FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration

CENTRAL DISTRICT • INDIAN RIVER LAGOON BASIN

Final TMDL Report

Nutrient TMDLs for Sykes Creek/Barge Canal (WBID 3044B)

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Acknowledgments

This TMDL report was developed based on the Banana River Lagoon main stem seagrass nutrient TMDL, which was in turn developed based on the Pollutant Load Reduction Goal (PLRG) for seagrass restoration in the Indian River Lagoon (IRL) and Banana River Lagoon, created by the St. Johns River Water Management District (SJRWMD). We would like to sincerely thank Mr. Joel Steward and Mr. Whitney Green from SJRWMD, who developed the seagrass PLRG, and Dr. Margret Lasi, who provided great helps on the atmospheric deposition data. In addition, during the process of developing this TMDL, both Dr. Phlips from University of Florida and Mr. Steward and Mr. Green provided very thoughtful analyses on possible causes of the observed elevation of chlorophyll a concentration in the period from 2009-2011. Mr. Green also provided thorough explanations on questions from the Department about the structure of the PLSM watershed model. We also sincerely thank the help from Ms. Virginia Barker and Mr. John Royal from the Brevard County Natural Resource Management, who provided important information regarding the hydrodynamics of Sykes Creek and possible impact from the mosquito impoundments to water quality condition in the creek.

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Total Maximum Daily Load Program

http://www.dep.state.fl.us/water/tmdl/index.htm

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http://www.dep.state.fl.us/legal/Rules/shared/62-303/62-303.pdf

STORET Program

http://www.dep.state.fl.us/water/storet/index.htm

2012 305(b) Report

http://www.dep.state.fl.us/water/docs/2012_integrated_report.pdf

Criteria for Surface Water Quality Classifications

http://www.dep.state.fl.us/water/wqssp/classes.htm

Basin Status Reports and Water Quality Assessment Reports

http://www.dep.state.fl.us/water/tmdl/stat_rep.htm

U.S. Environmental Protection Agency

Region 4: Total Maximum Daily Loads in Florida
http://www.epa.gov/region4/water/tmdl/florida/
National STORET Program
http://www.epa.gov/storet/

Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the nutrient Total Maximum Daily Load (TMDL) for the Sykes Creek/Barge Canal system, located in the Indian River Lagoon (IRL) Basin. This waterbody was verified for nutrient impairment due to elevated annual chlorophyll a (corrected for pheophytin, hereby referred to as corrected Chl*aC*) concentrations observed in 2009 and 2010. The waterbody was added to the Verified List of impaired waters for the IRL Basin by the Secretarial Order on February 7, 2012. The purpose of the TMDL is to establish allowable loadings of nutrients to the Sykes Creek/Barge Canal system such that the waterbody will meet the applicable water quality criteria for nutrients.

1.2 Identification of Waterbody

The Sykes Creek/Barge Canal System is located in northeast Brevard County, along the east central Florida Coast. The system drains part of the town of Merritt Island, which is located in between the IRL on the west and Banana River Lagoon (BRL) on the east. The system includes two major water features -- Sykes Creek and Barge Canal. The Barge Canal (or the Cape Canaveral Barge Canal), which was built in 1965 to allow the commercial transportation between Port Canaveral and the Intracoastal Waterway in the IRL, runs in an east-west direction slightly north of the State Road 528, and connects the IRL and BRL.

The Barge Canal divides Sykes Creek, which runs in a north to south direction, and its drainage basin, into the northern and southern parts. The part of the Sykes Creek drainage basin south of the Barge Canal is highly urbanized, and all the water quality data that were used to verify the nutrient impairment of the system were collected in this segment. The part of the original Sykes Creek drainage basin north of the Barge Canal remains relatively rural. The Sykes Creek segment north of the Barge Canal and the marsh areas flanking both the east and west sides of the creek segment have been impounded for mosquito control. The impounded marsh areas are currently under a rotational impoundment management (RIM), which allows the impounded areas to open to the Barge Canal through several culverts during the fall, winter, and spring seasons and close the impounded areas during the summer for mosquito control (Banner and Moulding, 1988). Because the impounded areas are open to the Barge Canal only during the dry season of the year, only a small portion of the stormwater runoff created in the northern Sykes Creek drainage basin may discharge to the south into the Barge Canal through two RIM ditches located to the west and east of the northern Sykes Creek segment or through several sets of culverts that connect the impounded areas with the Barge Canal. Most of the runoff getting into the Barge Canal is dissipated in the Barge Canal and goes either east toward BRL or west toward IRL. Very little runoff created in the northern basin reaches the southern segment of Sykes Creek (John Royal, Brevard County, personal communication). According to both the St. Johns River Water Management District (SJRWMD) and Brevard County (Mr. Whit Green and Mr. John Royal, personal communication), Sykes Creek functions more like a narrowed estuary than a creek. There is no dominant flow direction in the creek. The flow direction is mostly influenced by the wind. As the creek is connected to the Newfound Harbor in the south, it is reasonable to expect that the water quality condition in the system is significantly influenced by the water quality condition of the harbor. **Figure 1.1** shows the general location of the Sykes Creek/Barge Canal system in the IRL Basin. **Figure 1.2** shows the original drainage basin of Sykes Creek (including the drainage basin south and north of the Barge Canal).

For assessment purposes, the Department has divided the IRL Basin into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. This TMDL report addresses nutrient impairment in the Sykes Creek/Barge Canal system (WBID 3044B) in the IRL Basin. It should be noted that, although the name of the WBID implies that both Sykes Creek and Barge Canal were verified for nutrient impairment, out of more than 240 *ChlaC* samples used to verify the nutrient impairment, only 5 *ChlaC* samples were collected from Barge Canal in a single one sampling event in 2005. *ChlaC* concentration from this sampling event ranged between 1 µg/L and 6 µg/L and mostly below 4 µg/L. There was no sign that Barge Canal was impaired for ChlaC. Therefore, this TMDL focuses on the nutrient impairment of Sykes Creek. The watershed nutrient load reduction proposed in this TMDL will also benefit the nutrient condition of Barge Canal.

1.3 Background

This report was developed as part of the Department's watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the Florida Watershed Restoration Act (FWRA).

A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards, and provide important water quality restoration goals that will guide restoration activities.

In 2009, the Department adopted a set of nutrient TMDLs for the IRL and BRL mainstem segments to restore seagrass distribution in these lagoon segments (FDEP 2009). These TMDLs were based on the Pollutant Load Reduction Goal (PLRG) developed by SJRWMD (Steward et al. 2005). The Sykes Creek watershed is part of the drainage basin that contributes nutrients to the BRL. As later chapters of this report will discuss, the nutrient condition of Sykes Creek is significantly influenced by the water quality condition of the Newfound Harbor, which is part of the BRL lagoon system. Therefore, it is Department's understanding that achieving the nutrient loading targets established for the BRL mainstem segments to restore seagrass distribution should be sufficient to address the nutrient condition of Sykes Creek. For now, the Department's Watershed Planning and Coordination Section is actively working with local stakeholders in the BRL basin to development a basin management action plan (BMAP) to implement the mainstem nutrient TMDLs. These activities will also help reduce the amount of nutrients from the watershed that could have at least partially caused the verified impairment of Sykes Creek. These activities will depend heavily on the active participation of the SJRWMD, local governments, businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for impaired waterbodies.

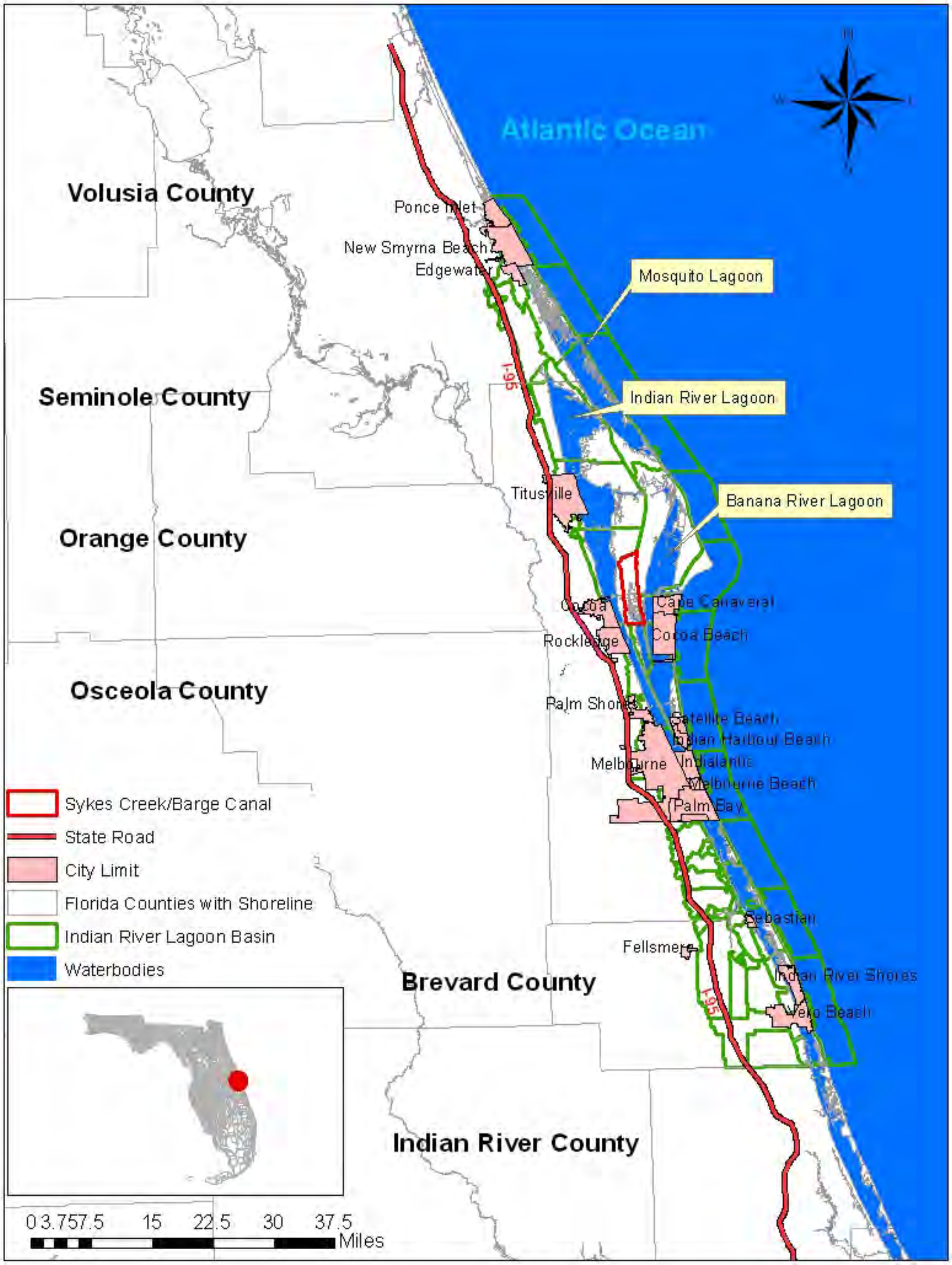

Figure 1.1. General Location of Sykes Creek/Barge Canal in the Indian River Lagoon Basin

