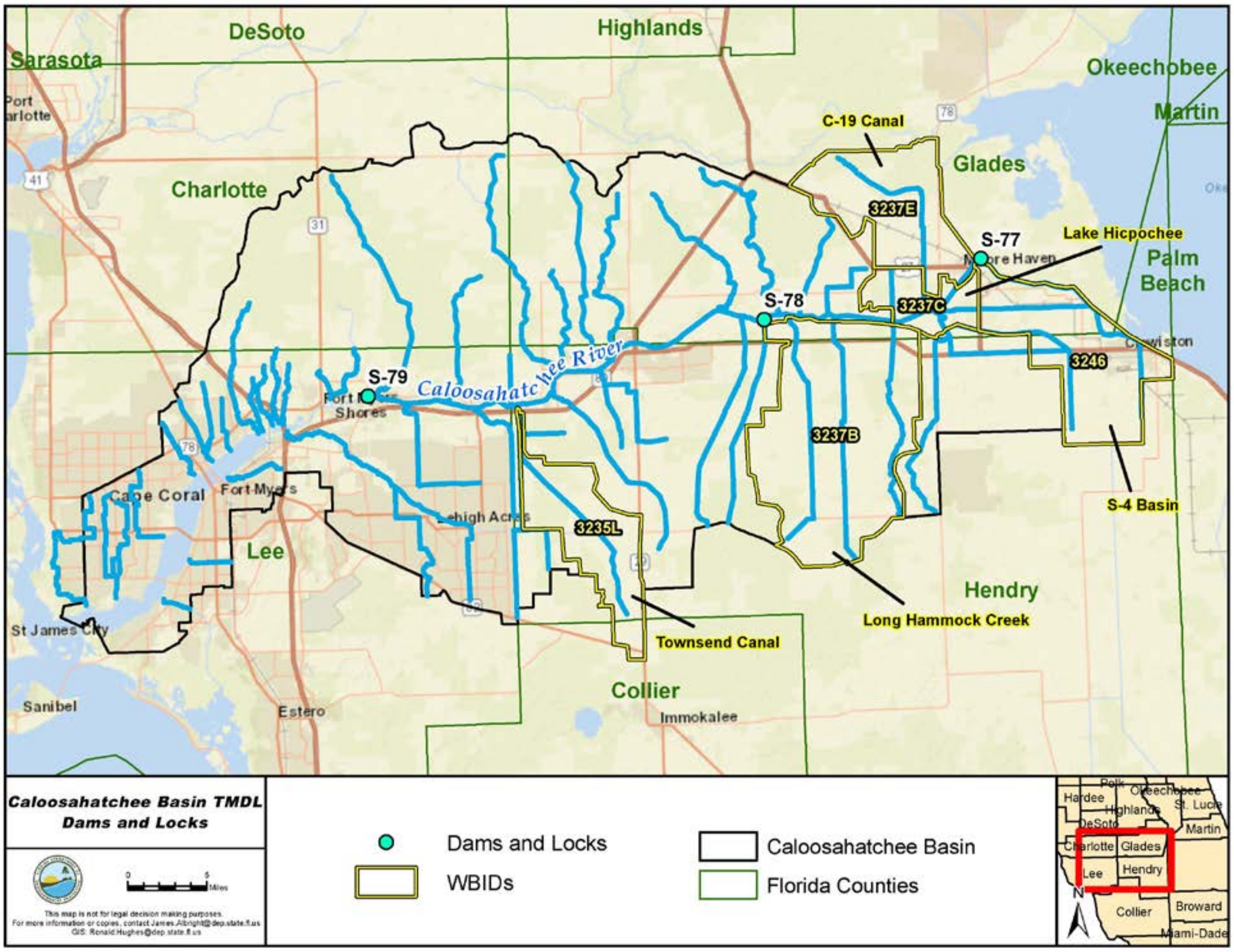

Figure 1.3. Lock control structures on the Caloosahatchee River/C-43 Canal. From upstream to downstream, these are S-77 (Moore Haven Lock), S-78 (Ortona Lock), and S-79 (Franklin Lock).

The five WBIDs included in this TMDL include the principal waterbodies located within the area of each WBID. The C-19 Canal, Lake Hicpochee, and Townsend Canal waterbodies are the same as their eponymous WBID names. The S-4 Basin and Long Hammock Creek contain multiple canals with different names which are highlighted in **Table 1.1.**

Table 1.1. Waterbodies located within each WBID

Waterbody (WBID)	Waterbodies Located Within Each WBID
S-4 Basin (3246)	Disston Main Canal, Flaghole Canal, Industrial Canal, L-1 Canal, Ninemile Canal
C-19 Canal (3237E)	C-19 Canal
Lake Hicpochee (3237C)	Lake Hicpochee
Long Hammock Creek (3237B)	Canal 3, 42-Foot Canal, Hilliard Canal
Townsend Canal (3235L)	Townsend Canal

1.3 Watershed Information

1.3.1 Population and Geopolitical Setting

The Caloosahatchee River Basin encompasses large portions of Glades, Hendry, Charlotte, and Lee Counties, along with a small piece of Collier County in the upstream (southern) portion of Townsend Canal. The basin is split between Glades and Hendry Counties. As of the 2010 Census, the population of Glades County was 12,884, with a density of 16 individuals per square mile; the population of Hendry County was 39,140, with a density of 34 individuals per square mile; and the population of Collier County was 321,520, with a density of 160 individuals per square mile (U.S. Census Bureau 2010).

The population densities in the Upper (East Northeast) Caloosahatchee River Basin are relatively low, with most of the area rural and agricultural. The main population centers in the basin are the Towns of Moore Haven, located in the C-19 Canal WBID, and Clewiston, in the S-4 WBID (see **Figure 1.2**). Moore Haven, the Glades County seat, has a population of 1,680 and a density of 1,508 people per square mile (U.S. Census Bureau 2010). Clewiston, located in Hendry County, southwest of Lake Okeechobee, has a population of 7,155 and a density of 1,524 people per square mile (U.S. Census Bureau 2010). Higher population densities are found downstream of the freshwater tributaries discussed in this report, specifically in the tidal portion of the Caloosahatchee River where the major cities of Fort Myers and Cape Coral are located.

1.3.2 Topography

The greater Caloosahatchee River Basin is situated in southwest Florida, south of the terminus of the Lake Wales Ridge, and bounded by Lake Okeechobee to the east, San Carlos Bay to the west, and the western Everglades to the south. The area has relatively low relief and gradual elevation changes. Most of the drainage area lies within 20 feet above sea level.

Chapter 2: Description of Applicable Water Quality Standards and Pollutants of Concern

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act (CWA) requires states to submit to the U.S. Environmental Protection Agency (EPA) lists of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. DEP has developed such lists, commonly referred to as 303(d) lists, since 1992.

The Florida Watershed Restoration Act (FWRA) (Section 403.067, Florida Statutes [F.S.]) directed DEP to develop, and adopt by rule, a science-based methodology to identify impaired waters. The Environmental Regulation Commission adopted the methodology as Chapter 62-303, F.A.C. (the IWR), in 2001. The rule was most recently amended in 2016.

The list of impaired waters in each basin, referred to as the Verified List of impaired waters (or Verified List), is also required by the FWRA (Subsection 403.067[4], F.S.). The state's 303(d) list is amended periodically to include basin updates.

2.2 Classification of the Waterbodies and Applicable Water Quality Standards

The S-4 Basin, C-19 Canal, Lake Hicpochee, Long Hammock Creek, and Townsend Canal are Class III (fresh) waterbodies, with a designated use of fish consumption, recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

The applicable Class III freshwater stream criterion for DO specifies that no more than 10 % of the daily average DO percent saturation values shall be below 38 % (Subparagraph 62-302.533[1][a]2., F.A.C.). The DO criterion also includes a natural background provision, which states that if it is determined that the natural background DO saturation in the waterbody (including values that are naturally low because of vertical stratification) is less than the applicable criterion listed above, then the applicable criterion shall be 0.1 milligram per liter (mg/L) below the DO concentration associated with the natural background DO saturation level.

2.3 Determination of the Pollutant of Concern

2.3.1 Data Providers

The data providers for the Caloosahatchee Tributary WBIDs are DEP and SFWMD. Water quality and biological assessment results for the period of record (2003 to 2015 for the most recent assessment) for variables relevant to DEP's waterbody assessment, collected by both sampling entities, are available upon request and are provided in IWR Database Run 53.

Figures 2.1 through **2.5** show the water quality and biological (Linear Vegetation Survey [LVS]) data sampling locations in the WBIDs. The coverage of LVS sampling stations is critical because this metric is used to verify that there is an ecologically healthy floral community. Excessive vegetative growth, particularly of certain rooted aquatic plant species such as water lettuce (*Pistia stratiotes*), can be correlated with increased rates of organic sediment accumulation that contribute to benthic oxygen demand. Benthic oxygen demand is dominated by respiration by benthic organisms, primarily bacteria, and is a function of the biogeochemical cycling of organic matter in the sediment. Macrophytes, influenced by water column nutrient concentrations, and watershed-derived sediment contribute to benthic oxygen demand.

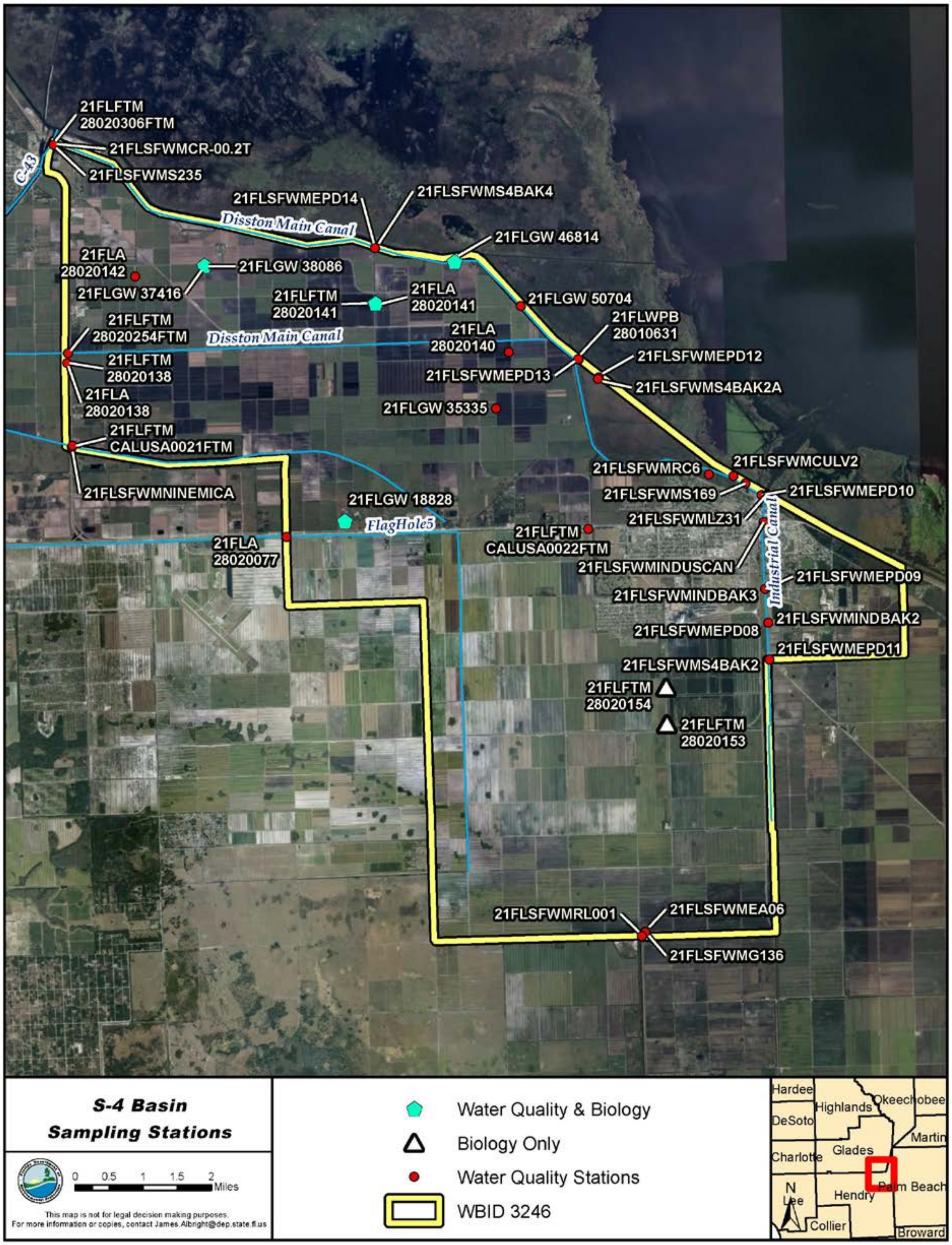

Figure 2.1. Sampling stations in the S-4 Basin (WBID 3246)

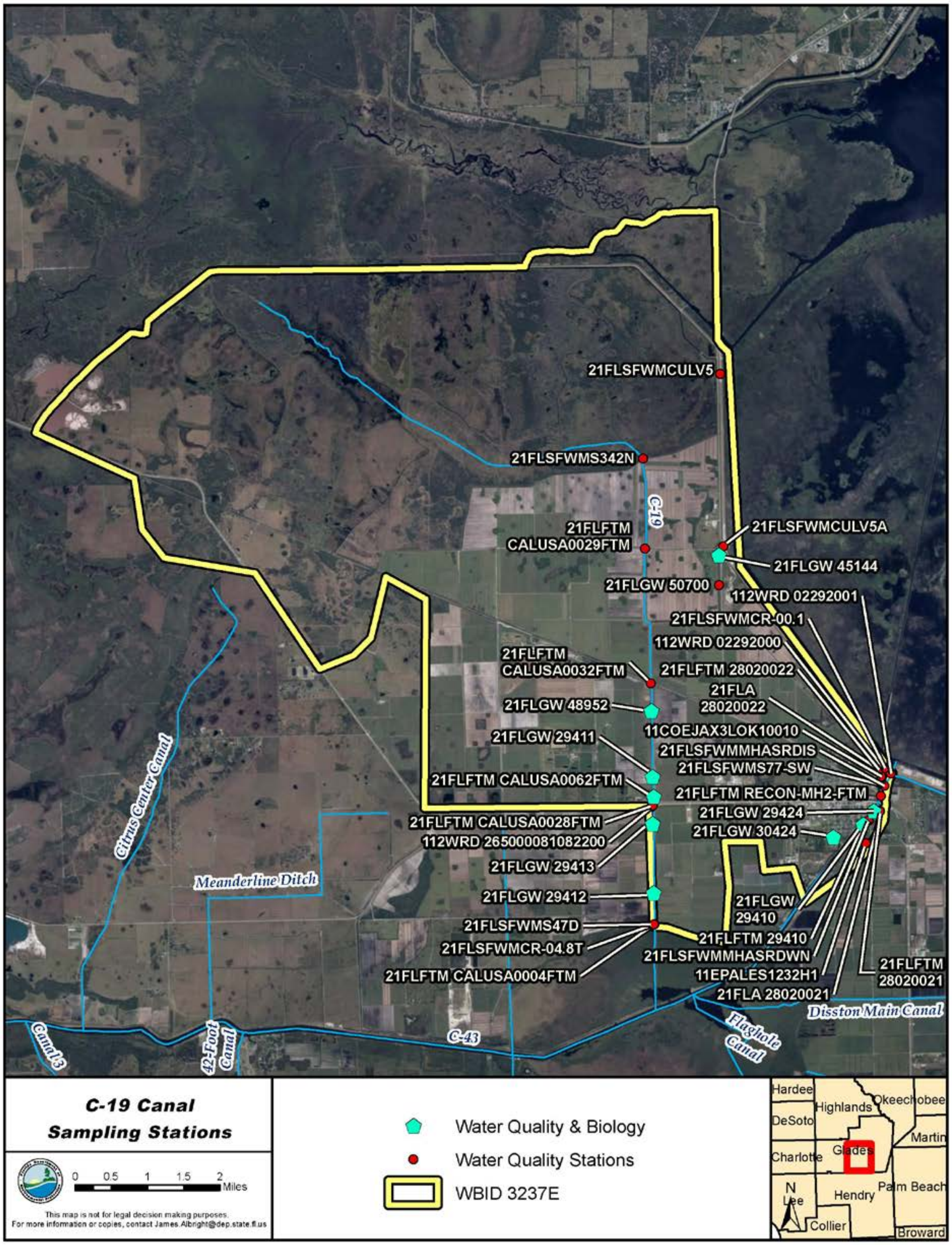

Figure 2.2. Sampling stations in C-19 Canal (WBID 3237E)

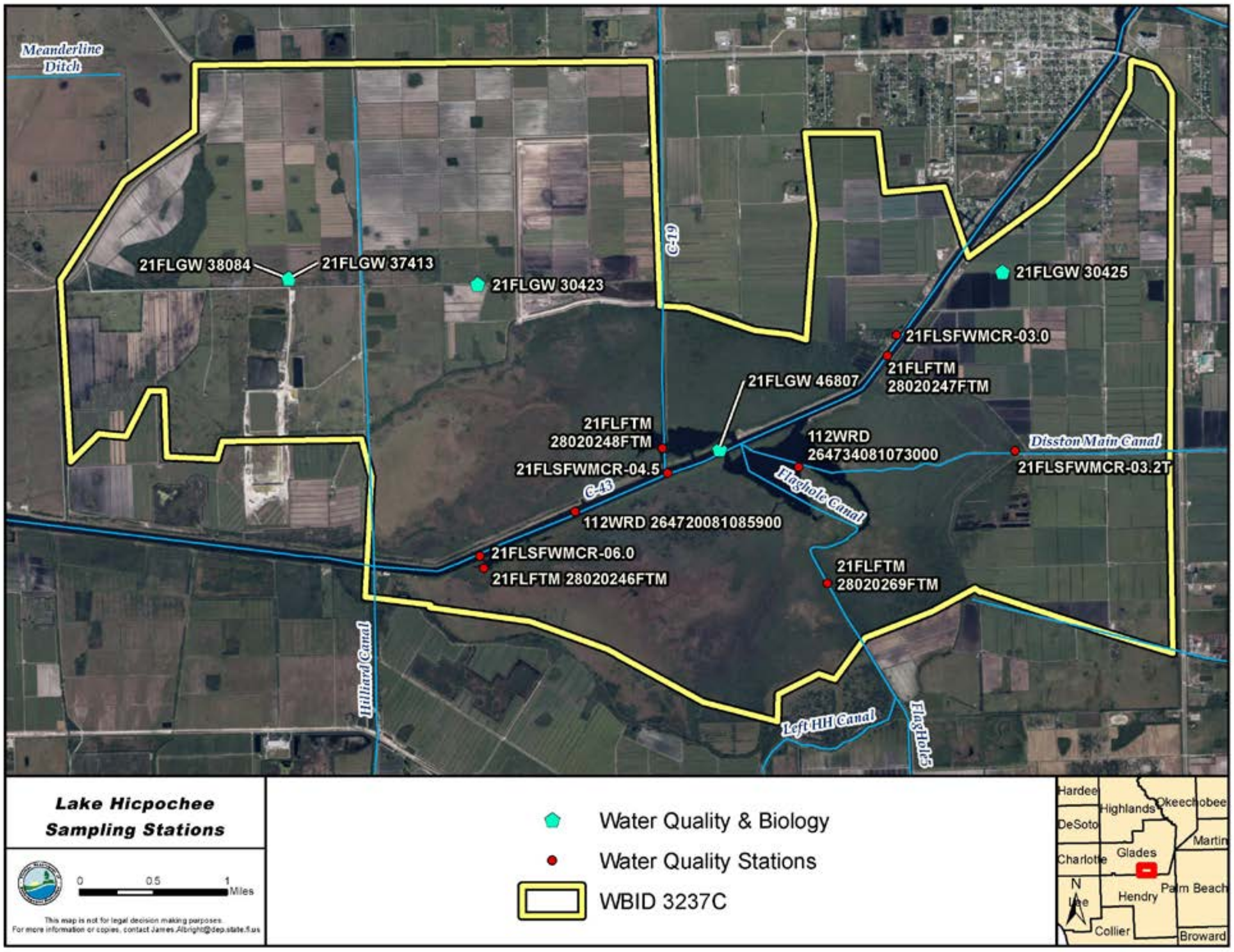

Figure 2.3. Sampling stations in Lake Hicpochee (WBID 3237C)