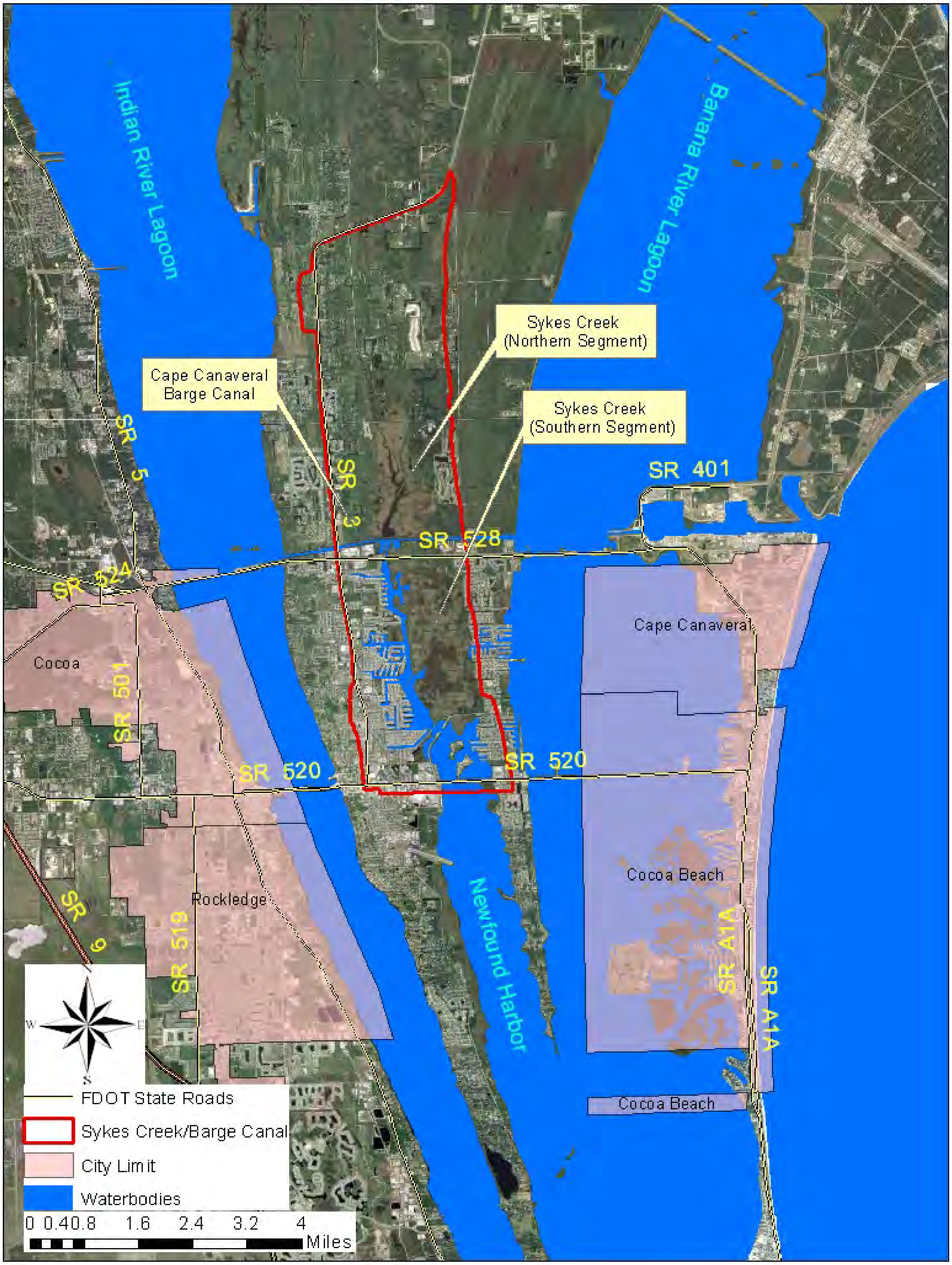

Figure 1.2. Sykes Creek and Barge Canal System

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the Clean Water Act requires states to submit to the EPA a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant source in each of these impaired waters on a schedule. The Department has developed these lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin is also required by the Florida Watershed Restoration Act (FWRA, Subsection 403.067[4], Florida Statutes [F.S.]), and the list is amended annually to include updates for each basin statewide.

Florida's 1998 303(d) list included 16 waterbodies in the IRL Basin. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001; the rule was modified in 2006 and 2007. The list of waters for which impairments have been verified using the methodology in the IWR is referred to as the Verified List.

2.2 Information on Verified Impairment

As is described in the IWR, the primary assessment index for estuary nutrient condition is the annual average chlorophyll *a* concentration corrected for pheophytin (*ChlaC*). A waterbody can be verified for nutrient impairment if the annual average concentration of the *ChlaC* exceeds the 11 µg/L assessment threshold during the verified period. A waterbody can also be verified for nutrient impairment if the annual average *ChlaC* concentration exceeds the historic minimum by more than 50% in two consecutive years during the verified period. The IWR also allows verifying nutrient impairment based on information other than *ChlaC* concentration. This other information includes, but not limited to, algal blooms, excessive macrophyte growth, decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation, changes in algal species richness, and excessive diel oxygen swings, can be considered for verifying nutrient impairment. The state DO water quality criteria for predominant marine water is that the DO concentration shall not average less than 5.0 mg/L in a 24-hour period and shall never be less than 4.0 mg/L. Normal daily and seasonal fluctuations above these levels shall be maintained.

The Sykes Creek/Barge Canal system (WBID 3044B) was listed on the 1998 303(d) list for dissolved oxygen (DO) and nutrients impairment. During Department's Cycle 1 water quality assessments for Group 5 IRL Basin (based on data collected in the period from January 1, 1999 through June 30, 2006), the DO condition for the WBID was found not impaired. Therefore, the DO impairment of the WBID was delisted from the 1998 303(d) list in 2009. There were not sufficient data to reach an assessment conclusion on the nutrient impairment during the Cycle 1 assessment process. During the Cycle 2 assessment (based on data collected in the period from January 1, 2004 through June 30, 2011), the DO condition of the creek was once again confirmed meeting the state water quality criteria. However, the WBID was verified for nutrient impairment based on the observation that the annual average *ChlaC* concentration exceeded the 11 µg/L assessment threshold in 2009 and 2010. The waterbody was put on Department's Verified Listed adopted through a Secretarial Order signed on February 7, 2012. **Table 1** shows the assessment results that caused the waterbody to be verified for nutrient impairment.

Table 2.1. Information Used to List WBID 3044B for Nutrient Impairment

Parameter	Summary of Observation
Annual Average *ChlaC* Concentration	2004 6 µg/L 2005 7 µg/L 2006 6 µg/L 2007 7 µg/L 2008 8 µg/L 2009 12 µg/L 2010 16 µg/L
Median TN Concentration	1.395 mg/L (# of samples = 168)
Median TP Concentration	0.05 mg/L (# of samples =172)
TN/TP Ratio	32
Final Assessment Result	Impaired. Phosphorus is the limiting nutrient.

As pointed out in **Chapter 1**, although the name of the WBID implies that both Sykes Creek and Barge Canal were verified for nutrient impairment, out of more than 240 *ChlaC* samples used to verify the nutrient impairment, only 5 *ChlaC* samples were collected from Barge Canal in a single one sampling event in 2005. *ChlaC* concentration from this sampling event ranged between 1 µg/L and 6 µg/L and mostly below 4 µg/L. There is no sign that Barge Canal is impaired for nutrient. Therefore, this TMDL focuses on the nutrient impairment of Sykes Creek. The watershed nutrient load reduction proposed in this TMDL will also benefit the nutrient condition of Barge Canal.

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface waters are protected for five designated use classifications, as follows:

Class I	**Potable water supplies**
Class II	**Shellfish propagation or harvesting**
Class III	**Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife**
Class IV	**Agricultural water supplies**
Class V	**Navigation, utility, and industrial use (there are no state waters currently in this class)**

The WBID 3044B is a Class III marine waterbody, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife:

The proposed TMDL addresses the Class III water quality criteria for nutrients.

3.2 Applicable Water Quality Standards and interpretation of the narrative nutrient criteria

While the Department is actively developing nutrient criteria for Florida estuaries, the State's existing nutrient criterion for estuary marine waters is, by far, narrative only—i.e., nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. A threshold commonly used for assessing the nutrient impairment in estuaries is the annual average *ChlaC* concentration of 11 µg/L, which is defined in the IWR (Chapter 62-303, F.A.C.). In addition, a waterbody can also be verified for nutrient impairment if the annual average *ChlaC* concentration increases above the historic minimum by more than 50% in at least two consecutive years. The IWR also allows the use of other information indicating an imbalance in flora or fauna due to nutrient enrichment, including, but not limited to, algal blooms, excessive macrophyte growth, a decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation, changes in algal species richness, and excessive diel oxygen swings.

As discussed in Chapter 2, WBID 3044B was verified for nutrient impairment based on the observation that the annual average *ChlaC* concentration in the Sykes Creek/Barge Canal system was elevated above the 11 µg/L impairment threshold in 2009 and 2010 in Department's Cycle 2 water quality assessment.

Chapter 4: ASSESSMENT OF SOURCES

4.1 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 failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act 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, including 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 Clean Water Act 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 6.1** 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.

4.2 Potential Sources of Pollutants in the IRL and Banana River Lagoon Watersheds

4.2.1 Point Sources

4.2.1.1 Wastewater Point Sources

Within the Sykes Creek watershed, there are no NPDES permitted wastewater facilities that discharge into the creek.

4.2.1.2 Municipal Separate Storm Sewer System Permittees

Like other nonpoint sources of pollution, urban stormwater discharges are associated with land uses and human activities, and are driven by rainfall and runoff processes leading to the intermittent discharge of pollutants in response to storms. The 1987 amendments to the Clean Water Act designated certain stormwater discharges from urbanized areas as point sources requiring NPDES stormwater permits. In October 2000, the EPA authorized the Department to implement the NPDES Stormwater Program in all areas of Florida, except for Indian tribal lands.

The Department's authority to administer the NPDES Program is set forth in Section 403.0885, F.S. The three major components of the NPDES stormwater regulations are as follows:

*(1) **Municipal Separate Storm Sewer System (MS4) permits** that are issued to entities that own and operate master stormwater systems, primarily local governments. Permittees are required to implement comprehensive stormwater management programs designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable.*

*(2) **Stormwater Associated with Industrial Activities,** which is regulated primarily by a multisector general permit that covers various types of industrial facilities. Regulated industrial facilities must obtain NPDES stormwater permit coverage and implement appropriate pollution prevention techniques to reduce contamination of stormwater.*

*(2) **Construction Activity Generic Permits** for projects that ultimately disturb one or more acres of land and that require the implementation of stormwater pollution prevention plans to provide erosion and sediment control during construction.*

In addition to the NPDES stormwater construction permitting regulations, Florida was the first state in the country to require the treatment of stormwater for all new developments with the adoption of the state Stormwater Rule in late 1981. The Stormwater Rule is a technology-based program that relies on the implementation of best management practices (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, state legislation created the Environmental Resource Permitting Program to consolidate stormwater quantity, stormwater quality, and wetlands protection into a single permit. Currently, the majority of Environmental Resource Permits are issued by the state's five water management districts, although the Department continues to do the permitting for specified projects.

The NPDES Stormwater Program was implemented in phases, with Phase I MS4 areas including municipalities having a population above 100,000. Because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase 1 of the MS4 Permitting Program on a countywide basis, which brings in all cities, Chapter 298 urban water control districts, and the Florida Department of Transportation (FDOT) throughout the 15 counties meeting the population criteria. Phase II of the NPDES Program was expanded in 2003 and requires stormwater permits for construction sites between 1 and 5 acres, and for local governments with as few as 10,000 people.

Although MS4 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. All Phase 1 MS4 permits issued in Florida include a reopener clause allowing permit revisions for implementing TMDLs once they are formally adopted by rule. Florida's Phase II MS4 Generic Permit has a "self-implementing" requirement once TMDLs are adopted that requires the MS4 permittee to update its stormwater management program (as needed) to meet its TMDL allocations.

The Sykes Creek watershed is covered by a Phase II MS4 permit issued to Brevard County (FLR04E052). The area is also covered by an MS4 permit held by the Florida Department of Transportation (FDOT)(FLR04E024).

4.2.2 Nonpoint Sources

Nonpoint source nutrient loads are loads discharged into Sykes Creek from diffused sources instead of through pipes or fixed outfalls. For Sykes Creek, the majority of nutrient loads come from the runoff created in the watershed, possible ground water input, and atmospheric deposition directly onto the surface of the creek.