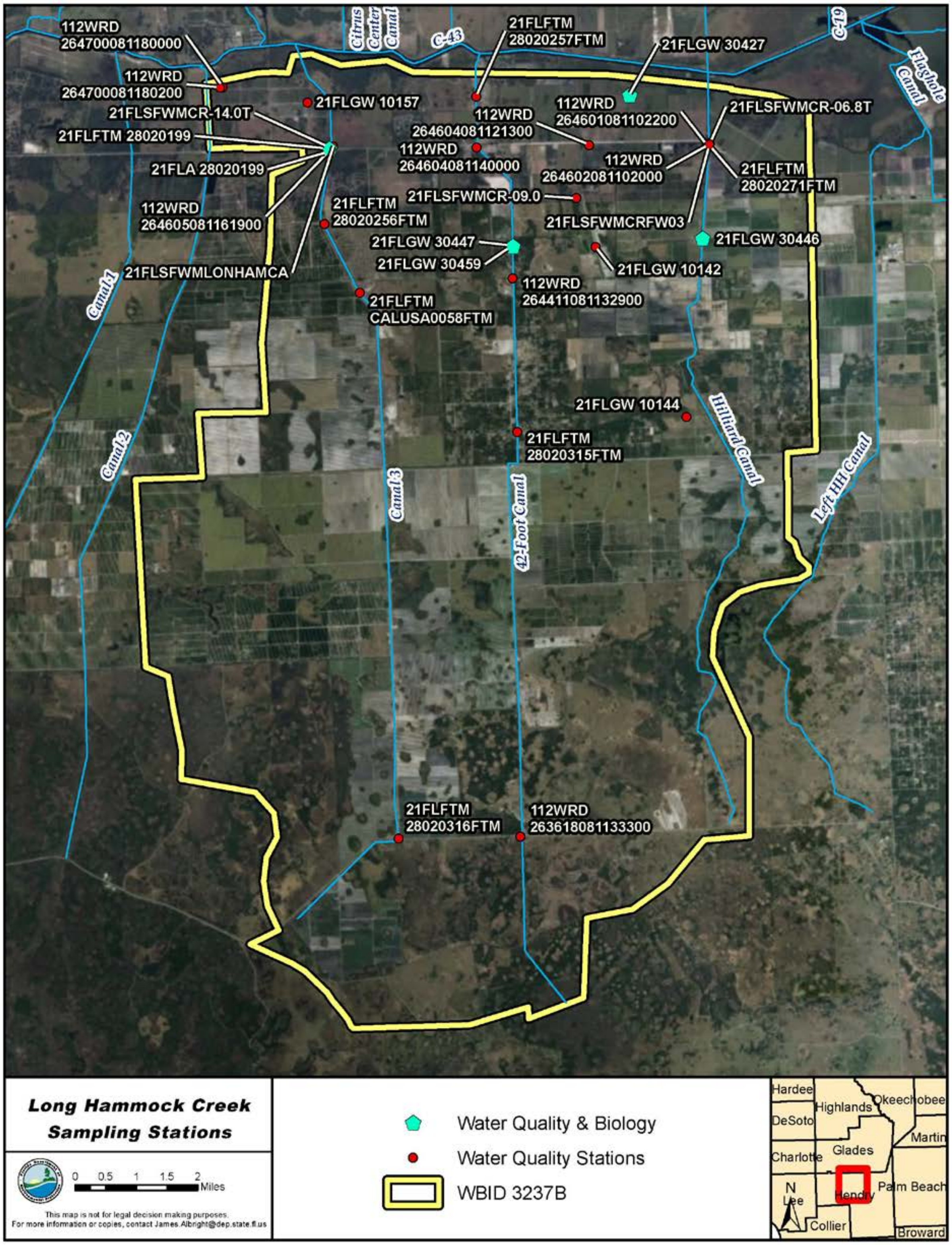

Figure 2.4. Sampling stations in Long Hammock Creek (WBID 3237B)

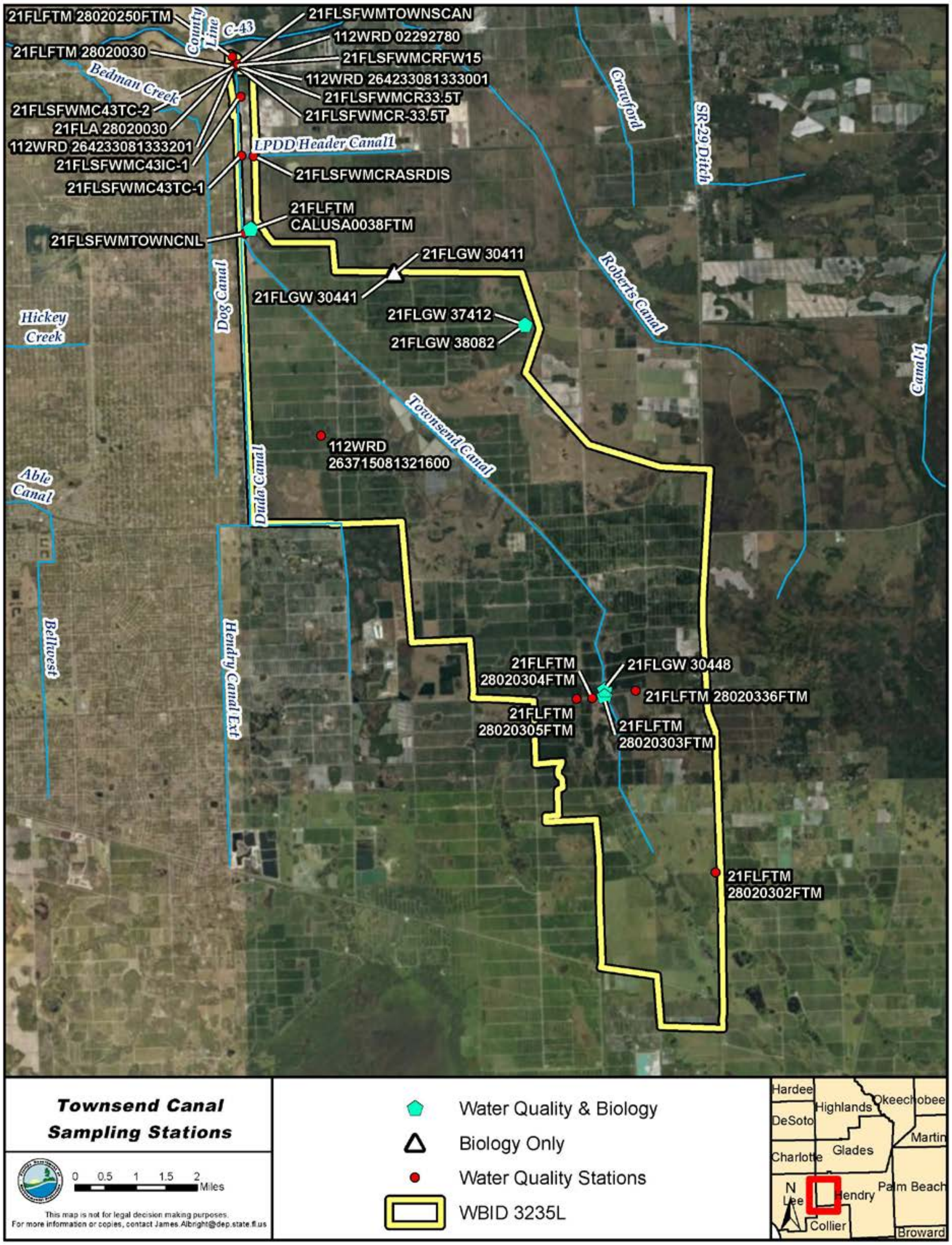

Figure 2.5. Sampling stations in Townsend Canal (WBID 3235L)

2.3.2 Information on Verified Impairment

As part of the statewide waterbody assessment process, each of Florida's major river basins is placed into one of five groups identified by number; the Caloosahatchee River Basin is in Group 3. These basin groups are evaluated every five years, and each five-year evaluation is assigned a cycle number. The data used in each of these assessments are from the seven and a half years prior to the assessment year. For the Group 3 basins, assessments were carried out in 2005 (Cycle 1), 2010 (Cycle 2), and 2016 (Cycle 3). The Cycle 1 assessment used data from January 1, 1997, to June 30, 2004; Cycle 2 used data from January 1, 2002, to June 30, 2009; and Cycle 3 used data from January 1, 2008, to June 30, 2015. The applicable DO criterion during the Cycle 1 and 2 assessments was expressed as mg/L. In Cycle 3, all waterbodies were reassessed using the revised DO criterion, which is expressed as percent saturation.

The waterbodies discussed in this document were included on the Verified List of impaired waters for the Caloosahatchee River Basin for DO impairments, and were adopted by Secretarial Order on June 17, 2005, for the Cycle 1 assessment; January 15, 2010, for the Cycle 2 assessment; and October 21, 2016, for the Cycle 3 assessment.

Regardless of the Cycle 1 and 2 assessments, all listed waterbodies were assessed under the DO percent saturation criterion (Subparagraph 62-302.533[1][a]2., F.A.C.), and were determined to be impaired using the procedures outlined in the IWR (Subparagraph 62-303.420[9], F.A.C.) including the appropriate time-of-day adjustments required for the DO percent saturation data analyses. **Table 2.1** summarizes the DO percent saturation data used in the Cycle 3 assessment. The water quality and biological data used in the assessment are available upon request.

Table 2.1. Summary of DO percent saturation assessment data used in the Cycle 3 assessment (number of total daily averages and number of excursions)

Waterbody (WBID)	Total Number of Daily Averages for Verified Period	Number of Daily Average Values Below 38 %
S-4 Basin (3246)	428	61
C-19 Canal (3237E)	255	67
Lake Hicpochee (3237C)	25	5
Long Hammock Creek (3237B)	49	11
Townsend Canal (3235L)	44	9

2.4 Downstream Protection

As described in **Section 1.2**, the S-4 Basin, C-19 Canal, Lake Hicpochee, Long Hammock Creek, and Townsend Canal discharge into the Caloosahatchee River, a Class III freshwater stream. None of the freshwater portions of the Caloosahatchee River/C-43 Canal downstream of Lake

Hicpochee is impaired for DO or nutrients. Because the reductions in contributing loads of total nitrogen (TN), total phosphorus (TP), and biochemical oxygen demand (BOD) under the TMDLs will reduce concentrations in the contributing waters to below the applicable TN and TP thresholds for peninsular streams, the TMDLs will be protective of the mainstem freshwater portion of the Caloosahatchee River.

The tidally influenced portions of the Caloosahatchee River downstream of S-79 are included in the Caloosahatchee Estuary TMDL (Bailey et al. 2009). These WBIDs are, from upstream to downstream, Caloosahatchee Tidal Segment 3 (WBID 3240C), Caloosahatchee Tidal Segment 2 (WBID 3240B), and Caloosahatchee Tidal Segment 1 (WBID 3240A). The existing Caloosahatchee Estuary TMDL requires a 22.8 % reduction in TN, while the total percent reduction in loading from all tributaries in this tributary TMDL is 26 %. In addition, the estuary TMDL did not include the reductions for TP or BOD required by the tributary TMDLs. These factors indicate that the reduced loads for nutrients and BOD contributed by the Caloosahatchee tributaries are protective of nutrient conditions in the Caloosahatchee Estuary.

Chapter 3: Assessment of Sources

3.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of the pollutant of concern in the target watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point sources or nonpoint sources. Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from septic systems; and atmospheric deposition.

However, the 1987 amendments to the CWA redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges, such as those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with CWA definitions, the term "point source" is used to describe traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 5.1** on **Expression and Allocation of the TMDL**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

3.2 Point Sources

3.2.1 Wastewater Point Sources

The City of Clewiston WWTF (FL 0040665), an NPDES facility located in the S-4 Basin (**Figure 3.1**), is included as a point source in the HSPF Model discussed in more detail in **Chapter 4**. The WWTF is a domestic wastewater plant permitted to discharge 1.5 million gallons per day (mgd) of treated effluent, annual average daily flow (AADF), to a slow-rate public access system for land application and irrigation use. The reuse system consists of 3 storage ponds with a total volume of 15 million gallons and 24 sprayfields with a total area of 193 acres. These fields are underdrained, and the underdrains discharge to Sugarland Drainage Ditch at Latitude 26° 43' 04" N, Longitude 80° 56' 37" W. The ditch runs east and immediately connects with a north–south canal identified as Canal Number 3. The canal ultimately discharges to the Industrial Canal, which in turn delivers water into the Caloosahatchee River/C-43 Canal.

The Glades County Correctional Wastewater Treatment Reuse Facility (FLA 016891) is located in the C-19 Canal WBID (**Figure 3.1**) and is included in the HSPF Model as a reuse facility. The Glades County Correctional Wastewater Facility is also a domestic wastewater plant and has a permitted discharge of 0.135 mgd to a 52-acre land application site that is isolated from surface waters by surrounding berms. It functions as a percolation pond and does not normally discharge to the Caloosahatchee River Basin. During TMDL development, wastewater treatment and reuse facilities in these WBIDs were evaluated and determined to have very low nutrient contributions.

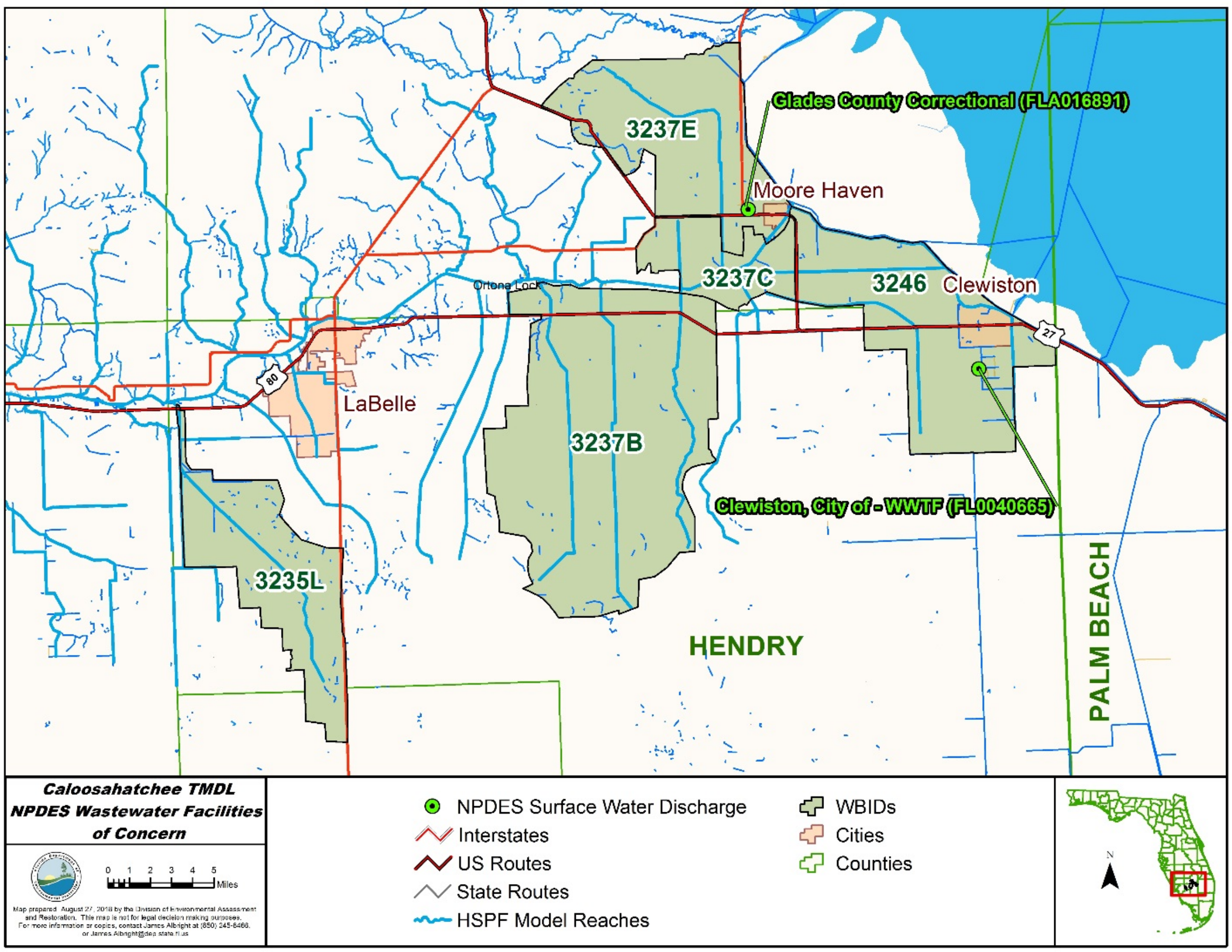

Figure 3.1. NPDES wastewater facilities in the tributary WBIDs

3.2.2 MS4 Permittees

The portion of the S-4 Basin located in the City of Clewiston is covered by the city's NPDES Phase II MS4 permit (FLR04E134). The C-19 Canal, Lake Hicpochee, and the northern portions of Long Hammock Creek and the S-4 Basin are included in Glades County's NPDES Phase II MS4 permit (FLR04E137). The remaining area of the S-4 Basin and Long Hammock Creek, along with the northern portion of Townsend Canal, are covered by Hendry County's NPDES Phase II MS4 permit (FLR04E138). Finally, the southern/upstream end of the Townsend Canal Watershed is covered by Collier County's NPDES MS4 Phase II permit (FLR04E037). **Figure 3.2** shows the boundaries of the MS4s in the Caloosahatchee River Basin TMDL WBIDs.

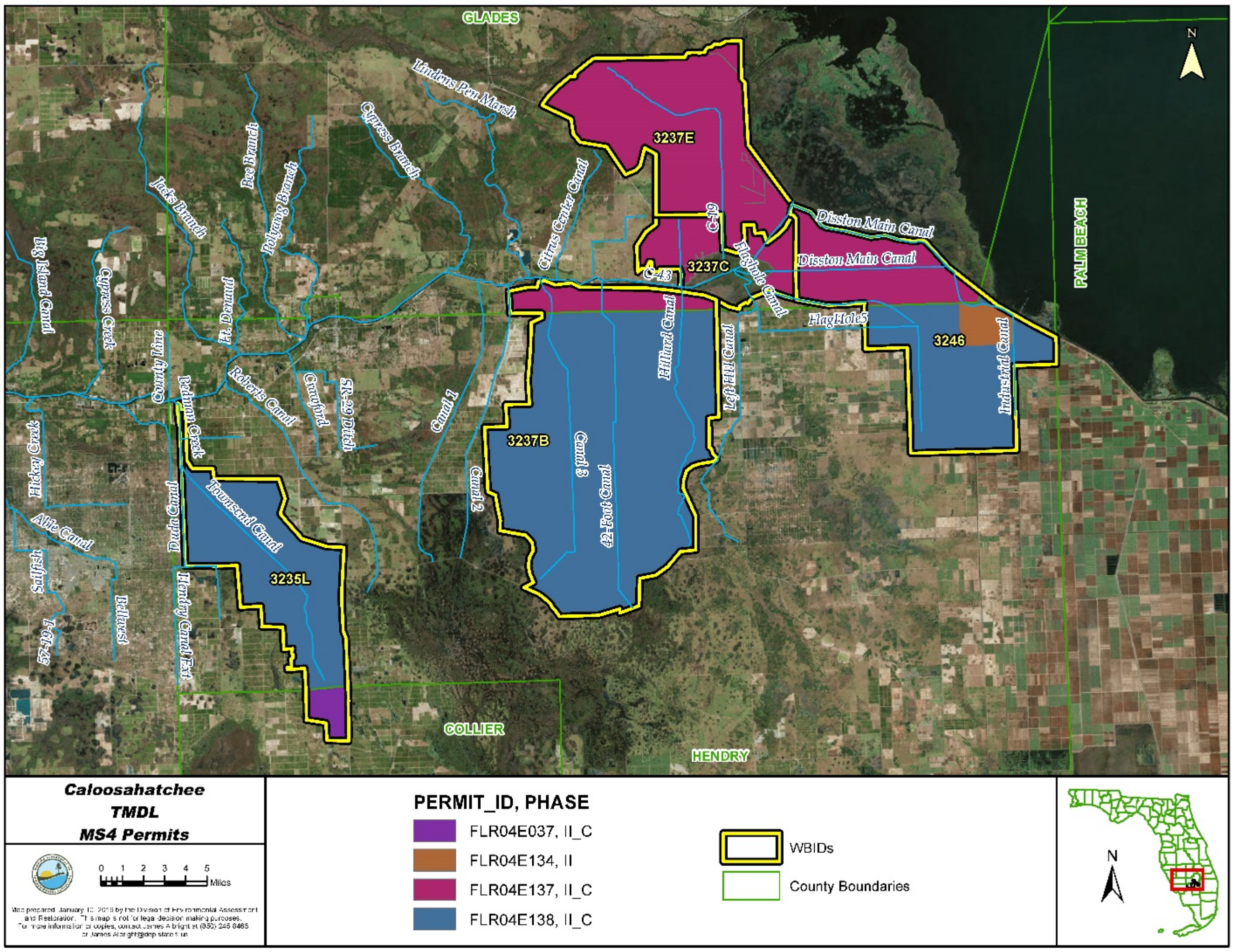

Figure 3.2. Location of MS4 permittees in the Caloosahatchee River Basin

3.3 Nonpoint Sources

Pollutant sources that are not NPDES wastewater or stormwater dischargers are generally considered nonpoint sources. Nutrient loadings to the Caloosahatchee tributary WBIDs are primarily generated from nonpoint sources. Nonpoint sources addressed in this analysis primarily include loadings from surface runoff, groundwater seepage entering the waterbodies, and precipitation directly onto the waterbody surfaces (atmospheric deposition).