For this TMDL, nutrient loads generated in the immediate watershed was estimated using a Pollutant Load Screening Model (PLSM) developed by the SJRWMD (Steward and Green 2006). The model was originally designed by Adamus and Bergman (1995). It is a GIS model that takes advantage of spatially differentiated information such as watershed land use pattern, soil distribution, hydrologic boundaries, and rain gauge networks. This model uses the following equation to estimate pollutant loads from the watershed:

$$L = \sum Aij * Cij * P * EMCi * (1 - T) \qquad \text{Equation 1}$$

Where:

L is the total nutrient load from a given watershed.
A_{ij} is the acreage of the land use (i) – soil type (j) combination ij in the watershed.
C_{ij} is the runoff coefficient for the land use (i) – soil type (j) combination ij in the watershed.
P is the annual rainfall.
$EMCi$ is the event mean concentration for a given land use type i.
T is the removal rate of pollutant through best management practice (BMP) measures.

In assessing the model's reliability in predicting nutrient pollutant loads, the model-simulated runoff volume and TN and TP loads were calibrated against the measured flow and loading estimates based on measured water quality data in four IRL drainage basins: Crane Creek, C-1 Canal of Turkey Creek, South Prong of Sebastian River, and Briar Creek (Green and Steward 2003). The SJRWMD concluded that PLSM predicted reasonably well the measured flow, and TN, TP, and TSS loads derived from measured concentrations and flow.

Ground water input from the Floridan aquifer does not represent a significant portion of the total water budget for the IRL system (Martin et al. 2004). Depending on the season, input from the surficial aquifer to the lagoon could be important. Nutrient contributions from the surficial aquifer were implicitly included in PLSM simulations as part of the budget for watershed flow and nutrient loads because the modeled flow was calibrated against the total flow instead of only surface runoff.

Based on stepwise regression analyses conducted by the SJRWMD, the atmospheric sources of nutrients do not significantly affect the relationship between watershed nutrient loadings and seagrass depth distributions at $\alpha = 0.15$ (Steward and Green 2006). Therefore, the atmospheric nutrient loadings were not included in the original effort to establish the areal watershed nutrient loading targets. However, as these loadings are part of the total nutrient budgets received by the lagoon segments, they were calculated in this TMDL report and added to both the existing total nutrient loadings and TMDLs.

In addition to the nutrient loads created through the watershed runoff, because of the hydrodynamic nature of the BRL systems, Sykes Creek may also receives nutrient-containing waters from the Newfound Harbor. As there was no measured data or reliable existing model to quantify the total loads entering and leaving Sykes Creek system from the surrounding BRL mainstem segments at the time this TMDL was developed, this TMDL did not calculate detailed nutrient loads from surrounding lagoon segments. The pollutant loading calculation of this TMDL focuses on nutrient loads from the watershed and atmospheric direct deposition onto the creek. But it should be pointed out that, while the Sykes Creek watershed needs to have reduced nutrient loadings in order to restore the creek nutrient condition as well as to protect the seagrass distribution in the BRL mainstem segments, the drainage basin of Banana River Lagoon also need to fulfill their seagrass nutrient loading targets established in the mainstem seagrass nutrient TMDLs (FDEP, 2009) to protect both the seagrass in the lagoon system and the nutrient condition of Sykes Creek.

4.2.2.1 Land Uses

Land use distribution is a critical factor that determines the nutrient loads created in a given watershed. Land use patterns influence the imperviousness of the watershed and determine the amount of runoff that can be generated in a given watershed area. Land use patterns also determine the concentrations of pollutants in the runoff produced in different land use areas and therefore determine the amount of a given pollutant that can be produced per acre of drainage basin. Land use information is a key spatially specific model input for simulating nutrient load using the PLSM model.

Table 4.1 summarizes the land use distribution in the watershed of Sykes Creek. The watershed was delineated based on the subbasin boundary defined in SJRWMD's PLSM model, which was determined from USGS 7.5 minute quadrangle maps at 5-foot contours intervals, aerial photogrammetric mapping, and on-file drainage maps or plans obtained from local governments. In the PLSM model, the drainage areas to Sykes Creek and Newfound Harbor are treated as single one watershed. Because of the hydrodynamic relationship between Sykes Creek and Newfound Harbor, water quality conditions in Newfound Harbor could have a significant impact on the nutrient condition of the creek. For the purpose of this TMDL, the immediate watershed of Sykes Creek also includes the drainage areas discharging to Newfound Harbor.

Figure 4.1 shows boundaries of WBIDs 3044B (Sykes Creek/Barge Canal) and 3044A (Newfound Harbor). As shown by the figure, the part of 3044B north of State Route 528 is not included in this TMDL as part of the Sykes Creek – Newfound Harbor watershed. The runoff created in the north Sykes Creek watershed either discharges toward north IRL or remains in the mosquito impoundments located on the east and west sides of the north Sykes Creek segment. Small amount of discharge from the mosquito impoundments into the Barge Canal may happen during the dry season. These discharges are mostly diluted in the Barge Canal and constitute an insignificant portion of the load entering the southern segment of Sykes Creek. In addition, the drainage area in between the Barge Canal and State Route 528 also drains primarily to the Barge Canal. The Sykes Creek – Newfound Harbor watershed areas summarized in **Table 4.1**, therefore, include only part of WBID 3044B south of the State Route 528 and the entire WBID 3044A.

Table 4.1. Land Use Summary for the Sykes Creek and Newfound Harbor Drainage Basin

FLUCCS	Description	Acreage	Percent Level 1 Land Use
1000	**Level 1 Land Use - Urban and Build-Up**	**2877.0**	**49%**
1100	Low Density Residential	86.7	
1190	Low Density Residential (under construction)	23.8	
1200	Medium Density Residential	801.9	
1300	High Density Residential	1225.5	
1390	High Density Residential (under construction)	19.0	
1400	Commercial and Service	495.4	
1550	Other Light Industrial	12.9	
1700	Institutional	179.5	
1800	Recreational	32.3	
1840	Marinas and Fish Camps	0.1	
2000	**Level 1 Land Use - Agriculture**	**107.7**	**2%**
2110	Improved Pastures	0.7	
2150	Field Crops	0.1	
2210	Citrus Groves	87.4	
2240	Abandoned Grove	14.6	
2500	Specialty Farm	4.9	
3000	**Level 1 Land Use - Rangeland**	**155.5**	**3%**
3100	Herbaceous Rangeland	57.0	
3200	Shrub and Brush Land Rangeland	95.0	
3300	Mixed Rangeland	3.5	
4000	**Level 1 Land Use - Upland Forest**	**185.6**	**3%**
4110	Pine Flatwoods	13.2	
4200	Upland Harwood Forests	0.9	
4340	Hardwood-Conifer Mixed	168.0	
4370	Australian Pine	3.6	
5000	**Level 1 Land Use - Water**	**730.4**	**12%**
5100	Streams and Waterways	168.4	
5200	Lakes	18.5	
5300	Reservoirs	132.1	
5400	Bays and Estuaries	65.3	
5430		346.1	
6000	**Level 1 Land Use - Wetlands**	**1602.1**	**27%**
6120	Mangroves Swamps	295.7	
6170	Mixed Wetland Hardwoods	86.7	
6300	Wetland Forested Mixed	66.4	
6410	Freshwater Marshes	61.3	
6420	Saltwater Marshes	843.2	
6440	Emergent Aquatic Vegetation	2.4	
6460		246.4	

7000	**Level 1 Land Use - Barren Lands**	**38.6**	**1%**
7400	Disturbed Lands	20.5	
7430	Spoil Areas	18.1	
8000	**Level 1 Land Use - Transportation, Communication, and Utilities**	**194.5**	**3%**
8110	Airports	101.6	
8140	Roads and Highways	92.8	
Total	**Total Land Use**	**5891.3**	

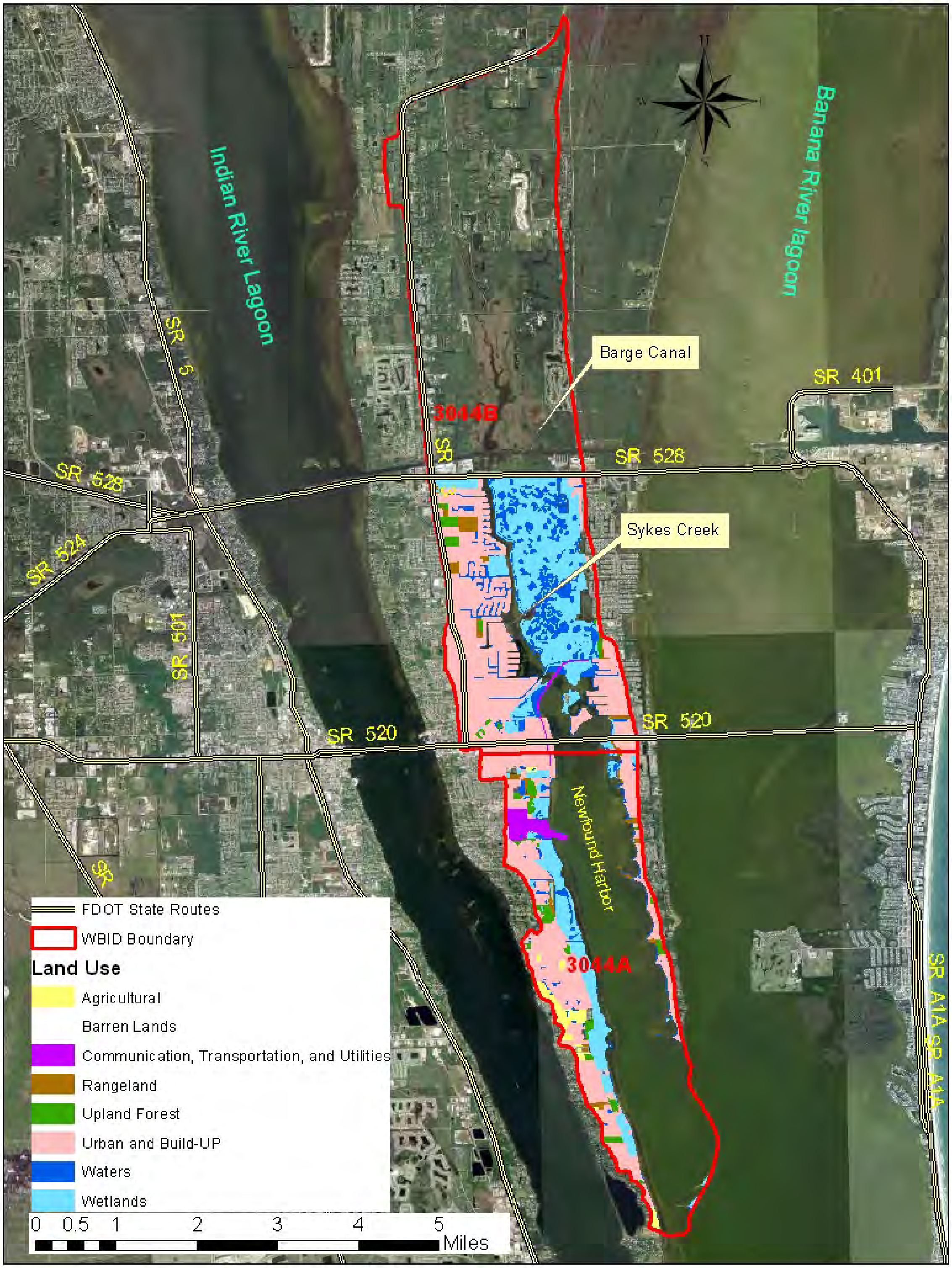

Figure 4.1. Spatial Distribution of Land Use Pattern (Year 2000) in Sykes Creek-Newfound Harbor Watershed

The PLSM model simulates nutrient loads based on the Level 3 land use of the Florida Land Use, Cover, and Forms Classification System (FLUCCS). This analysis used SJRWMD's year 2000 land use GIS coverage. The surface areas of Sykes Creek and Newfound Harbor, represented by FLUCCS codes of 5100 and 5400, respectively, were not considered part of the watersheds and, therefore, were not included in the water areas of the watershed in **Table 4.1**. **Table 4.1** also tabulates the acreage of aggregated Level I land uses and the percent distribution of each Level I land use category in the entire watershed.

According to the table, the land use type occupies the largest watershed area is the urban and build-up lands, which is about 2,877 acre and accounts for about 49% of the total watershed areas. Of the total urban land area, the high density residential, medium density residential, and commercial and service areas are the three largest urban land use categories, which, together, account for about 43% of the total watershed area. Second to the urban land are the 730 and 1,602 acres of water and wetland areas, which account for about 12% and 27% of the watershed areas, respectively. The vast majority of the water and wetland areas are located on the east side of Sykes Creek and within a mosquito impoundment area. Agricultural lands, which account for only about 2% of the watershed areas, mainly located close to the southern end of the Merritt Island and discharge directly to the Newfound Harbor. Other than the land use types described above, rangeland, upland forest, and barren land areas account for about 7% of the watershed areas, with the remaining 3% of the watershed areas occupied by land areas used for communication, transportation, and utility purposes. Overall, the human influenced land use areas are mostly located on the west side of Sykes Creek.

Because SJRWMD's PLSM model used the year 2000 land use to simulate the existing loads, for this TMDL, it is desirable to examine the year 2009 land use, which is the most recent SJRWMD land use shapefile, to see the possible change of land use patterns over the years in the Sykes Creek – Newfound Harbor immediate watershed. **Table 4.2** lists both the 2000 and 2009 land use acreages and comparison of the land use change between the two land use shapefiles. **Figure 4.2** shows the spatial distribution of land uses in the Sykes Creek – Newfound Harbor immediate watershed in 2009 shapefile.

Table 4.2. Comparison of 2000 and 2009 Land Uses in the Sykes Creek - Newfound Harbor Watershed

FLUCCS	Description	2000 Acreage	2009 Acreage	Level 1 Land Use Difference (Acres)
1000	**Level 1 Land Use - Urban and Build-Up**	**2877.0**	**3078.0**	**201.0**
1100	Low Density Residential	86.7	221.3	
1180	Rural Residential	-	9.9	
1190	Low Density Residential (under construction)	23.8	0.0	
1200	Medium Density Residential	801.9	1899.8	
1300	High Density Residential	1225.5	157.9	
1390	High Density Residential (under construction)	19.0	-	
1400	Commercial and Service	495.4	528.7	
1550	Other Light Industrial	12.9	2.9	
1700	Institutional	179.5	219.1	

FLUCCS	Description	2000 Acreage	2009 Acreage	Level 1 Land Use Difference (Acres)
1800	Recreational	32.3	-	
1840	Marinas and Fish Camps	0.1	0.1	
1850	Parks and Zoos	--	29.7	
1860	Community Recreational Facilities	-	3.8	
1890	Other Recreational	-	4.8	
2000	**Level 1 Land Use - Agricultural**	**107.7**	**18.7**	**-89.0**
2110	Improved Pastures	0.7	-	
2150	Field Crops	0.1	-	
2210	Citrus Groves	87.4	13.9	
2240		14.6	-	
2410	Tree Nurseries	-	4.8	
2500	Specialty Farm	4.9	-	
3000	**Level 1 Land Use - Rangeland**	**155.5**	**138.7**	**-16.9**
3100	Herbaceous Rangeland	57.0	60.1	
3200	Shrub and Brush Land Rangeland	95.0	27.6	
3300	Mixed Rangeland	3.5	50.9	
4000	**Level 1 Land Use - Upland Forest**	**185.6**	**149.0**	**-36.5**
4110	Pine Flatwoods	13.2	13.7	
4200	Upland Harwood Forests	0.9	0.9	
4340	Hardwood-Conifer Mixed	168.0	127.3	
4370	Austrialian Pine	3.6	7.2	
5000	**Level 1 Land Use - Waters**	**730.4**	**730.0**	**-0.4**
5100	Streams and Waterways	168.4	176.6	
5200	Lakes	18.5	1.2	
5300	Reservoirs	132.1	132.8	
5400	Bays and Estuaries	65.3	67.1	
5430	Enclosed saltwater ponds within a salt marsh	346.1	352.4	
6000	**Level 1 Land Use - Wetlands**	**1602.1**	**1571.8**	**-30.2**
6120	Mangroves Swamps	295.7	688.2	
6170	Mixed Wetland Hardwoods	86.7	88.6	
6300	Wetland Forested Mixed	66.4	2.9	
6410	Freshwater Marshes	61.3	8.3	
6420	Saltwater Marshes	843.2	493.0	
6430	Wet prairies	-	0.8	
6440	Emergent Aquatic Vegetation	2.4	6.6	
6460	Mixed scrub-shrub wetland	246.4	250.5	
6500	Non-vegetated wetland	-	32.9	
7000	**Level 1 Land Use - Barren Lands**	**38.6**	**0.0**	**-38.6**
7400	Disturbed Lands	20.5	-	

FLUCCS	Description	2000 Acreage	2009 Acreage	Level 1 Land Use Difference (Acres)
7430	Spoil Areas	18.1	-	
8000	**Level 1 Land Use - Transportation, Communication and Utilities**	**194.5**	**205.1**	**10.6**
8110	Airports	101.6	102.1	
8140	Roads and Highways	92.8	99.0	
8370	Surface water collection basins	-	4.0	
Total	**Total Land Use**	**5891.3**	**5891.3**	

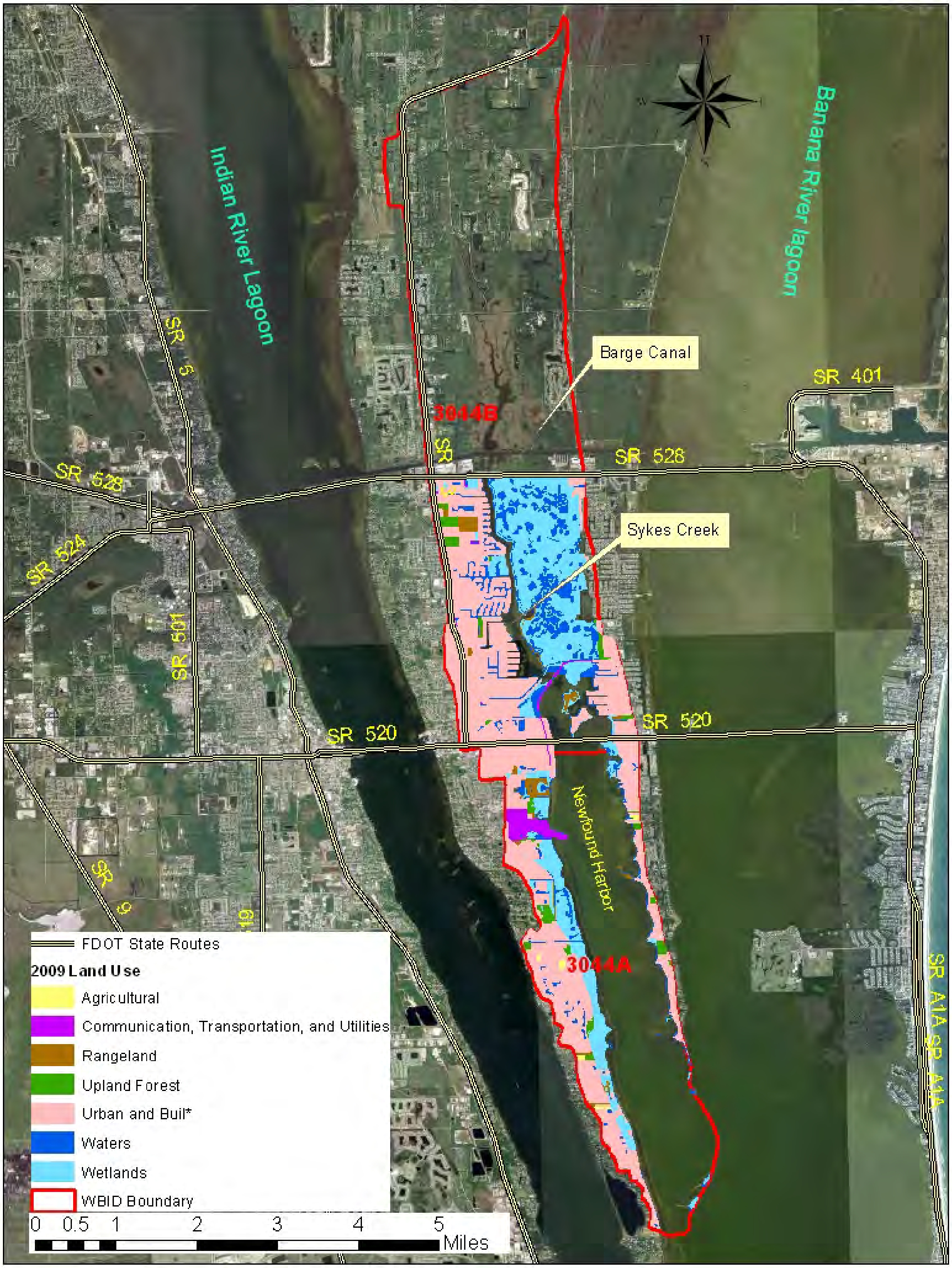

Figure 4.2. Spatial Distribution of Land Use Pattern (Year 2009) in Sykes Creek-Newfound Harbor Watershed

Based on **Table 4.2**, the major difference between the years 2000 and 2009 land use distribution is that the total acreages of urban and build-up and transportation, communication, and utilities land uses increased and natural and rural land uses decreased in 2009. The increase of urban lands mainly took place for low density residential, commercial, and institutional, and recreational land areas. There is a significant decrease in high density residential areas (from 1225.5 acre to 157.9 acre) and a large increase in medium density residential areas (from 801.9 acre to 1899.9 acre). But the sum of both land uses stays relatively constant (2074 acre in 2000 and 2057 acre in 2009). It is possible that the change is due to the change of land classification instead of an actual physical change on the ground. Overall, the total increase of urban and build-up and transportation, communication, and utilities land uses amount to about 212 acres, which represents about 7% change of these land uses in 2000 and account for about 3.6% of the total area of the Sykes Creek – Newfound Harbor watershed. The scale of the change is relatively small.

4.2.2.2 Soil Type

Another important aspect of the watershed is the soil type. Soil type affects the hydrologic characteristics of the watershed through affecting the water transmission capacity of the soil, which in turn determines the potential of the watershed to produce runoff and pollutant loads. Based on the United States Department of Agriculture/Natural Resource Conservation Service (USDA/NRCS), soils can be classified based on their hydrologic characteristics into hydrologic soil groups (HSGs). The HSGs are generally determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable. A four-HSG classification is generally used to group soils based on their hydrologic characteristics (**Table 4.3**):

Table 4.3. Hydrologic Characteristics of the Four HSGs (NRCS, 2007)

HSGs	Runoff Potential	Clay Content	Sand Content	Saturated Conductivity (inch/hour)	Depth to Impervious Layer (inch)	Depth to Water Table (inch)
Group A	Low	< 10%	> 90%	5.67	> 20	> 24
Group B	Moderately low	10% - 20%	50% - 90%	1.42 – 5.67	> 20	> 24
Group C	Moderately high	20% - 40%	< 50%	0.14 – 1.42	> 20	> 24
Group D	High	>40%	< 50%	< 0.14	< 20	< 24

Certain wet soils are placed in group D based solely on the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained conduction and the second to the undrained condition. For the purpose of hydrologic soil group classification, adequately drained means that the seasonal high water table is kept at least 24 inches below the surface in a soil where it would be higher in a natural state (NRCS, 2007).

The soil coverage used by the SJRWMD in developing the PLSM model was from the USDA/NRCS's 1:24,000 Soil Survey Geographic (SSURGO) coverage. This soil coverage was created by NRCS around 1990. In addition to the four HSGs and their related dual soil groups, this coverage also include a "W" soil group to represent soil areas that are constantly covered by water, and a "U" soil group to represent urban soils whose HSG designation could not be determined. **Table 4.4** summarizes the acreage of the Sykes Creek – Newfound Harbor watershed that are covered by different soil types. **Figure 4.3** shows the spatial distribution of HSGs in the Sykes Creek – Newfound Harbor watershed.