3.3.1 Land Uses and Surface Runoff

Land use is one of the most important factors in determining nutrient loadings from the Caloosahatchee River Basin. Nutrients can be flushed into a receiving water through surface runoff and stormwater conveyance systems during stormwater events. Different land use types have different build-up and wash-off rates for water quality constituents. These empirically derived rates are represented as event mean concentrations (EMCs), expressed as the mass of a pollutant per unit volume of water.

Both human land use areas and natural land areas generate nutrient runoff, although human land uses typically generate greater nutrient loads per unit of land surface area than natural lands. Land use was processed from SFWMD's 2008–09 land use geographic information system (GIS) coverage (**Figure 3.3**) and is described in Section 2.2.6 of the Modeling Report (Tetra Tech 2017). Overall for the 2008–09 land use, the largest land use in the Caloosahatchee tributaries consisted of agricultural land uses such as sugar production, citrus groves, and rangeland. These agricultural land uses predominate in the tributary watersheds (81 % in the S-4 Basin, 67 % in the C-19 Canal, 59 % in Lake Hicpochee, 69 % in Long Hammock Creek, and 87 % in Townsend Canal). For the modeling work, these land uses were used to determine impervious and pervious surface coverage and to estimate the flows and loads from the watersheds throughout the Caloosahatchee River Basin. Nutrient loading rates from the different land uses were obtained from literature values (Harper 1994; Soil and Water Engineering Technology [SWET] 2008).

The 2008–09 coverage was selected because the coverage occurs near the middle of the modeling period (1996 through 2014). Comparisons were made between land use coverages to assess how land use changed over this period. The analyses broke down land use by pervious and impervious cover types. For impervious coverage, delineations from 2006 and 2011 were compared, showing an overall change in imperviousness classification of 0.05 %. This is discussed in detail in Section 2.2.6.1.1 in the Modeling Report (Tetra Tech 2017).

The second set of analyses was based on a series of comparisons of the pervious land use classifications from the 2004, 2008–09, and 2012 coverages. The change in land use classification in each coverage was less than 1 % for most sub-basins. The biggest change was in the conversion of citrus grove acreage to improved and unimproved pastures. One of the largest single factors in this conversion was changing land use from citrus groves to unimproved pasture in the area where the Caloosahatchee River (C-43) West Basin Reservoir Project will be located. A detailed description of the comparisons can be found in Section 2.2.6.2 of the Modeling Report (Tetra Tech 2017). **Tables 3.1** through **3.5** summarize the area allocated to each land use.

Table 3.1. SFWMD 2009 land use in the S-4 Basin Watershed

Code	Land Use	Square Miles	Acres	%
1100	Low-Density Residential	1	589	1
1200	Medium-Density Residential	2	1,537	4
1300	High-Density Residential	0	75	0
1400	Commercial	1	485	1
1500	Light Industrial	2	1,328	3
1700	Institutional	1	297	1
1800	Recreational	0	252	1
1900	Open Land	0	220	1
2000	Agriculture	55	35,423	80
3000 and 7000	Rangeland	1	924	2
4000	Forest/Rural Open	0	71	0
5000	Water	1	775	2
6000	Wetlands	2	1,317	3
8000	Communication and Transportation	1	491	1
	Total	**67**	**43,784**	**100**

Table 3.2. SFWMD 2009 land use in the C-19 Canal Watershed

Code	Land Use	Square Miles	Acres	%
1100	Low-Density Residential	1	446	1
1200	Medium-Density Residential	01	354	1
1300	High-Density Residential	0	19	0
1400	Commercial	0	107	0
1500	Light Industrial	0	14	0
1600	Extractive/Quarries/Mines	0	308	1
1700	Institutional	0	173	1
1900	Open Land	0	195	1
2000	Agriculture	40	25,754	67
3000 and 7000	Rangeland	3	1,838	5
4000	Forest/Rural Open	5	2,927	8
5000	Water	1	442	1
6000	Wetlands	8	5,117	13
8000	Communication and Transportation	1	503	1
	Total	**60**	**38,197**	**100**

Table 3.3. SFWMD 2009 land use in the Lake Hicpochee Watershed

Code	Land Use	Square Miles	Acres	%
1100	Low-Density Residential	0	109	1
1600	Extractive/Quarries/Mines	0	181	1
1900	Open Land	0	10	0
2000	Agriculture	13	8,391	59
3000 and 7000	Rangeland	1	333	2
4000	Forest/Rural Open	0	5	0
5000	Water	1	571	4
6000	Wetlands	7	4,614	32
8000	Communication and Transportation	0	61	1
	Total	**22**	**14,275**	**100**

Table 3.4. SFWMD 2009 land use in the Long Hammock Canal Watershed

Code	Land Use	Square Miles	Acres	%
1100	Low-Density Residential	4	2,352	3
1200	Medium-Density Residential	0	26	0
1400	Commercial	0	45	0
1700	Institutional	0	8	0
1800	Recreational	0	53	0
1900	Open Land	3	1,668	2
2000	Agriculture	91	57,999	69
3000 and 7000	Rangeland	6	3,720	4
4000	Forest/Rural Open	7	4,217	5
5000	Water	1	301	0
6000	Wetlands	21	13,551	16
8000	Communication and Transportation	1	340	1
	Total	**134**	**84,280**	**100**

Table 3.5. SFWMD 2009 land use in the Townsend Canal Watershed

Code	Land Use	Square Miles	Acres	%
1100	Low-Density Residential	0	285	1
1200	Medium-Density Residential	0	10	0
1400	Commercial	0	58	0
1700	Institutional	0	4	0
2000	Agriculture	43	27,325	87
3000 and 7000	Rangeland	1	356	1
4000	Forest/Rural Open	0	219	1
5000	Water	0	153	1
6000	Wetlands	5	2,971	9
8000	Communication and Transportation	0	23	0
	Total	**49**	**31,404**	**100**

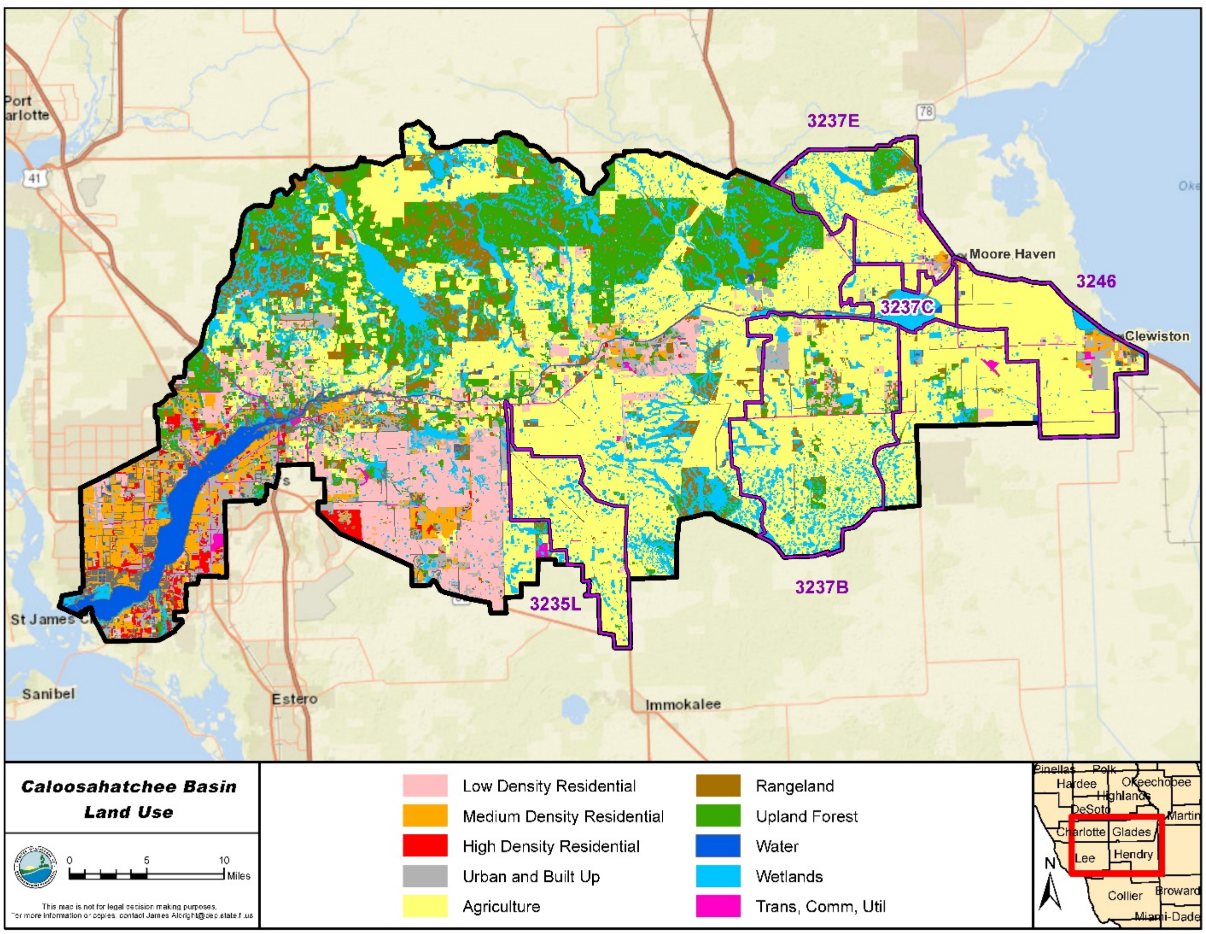

Figure 3.3. SFWMD land use in the Caloosahatchee River Basin in 2009

3.3.2 Onsite Sewage Treatment and Disposal Systems (OSTDS)

OSTDS, including septic tanks, are commonly used where providing central sewer service is not cost-effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS are a safe means of disposing of domestic waste. The effluent from a well-functioning system is comparable to secondarily treated wastewater from a wastewater treatment plant. OSTDS can be a source of nutrients and other pollutants to both groundwater and surface water. The HSPF Model included inputs of nitrogen, phosphorus, and BOD derived from OSTDS sources.

Figures 3.4 through **3.8** show the OSTDS locations in each of the tributary watersheds. These locations were obtained from the 2016 Florida Department of Health (DOH) GIS coverage as well as GIS coverage provided by Lee County. There are 3,358 OSTDS throughout the tributary WBIDs, with 2,329 in Hendry County and 1,422 in Glades County. Of these, there are 1,585 in the S-4 Basin (WBID 3246), 1,074 in C-19 Canal (WBID 3237E), 84 in Lake Hicpochee (WBID 3237C), 673 in Long Hammock Creek (WBID 3237B), and 122 in Townsend Canal (WBID 3235L). Section 2.2.7 of the Modeling Report (Tetra Tech 2017) describes the representation of OSTDS in the HSPF Model. In the 2017 version of the HSPF Model, OSTDS flows and loads were explicitly represented for each model sub-basin.