Based on **Table 4.4**, B/D and D soil groups occupy the largest areas, which account for 25% and 32% of the watershed area. Most of the B/D soils are distributed on the west edge of the watershed, while most of the D soils appear in the mosquito impoundment on the east side of Sykes Creek and on the west side of the Newfound Harbor (**Figure 4.3**). In addition, C soil, which has the moderately high runoff potential, and the areas constantly covered by water, occupied about 17% and 7% of the watershed area, respectively. The C type soils are mostly distributed in the west side of Sykes Creek, while the vast majority of the areas constantly covered by water mainly exist in the mosquito impoundment area on the east side of the creek and also in the residential canals located in the residential areas on the west side of the creek. Most of the A type soils exist close to the southern part of the watershed that discharges into the Newfound Harbor, and occupy about 13% of the watershed area. No B type soils were identified in the watershed. A general impression from **Figure 4.3** is that the Sykes Creek – Newfound Harbor watershed has a relatively high runoff creation potential.

Table 4.4. Acreage of the Sykes Creek - Newfound Harbor Watershed Occupied by Different Hydrologic Soil Groups (NRCS 1990 Data)

HSG	Acreage	Percent Acreage
A	755.0	13%
B/D	1483.3	25%
C	984.5	17%
C/D	61.4	1%
D	1888.4	32%
U	297.5	5%
W	421.2	7%
Total	5891.3	100%

In 2010, NRCS published its updated SSURGO soil coverage. It is therefore desirable to examine the difference between the 2010 SSURGO HSG distribution and the HSG distribution used in SJRWMD's PLSM model. **Table 4.5** listed the acreage of different HSGs in the Sykes Creek – Newfound Harbor watershed based on the 2010 SSURGO shapefile. **Figure 4.4** shows the spatial distribution of HSGs in the watershed based on the 2010 GIS data.

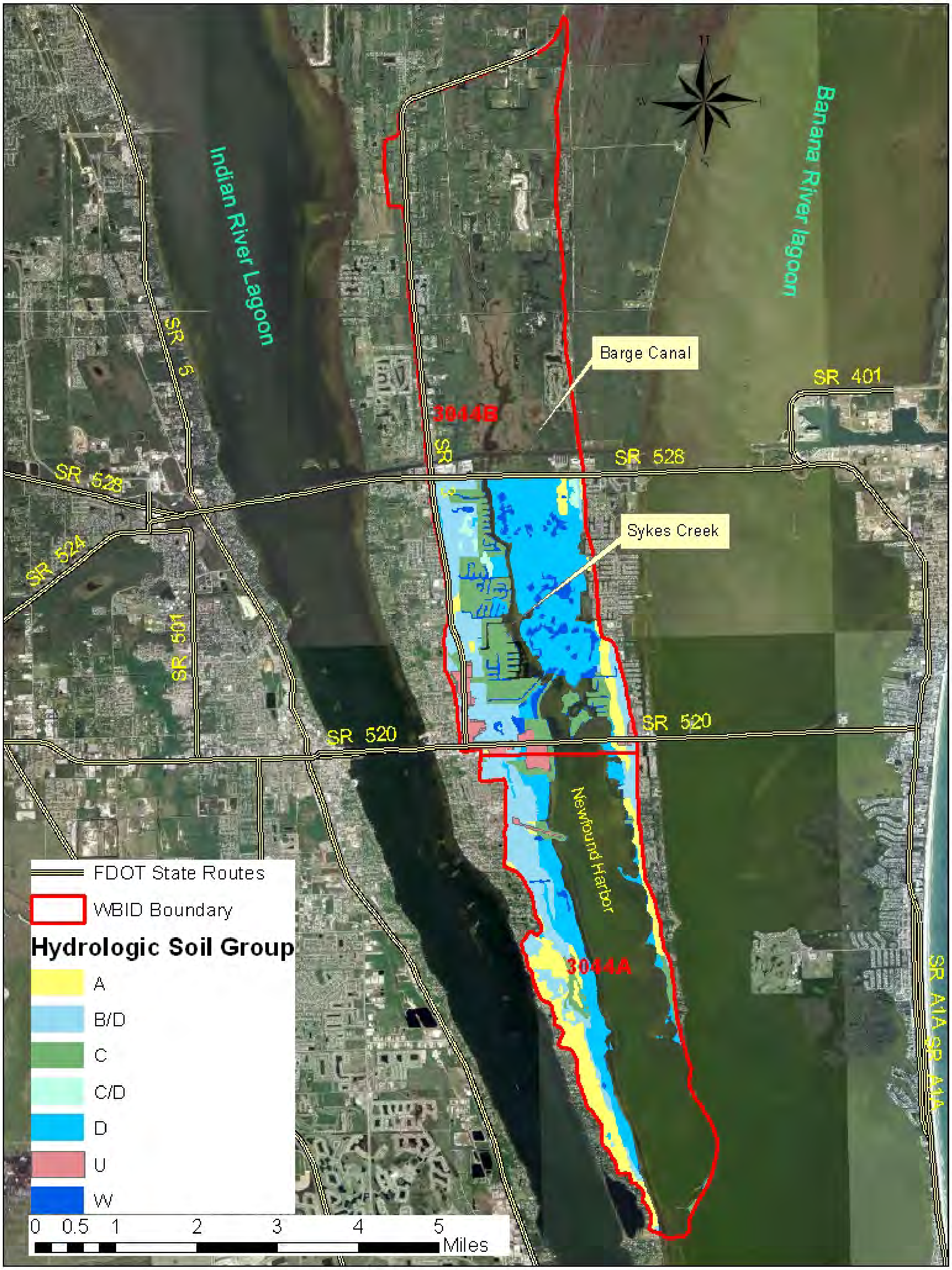

Figure 4.3. Hydrologic Soil Distribution in the Sykes Creek – Newfound Harbor Watershed (NRCS 1990 Data)

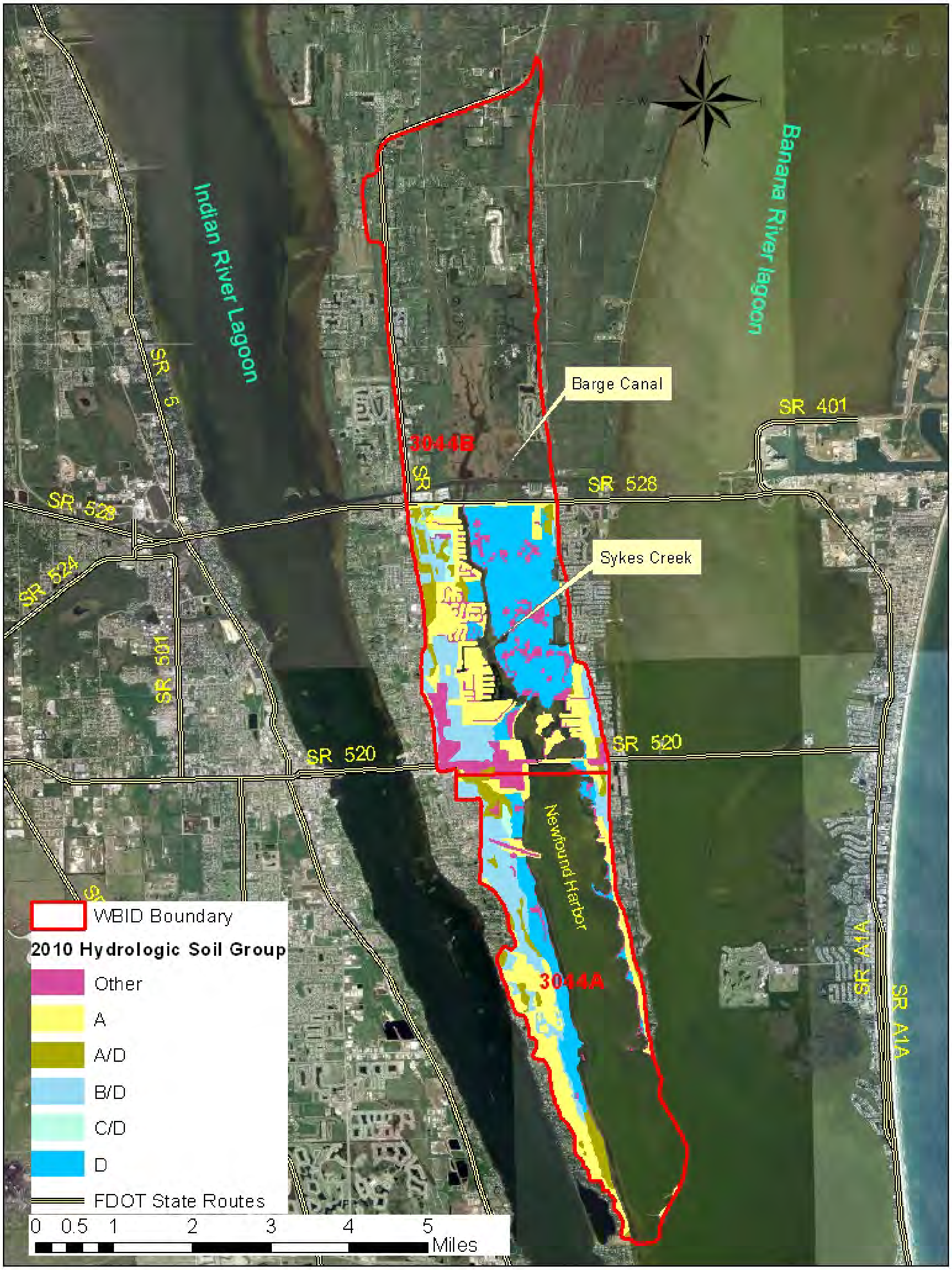

Figure 4.4. Hydrologic Soil Distribution in the Sykes Creek – Newfound Harbor Watershed (NRCS 2010 Data)

Table 4.5. Acreage of the Sykes Creek - Newfound Harbor Watershed Occupied by Different Hydrologic Soil Groups (NRCS 2010 Data)

HSG	Acreage	Percent
A	1725.9	29%
A/D	527.1	9%
B/D	1100.3	19%
C/D	83.1	1%
D	1665.4	28%
Other	789.3	13%
Total	5891.3	100%

The difference between the 1990 and 2010 HSG distributions is significant (**Tables 4.4 and 4.5**). The largest difference is that the C soil in the 1990 shapefile is completely disappeared in the 2010 shapefile. Almost all C soils are reclassified as A soils. In addition, a significant amount of the B/D soils were re-classified into A/D soils in the 2010 dataset. A/D soils do not exist in the 1990 dataset. Another significant change in the 2010 dataset is that W and U soil classifications disappear. Most W soil, especially those located in the mosquito impoundment areas and within the residential canal areas, are not classified in the 2010 dataset. These soil types are represented as “other” soil on **Table 4.5**. “U” soils are also now in the “Other” category.

Compared to the 1990 dataset, the A soil becomes the soil type that occupies the largest drainage basin areas in the Sykes Creek – Newfound Harbor watershed, changing from occupying only 13% of the total watershed area in the 1990 dataset to occupying about 29% of the watershed area in the 2010 dataset. The second largest soil group in the 2010 dataset is the D soil, which occupies about 1665 acre of the watershed and accounts for about 28% of the watershed areas. The percent watershed area occupied by the D soil in the 2010 dataset decreases from 32% in the 1990 dataset. B/D soil also decreased from about 25% of the watershed area in the 1990 dataset to about 19% of the watershed area in the 2010 dataset. The general direction of the change is that the infiltration potential of the watershed increased and therefore reduced the amount of runoff potential in the watershed.

4.2.2.3 Runoff Coefficient and Land Use/Soil Group Combinations

One of the most important parameters for PLSM to simulate the annual runoff is the runoff coefficient. This parameter represents the percent total rainfall falling onto a given watershed that becomes the runoff. The runoff coefficient is influenced by the land use and soil patterns in the watershed. When setting up the PLSM model, SJRWMD staff assigned a unique runoff coefficient to each land use – HSG combination. These runoff coefficients were mostly from Adamus and Bergman (1998) and later modified with data from Harper (1994). Several other modifications were conducted as follows (Mr. Whit Green, personal communication):

(1) The runoff coefficients for U soil were calculated as the mean of runoff coefficients of types A, B, C, and D soil group of particular land use.
(2) The runoff coefficients for W soil were assigned runoff coefficients of U soils if the soil survey results did not completely match up with the land use results. Otherwise, the runoff coefficients of W soil would be assigned as 1.000.

(3) The runoff coefficients for C/D and B/D soil groups used the runoff coefficients of D for underdeveloped area. For developed area, the C/D and B/D runoff coefficients were assigned as C or B runoff coefficients.
(4) For low density residential areas, if the housing density is less than 1 unit/acre, the runoff coefficients assumed the runoff coefficients for the D soil. Otherwise, runoff coefficients of B soils were used.
(5) For low density residential areas with certain drainage improvements, but the improvement were not sufficient to lower the water table over the entire site, the runoff coefficients of B/D soils assumed the average values of B and D soil for a given land use category.

Table 4.6 shows the runoff coefficients assigned to each land use – HSG soil combination in the Sykes Creek – Newfound Harbor watershed. The red-font highlighted runoff coefficients are for those land use – HSG soil combinations that do not exist in the Sykes Creek – Newfound Harbor watershed, but are provided to show the runoff coefficients relationship among different HSG groups of the same land groups.

4.2.2.4 Event Mean Concentrations (EMCs) and Land Uses

Event mean concentrations (EMC) represent the concentrations of pollutants contained in the runoff. It is a required component of the PLSM model in estimating nutrient loads from a given watershed. Most of the EMCs used in this TMDL were cited from Adamus and Bergman (1998), and supplemented with literature values from Harper (1994), Hendrickson and Konwinski (1998), and Zhang et al., (2002). EMC values were also adjusted based on results from local studies and through model calibration. **Table 4.7** shows a summary of TN and TP EMCs for different land use types included in SJRWMD's PLSM model that covers the Sykes Creek – Newfound Harbor immediate watershed.

It should be noted that the PLSM model assumes that the net nutrient loads from wetland areas are zero. This assumption was used primarily because the wetland areas can be either sink or source of nutrients, depending on the vegetative and soil composition, hydroperiod, and hydrological connectivity. Because at the time when the PLSM model was developed, no detailed local information was available regarding whether wetlands were sources of nutrients or not, SJRWMD assumed a neutral role for wetlands nutrient dynamics.

4.2.2.5 Rainfall

Rainfall is the driving force in a watershed to create pollutant loads. In simulating the watershed nutrient contribution under the existing condition, SJRWMD's PLSM model used a 30-year long-term average annual rainfall for the period from 1975 through 2005. In the Indian River Lagoon and adjacent areas, stations that have 30-years of rainfall records are all National Weather Service stations, which include stations located at the Daytona Beach International Airport, City of Titusville, Melbourne International Airport, Vero Beach Airport, and Fort Pierce. The rainfall amount used in a specific IRL basin area in the PLSM model was calculated as the mean average annual rainfall from nearby stations using the Thiessen Polygon method. The Sykes Creek – Newfound Harbor watershed is influenced by two weather stations including the one located in City of Titusville and the one located at the Melbourne International Airport. The 30-year long-term average annual rainfalls for these two stations were 54.7 inches and 48.3 inches,

Table 4.6. Runoff Coefficients Assigned to Each Land Use - HSG Soil Combination

FLUCCS Code	A	B	C	D	B/D	C/D
1100	0.17	0.230	0.286	0.342	0.342	0.342
1190	0.16	0.181	0.202	0.223	0.223	0.223
1200	0.22	0.304	0.389	0.473	0.304	0.389
1300	0.63	0.662	0.692	0.733	0.662	0.692
1390	0.16	0.181	0.202	0.223	0.223	0.223
1400	0.88	0.887	0.888	0.900	0.887	0.888
1550	0.54	0.577	0.609	0.642	0.577	0.609
1700	0.69	0.741	0.786	0.856	0.741	0.786
1800	0.12	0.155	0.182	0.210	0.183	0.196
1840	0.23	0.319	0.407	0.494	0.319	0.407
2110	0.25	0.305	0.359	0.405	0.405	0.405
2150	0.18	0.256	0.334	0.411	0.411	0.411
2210	0.25	0.268	0.285	0.302	0.268	0.285
2240	0.25	0.268	0.285	0.302	0.268	0.285
2500			0.454			
3100	0.10	0.195	0.300	0.411	0.411	0.411
3200	0.06	0.176	0.287	0.400	0.400	0.400
3300	0.06	0.176	0.287	0.400	0.400	0.400
4110	0.10	0.206	0.309	0.413	0.413	0.413
4200	0.10	0.206	0.309	0.413	0.413	0.413
4340	0.10	0.206	0.309	0.413	0.413	0.413
4370	0.10	0.206	0.309	0.413	0.413	0.413
5100	1.00	1.000	1.000	1.000	1.000	1.000
5200	0.50	0.500	0.500	0.500	0.500	0.500
5300	0.50	0.500	0.500	0.500	0.500	0.500
5400	1.00	1.000	1.000	1.000	1.000	1.000
5430	1.00	1.000	1.000	1.000	1.000	1.000
6120	0.19	0.228	0.266	0.303	0.303	0.303
6170	0.19	0.228	0.266	0.303	0.303	0.303
6300	0.19	0.228	0.266	0.303	0.303	0.303
6410	0.19	0.228	0.266	0.303	0.303	0.303
6420	0.19	0.228	0.266	0.303	0.303	0.303
6440	0.19	0.228	0.266	0.303	0.303	0.303
6460	0.19	0.228	0.266	0.303	0.303	0.303
7400	0.16	0.181	0.202	0.223	0.223	0.223
7430	0.16	0.169	0.169	0.169	0.169	0.169
8110	0.32	0.399	0.473	0.546	0.399	0.473
8140	0.63	0.703	0.777	0.850	0.703	0.777

Table 2.7. TN and TP EMCs for Different Land Uses in the Sykes Creek – Newfound Harbor Watershed (mg/L)

FLUCCS	TN EMC (mg/L)	TP EMC (mg/L)
1100	1.85	0.220
1190	1.38	0.080
1200	2.23	0.316
1300	2.10	0.516
1390	1.38	0.080
1400	1.93	0.497
1550	1.55	0.150
1700	1.80	0.478
1800	1.25	0.080
1840	1.58	0.150
2110	2.80	0.576
2150	2.52	0.265
2210	1.92	0.506
2240	1.49	0.280
2500	2.32	0.500
3100	1.20	0.064
3200	1.20	0.064
3300	1.20	0.064
4110	0.70	0.090
4200	0.70	0.090
4340	0.70	0.090
4370	0.70	0.090
5100	0.60	0.050
5200	0.60	0.110
5300	0.60	0.135
5400	0.00	0.000
5430	0.00	0.000
6120	0.00	0.000
6170	0.00	0.000
6300	0.00	0.000
6410	0.00	0.000
6420	0.00	0.000
6440	0.00	0.000
6460	0.00	0.000
7400	1.38	0.109
7430	1.25	0.202
8110	1.15	0.150
8140	1.18	0.480

respectively. **Figure 4.5** shows areas of the Sykes Creek – Newfound Harbor watershed that are influenced by each rainfall zone.

4.2.2.6 BMP

At the time when the PLSM model for the IRL basins was developed, no information was available regarding the detailed spatial distribution, types, and treatment efficiencies of stormwater treatment facilities in the IRL-BRL basin. Therefore, the PLSM model assumed that any urban constructions happened after 1984 (when the state stormwater rule was implemented) were developed with stormwater treatment facilities. Generalized treatment efficiencies were applied in the PLSM model, which include 30 percent removal of TN and 50% removal of TP by these stormwater treatment facilities. No stormwater treatment types were distinguished in the PLSM model. **Figure 4.6** shows areas of the Sykes Creek – Newfound Harbor watershed that are covered by the generalized stormwater treatment facilities.

4.2.2.7 Summary of Nutrient Loads from the Sykes Creek – Newfound Harbor Watershed

Based on the information provided in above sections, nutrient loads from the Sykes Creek – Newfound Harbor watershed were calculated using Equation (1). Estimated watershed nutrient loads for aggregated Level I land uses are summarized in **Table 4.8**.

Based on **Table 4.8**, the largest contributor of nutrients in the Sykes Creek – Newfound Harbor watershed is the Urban and Built-Up area, which contributes about 37,965 lbs/year of TN and 8,613 lbs/year of TP, accounting for about 88% and 91% of the TN and TP loads from the entire watershed, respectively. Other human land use areas, such as areas occupied by Agriculture and Transportation, Communication, and Utilities, contribute about 595 and 1,411 lbs/year of TN loads, respectively, and 149 and 409 lbs/year of TP, respectively. The percent contribution of TN from agricultural and transportation, communication, and utilities areas account for about 1.4% and 3.3%, respectively. Percent contributions of TP loads from these areas are 1.6% and 4.3%, respectively. Nutrient loads from natural land areas, including Upland Forest and Water, are about 2,173 lbs/year of TN and 251 lbs/year of TP, accounting for about 5.1% of the TN loads and 2.6% of the TP loads from the entire Sykes Creek – Newfound Harbor watershed. As is pointed out in **Section 4.2.2.4**, because the runoff EMCs of TN and TP from the wetland areas were assumed to be zero, the annual load from wetlands is also assumed to be zero.