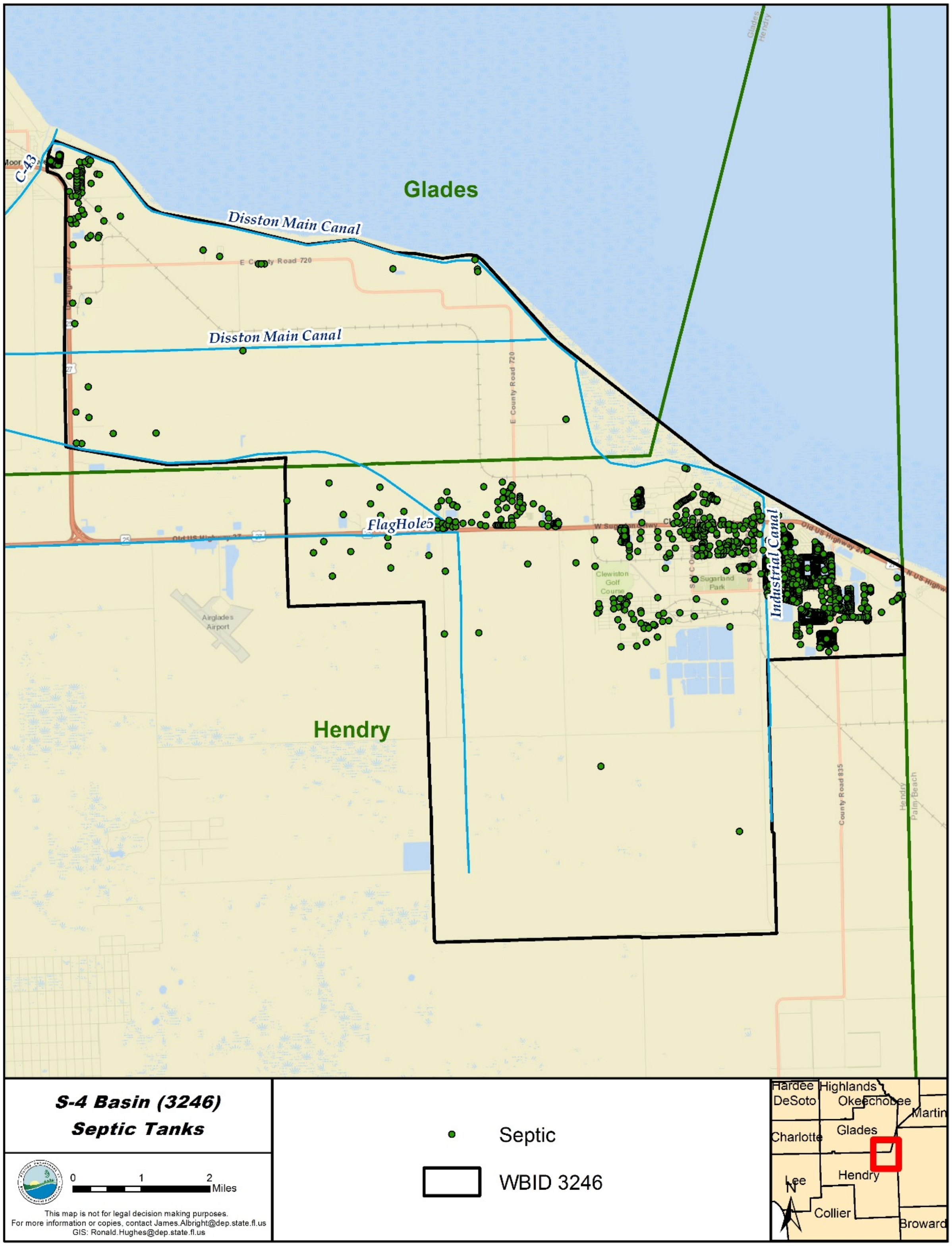

Figure 3.4. OSTDS in the S-4 Basin Watershed

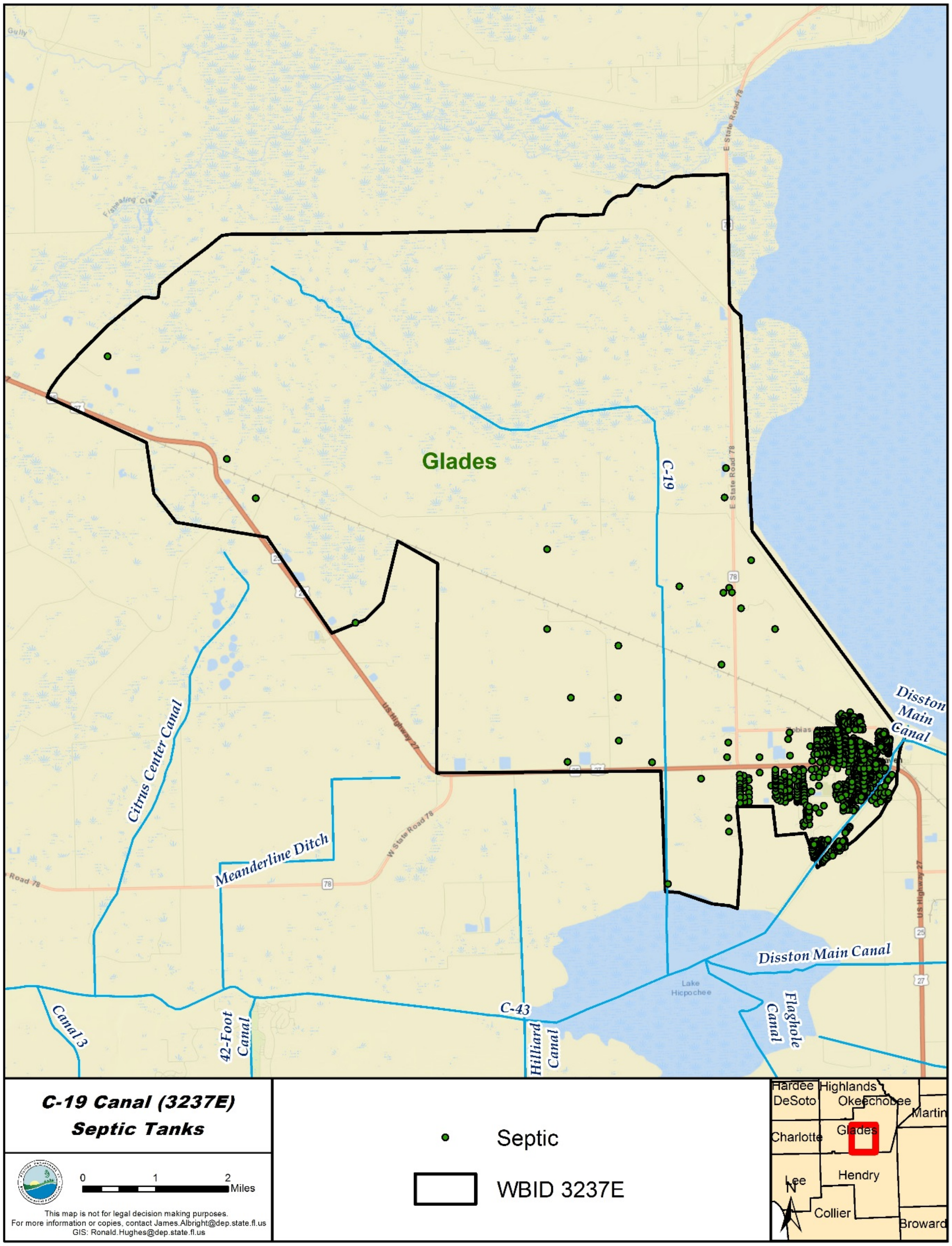

Figure 3.5. OSTDS in the C-19 Canal Watershed

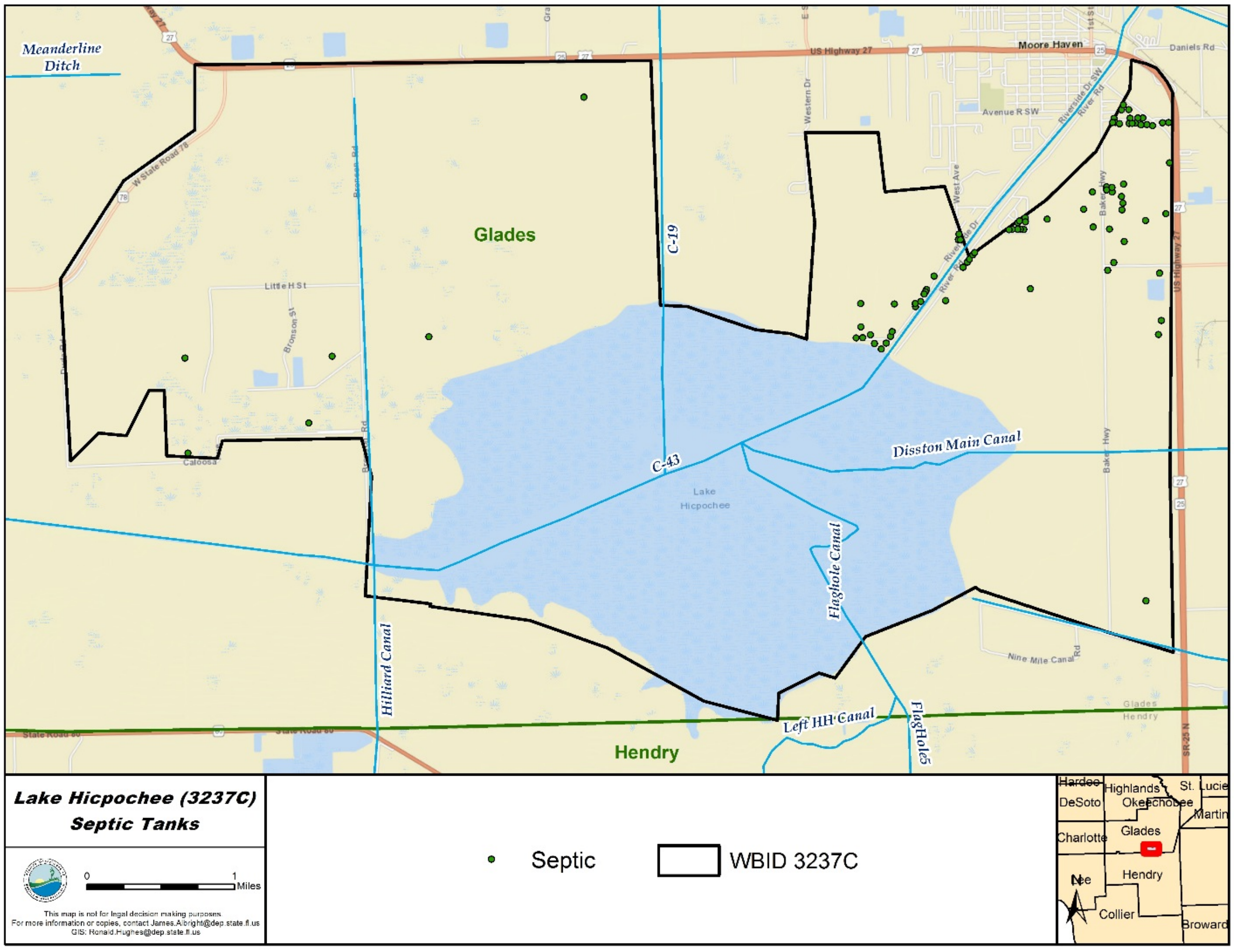

Figure 3.6. OSTDS in the Lake Hicpochee Watershed

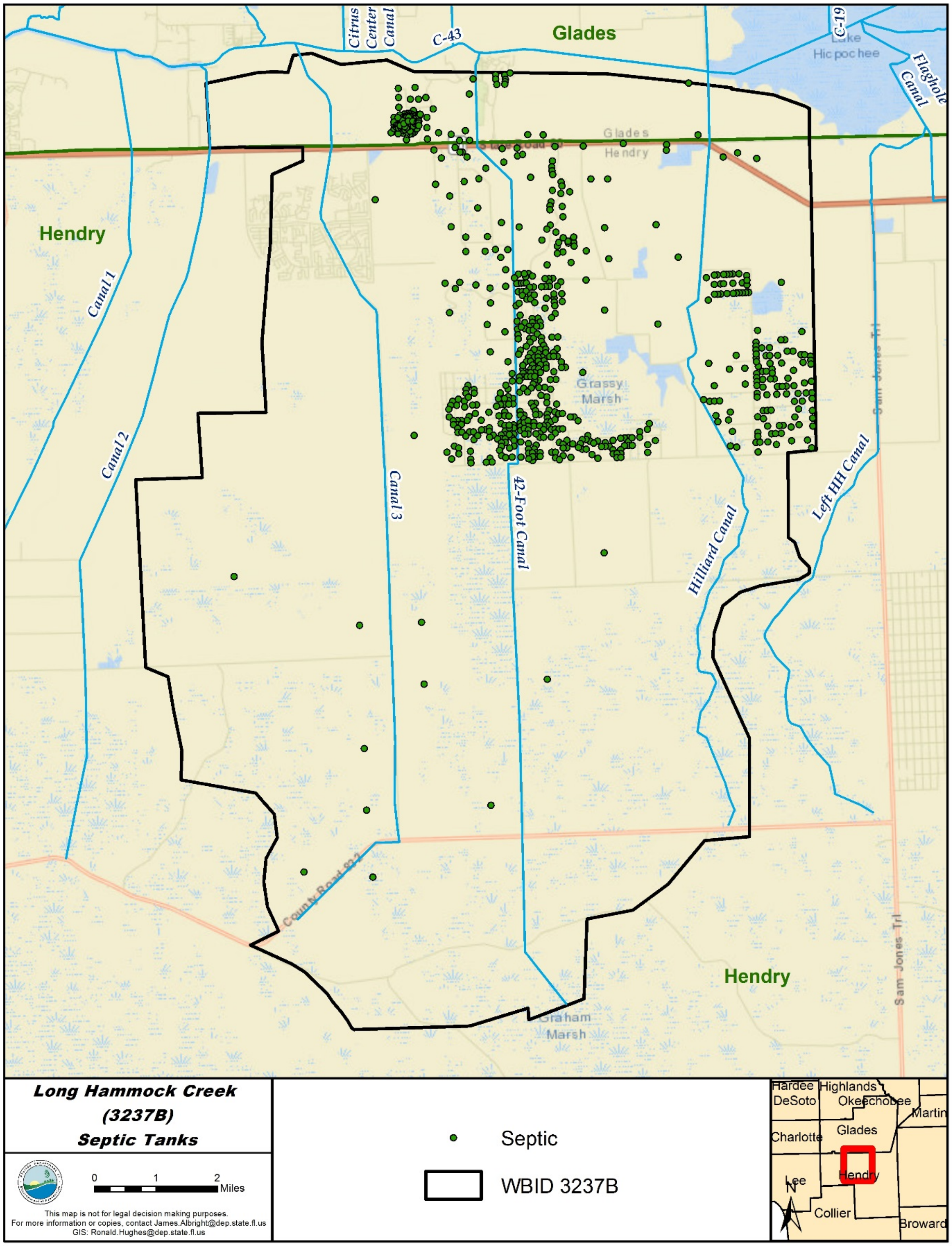

Figure 3.7. OSTDS in the Long Hammock Creek Watershed

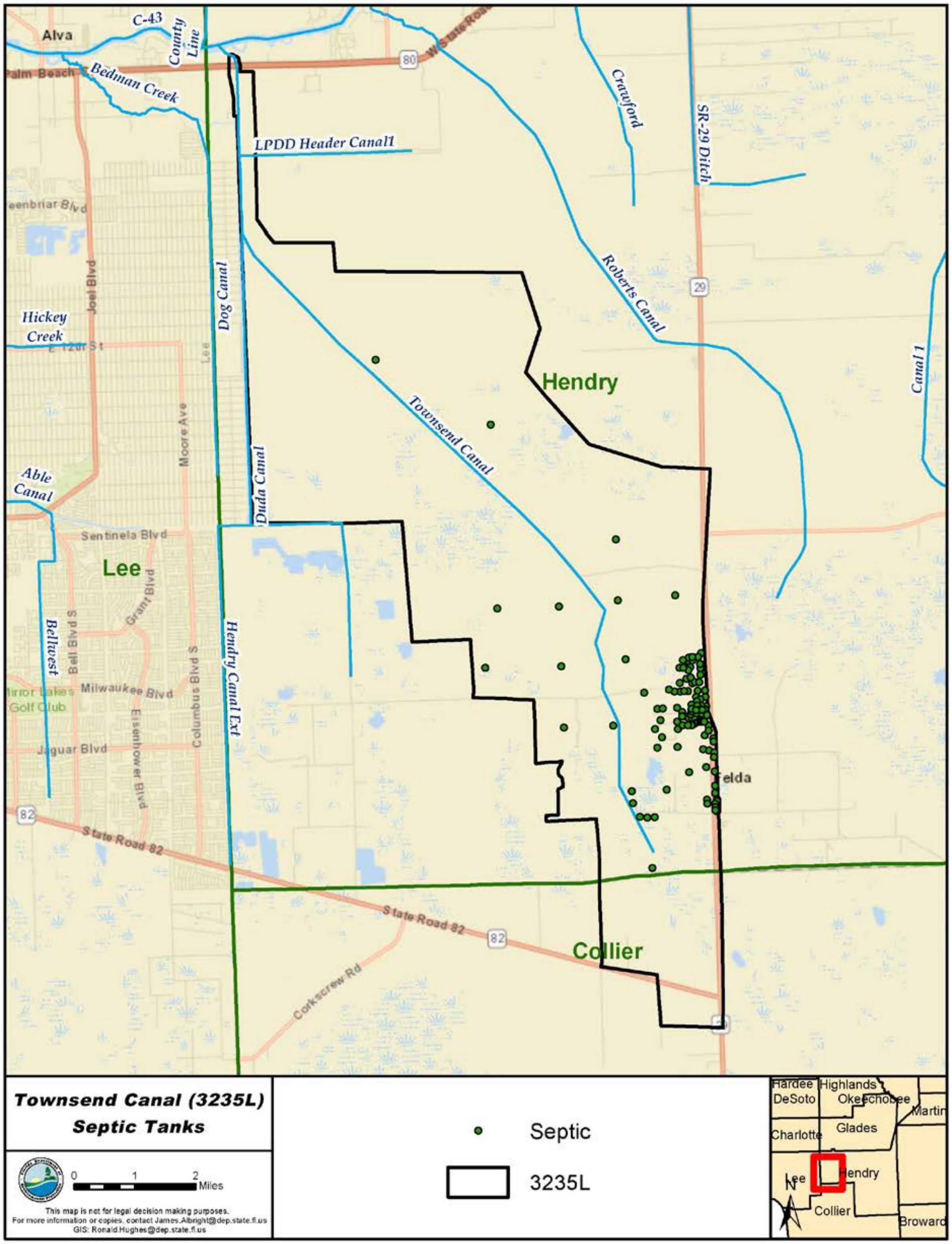

Figure 3.8. OSTDS in the Townsend Canal Watershed

3.3.3 Atmospheric Deposition

Nutrient loads from the atmosphere are an important component of the nutrient budget in many Florida waterbodies. Nutrients are delivered through two pathways: wet atmospheric deposition with precipitation and dry particulate-driven deposition. Wet deposition is mediated through precipitation events and dry deposition through continuous diffusion and sedimentation of gases and particles suspended in the atmosphere. Nitrogen loading in particular is an important component of nutrient contribution from the atmosphere to watersheds. Atmospheric deposition to terrestrial portions of the Caloosahatchee River Basin is represented in the HSPF Model. Loading from atmospheric deposition directly onto the water surface is also represented.

Both forms tend to selectively deposit different nitrogenous species. Wet deposition is primarily in the form of ammonium (NH_4) and nitrate (NO_3). Over the model period, NH_4 concentrations of wet deposition typically ranged from 0.01 to 0.40 mg/L, and NO_3 typically ranged from 0.05 to 0.40 mg/L. Dry deposition is primarily in the form of ammonium (NH_4), nitric acid (HNO_3), and nitrate (NO_3). Nitric acid (HNO_3) typically varied between 0.05 and 0.15 kilograms per hectare per 3 months (kg/ha/3-months), NO_3 ranged from 0.2 to 0.4 kg/ha/3-months, and NH_4 loads ranged from 0.2 to 0.5 kg/ha/3-months. Section 2.2.10 of the Modeling Report (Tetra Tech 2017) provides details of how the simulated atmospheric deposition was applied to the watershed.

3.4 Estimating Watershed Loadings

3.4.1 HSPF Model Approach and Watershed Geography

To simulate water quality in the Caloosahatchee River Basin and account for both in-waterbody processes and watershed loads, a watershed model was used. A dynamic model developed in the late 1960s (originally as the Stanford Watershed Model), HSPF has been maintained by both the EPA and U.S. Geological Survey (USGS). The model uses a series of algorithms to simulate hydrologic processes and water quality. Continuous rainfall and other meteorological records are used to simulate land surface processes (e.g., evaporation, water withdrawals, irrigation, diversion, wastewater discharges, infiltration, and active and deep groundwater reservoir storage), and the runoff and associated water quality are then integrated with in-stream hydraulic and sediment-chemical interactions (Bicknell et al. 2014).

The model 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 more pervious or impervious unit areas discharging into one or more reaches. The HSPF Model simulates watershed hydrology and nonpoint source loads for organic matter, sediments, and nutrients in a watershed network of delineated sub-basins.

This analysis used an HSPF Model set up and calibrated for the entire Caloosahatchee River Basin to determine the assimilative capacity of the five impaired tributary WBIDs in the basin.

Details of how the model was developed can be found in The Modeling Report (Tetra Tech 2017).

In modeling hydrologic runoff from the land, the HSPF Model simulates processes that impact the volume and timing of surface flow, interflow, and baseflow. These include interception, infiltration, percolation, soil moisture storage, evapotranspiration, groundwater recharge, and instream flow transport. The model can simulate a wide variety of constituents, such as DO, BOD, temperature, sediment, various species of nutrients (e.g., ammonia, nitrate-nitrite, organic nitrogen, orthophosphorus, and organic phosphorus) as well as phytoplankton.

The HSPF Model set up for the Caloosahatchee River Basin, which includes 121 sub-basins, represents an update of the model developed for the Caloosahatchee Estuary TMDL (Bailey et al. 2009). The first model update in 2014 extended the model simulation period and adjusted the model boundaries. As a result of subsequent refinement, DEP produced a 2017 version that extended the model simulation period through December 2014, added septic and reuse facilities, revised agricultural irrigation and point source representation, added land use classifications, and updated the hydrology and water quality calibration. The 2017 updated model was used for this TMDL development. Section 2.2 of the Modeling Report (Tetra Tech 2017) provides details of the watershed delineation. A clipped version of the model restricted to the upstream model reaches around the S-4 Basin, C-19 Canal, and Lake Hicpochee was also generated. Its purpose was to improve the model calibration in the uppermost reaches and to create a streamlined version of the overall model to allow for shorter processing times. The refinements in the Clipped Model were only made to water quality calibration, not to the hydrology. **Figure 3.9** shows the modeled individual reaches comprising the hydrologic network for the HSPF Model. The purple lines indicate the hydrology for the clipped model, and the lighter blue lines show the whole HSPF Model extending downstream to Townsend Canal. The figure does not include the rest of the network below this point. The Clipped Model report has been appended to the overall Modeling Report (Tetra Tech 2017) as Appendix E.

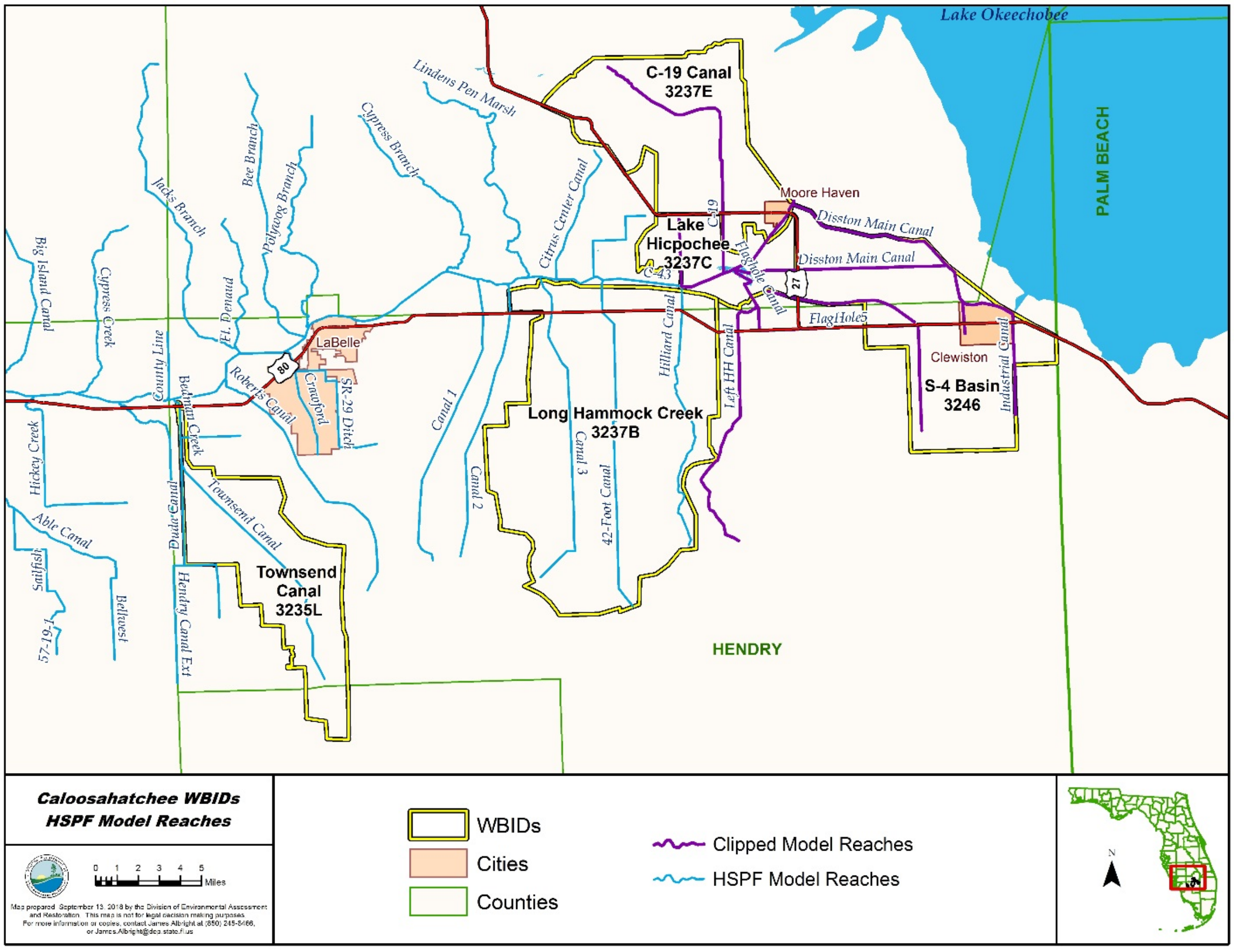

Figure 3.9. Model reaches in the tributary WBIDs for the full Caloosahatchee HSPF Model and the clipped model

SFWMD's 2009 land use coverage was used to define land use in the model because it best represented the model period for which the simulations were run. This was supplemented with additional land use classifications for agricultural land and Florida Department of Transportation (FDOT) roads and rights-of-way, as well as effective impervious coverage from the 2011 National Land Cover Database. Section 2.2.6 of the Modeling Report (Tetra Tech 2017) provides details on the land use inputs to the HSPF Model.

3.4.2 Flow Conditions

Pumping for agricultural irrigation occurs in the southeast portion of the Caloosahatchee River Basin and results in a pattern of bidirectional flow in that area, particularly in the S-4 Basin. Pumping also occurs at S-77 for flood protection, causing bidirectional flow between the S-77 and S-78 structures. Both privately and publicly owned and operated pump stations are located on small canals that flow into Townsend Canal in the Townsend Canal WBID. Long Hammock

Creek contains three canals running roughly south to north to discharge into the Caloosahatchee River. The easternmost of these canals, Canal 3, also has associated pumping stations. In the S-4 Basin, pumps are located in Flaghole Canal, Disston Canal, Hendry-Hilliard Canal, Hilliard Canal, and Industrial Canal.

As part of the update from the previous model version, flow stations were updated, and agricultural pumping and related simulated bidirectional flows were added to the 2017 HSPF Model. The model was also redelineated with cutoffs at these pumping stations to simulate the ponding that can occur at the sites. Sections 2.2.1 and 2.2.2 of the Modeling Report (Tetra Tech 2017) describe these changes in more detail.

The Industrial Canal, located in the S-4 Basin, comprises five connected canals with interconnected flows between Lake Okeechobee and the Caloosahatchee River. SFWMD regulates these flows through various structures whose operation is dependent on Lake Okeechobee stage. There are four boundary structures: S-235 (which connects the LD-3 Canal to the Caloosahatchee River), S-4 (which is the main pump connecting the entire network to Lake Okeechobee), L-D1 (whose culverts connect the canal network to Lake Okeechobee through the dike/levee), and S-310 (which connects Lake Okeechobee to the C-21 Canal).

There is one internal structure (S-169), one boundary privately owned structure operated by the South Florida Conservancy District (EPD07) and a bidirectional structure (DICD3) operated by the Disston Island Conservancy District. Water in the Industrial Canal is used for agriculture in the S-4 Basin and also exits the canal through the S-4 Basin interior via a system of culverts and pumps. The HSPF Model explicitly includes L-D1 and the S-310 structures.

Other structures, such as DICD3 and EPD0, are implicitly represented through the agricultural pumping setup in the model but could not be explicitly modeled because requested location and operation data were not provided for these additional structures. Therefore, the general operations of the known structures were represented to the best extent possible in the HSPF Model, given the hydraulic limitations of HSPF.

3.4.3 Boundary Conditions

The loads entering the Caloosahatchee River Basin are generated in part by the surrounding watersheds, but there is also a sizable contribution of flows and loads from upstream. The upstream boundary for the HSPF Model was defined by the Lake Okeechobee discharges at the S-77 lock to the Caloosahatchee River/C-43 Canal and the S-310 lock and LD-1 Canal seepage to the Industrial Canal. 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; this occurred 6 % of the time during the model simulation period.

During back-pumping, the flow of water in the Caloosahatchee River reverses and moves towards Lake Okeechobee. Water quality data were used to estimate concentrations in the boundary flows. Data from Station 21FLSFWMS77, located immediately upstream of S-77, were used to construct the water quality time series associated with positive flows. This station is shown in the **Figure 2.2** map of water quality station locations in the C-19 Canal WBID. Records of daily average flows were used to indicate when water flowed from Lake Okeechobee into the Caloosahatchee River. Input loads were tabulated for days with positive flows by using the positive flow volume and concentrations for that day. On days with negative flows, flows were withdrawn from all reaches between S-78 and S-77. Sections 2.2.4 and 2.2.11 of the Modeling Report provide more information on the methodology used to estimate the modeled boundary conditions (Tetra Tech 2017).

The methodology above allowed for the model to replicate existing conditions, but it was also necessary to match background conditions, and this meant that the background conditions for Lake Okeechobee needed to be determined. In order to determine these background conditions, the hydraulics of the system were kept unchanged while water quality conditions in Lake Okeechobee were set to match the existing Lake Okeechobee TMDL (DEP 2001a). This scenario was generated using a target TP concentration of 0.04 mg/L and a TN concentration of 1.2 mg/L. The TP value was a concentration equivalent based on the TP loads established by the Lake Okeechobee TMDL (DEP 2001a). Historical relationships of TN and TP in Lake Okeechobee discharge were then used to determine a likely TN:TP ratio, in order to estimate TN concentrations if TP were to achieve its targeted concentrations. DEP's Caloosahatchee River Estuary TMDL used a TN concentration of 1.2 mg/L for the Lake Okeechobee background condition (Bailey et al. 2009). 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. Assumed TP and TN speciation percentages of water from Lake Okeechobee were 66 % organic phosphorus and 34 % phosphate for TP, and 90 % organic nitrogen, 4 % nitrate, and 6 % nitrite for TN. In addition, a total organic carbon (TOC) concentration of 17.89 mg/L was used in the model.

3.4.4 Meteorology

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; therefore, accurate estimates of quantities and timing of precipitation events are critical.

As mentioned previously, loadings derived from atmospheric deposition were partially derived from precipitation. Meteorological inputs for the HSPF Model were developed from Next-Generation Radar (NEXRAD) data from National Weather Service radars located at Tampa, Melbourne, Jacksonville, Miami, Tallahassee, and Key West. Section 2.2.5 of the Modeling Report (Tetra Tech 2017) describes in greater detail the process of adjusting and gap-filling the precipitation data.

Chapter 4: Determination of Assimilative Capacity

4.1 Determination of Loading Capacity

The goal of this TMDL analysis was to determine the assimilative capacity of the S-4 Basin, C-19 Canal, Lake Hicpochee, Long Hammock Creek, and Townsend Canal and to identify the maximum allowable TN, TP, and BOD loadings from these waterbodies, so that they attain the DO criterion and thus maintain their function and designated use as Class III waters. Depressed DO caused by nutrient enrichment, and the resulting problems related to eutrophication, tend to be widespread and are frequently manifested far (in both time and space) from their sources. Addressing low DO tied to eutrophication involves relating water quality and biological effects such as photosynthesis, decomposition, and nutrient recycling as acted on by environmental factors (rainfall, point source discharge, etc.) to the timing and magnitude of constituent loads supplied from various categories of pollution sources.

4.2 Critical Conditions and Seasonal Variation

Assimilative capacity should be related to some specific hydrometeorological condition during a selected period or to some range of expected variation in these conditions. The estimated assimilative capacity in this report is based on annual conditions, rather than critical/seasonal conditions, because the net change in overall primary productivity in the waterbody segments is a critical factor and is better addressed on an annual basis. Seasonal variability is captured in the model, which is calibrated to a range of meteorological conditions. As detailed in the water quality calibration and validation discussion in **Section 4.3.3**, the model calibrates well against observed data. Furthermore, the loading can be expressed as daily equivalents but will be implemented in practice over a longer period.

To account for interannual variability, the TMDL was based on the maximum seven-year rolling average loading from the entire modeled period from 1996 to 2014 that attained the DO criterion in every year. A single year can vary significantly due entirely to stochastic effects which overwhelm the central tendency for the system, and this would adversely weight the TMDL towards extreme values. An average will reduce the impact of outlier years and the period of seven years was selected because this should capture both drought and wet years. Because nutrient loading to a waterbody is predominantly influenced by precipitation in each year and, in these agricultural basins, by several other variables that vary from year to year and season to season (e.g., irrigation requirements, specific crop coverage and harvest time), a daily or annual load assignment or measurement is not particularly useful. Taking a long-term or rolling average also has the advantage of removing the precipitation effect in favor of better capturing the impact of the watershed loadings. A simple rolling average is an average of the last *n* values (in this case seven years of annual averages) in a dataset, applied row by row to obtain a series of averages.

The moving window of averages starts at seven years after the start of the time series and ends in the last year.

4.3 Water Quality Modeling to Determine Assimilative Capacity

4.3.1 Hydrology Calibration for the HSPF Model for the Caloosahatchee Tributaries

To calibrate and validate the modeled hydrology, model outputs were compared with measured data from 20 gauges operated by USGS and DEP. **Figure 4.1** shows the location of all hydrology calibration and validation stations used in the calibration of the Caloosahatchee HSPF Model. The distribution of hydrology stations was driven by available station locations and by the need to optimize performance in the more dynamic areas such as the tidal portion of the Caloosahatchee and associated freshwater tributaries.

There were also four USGS stations in the main stem of the Caloosahatchee/C-43 Canal: USGS 02292000 (at Moore Haven), USGS 02292010 (at S-77/Moore Haven Lock), USGS 02292480 (S-78/Ortona Lock), and USGS 02292900 (S-79/Franklin Lock). These bracket the upper and lower bounds of the Caloosahatchee. Additionally, USGS 26451408150700 (Industrial Canal) provides another hydrology calibration point in the upstream agricultural area in the S-4 Basin. Section 2.3.1 of the Modeling Report (Tetra Tech 2017) provides more information on the calibration and validation stations.

The model calibration was based on graphical and statistical comparisons between the model predictions and the observations. Plots were created to compare the observed flows with the model predictions for mean monthly flows, mean daily flows, flow exceedance, and monthly flow regression. Various goodness-of-fit statistics were calculated, including correlation coefficients, percent error, and Nash-Sutcliffe model efficiency coefficients (NSE). Section 2.3.2 of the Modeling Report (Tetra Tech 2017) describes the calculated statistics.

While the first two metrics are widely used general statistics, the NSE is a specific hydrologic modeling statistic (Nash and Sutcliffe 1970). It is widely applied in the hydrologic sciences and is one of the most important calculations for the evaluation of continuous-hydrograph simulation programs. These statistics were compared with general model performance metrices (Donigian 2002; McCutcheon et al. 1990) and were given a qualitative rating of "very good," "good," "fair," and "poor."

Qualitatively, these scores are derived from percent difference. For a hydrology calibration range of "very good," values are those where there is less than a 10 % difference, for "good" the range is a 10 % to 15 % difference, for "fair" the range is a 15 % to 25 % difference, and for “poor” the range is greater than a 25 % difference. Section 2.3.3 of the Modeling Report describes the calibration performance and the results of these comparisons. The calibration plots for various parameters are available in the appendices to the Modeling Report prepared by Tetra Tech

(2017). Monthly calibration plots for USGS gauge stations in the Caloosahatchee River watershed are available on request.

Table 4.1 summarizes the hydrology calibration statistics for the model. The table shows the statistics (R^2, NSE, and percent error) along with the qualitative ratings (from "poor" to "very good") of each statistic. Overall the HSPF Model predicted flows very well in watersheds where flows were predominantly uninhibited and was weaker in areas where weirs and structures inhibited natural flow.

For instance, calibration performance was poor at USGS 26451408150700 Industrial Canal because of 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. Because of 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. In reality, it is routed through numerous smaller canals to the interior of the basin downstream of USGS 26451408150700.

Therefore, the overall water balance of the S-4 Basin was maintained, but because of the routing, the model under-simulates high flows at USGS 26451408150700. Differences in model performance at some DEP stations in smaller tributaries may be caused by the limited amount of data collected at some stations and by potential data collection errors.

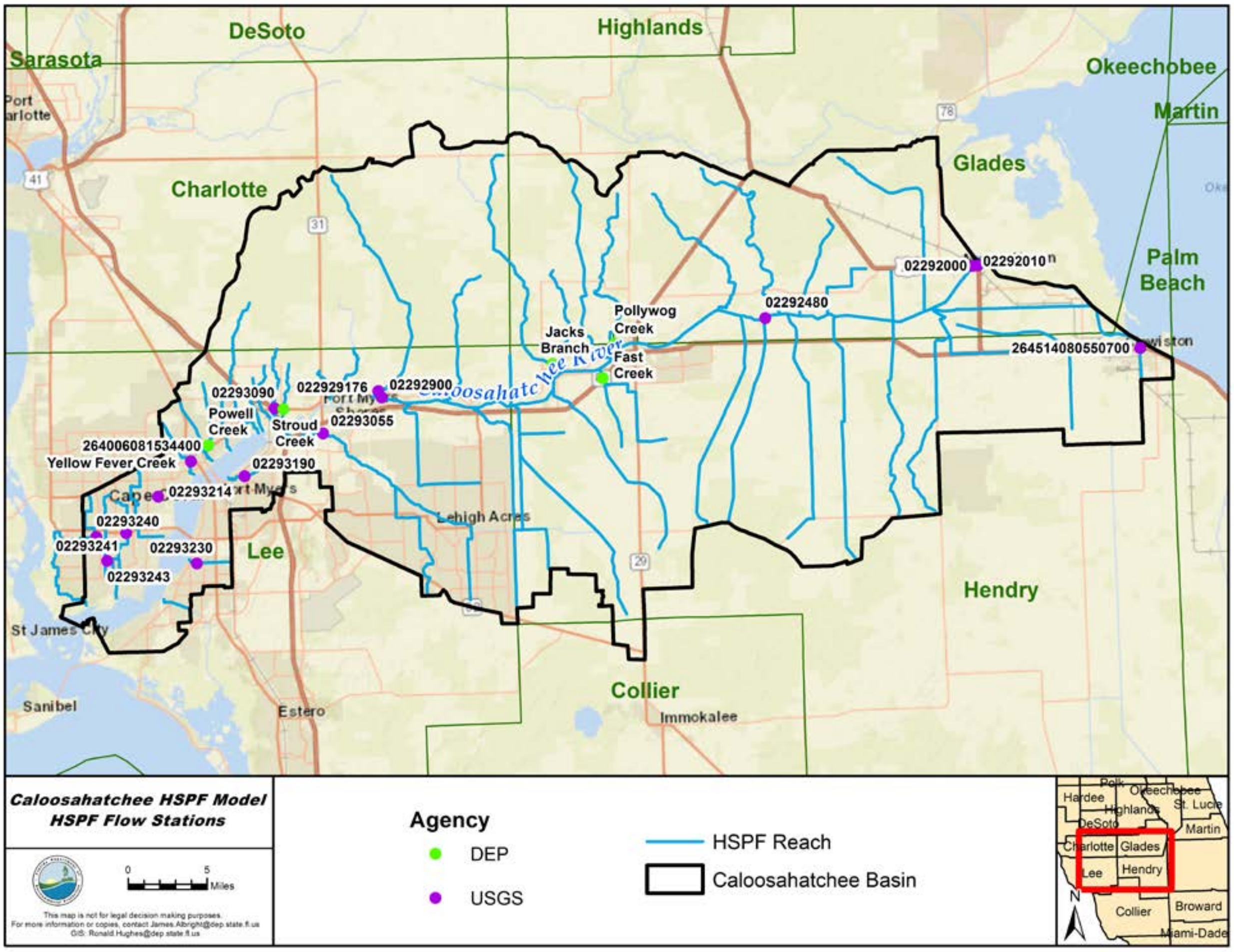

Figure 4.1. Location of all USGS and DEP flow stations used for calibration and validation of the Caloosahatchee HSPF Model

Table 4.1. Statistical summary of 2017 Caloosahatchee River Basin HSPF Model hydrologic calibration result

Columns show the R^2, NSE, and percent error, with adjacent columns showing the qualitative rating of each statistic.
Abbreviations: NC = Not calculated, P = Poor, F = Fair; G = Good; VG = Very good

Station ID	R^2 (monthly)	R^2 Rating	NSE	NSE Rating	NSE (monthly)	NSE (monthly) Rating	Total Volume % Error	Total Volume % Error Rating
USGS 02292000	0.99	VG	0.98	VG	0.99	VG	6.1	VG
USGS 02292010	0.99	VG	0.97	VG	0.99	VG	-6.5	VG
USGS 02292480	0.92	VG	0.84	VG	0.92	VG	-3.5	VG
USGS 26451400550700	0.97	VG	0.29	P	0.5	P	-56.4	P
USGS 02292900	0.9	VG	0.78	G	0.85	VG	-16.8	F
USGS 02293230	0.76	G	-0.15	P	0.39	P	38.2	P
USGS 02293240	0.69	F	0.26	P	0.24	P	-55.8	P
USGS 02293241	0.65	F	0.47	P	0.61	F	-10	VG
USGS 022929176	0.87	VG	0.79	G	0.84	VG	0.8	VG
USGS 02293055	0.8	G	0.47	P	0.73	G	8.8	VG
USGS 02293090	0.83	VG	0.68	F	0.79	G	28.9	P
UGS 02293190	0.86	VG	0.35	P	0.85	VG	6.1	VG
USGS 02293243	0.65	F	0.44	P	0.58	P	-6.7	VG
USGS 264006081534400	0.8	G	0.27	P	0.58	P	-40.3	P
DEP Jacks Branch	0.85	VG	0.62	F[c]	0.8	G	-10.2	G
DEP Fast Creek	0.3	P	NC	NC	NC	NC	NC	NC
DEP Pollywog Creek	0.15	P	NC	NC	NC	NC	NC	NC
DEP Powell Creek	0.46	P	NC	NC	NC	NC	NC	NC
DEP Stroud Creek	0.82	VG	NC	NC	NC	NC	NC	NC
DEP Yellow Fever Creek	0.39	P	NC	NC	NC	NC	NC	NC

4.3.2 Water Quality Calibration for the HSPF Model for the Caloosahatchee Tributaries

The instream water quality model calibration for the 2017 complete watershed HSPF Model was calibrated to select locations (50 stations at 33 unique locations, with 14 locations for calibration and 19 for validation) in the Caloosahatchee River Basin. Those locations were primarily limited to IWR stations with long periods of historical sampling data. These selected calibration stations represented the conditions of the stream from which they were collected; however, each particular stream may not be representative of all streams in a WBID.

The HSPF Model was calibrated overall with the assumption that acceptable calibrations at selected calibration locations produced acceptable model results in other non-calibration streams.

Figure 4.2 shows the location of these stations for the complete 2017 HSPF Model, and **Figure 4.3** shows the location of calibration and validation stations in the clipped model.

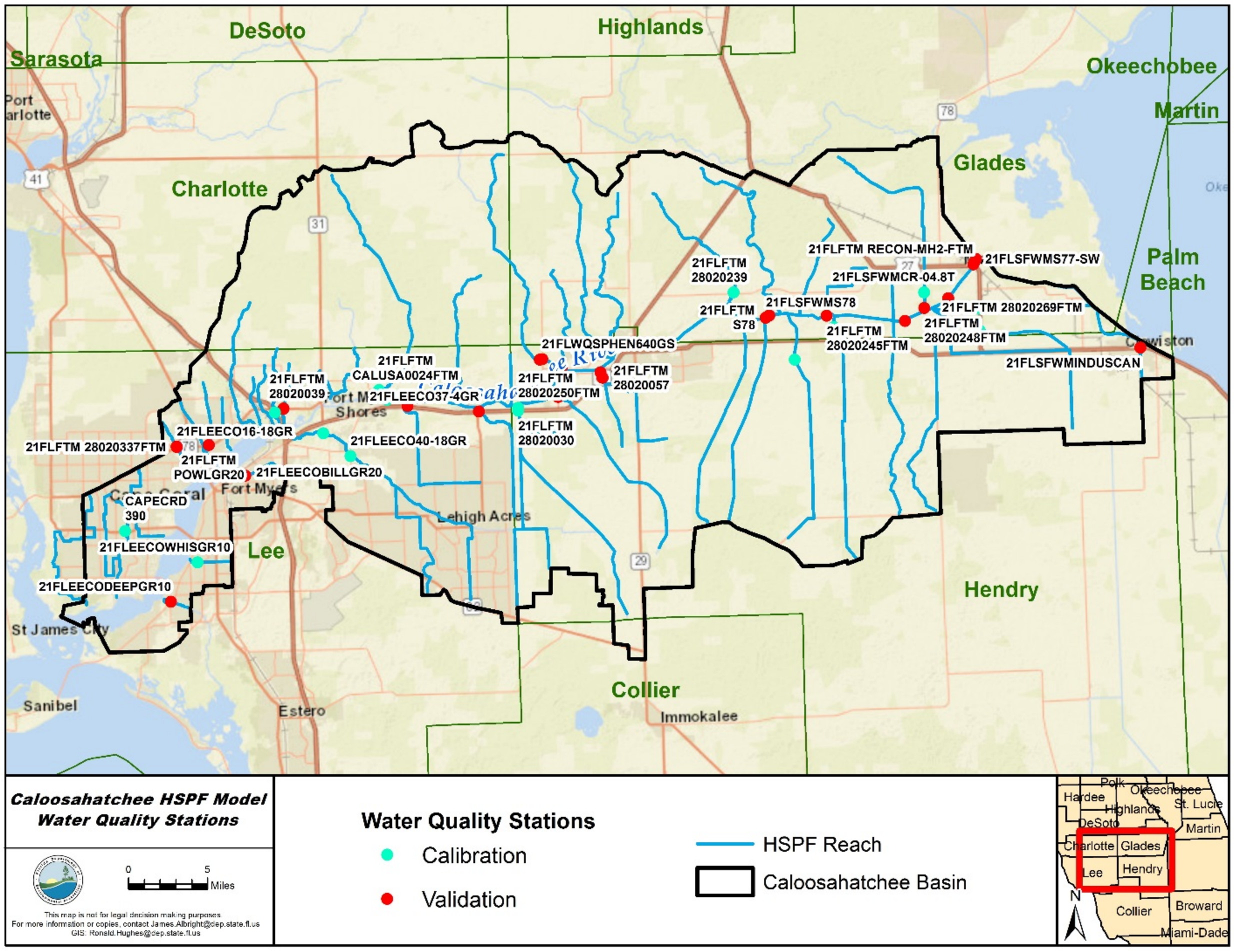

Figure 4.2. Location of all USGS and DEP water quality stations used for calibration and validation of the Caloosahatchee HSPF Model