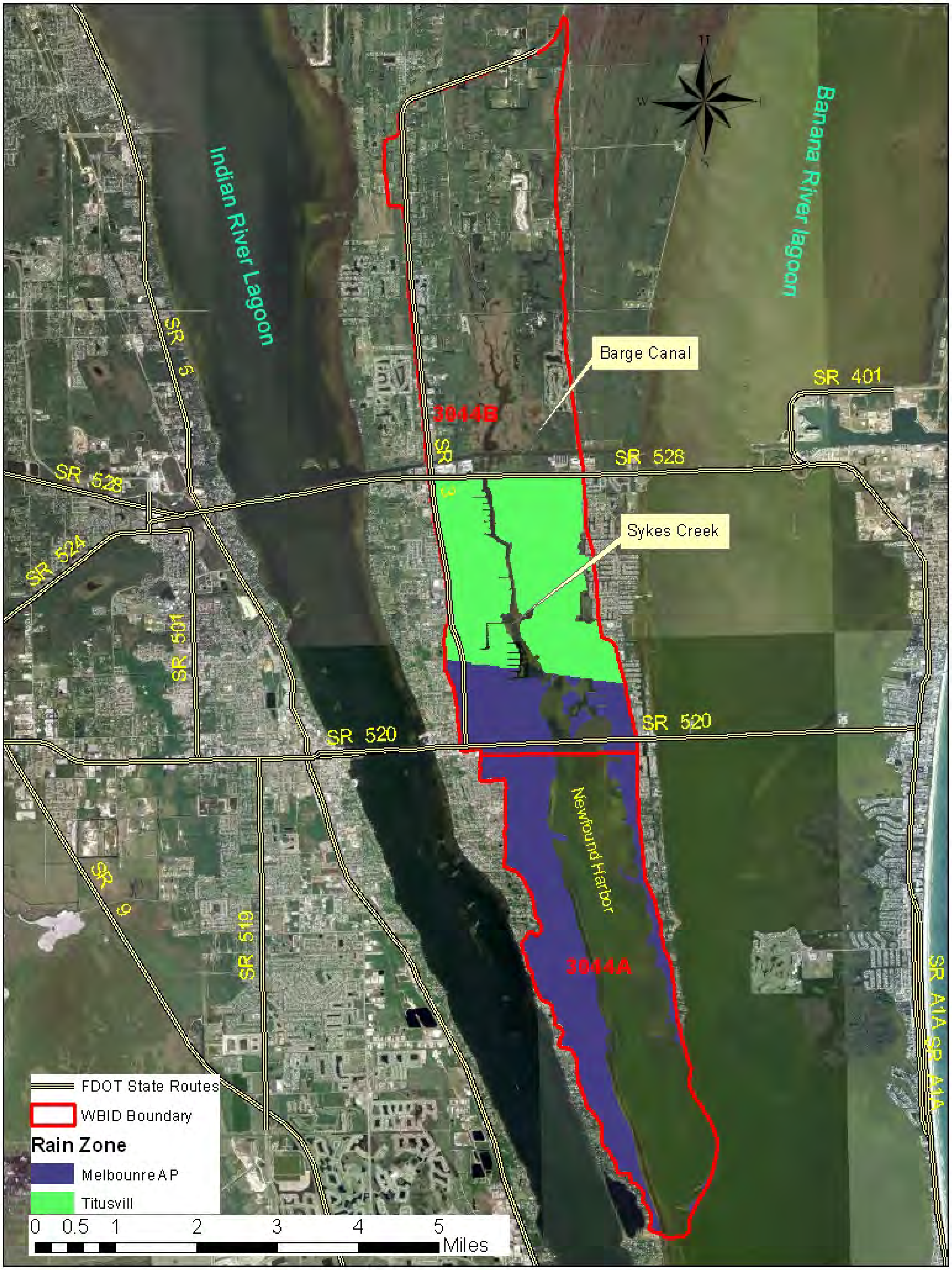

Figure 4.5. Rainfall Zones of the Sykes Creek – Newfound Harbor Watershed

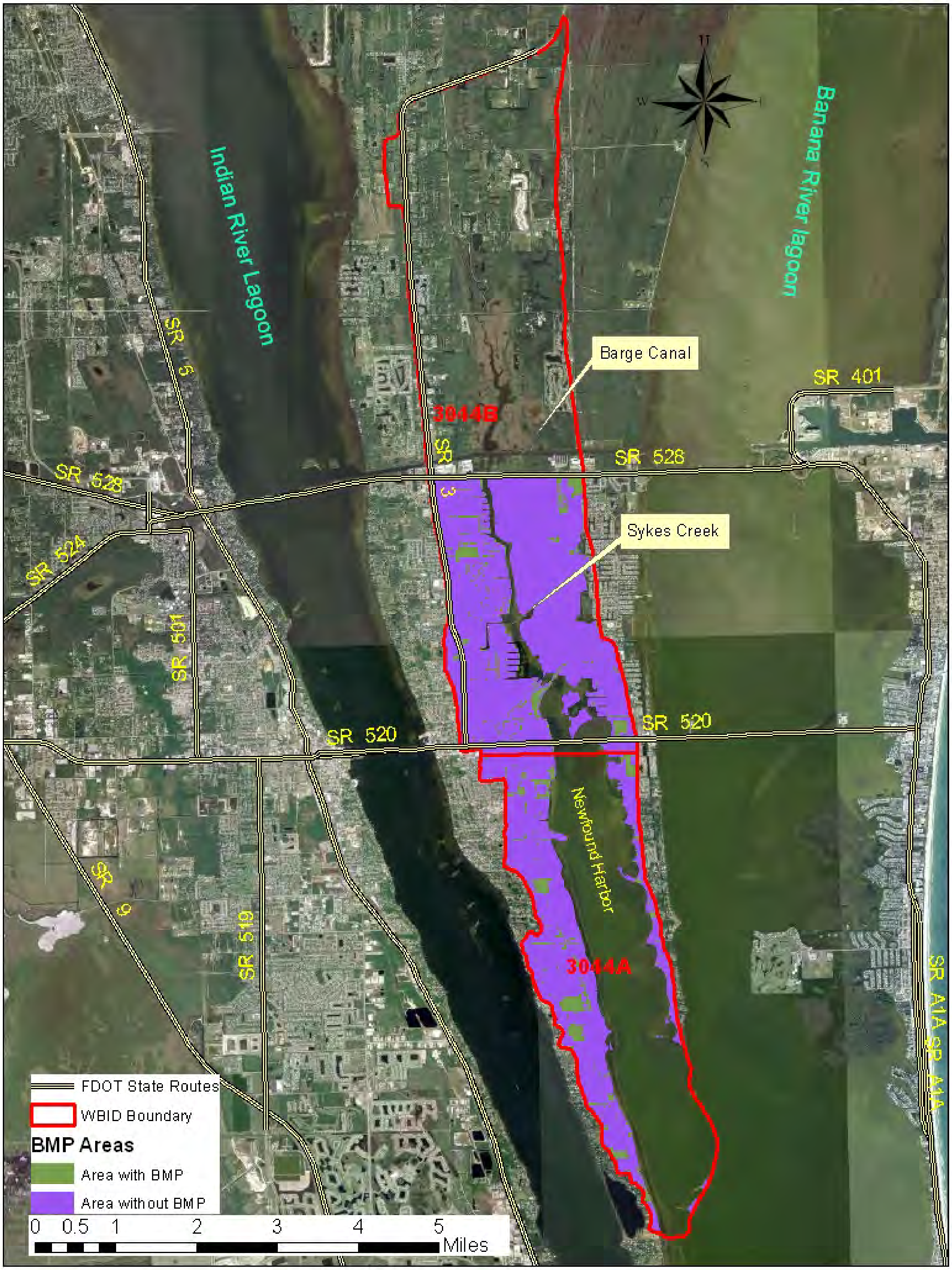

Figure 4.6. BMP Distribution in the Sykes Creek – Newfound Harbor Watershed

Table 4.8. Nutrient Loads from the Sykes Creek - Newfound Harbor Watershed

Row Labels	Acreage	TN Annual Loads (lbs/year)	TP Annual Loads (lbs/year)	Percent TN Loads	Percent TP Loads
Urban and Built-Up	2877.0	37965.3	8612.8	88.4%	90.9%
Agricultural	107.7	594.7	148.7	1.4%	1.6%
Rangeland	155.5	705.4	37.6	1.6%	0.4%
Upland Forest	185.6	521.5	67.1	1.2%	0.7%
Water	730.4	1651.0	184.2	3.8%	1.9%
Wetlands	1602.1	0.0	0.0	0.0%	0.0%
Barren Land	38.6	109.3	12.5	0.3%	0.1%
Transportation, Communication, and Utilities	194.5	1410.5	409.4	3.3%	4.3%
Total	5891.3	42957.7	9472.3	100.0%	100.0%

As discussed in **Sections 4.2.2.1** and **4.2.2.2**, the 2009 land use dataset shows that there is a 7% increase in the Urban and Build-Up land use area. In addition, the NRCS 2010 soil classification shows a significant increase in A soil and a decrease in C soil, suggesting that the overall rainfall infiltration potential may increase and the potential of nutrient load production may decrease with the new dataset. It is therefore desirable to examine how these changes may impact the nutrient load estimation from the watershed. To do this, following steps were taken by the Department to update the original PLSM model using the new land use and HSG soil information.

(1) The 2010 NRCS SSURGO soil coverage was clipped using the Sykes Creek – Newfound Harbor watershed boundary shapefile to create a SSURGO soil shapefile for the watershed.
(2) As discussed in Section 4.2.2.2, soil types in about 13% of the watershed areas are not classified into any HSGs. For these areas, the missing soil HSG classification was populated by referring to the “MUNAME” (soil name) information provided in the NRCS SSURGO shapefile attribute table. Those unclassified soils with a “MUNAME” of Water, were assigned an HSG classification of “W”. Those unclassified soils with a “MUNAME” of Urban Land were assigned an HSG classification of “U”. This HSG classification appeared to be consistent with the “W” and “U” classification in SJRWMDL PLSM model.
(3) The SJRWMD 2009 land use shapefile was clipped using the Sykes Creek – Newfound Harbor Watershed boundary shapefile to create a 2009 land use shapefile for the watershed.
(4) A spatial union operation was conducted on shapefiles created in (2) and (3) to bring both land use and soil information into the same attribute table. The product shapefile from the spatial union operation was then spatially united with SJRWMD’s PLSM model shapefile to incorporate it into the final product shapefile information on rain zones and BMP.
(5) Two lookup tables, including one for runoff coefficients for different land use – HSG soil combinations and one for EMCs for different land uses, were created using SJRWMD’s PLSM model that covers the Banana River Lagoon drainage basin. The runoff coefficients and EMCs were then incorporated into the product shapefile created in (4) using ArcGIS’s Join operation. Due to the reclassification of the HSGs in NRCS’s 2010

SSURGO soil coverage and land use in SJRWMD's 2009 land use shapefile, several land uses and land use – HSG combinations never appeared in the previous version of the PLSM model. For example, A/D soil is an HSG that never appeared in previous version of the PLSM model. To assign runoff coefficients to land use – A/D soil group combinations, the method used by SJRWMD described in **Section 4.2.2.3** was used. If the A/D soil combines with a high intensity human land use, the A soil runoff coefficient of the land use would be used. If the A/D soil combines with a natural land or low intensity human land use, the D soil runoff coefficient of the land use would be assigned to the combination. Several land use types did not exist in the previous version of the PLSM model for the Banana River Lagoon, such as "Residential, rural – one unit on 2 or more acres (FLUCCS code 1180)", "Parks or zoos (FLUCCS code 1850)", "Surface water collection basin (FLUCCS code 8370), etc." The runoff coefficients and EMCs for these land uses were borrowed from the PLSM models developed from the north IRL and central IRL drainage basin.

(6) After the above processes were conducted, nutrient loads from the Sykes Creek – Newfound Harbor watershed was re-calculated using Equation (1). The re-calculated nutrient loads are tabulated in **Table 4.9**.

Table 4.9. Nutrient Loads through runoff from the Sykes Creek - Newfound Harbor Watershed Based on 2009 Land Use and NRCS 2010 SSURGO Soil Coverage

Row Labels	Acreage	TN Annual Loads (lbs/year)	TP Annual Loads (lbs/year)	Percent TN Loads	Percent TP Loads
Urban and Built-Up	3078.0	28405.4	5667.5	87.3%	89.1%
Agricultural	18.7	88.8	23.0	0.3%	0.4%
Rangeland	138.7	603.0	31.3	1.9%	0.5%
Upland Forest	149.0	427.4	54.8	1.3%	0.9%
Water	730.0	1650.2	181.6	5.1%	2.9%
Wetlands	1571.8	0.0	0.0	0.0%	0.0%
Transportation, Communication, and Utilities	205.1	1376.6	404.9	4.2%	6.4%
Total	5891.3	32551.3	6363.3	100.0%	100.0%

As shown in **Table 4.9**, the recalculated TN and TP loads are 32,551 lbs/year and 6,363 lbs/year, respectively. Compared to the TN and TP loads calculated using the previous PLSM model developed by the SJRWMD, which are 42,958 lbs/year of TN and 9,472 lbs/year of TP, the TN and TP watershed loads reduced by 24% and 33%, respectively. Most likely, these reductions were caused by the re-classification of much of the C soil areas into A soil areas. This change of HSG classification caused the runoff estimation to be significantly reduced, which in turn caused the watershed runoff loading simulation to be reduced.

One thing that needs to be pointed out is that, SJRWMD's PLSM model was calibrated against the total stream flow instead of just surface runoff. The calibration was conducted using the available flow gauge stations located in several major tributaries in the central IRL basin and then applied to the north IRL and BRL watershed because there are no major tributaries that are gauged in these latter two basins. Therefore, it could be considered that SJRWMD's PLSM model for the BRL basin also implicitly includes a baseflow component. When the model was updated using the reclassified NRCS HSG dataset, because of the significant increase in A soil and significant decrease in C soil, it is expected that the rainfall infiltration of the watershed will increase and, therefore, runoff will decrease, and so will the nutrient loads production via runoff. However, what does not discharge to Sykes Creek through runoff goes to the baseflow. The entire Sykes Creek – Newfound Harbor watershed is so narrow that most of the watershed area is less than 1 mile wide. In addition, the confining layer that separates the surficial aquifer from the Floridan aquifer in this area is relatively shallow (Toth, 1988), it is expected that a significant amount of the rainfall infiltration will eventually reach Sykes Creek through the baseflow pathway. No data were available at the time this TMDL was developed to accurately estimate how much of the infiltration would eventually reach the creek. Therefore, using the load simulation from SJRWMD's version of the PLSM model, which implicitly includes the baseflow component of the loading, appears to be more appropriate to estimate the total nutrient loads from the Sykes Creek – Newfound Harbor watershed than assuming that the total nutrient loads from the watershed only includes the runoff loads by using the load estimations based on updated NRCS HSG soil classification.