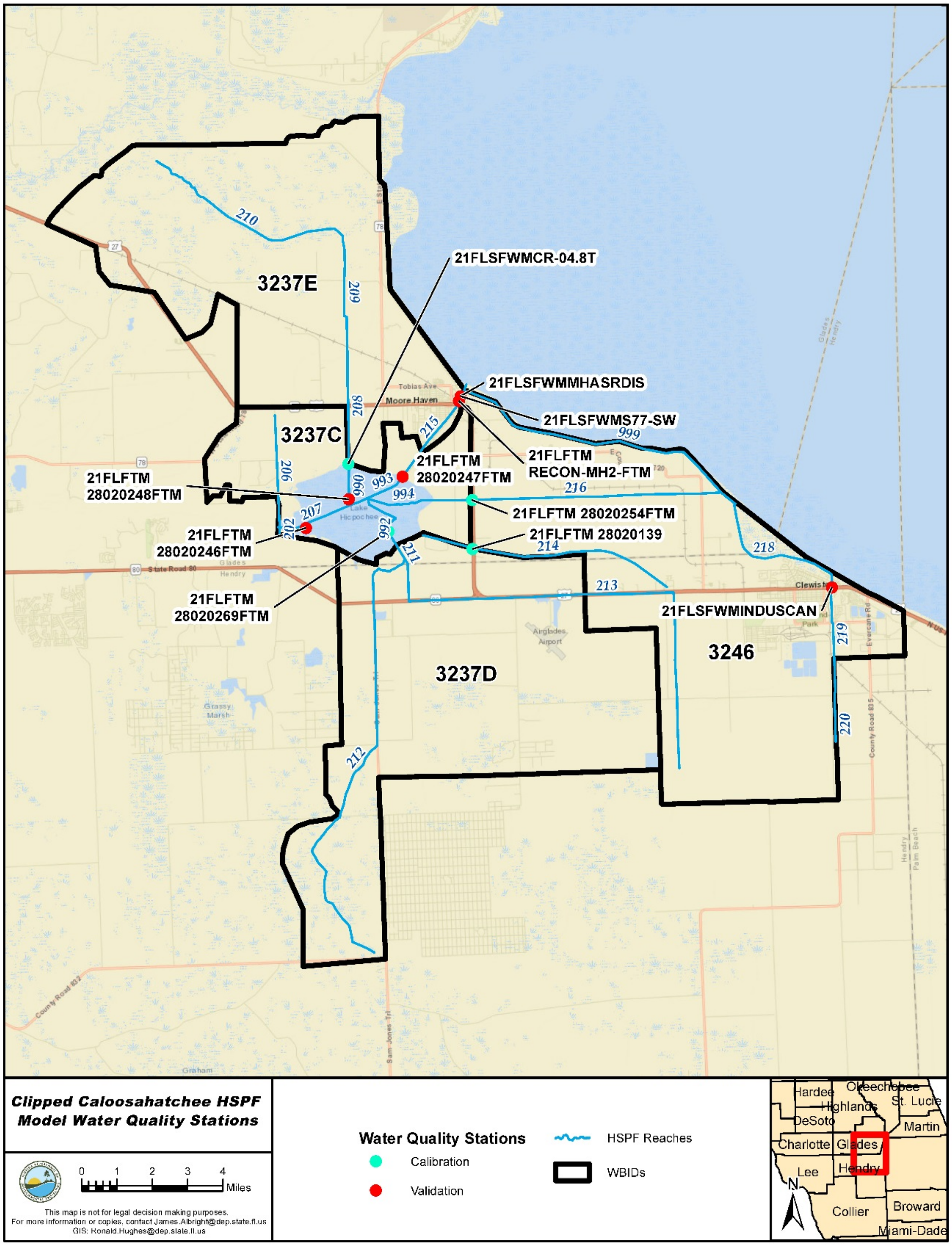

Figure 4.3. Location of all USGS and DEP water quality stations used for calibration and validation of the clipped model

For the 2017 HSPF Model, the water quality calibrations were generally acceptable to good for most modeled water quality parameters in the Caloosahatchee River tributaries. Section 2.4.4.3 of the Modeling Report (Tetra Tech 2017) provides a detailed description of the calibration for all modeled water quality parameters. As with the hydrology calibrations, graphical figures were developed to assess the temporal representation of the model compared with observed data on a daily and annual basis. Plots were created to compare daily observed data with modeled daily data to determine if the model was able to represent the seasonal trends and magnitudes of the measured data. Annual concentration box-and-whisker and regression plots were also developed to evaluate model representation.

The Modeling Report (Tetra Tech 2017) provides calibration plots for the 2017 HSPF Model showing comparisons between observed and predicted time series of total suspended solids (TSS), ammonia, nitrate-nitrite, organic nitrogen, total Kjeldahl nitrogen (TKN), TN, TP, BOD, DO concentrations, DO percent saturation, chlorophyll *a*, BOD, and temperature. The graphical analyses were complemented with a series of statistical tables that evaluated percent error on a daily, monthly, and annual basis. A number of statistical measures are provided in addition to the percent error, including R^2 statistics. Note that the R^2 values are generally low, however the R^2 is not dictating the performance grading as this statistic is extremely sensitive to the timing of the comparison datasets (in this case observations and simulations) and can be a biased statistic. For nutrients, more weight is given to the percent error (PE) and index of agreement (IA), as well as the visual calibration. 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 measured data (related to the accuracy of lab analyses, limits of quantification, methods of detection, etc.), 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 unique criteria to accept or reject the model. The fundamental purpose of the comparison figures, grades, and statistics is to help identify the strengths and limitations of the models to help the department make informed decisions based on the model simulations. Example time series figures displaying simulated vs observed nutrient concentrations are shown for the C-19 Canal in **Figures 4.4** through **4.7**. All other time series comparisons are available in the Modeling Report (Tetra Tech 2017).

None of the stations associated with the tributaries had enough sample points for daily paired regression analysis, and they were not associated with USGS flow gauges for load analysis. Therefore, the analysis was based on the time series results compared with the limited dataset at each location. The initial stations evaluated were RCH192 Long Hammock Canal (21FLFTM 28020256FTM), RCH208 C-19 (21FLSFWMCR-04.8T), 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; thus, a bias determination could not be made. Ammonia concentrations were generally in range compared with observed data but biased low at C-19 Canal. Organic nitrogen and TKN concentrations were generally in the high range compared with observed data. In the S-4 Basin, the simulations were generally biased low. TN concentrations were generally in the high range compared with observed data but low in the simulation. In the S-4 Basin, the simulation was generally biased low at Ninemile Canal. TP concentrations were generally in range compared with observed data but biased high at Long Hammock Canal. Carbonaceous BOD 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.

For the clipped model, local calibration was improved via better local optimization and incorporation of all available water quality stations. The Clipped Model Report describes the changes made to the water quality calibration and provides additional calibration graphs. The focus for the Clipped Model was to specifically improve and optimize calibrations of TN, TP, and DO percent saturation. For instance, in the S-4 Basin the TN calibration for RCHRES 216 improved from fair to very good, and the TP statistics remained in the good to very good range.

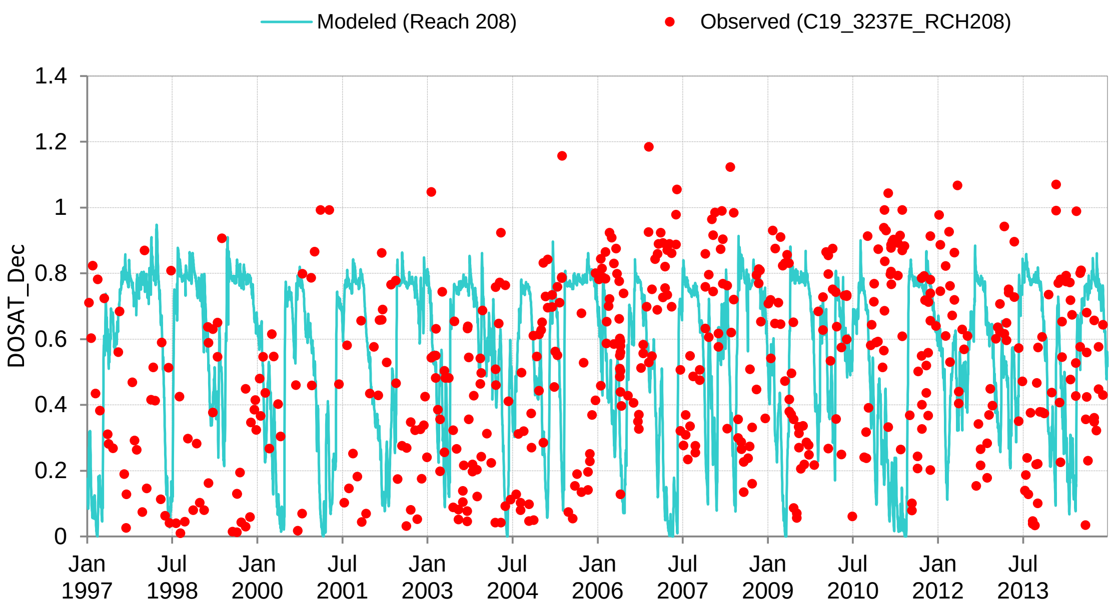

Figure 4.4 DO calibration time series graph for all measured data from Reach 208 in the C-19 Canal

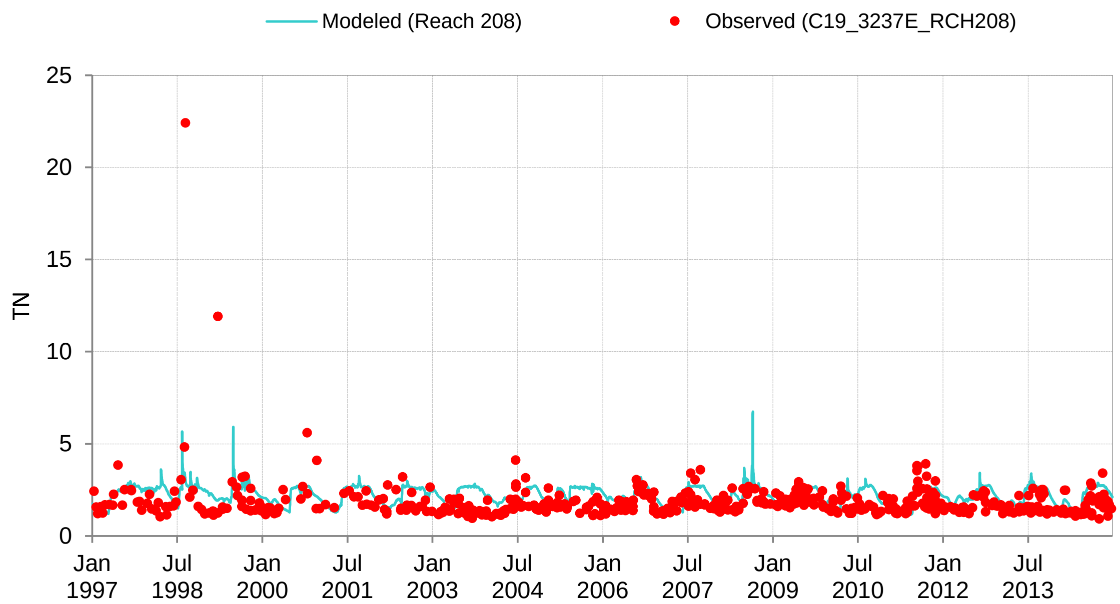

Figure 4.5 TN calibration time series graph for all measured data from Reach 208 in the C-19 Canal

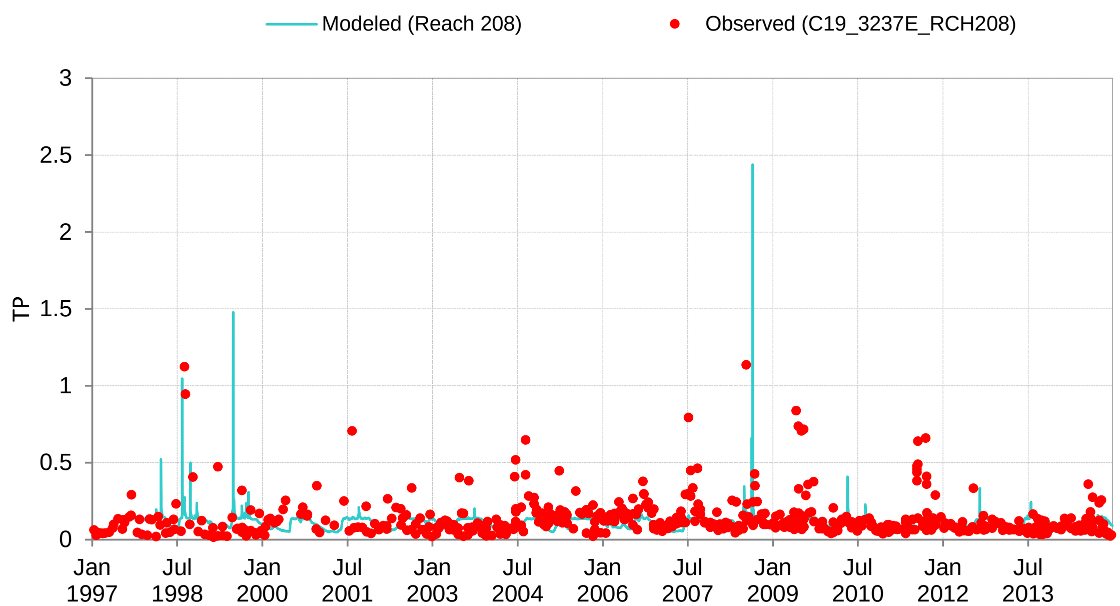

Figure 4.6 TP calibration time series graph for all measured data from Reach 208 in the C-19 Canal

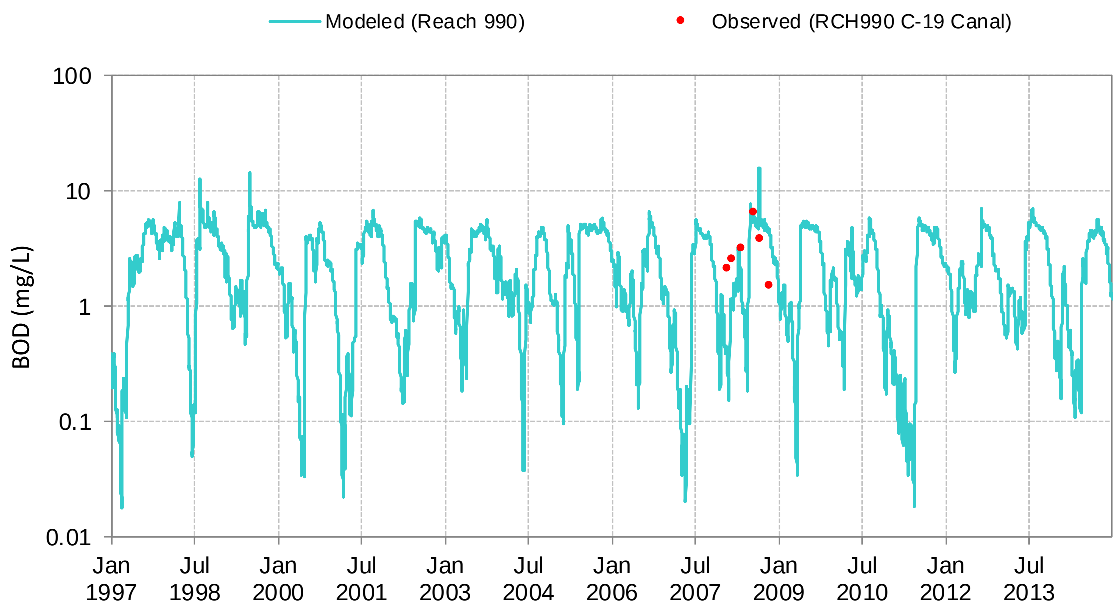

Figure 4.7 BOD calibration time series graph for all measured data from Reach 208 in the C-19 Canal

Tables 4.2 through **4.5** list the water quality calibrations for the Caloosahatchee River tributaries and combine results from both the 2017 HSPF Model calibration and the Clipped Model calibration. For the S-4 Basin, C-19 Canal, and Lake Hicpochee, the statistics are derived from the Clipped Model. Although all the water quality stations in these WBIDs were used in the calibration, the summary statistics are only provided for the stations with sufficient data sets. For Long Hammock Creek and Townsend Canal, the complete 2017 HSPF Model was used to generate the comparison statistics.

Table 4.2 summarizes the monthly average observed and modeled DO percent saturation comparison statistics for the DO calibration. Each calibration/validation station in the table was assigned to a reach in a WBID. **Table 4.3** lists the same statistics for the monthly average TN data for the TN calibration, and **Table 4.4** lists the statistics for the monthly average TP data for the TP calibration. Because water temperature is a critical physical determinant of DO, **Table 4.5** lists the monthly average temperature data for the temperature calibration. **Table 4.6** lists the monthly average BOD data for the BOD calibration. Note that comparatively little BOD monitoring data were available in the impaired WBIDs; these locations had less than 20 data points. When limited monitoring data are available, calculated statistics can be misleading. Therefore, these statistics should not be used to judge the model. Time series figures displaying simulated vs observed BOD concentrations have been provided for stations located in the TMDL

WBIDs. These figures show that the calibrated BOD concentrations similar to the measured data and match the overall trends and magnitudes.

The statistics listed in **Tables 4.2** through **4.5** use monthly averages because the potential impacts from seasonal effects on DO and temperature may affect the comparisons made on annual averages if there are seasonal biases in the sampling for the measured data. Monthly comparisons remove this seasonal effect. However, both annual and monthly comparisons were made, and these statistics are available upon request.

Table 4.2. Statistical summary of Caloosahatchee tributary WBID modeled monthly average DO calibration

Columns show the R^2 and percent error, with adjacent columns showing the qualitative rating of each statistic.
Abbreviations: P = Poor, F = Fair; G = Good; VG = Very good

WBID	Location	IWR Station IDs	Average % Error	Average % Error Rating	Median % Error	Median % Error Rating	R^2	R^2 Rating
3246	Ninemile Canal	21FLFTM 28020139	241.3	P	314.4	P	0.03	P
3246	Disston Canal	21FLFTM 28020254FTM	104.3	P	180.2	P	0.12	P
3246	Industrial Canal	21FLSFWMINDUSCAN	-37.6	P	-36.9	P	0.82	VG
3237E	C-19	21FLSFWMCR-04.8T	-16.8	G	-17.6	G	0.48	P
3237E	C-19 Canal	21FLFTM 28020248FTM	-16.5	G	-10.4	VG	0.35	P
3237C	Caloosahatchee (S-77)	21FLFTM 28020247FTM 21FLFTM RECON-MH2-FTM 21FLFTM RECON-MH-FTM 21FLSFWMMHASRDIS 21FLSFWMS77 21FLSFWMS77-SW	6.4	VG	-1.0	VG	0.90	VG
3237C	Lake Hicpochee LH2	21FLFTM 28020246FTM	-19.0	G	-19.8	G	0.47	P
3237B	C-4 Canal	21FLFTM 28020257FTM	-11.0	VG	-15.2	G	0.23	P
3237B	Long Hammock Canal	21FLFTM 28020256FTM	-31.0	F	-26.2	F	0.13	P
3235L	Townsend Canal	21FLFTM 28020030 21FLFTM 28020250FTM	10.2	VG	13.4	VG	0.29	P

Table 4.3. Statistical summary of Caloosahatchee tributary WBID modeled TN calibration

Columns show the R^2 and percent error, with adjacent columns showing the qualitative rating of each statistic.
Abbreviations: P = Poor, F = Fair; G = Good; VG = Very good

WBID	Location	IWR Station IDs	Average % Error	Average % Error Rating	Median % Error	Median % Error Rating	R^2	R^2 Rating
3246	Ninemile Canal	21FLFTM 28020139	-32.1	G	-28.6	VG	0.00	P
3246	Disston Canal	21FLFTM 28020254FTM	-54.6	F	-44.7	G	0.02	P
3246	Industrial Canal	21FLSFWMINDUSCAN	-14.3	VG	-11.1	VG	0.32	P
3237E	C-19	21FLSFWMCR-04.8T	23.5	VG	11.6	VG	0.76	G
3237E	C-19 Canal	21FLFTM 28020248FTM	17.1	VG	13.4	VG	0.36	P
3237C	Caloosahatchee (S-77)	21FLFTM 28020247FTM 21FLFTM RECON-MH2-FTM 21FLFTM RECON-MH-FTM 21FLSFWMMHASRDIS 21FLSFWMS77 21FLSFWMS77-SW	15.9	VG	13.9	VG	0.07	P
3237C	Lake Hicpochee LH2	21FLFTM 28020246FTM	0.1	VG	6.6	VG	0.00	P
3237B	C-4 Canal	21FLFTM 28020257FTM	31.5	G	30.2	G	0.45	P
3237B	Long Hammock Canal	21FLFTM 28020256FTM	91.8	P	83.9	P	0.13	P
3235L	Townsend Canal	21FLFTM 28020030 21FLFTM 28020250FTM	41.7	G	39.4	G	0.08	P

Table 4.4. Statistical summary of Caloosahatchee tributary WBID modeled TP calibration

Columns show the R^2 and percent error, with adjacent columns showing the qualitative rating of each statistic.
Abbreviations: P = Poor, F = Fair; G = Good; VG = Very good

WBID	Location	IWR Station IDs	Average % Error	Average % Error Rating	Medan % Error	Median % Error Rating	R^2	R^2 Rating
3246	Ninemile Canal	21FLFTM 28020139	87.9	P	99.0	P	0.13	P
3246	Disston Canal	21FLFTM 28020254FTM	65.9	P	105.8	P	0.23	P
3246	Industrial Canal	21FLSFWMINDUSCAN	24.8	VG	30.3	G	0.19	P
3237E	C-19	21FLSFWMCR-04.8T	-53.9	F	-34.4	G	0.49	P
3237E	C-19 Canal	21FLFTM 28020248FTM	15.4	VG	45.1	F	0.17	P
3237C	Caloosahatchee (S-77)	21FLFTM 28020247FTM 21FLFTM RECON-MH2-FTM 21FLFTM RECON-MH-FTM 21FLSFWMMHASRDIS 21FLSFWMS77 21FLSFWMS77-SW	42.0	G	40.4	G	0.16	P
3237C	Lake Hicpochee LH2	21FLFTM 28020246FTM	186.5	P	231.2	P	0.08	P
3237B	C-4 Canal	21FLFTM 28020257FTM	52.6	F	44.8	G	0.14	P
3237B	Long Hammock Canal	21FLFTM 28020256FTM	203.1	P	250.1	P	0.07	P
3235L	Townsend Canal	21FLFTM 28020030 21FLFTM 28020250FTM	-23.3	VG	-18.7	VG	0.00	P

Table 4.5. Statistical summary of Caloosahatchee tributary WBID modeled temperature calibration

Columns show the R^2 and percent error, with adjacent columns showing the qualitative rating of each statistic.
Abbreviations: P = Poor, F = Fair; G = Good; VG = Very good

WBID	Location	IWR Station IDs	Average % Error	Average % Error Rating	Median % Error	Median % Error Rating	R^2	R^2 Rating
3246	Ninemile Canal	21FLFTM 28020139	3.4	VG	1.3	VG	0.86	VG
3246	Disston Canal	21FLFTM 28020254FTM	3.1	VG	1.2	VG	0.84	VG
3246	Industrial Canal	21FLSFWMINDUSCAN	2.1	VG	0.1	VG	0.97	VG
3237E	C-19	21FLSFWMCR-04.8T	3.0	VG	2.7	VG	0.92	VG
3237E	C-19 Canal	21FLFTM 28020248FTM	0.5	VG	-4.4	VG	0.85	VG
3237C	Caloosahatchee (S-77)	21FLFTM 28020247FTM 21FLFTM RECON-MH2-FTM 21FLFTM RECON-MH-FTM 21FLSFWMMHASRDIS 21FLSFWMS77 21FLSFWMS77-SW	1.1	VG	-0.3	VG	0.99	VG
3237C	Lake Hicpochee LH2	21FLFTM 28020246FTM	-0.1	VG	-3.6	VG	0.89	VG
3237B	C-4 Canal	21FLFTM 28020257FTM	3.4	VG	-2.5	VG	0.79	G
3237B	Long Hammock Canal	21FLFTM 28020256FTM	0.3	VG	-2.0	VG	0.86	VG
3235L	Townsend Canal	21FLFTM 28020030 21FLFTM 28020250FTM	-1.3	VG	-2.5	VG	0.95	VG

Table 4.6. Statistical summary of Caloosahatchee tributary WBID modeled BOD calibration

Columns show the R^2 and percent error, with adjacent columns showing the qualitative rating of each statistic.
Abbreviations: NC = Not calculated, P = Poor, F = Fair; G = Good; VG = Very good

WBID	Location	IWR Station IDs	Average % Error	Average % Error Rating	Median % Error	Median % Error Rating	R^2	R^2 Rating
3246	Ninemile Canal	21FLFTM 28020139	NC	NC	NC	NC	NC	NC
3246	Disston Canal	21FLFTM 28020254FTM	-89.7	P	-91.1	P	0.32	P
3246	Industrial Canal	21FLSFWMINDUSCAN	NC	NC	NC	NC	NC	NC
3237E	C-19	21FLSFWMCR-04.8T	NC	NC	NC	NC	NC	NC
3237E	C-19 Canal	21FLFTM 28020248FTM	-24.2	VG	-27.0	VG	0.25	P
3237C	Caloosahatchee (S-77)	21FLFTM 28020247FTM 21FLFTM RECON-MH2-FTM 21FLFTM RECON-MH-FTM 21FLSFWMMHASRDIS 21FLSFWMS77 21FLSFWMS77-SW	-36.3	G	-19.6	VG	0.01	P
3237C	Lake Hicpochee LH2	21FLFTM 28020246FTM	-64.5	P	-64.0	P	0.09	P
3237B	C-4 Canal	21FLFTM 28020257FTM	211.9	P	223.7	P	0.25	P
3237B	Long Hammock Canal	21FLFTM 28020256FTM	3.6	VG	-2.0	VG	0.67	F
3235L	Townsend Canal	21FLFTM 28020030 21FLFTM 28020250FTM	70.4	P	21.6	VG	0.01	P

4.3.3 Determining Existing Loading with the Calibrated 2017 HSPF Model

To isolate the loading from land uses in the Caloosahatchee River Basin, simulated nutrient concentrations for water entering the basins from Lake Okeechobee were set to approximate the concentration equivalents that would be achieved under the reduced loads from the adopted Lake Okeechobee TP TMDL (DEP 2001a). Details on the nutrient concentrations and how they were applied in the model are described in **Section 3.4.3** of this report and in **Section 2.5.2** of the Modeling Report (Tetra Tech 2017). **Section 2.2.4** of the Modeling Report (Tetra Tech 2017) describes the locations of Lake Okeechobee boundary inputs.

Output loads for all water quality parameters were calculated for the HSPF reach segments. As described previously, HSPF takes into account the incoming loads from the land surface, incorporates in-stream attenuation and in-stream processes, and then provides outflow values for the loads leaving each modeled reach. To derive the loads from each WBID, the local loads and their upstream contributions were summed. The estimated annual TN, TP, and BOD nutrient loads entering the impaired tributary WBIDs were summed for each WBID, based on all the modeled watersheds and reaches that contribute to each WBID. The C-19 Canal, Long Hammock Creek, and Townsend Canal receive inputs from only their surrounding watersheds.

The S-4 Basin and Lake Hicpochee receive contributions from upstream waters as well as their local watersheds, and these loads were included in the total loading estimates. The S-4 Basin load includes a portion from Lake Okeechobee as well as Ninemile Canal. Lake Hicpochee receives loads from the S-4 Basin and C-19 Canal, in addition to significant loading from Ninemile Canal and Lake Okeechobee. For both of these waterbodies, for the purposes of determining percent reductions, the current condition loading was estimated as the modeled current condition loads for the local watersheds, while the upstream contributions for waters with existing TMDLs or receiving TMDLs in this report were set to their modeled TMDL scenario load contributions.

In this way, the total loads in the watershed (both local and from upstream contributions) were accounted for, but the reductions were based entirely on the loading reductions from the local watershed. In the case of Lake Hicpochee, the loads were based on the loads from TMDL waters (S-4 Basin, C-19 Canal, and Lake Okeechobee) being set to their modeled adopted TMDL loads, while the loads from the immediate Lake Hicpochee contributing watershed and Ninemile Canal were based on the modeled current condition loads. The reductions for Lake Hicpochee are based entirely on the load from the Lake Hicpochee and Ninemile Canal Watersheds.

To account for interannual variation, the maximum seven-year rolling average of the modeled loads from the calibrated model was calculated. The period of seven years covers typical drought and above-average rain years in Florida in each rolling average window. **Appendix B** contains the complete list of 7-year rolling average loads with the maximum rolling average loads highlighted. **Table 4.7** also lists the maximum rolling average loads for TN, TP, and BOD in each WBID, and the numbers reflect the simulated current existing condition nutrient loading for the five impaired WBIDs during the modeled period. Although the BOD calculations include the organic components of TN and TP, **Table 4.7** and the subsequent tables showing TN, TP, and BOD loads include all components comprising TN and TP to account for each of the three parameters individually for regulatory purposes.

These loads provide a baseline for the nutrients and potential eutrophication contributing to low DO in these waterbodies. Further modeling, discussed in **Section 4.4**, was used to determine the nutrient load reductions needed to reduce the frequency of DO excursions below the criterion and thus restore the systems.

Table 4.7. Current Caloosahatchee River Basin tributaries HSPF Model scenario, maximum seven-year rolling average nutrient loads, 1996–2014

Waterbody (WBID)	Maximum 7-Year Rolling Annual Average TN Loads (lbs)	Maximum 7-Year Rolling Annual Average TP Loads (lbs)	Maximum 7-Year Rolling Annual Average BOD Loads (lbs)
S-4 Basin (3246)	559,666	39,269	921,340
C-19 Canal (3237E)	150,963	9,896	361,071
Lake Hicpochee (3237C)	4,282,254	232,916	5,927,159
Long Hammock Creek (3237B)	569,554	43,774	1,334,760
Townsend Canal (3235L)	480,366	46,063	1,077,001

4.3.4 Natural Background Loading

It is critical to ensure that the proposed reductions for a TMDL do not abate natural conditions; in other words, the reductions should only apply to the anthropogenic loading contribution. To estimate the natural background loading in these waterbodies, all point source, reuse, and OSTDS inputs were removed, and all nonpoint source–related water quality parameters (i.e., build-up/wash-off coefficients and their related EMCs) were changed to those of natural land. The conversions were based on soil type, with hydric soils converted to wetlands and nonhydric soils converted to upland forest.

These areas were used to calculate natural background conditions, with no alterations made to the calibrated hydrology. Pumping and irrigation influences on flow in the watersheds were maintained. This natural background scenario used TN, TP, and TOC concentrations (as detailed in **Section 3.4.3** in the discussion of boundary conditions, these are estimated concentrations derived from the load values in the Lake Okeechobee TMDL) for the Lake Okeechobee boundary conditions assumed to be meeting the 2001 TMDL (DEP 2001a).

Because land use characteristics and practices influence reach-dependent benthic oxygen demand (BENOD), BENOD coefficients were reduced by 40 % for the natural background model run. This assumption was also supported by analyses during model development (Tetra Tech 2017). When BENOD was decreased in model runs, the simulated DO concentrations either increased or remained the same. If simulated weirs were present—representing weirs, structures, ponding, or other obstructions—stream velocities were slower, and decreasing BENOD caused an increase in DO.

Although these systems are substantially altered by humans, the natural background scenario should provide a reasonable estimate of the loading that may be achievable under current hydrologic conditions. As with the existing conditions modeling, total loads to each WBID calculated from the natural background scenario were used to derive the maximum seven-year rolling average loads for natural background conditions.

4.4 Calculation of the TMDLs

The TMDL scenario was developed through an iterative series of nutrient reductions to attain the DO criterion (including the natural background provision) in the five WBIDs. The first step was to reduce TN, TP, and BOD concentrations from surface runoff and OSTDS contribution by a given percentage until the allowable DO criterion exceedance rate (10 %) was met. Model output was then evaluated for changes in TN load in each WBID. In each iteration, because BENOD was assumed to be 40 % lower under natural background than existing conditions, it was reduced relative to the percent anthropogenic TN reduction achieved in the previous iteration. The annual nutrient loads were computed for each year of the modeled period, from 1996 to 2014.

To attain the DO criterion in the S-4 Basin and C-19 Canal, TN, TP, and BOD were reduced by 50 %. In Lake Hicpochee and Townsend Canal, TN, TP, and BOD were reduced by 38 %. In Long Hammock Creek, TN, TP, and BOD were reduced by 45 %. As described above, these load reductions were achieved solely by decreasing constituent concentrations in surface runoff and septic contributions, rather than by reducing flows and concentrations.

The TMDL scenario is the nutrient reduction that achieves the criterion for DO, where no more than 10 % of the daily average DO percent saturation values fall below 38 %. For instance, in the C-19 Canal, the modeled DO excursion rate was 23 % under current conditions, 9 % under the TMDL scenario, and 7 % under the natural background scenario. As a result of reducing nutrient loading by the values indicated in the TMDL run, DO percent saturation should fall below 38 % at a frequency of 10 % or less.

Table 4.8. Reaches used to determine modeled DO percent saturation

Waterbody (WBID)	Reaches Used to Provide Modeled DO Percent Saturation
S-4 Basin (3246)	214, 216, 217, 218, 219, 220
C-19 Canal (3237E)	208, 209, 210
Lake Hicpochee (3237C)	206, 207
Long Hammock Creek (3237B)	191, 192, 193, 194, 199, 200, 202, 203, 204
Townsend Canal (3235L)	162, 163

Table 4.8 identifies which model reaches (RCHRES) provided the modeled DO percent saturation values used to assess the impact of simulated nutrient reductions on simulated DO, and **Table 4.9** lists the resulting DO percent saturation excursion rates (the percent of modeled DO percent saturation falling below 38 %) under the current conditions and TMDL scenario. The

excursion rate in the TMDL scenario for the S-4 Basin fell below the natural background, resulting in greater reductions under the TMDL scenario than under the natural background scenario. Therefore, to avoid abating natural conditions, the natural background scenario loads were used instead of the TMDL scenario loads.

Table 4.9. Modeled DO percent saturation excursion rate under existing conditions and TMDL conditions

Waterbody (WBID)	Existing Conditions Excursion Rate (%)	TMDL Scenario Excursion Rate (%)
S-4 Basin (3246)	22	7
C-19 Canal (3237E)	23	10
Lake Hicpochee (3237C)	14	7
Long Hammock Creek (3237B)	5	0
Townsend Canal (3235L)	12	1

Loads were generated for each modeled reach, and these local loads were combined based on the watershed area. Additionally, any upstream components were accounted for in cases where local watershed loads were supplemented by in-stream loads from upstream waters. For instance, the total loads for Lake Hicpochee included upstream contributions from the S-4 Basin (including Disston Canal and the LD-1 Canal), C-19 Canal, Ninemile Canal, and the Lake Okeechobee TMDL loads. The TMDLs were calculated using the maximum of seven-year rolling average loads achieved in the final TMDL model scenario. As discussed previously, the use of these seven-year rolling averages reduces the impact of year-to-year stochastic effects over shorter periods. It is assumed that nutrient management practices implemented on the adoption of these TMDLs will include practices that reduce both TN and TP, and subsequently BOD and benthic oxygen demand, in all years. Model output for 1996 through 2014 was used for calculating the TMDLs.

As mentioned in Section 4.3.3, **Appendix B** shows the annual output loads for each watershed for TN, TP, and BOD as well as the calculations of the maximum seven-year rolling average for each parameter in each WBID. **Table 4.10** lists the maximum of the seven-year rolling averages of modeled nutrient loads under the TMDL condition. These values represent the reductions in TN, TP, and BOD of the loads listed in **Table 4.7** that will result in the waterbodies attaining the DO criterion (which incorporates natural background).

Table 4.10. Caloosahatchee River Basin tributaries TMDL condition, maximum nutrient seven-year rolling average loads, 1996–2014

Waterbody (WBID)	Maximum 7-Year Rolling Annual Average TN Loads (lbs)	Maximum 7-Year Rolling Annual Average TP Loads (lbs)	Maximum 7-Year Rolling Annual Average BOD Loads (lbs)
S-4 Basin (3246)	430,844	28,622	664,946
C-19 Canal (3237E)	78,114	5,167	186,354
Lake Hicpochee (3237C)	4,211,272	234,851	5,818,635
Long Hammock Creek (3237B)	330,381	25,384	773,946
Townsend Canal (3235L)	300,564	28,749	673,151

Chapter 5: Determination of Loading Allocations

5.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating loads to all the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which accounts for uncertainty in the relationship between effluent limitations and water quality:

$$\textbf{TMDL} = \sum \textbf{WLAs} + \sum \textbf{LAs} + \textbf{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\textbf{TMDL} \cong \sum \textbf{WLAs}_{\textbf{wastewater}} + \sum \textbf{WLAs}_{\textbf{NPDES Stormwater}} + \sum \textbf{LAs} + \textbf{MOS}$$

The various components of the revised TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as "percent reduction" because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of best management practices (BMPs).

This approach is consistent with federal regulations (40 Code of Federal Regulations [CFR] § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure.

These TMDLs are based on the maximum of seven-year rolling averages of HSPF Model–simulated nutrient loads for 1996 through 2014 under the TMDL model run that attains the DO criterion. The TMDLs for the Caloosahatchee River Basin tributaries are expressed as seven-year rolling averages as TN, TP, and BOD loads and represent the loads that the waterbodies can assimilate and achieve the generally applicable numeric nutrient criteria (NNC) for DO of fewer than 10 % of observations at less than 38 % saturation, or attain natural background DO concentrations, thus protecting the waterbodies' designated uses. **Table 5.1** lists the TMDLs for the Caloosahatchee River Basin tributaries.

Table 5.1. TMDL components for nutrients in the Caloosahatchee River Basin tributaries

[1] The TMDL represents a 7-year rolling average of annual loads, not to be exceeded. Dividing by 365 yields daily TMDL loads.
[2] The required percent reductions listed in this table represent the reduction from all sources.
[3] MOS is implicit.
NA = Not applicable

Waterbody (WBID)	Parameter	TMDL (maximum 7-year average load in lbs)[1]	WLA Wastewater (% reduction)[2, 3]	WLA NPDES Stormwater (% reduction)[2, 3]	LA (% reduction)[2, 3]
S-4 Basin (3246)	TN	430,844	NA	23	23
S-4 Basin (3246)	TP	28,622	NA	27	27
S-4 Basin (3246)	BOD	664,946	NA	28	28
C-19 Canal (3237E)	TN	78,114	NA	48	48
C-19 Canal (3237E)	TP	5,167	NA	48	48
C-19 Canal (3237E)	BOD	186,354	NA	48	48
Lake Hicpochee (3237C)	TN	4,175,743	NA	2	2
Lake Hicpochee (3237C)	TP	227,423	NA	2	2
Lake Hicpochee (3237C)	BOD	5,768,701	NA	3	3
Long Hammock Creek (3237B)	TN	330,381	NA	42	42
Long Hammock Creek (3237B)	TP	25,384	NA	42	42
Long Hammock Creek (3237B)	BOD	773,946	NA	42	42
Townsend Canal (3235L)	TN	300,564	NA	37	37
Townsend Canal (3235L)	TP	28,749	NA	38	38
Townsend Canal (3235L)	BOD	673,151	NA	37	37

5.2 Load Allocation

To achieve the LA, the reductions in TN, TP, and BOD listed in **Table 5.1** will be required. The TMDLs are based on the percent reduction in total watershed loading; however, it is not DEP's intent to abate natural conditions. It should be noted that the LA includes loading from stormwater discharges regulated by DEP and the water management districts that are not part of the NPDES stormwater program (see **Appendix A**).

5.3 Wasteload Allocation

5.3.1 NPDES Wastewater Discharges

As noted in **Chapter 3**, the City of Clewiston WWTF (Permit FL 0040665) discharges to land application and reuse sprayfields in the S-4 Basin, with underdrains discharging to surface waters. Also, the Glades County Correctional Wastewater Treatment Reuse Facility listed in **Chapter 3** discharges to a land application site that is isolated from surface waters by surrounding berms; it does not continuously discharge to the Caloosahatchee River Basin. No percent reductions are required to the permitted discharge from either facility, as the permitted contribution is *de minimus*.

5.3.2 NPDES Stormwater Discharges

The permittees in the S-4 Basin are the City of Clewiston (Permit ID FLR04E134), Glades County (Permit ID FLR04E137), and Hendry County (Permit ID FLR04E138). Areas under county jurisdiction in the watershed are responsible for a 23 % reduction in TN, a 27 % reduction in TP, and a 28 % reduction in BOD from the current anthropogenic loading.

The permittee located in the C-19 Canal Watershed is Glades County (Permit ID FLR04E137). Areas under county jurisdiction in the watershed are responsible for a 48 % reduction in TN, a 48 % reduction in TP, and a 48 % reduction in BOD from the current anthropogenic loading.

The only NPDES permittee in the Lake Hicpochee Watershed is Glades County (Permit ID FLR04E137). Areas under county jurisdiction in the watershed are responsible for a 2 % reduction in TN, a 2 % reduction in TP, and a 3 % reduction in BOD from the current anthropogenic loading.

The MS4 permittees in the Long Hammock Creek Watershed are Glades County (Permit ID FLR04E137) and Hendry County (Permit ID FLR04E138). Areas under county jurisdiction in the watershed are responsible for a 42 % reduction in TN, a 42 % reduction in TP, and a 42 % reduction in BOD from the current anthropogenic loading.

Finally, the permittees in the Townsend Canal Watershed are Hendry County (Permit ID FLR04E138) and Collier County (Permit ID FLR04E037). Areas under county jurisdiction in the watershed are responsible for a 37 % reduction in TN, a 38 % reduction in TP, and a 37 % reduction in BOD from the current anthropogenic loading.

5.4 Margin of Safety (MOS)

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings. Consistent with the recommendations of the Allocation Technical Advisory Committee (DEP 2001b), an implicit MOS was used in the development of these TMDLs. The MOS is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody (CWA, Section 303[d][1][c]).

The MOS was implicitly accounted for through various conservative assumptions in the modeling and in the derivation of the TMDLs. Part of the MOS derives from the nutrient loads from Lake Okeechobee that are assumed to always equal the TMDL target concentrations. However, to meet the TMDLs, the concentrations in some periods will need to be below the TMDL targets. In reality, to meet the TMDLs at all times (bounded on the high end) based on normal fluctuations, there would necessarily be periods when the outputs from Lake Okeechobee would fall below the TMDL loads. Therefore, the modeling represents a worst-case situation where Lake Okeechobee is contributing the absolute maximum load possible, while still achieving its TMDLs. Another conservative element relates to the fact that the TMDL modeling period only extends to 2014, which does not account for any water quality improvements resulting from the implementation of agricultural BMPs in the basin since 2014.

An additional conservative assumption was made in the estimation of BENOD by setting a maximum 95 % relative benthic oxygen demand reduction, under the assumption that benthic oxygen demand was 40 % lower under natural land use than existing conditions, and this value was reduced relative to the percent anthropogenic TN reduction achieved in the previous scenario. If the model scenario achieved greater than a 95 % reduction from the anthropogenic TN load for a given sub-basin, then the resulting benthic oxygen demand was 0.95 x 0.40 = 0.38, or 38 %. Finally, the use of a 7-year rolling average helps detect longer-term trends and patterns of causal relationships that are not readily apparent in annual or monthly averages.

Chapter 6: Implementation Plan Development and Beyond

6.1 Implementation Mechanisms

Following the adoption of a TMDL, implementation takes place through various measures. The implementation of TMDLs may occur through specific requirements in NPDES wastewater and MS4 permits, and, as appropriate, through local or regional water quality initiatives or basin management action plans (BMAPs).

Facilities with NPDES permits that discharge to a TMDL waterbody must implement the permit conditions that reflect target concentrations, reductions, or WLAs identified in the TMDL. NPDES permits are required for Phase I and Phase II MS4s as well as domestic and industrial wastewater facilities that discharge wastewater to surface waters. MS4 permits require a permit holder to prioritize and act to address a TMDL unless management actions to achieve that TMDL are already defined in a BMAP or other form of restoration plan (e.g., a reasonable assurance plan).

6.2 BMAPs

Information on the development and implementation of BMAPs is contained in Section 403.067, F.S. (the FWRA). DEP or a local entity may initiate and develop a BMAP that addresses some or all the contributing areas to the TMDL waterbodies. BMAPs are adopted by the DEP Secretary and are legally enforceable.

BMAPs describe the fair and equitable allocations of pollution reduction responsibilities to the sources in the watershed, as well as the management strategies that will be implemented to meet those responsibilities, funding strategies, mechanisms to track progress, and water quality monitoring. Local entities—such as wastewater facilities, industrial sources, agricultural producers, county and city stormwater systems, military bases, water control districts, state agencies, and individual property owners—usually implement these strategies. BMAPs can also identify mechanisms to address potential pollutant loading from future growth and development.

The Lake Okeechobee BMAP covers portions of the Caloosahatchee River Basin, including the S-4 Basin, C-19 Canal, Lake Hicpochee, Ninemile Canal, and Long Hammock Creek. Townsend Canal is the only WBID in this TMDL analysis that is not included in the existing Lake Okeechobee BMAP area. Although the existing Lake Okeechobee TMDL is for TP only, reductions in both TN and TP are implicit in BMAP activities.

The Caloosahatchee Estuary BMAP is in effect for the tidal portion of the Caloosahatchee and the surrounding contributing watershed, although the existing BMAP does not yet extend upstream of S-79 into the Caloosahatchee River. For this reason, this TMDL for the

Caloosahatchee Tributaries provides an important link between current BMAP projects and ties the disconnected portions of the watershed into ongoing restoration efforts.

6.3 Implementation Considerations for the Waterbodies

In addition to addressing reductions in watershed pollutant contributions to impaired waters during the implementation phase, it may also be necessary to consider the results of any associated remediation efforts on surface water quality. For the Caloosahatchee River Basin, these projects currently include the Lake Hicpochee Shallow Storage and Hydrologic Enhancement Project and the C-43 West Basin Storage Reservoir.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, DEP stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations, as authorized under Part IV of Chapter 373, F.S.

Chapter 62-40, F.A.C., also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) Program plan, other watershed plan, or rule. Stormwater PLRGs can be a major component of the load allocation part of a TMDL. For instance, they have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal CWA Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES stormwater program in 1990 to address stormwater discharges associated with industrial activity, including 11 categories of industrial activity, construction activities disturbing 5 or more acres of land, and large and medium MS4s located in incorporated places and counties with populations of 100,000 or more.

However, because the master drainage systems of most local governments in Florida are physically interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 special districts; community development districts, water control districts, and FDOT throughout the 15 counties meeting the population criteria. DEP received authorization to implement the NPDES stormwater program in 2000. The authority to administer the program is set forth in Section 403.0885, F.S.

The Phase II NPDES stormwater program, promulgated in 1999, addresses additional sources, including small MS4s and small construction activities disturbing between 1 and 5 acres, and urbanized areas serving a minimum resident population of at least 1,000 individuals. While these urban stormwater discharges are technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that Phase I MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: HSPF Model Scenario Loads and Rolling Averages

Table B.1. S-4 Basin (WBID 3246) existing condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the seven-year rolling average for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	375,593		19,595		616,192	
1997	279,560		14,382		492,918	
1998	1,007,470		120,691		1,808,366	
1999	733,574		42,578		1,220,850	
2000	411,881		21,503		616,058	
2001	375,207		18,381		656,447	
2002	734,378	**559,666**	37,755	**39,269**	1,038,550	**921,340**
2003	257,692	542,823	14,185	38,497	471,475	900,666
2004	357,135	553,905	17,814	38,987	634,934	920,954
2005	567,937	491,115	33,353	26,510	1,013,602	807,417
2006	289,790	427,717	14,792	22,540	481,635	701,814
2007	190,044	396,026	9,097	20,768	353,490	664,305
2008	710,589	443,938	80,656	29,665	1,246,485	748,596
2009	504,644	411,119	25,734	27,947	858,463	722,869
2010	205,499	403,663	13,119	27,795	339,850	704,065
2011	416,500	412,143	20,862	28,230	636,601	704,304
2012	274,258	370,189	14,587	25,550	434,606	621,590
2013	270,248	367,397	13,446	25,357	440,399	615,699
2014	287,076	381,259	14,635	26,148	447,819	629,175

Table B.2. C-19 Canal (WBID 3237E) existing condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the seven-year rolling average for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	85,549		3,817		203,909	
1997	97,402		4,321		231,920	
1998	242,470		13,851		582,490	
1999	311,940		20,748		748,370	
2000	56,081		2,450		133,725	
2001	119,731		5,434		285,200	
2002	126,612	148,541	5,676	8,042	301,610	355,318
2003	102,502	**150,963**	4,561	8,149	244,180	**361,071**
2004	42,182	143,074	1,824	7,792	100,395	342,281
2005	186,888	135,134	8,562	7,037	445,160	322,663
2006	79,539	101,934	3,615	4,589	189,813	242,869
2007	65,765	103,317	2,881	4,651	156,589	246,135
2008	349,350	136,120	40,810	9,704	847,810	326,508
2009	131,864	136,870	5,931	9,741	314,050	328,285
2010	52,637	129,746	2,518	9,449	125,914	311,390
2011	110,740	139,540	4,954	**9,896**	263,740	334,725
2012	66,341	122,319	3,055	9,109	158,745	293,809
2013	156,848	133,364	7,367	9,645	373,700	320,078
2014	71,613	134,199	3,152	9,684	170,475	322,062

Table B.3. Lake Hicpochee (WBID 3237C) existing condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the 7-year rolling average for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	1,578,576		87,043		2,021,965	
1997	941,158		45,563		1,210,492	
1998	7,545,651		428,095		10,038,628	
1999	3,255,660		180,888		4,665,078	
2000	2,235,018		120,011		2,802,285	
2001	779,829		35,948		1,009,090	
2002	2,687,912	2,717,686	138,364	147,987	3,403,947	3,593,069
2003	6,149,315	3,370,649	341,457	184,332	8,647,951	4,539,639
2004	4,763,537	3,916,703	251,720	213,783	6,604,253	5,310,176
2005	10,104,506	**4,282,254**	562,021	**232,916**	14,357,508	**5,927,159**
2006	1,756,257	4,068,053	91,926	220,207	2,312,206	5,591,034
2007	570,678	3,830,291	26,613	206,864	710,735	5,292,241
2008	1,948,940	3,997,306	186,985	228,441	2,801,938	5,548,362
2009	1,588,328	3,840,223	86,085	220,972	2,022,488	5,351,011
2010	3,143,714	3,410,851	189,032	199,197	4,091,077	4,700,029
2011	832,816	2,849,320	38,319	168,712	1,029,720	3,903,667
2012	2,219,126	1,722,837	120,011	105,567	2,974,023	2,277,455
2013	5,238,217	2,220,260	267,486	130,647	8,216,692	3,120,953
2014	1,761,893	2,390,433	89,282	139,600	2,394,075	3,361,430

Table B.4. Long Hammock Creek (WBID 3237B) existing condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the 7-year rolling average for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	195,699		8,794		463,415	
1997	204,152		9,100		481,595	
1998	539,245		28,916		1,268,868	
1999	1,073,192		109,600		2,530,740	
2000	312,585		14,376		732,765	
2001	884,566		49,115		2,061,322	
2002	451,187	522,947	21,050	34,422	1,054,097	1,227,543
2003	224,521	527,064	9,975	34,590	530,045	1,237,062
2004	199,188	526,355	8,769	34,543	469,854	1,235,384
2005	841,640	**569,554**	43,524	36,630	1,964,500	**1,334,760**
2006	242,764	450,922	11,046	22,551	570,671	1,054,751
2007	297,976	448,835	13,542	22,432	702,199	1,050,384
2008	958,342	459,374	162,698	38,658	2,306,530	1,085,414
2009	701,625	495,151	39,861	41,345	1,640,175	1,169,139
2010	290,249	504,541	13,314	41,822	685,433	1,191,337
2011	495,049	546,806	22,434	**43,774**	1,156,576	1,289,441
2012	264,483	464,355	12,195	39,299	623,009	1,097,799
2013	602,138	515,695	28,636	41,812	1,407,435	1,217,337
2014	287,995	514,269	13,260	41,771	679,970	1,214,161

Table B.5. Townsend Canal (WBID 3235L) existing condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the 7-year rolling average for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	119,131		4,906		266,895	
1997	139,796		5,617		313,749	
1998	216,757		9,455		484,972	
1999	846,260		117,897		1,920,220	
2000	780,640		100,387		1,759,560	
2001	887,390		70,089		1,973,290	
2002	145,326	447,900	5,677	44,861	323,457	1,006,020
2003	203,054	459,889	8,140	45,323	452,224	1,032,496
2004	174,265	464,813	6,848	45,499	388,409	1,043,162
2005	325,625	**480,365**	13,404	**46,063**	721,847	**1,077,001**
2006	192,179	386,926	8,430	30,425	428,196	863,855
2007	99,819	289,665	3,964	16,650	223,782	644,458
2008	812,170	278,920	184,017	32,926	1,882,170	631,441
2009	174,223	283,048	6,985	33,112	387,153	640,540
2010	158,281	276,652	6,766	32,916	356,641	626,885
2011	223,732	283,718	9,074	33,234	496,640	642,347
2012	179,880	262,898	7,400	32,377	401,245	596,547
2013	504,880	307,569	22,227	34,347	1,117,430	695,009
2014	214,192	323,908	9,381	35,121	478,907	731,455

Table B.6. S-4 Basin (WBID 3246) TMDL condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the 7-year rolling average for each parameter is indicated in bold font and light blue shading. Note that the maximum rolling averages used in calculating percent reductions are derived from the natural conditions run for the S-4 Basin because they are greater than those derived from the TMDL model scenario.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	314,490		16,754		447,492	
1997	220,307		11,504		321,111	
1998	729,997		73,238		1,233,739	
1999	474,040		26,849		792,125	
2000	354,035		18,931		483,974	
2001	236,252		11,616		396,242	
2002	621,198	**421,474**	32,282	**27,311**	845,310	**645,713**
2003	209,438	406,467	11,354	26,539	314,282	626,683
2004	262,740	412,529	13,235	26,787	411,386	639,580
2005	362,471	360,025	21,046	19,331	625,023	552,620
2006	225,725	324,551	11,865	17,190	325,122	485,905
2007	135,971	293,399	6,575	15,425	205,811	446,168
2008	406,840	317,769	43,259	19,945	751,376	496,901
2009	335,661	276,978	17,699	17,862	537,441	452,920
2010	161,414	270,117	9,753	17,633	250,609	443,824
2011	287,617	273,671	14,460	17,808	449,970	449,336
2012	211,643	252,124	11,157	16,396	322,702	406,147
2013	202,065	248,744	10,149	16,150	321,659	405,653
2014	230,467	262,244	11,742	16,889	350,564	426,332

Table B.7. C-19 Canal (WBID 3237E) TMDL condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the 7-year rolling averages for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	43,689		1,974		103,994	
1997	49,595		2,224		117,946	
1998	125,952		7,277		301,680	
1999	163,317		10,916		390,260	
2000	28,559		1,261		67,989	
2001	61,393		2,826		145,978	
2002	65,460	76,852	2,993	4,210	155,677	183,361
2003	52,522	**78,114**	2,372	4,267	124,949	**186,354**
2004	21,429	74,090	935	4,083	50,919	176,779
2005	97,043	69,960	4,544	3,692	230,620	166,627
2006	40,618	52,432	1,867	2,400	96,775	124,701
2007	33,412	53,125	1,477	2,431	79,463	126,340
2008	184,570	70,722	21,282	5,067	446,890	169,328
2009	68,077	71,096	3,120	5,085	161,819	170,205
2010	26,763	67,416	1,290	4,931	63,929	161,488
2011	56,898	72,483	2,587	**5,167**	135,296	173,542
2012	33,666	63,429	1,563	4,741	80,484	152,094
2013	81,124	69,216	3,880	5,028	192,949	165,833
2014	36,400	69,643	1,618	5,048	86,548	166,845

Table B.8. Lake Hicpochee (WBID 3237C) TMDL condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the 7-year rolling averages for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	1,536,638		85,404		1,964,758	
1997	894,776		43,691		1,142,579	
1998	7,393,409		412,984		9,797,069	
1999	3,038,755		165,850		4,324,018	
2000	2,184,850		118,106		2,736,705	
2001	654,076		30,593		824,781	
2002	2,588,240	2,612,963	134,045	141,525	3,262,345	3,436,036
2003	6,108,169	3,266,039	339,746	177,859	8,585,524	4,381,860
2004	4,722,452	3,812,850	250,065	207,341	6,551,979	5,154,632
2005	9,933,658	**4,175,743**	553,554	**227,423**	14,095,554	**5,768,701**
2006	1,705,680	3,985,304	89,854	216,566	2,239,232	5,470,874
2007	526,265	3,748,363	24,910	203,252	650,951	5,172,909
2008	1,695,921	3,897,198	145,830	219,715	2,373,932	5,394,217
2009	1,439,364	3,733,073	78,615	211,796	1,807,223	5,186,342
2010	3,103,756	3,303,871	187,173	190,000	4,035,562	4,536,348
2011	730,574	2,733,603	33,977	159,131	885,816	3,726,896
2012	2,178,236	1,625,685	118,237	96,942	2,916,624	2,129,906
2013	5,155,949	2,118,581	263,769	121,787	8,087,612	2,965,389
2014	1,712,147	2,287,992	87,130	130,676	2,321,993	3,204,109

Table B.9. Long Hammock Creek (WBID 3237B) TMDL condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the 7-year rolling averages for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	112,949		5,256		267,802	
1997	117,972		5,440		278,516	
1998	313,416		17,271		737,718	
1999	622,838		62,950		1,466,428	
2000	179,913		8,528		421,852	
2001	513,001		29,079		1,194,806	
2002	261,066	303,022	12,560	20,155	610,243	711,052
2003	130,172	305,482	6,006	20,262	307,717	716,754
2004	115,136	305,077	5,255	20,236	271,982	715,821
2005	490,541	**330,381**	26,088	21,495	1,144,596	**773,946**
2006	139,793	261,375	6,562	13,440	328,879	611,439
2007	172,415	260,303	8,129	13,383	406,762	609,284
2008	554,575	266,243	91,902	22,357	1,333,714	629,128
2009	405,683	286,902	23,471	23,916	947,812	677,352
2010	168,997	292,449	8,062	24,210	399,651	690,485
2011	287,140	317,021	13,477	**25,384**	671,015	747,490
2012	152,263	268,695	7,245	22,692	359,140	635,282
2013	349,411	298,641	17,163	24,207	817,227	705,046
2014	166,105	297,739	7,891	24,173	392,573	703,019

Table B.10. Townsend Canal (WBID 3235L) TMDL condition HSPF Model scenario annual loads and seven-year rolling averages, 1996–2014

Note: The maximum of the seven-year rolling average for each parameter is indicated in bold font and light blue shading.

Year	TN (lbs/yr)	TN Rolling 7-Year Average	TP (lbs/yr)	TP Rolling 7-Year Average	BOD (lbs/yr)	BOD Rolling 7-Year Average
1996	74,312		3,064		166,134	
1997	87,266		3,509		195,329	
1998	135,600		5,936		302,842	
1999	529,530		73,438		1,199,890	
2000	488,230		62,550		1,099,580	
2001	555,530		43,845		1,234,580	
2002	90,727	280,171	3,551	27,985	201,516	628,553
2003	127,004	287,698	5,113	28,278	282,403	645,163
2004	108,791	290,773	4,287	28,389	242,093	651,843
2005	204,139	**300,564**	8,458	**28,749**	451,997	**673,151**
2006	120,108	242,076	5,280	19,012	267,094	539,895
2007	62,235	181,219	2,470	10,429	139,117	402,686
2008	507,640	174,378	114,416	20,511	1,175,530	394,250
2009	108,828	176,964	4,376	20,629	241,396	399,947
2010	98,772	172,930	4,227	20,502	222,085	391,330
2011	140,098	177,403	5,713	20,706	310,543	401,109
2012	112,294	164,282	4,635	20,160	250,174	372,277
2013	316,458	192,332	14,024	21,409	700,113	434,137
2014	133,947	202,577	5,887	21,897	299,041	456,983