In addition, while the absolute total load estimations between using SJRWMD's version of the PLSM model and using the PLSM model updated with NRCS HSG reclassification dataset are significantly different, the relative distribution of nutrient loads from different land use types between the two datasets are not significantly different (**Figures 4.7a and 4.7b**). Whichever method is used, the contribution from the urban and build-up areas contribution close to 90% of the TN and TP loads from the watershed. The similarity between relative contribution distributions among different land use types using these two different model suggests that, even if the SJRWMD's version of the PLSM model used an early dataset of the HSG classification, the model still produce a good estimation on the relative distribution of loads among different land uses, which may prove to be helpful in the final load allocation.

Based on the discussion provided above, this TMDL will use SJRWMD's PLSM model results to quantify the existing loading from the Sykes Creek – Newfound Harbor watershed.

4.2.2.8 Nutrient Loads from the Atmospheric Deposition Directly onto the Water Surface of Sykes Creek – Newfound Harbor

As discussed in **Section 4.2.2**, although no significant correlation was observed between the seagrass depth limit and nutrient loads through atmospheric deposition directly onto the lagoon surface, atmospheric deposition does contribute to the nutrient loadings to the Sykes Creek – Newfound Harbor. Therefore, nutrient loadings through atmospheric deposition are calculated in this TMDL report and added to the existing loadings and TMDLs.

The water surface areas used to calculate the direct atmospheric deposition include the surface area of Sykes Creek (represented by the FLUCCS code of 5100) and the surface area of Newfound Harbor (represented by the FLUCCS code of 5400). Again, because of the hydrodynamic relationship between Newfound Harbor and Sykes Creek, atmospheric loads of nutrients to the surface of the receiving water include the loads onto the surface of the harbor. Of the total 3,856 acres of the water surface areas used to calculate the direct atmospheric deposition loads, 3,368 acres are the surface areas of Newfound Harbor, which accounts for about 87% of the water surface area used in this report to calculate the atmospheric loadings. The surface area of Sykes Creek is relatively small, which is only about 488 acres, and

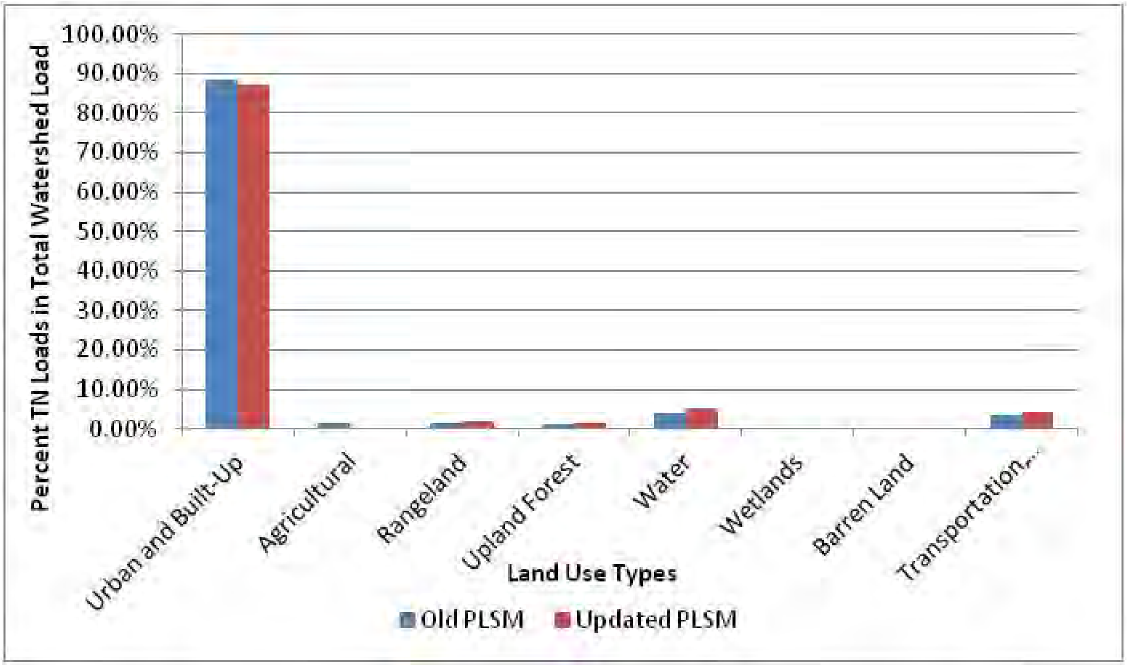

Figure 4.7a. Percent TN Loads from Different Land Use Types in Total TN Loads from The Sykes Creek – Newfound Harbor Watershed

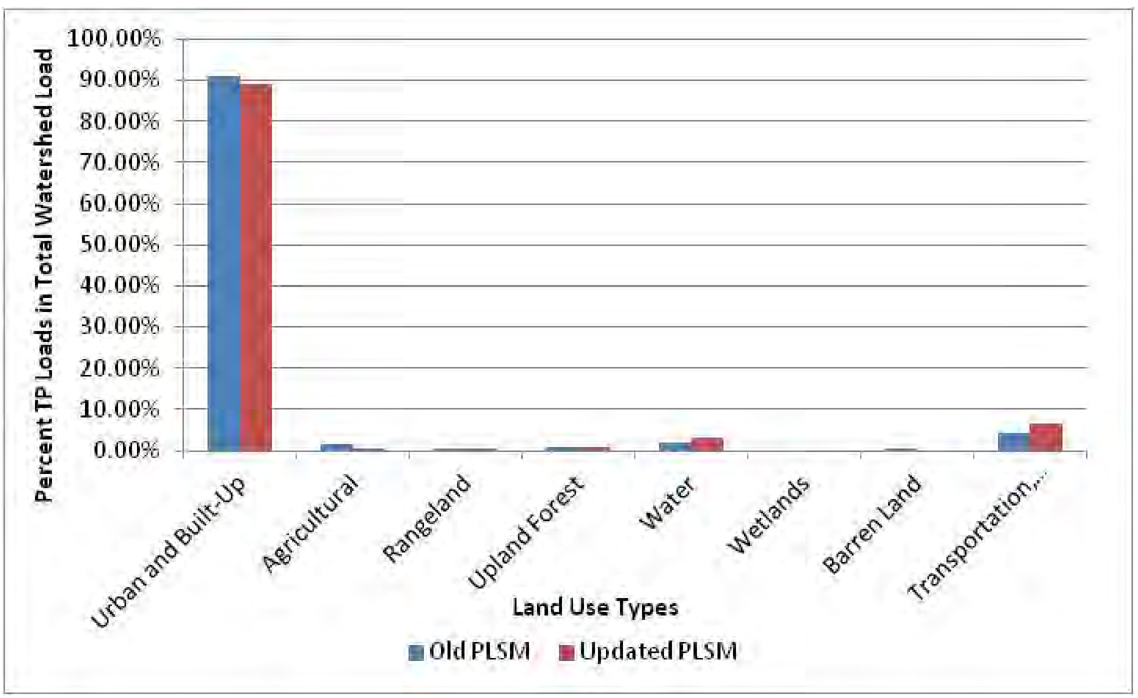

Figure 4.7b. Percent TP Loads from Different Land Use Types in Total TP Loads from The Sykes Creek – Newfound Harbor Watershed

accounts for about 13% of the total water surface area used in this TMDL for the direct atmospheric deposition calculation.

The SJRWMD provided the bulk TN and TP atmospheric deposition rates used in this TMDL report (J.W. Steward, M. Lasi, and W.C. Green, personal communication). These rates were estimated based on data collected from an atmospheric deposition site (IRL 141) located at Sebastian Inlet in the period from 2001 through 2006. Site IRL 141 belongs to the Clear Air Status and Trends Network (CASTNET), which has been sponsored by the EPA since 2006. Between 2001 and 2006, SJRWMD maintained the site (Rogers 2007).

Typically, CASTNET sites only collect dry deposition data. However, at Site IRL 141, the SJRWMD maintains a wet deposition collector, which collects the wet deposition data using a protocol similar to that used by the National Atmospheric Deposition Program (NADP). The bulk deposition rates for TN and TP used in this TMDL were the sum of the CASTNET dry deposition rate and the NADP-style wet deposition rate. Because the CASTNET sites typically do not measure ammonia gas and organic nitrogen, the dry deposition data were adjusted for ammonia and organic nitrogen with a multiplication factor of 1.25, based on published literature (Poor et al. 2001, Russel et al. 2003, Barna et al. 2008). Areal wet deposition rate is related to rainfall.

Because the SJRWMD used long-term average annual rainfall for the period from 1975 to 2005 to simulate long-term average annual TN and TP loadings from the watershed, the average annual areal wet deposition rates estimated based on 2001 through 2006 data (44 inches of average annual rainfall for the period, J. W. Steward, M. Lasi, and W.C. Green, personal communication) were adjusted with the long-term average annual rainfall (1975 to 2005). The long-term average annual rainfall values applied to the Sykes Creek – Newfound Harbor area is 51.5 inches per year, which is the average long-term mean annual rainfall of the two weather stations located in City of Titusville (54.7 inches/year) and Melbourne International Airport (48.3 inches/year).

Total atmospheric TN and TP loadings depositing directly onto the lagoon surface were calculated by multiplying the areal atmospheric deposition rates by the surface area of the Sykes Creek – Newfound Harbor system. The areal atmospheric TN and TP loads adjusted for the 30-year long-term average annual rainfall for the area are 4.00 lb/ac/year of TN and 0.086 lb/ac/year of TP. These numbers, times the 3,856 acre of the Sykes Creek – Newfound Harbor surface area, result in 15,424 lbs/year of TN and 332 lbs/year of TP falling directly onto the surface of the receiving water from atmosphere.

4.2.2.9 Summary of the Nonpoint Source Loads

As discussed previously, this TMDL focuses on calculating nutrient loadings created in the immediate drainage areas of the Sykes Creek – Newfound Harbor watershed. The estimated TN loads entering the system are 42,958 lbs/year from the watershed through runoff (including baseflow) and 15,424 lbs/year from direct atmospheric deposition onto the surface of the Sykes Creek – Newfound Harbor system. The total nonpoint source TN loads entering the system are 42,958 lbs/year + 15,424 lbs/year = 58,382 lbs/year. Atmospheric deposition of TN accounts for about 26% of the total nonpoint source TN load entering the system. The estimated TP loads entering the system are 9,472 lbs/year from the watershed through runoff (including baseflow) and 332 lbs/year from direct atmospheric deposition onto the surface of the Sykes Creek – Newfound Harbor system. The total nonpoint source TP loads entering the system are 9,472 lbs/year + 332 lbs/year = 9,804 lbs/year. Atmospheric deposition of TP accounts for about 3.4% of the total nonpoint source TP load entering the system.

Because of the hydrodynamic relationship between the Newfound Harbor with Sykes Creek and Newfound Harbor with the rest of the Banana River Lagoon, nutrient loads entering the Sykes Creek – Newfound Harbor system from the immediate watershed are not the only nutrient entering the system. However, because there wasn't a model to simulate nutrient loads contribution from other areas of the Banana River Lagoon, no detailed calculation on nutrient loads from the other areas of the lagoon were included in this TMDL. However, it should be pointed out that, while the TMDL required reduction needs to be applied to the immediate watershed of the Sykes Creek – Newfound Harbor system, other parts of the Banana River Lagoon should also be compliant to the nutrients targets established in the main stem seagrass TMDLs (FDEP 2009) in order to help the Sykes Creek – Newfound Harbor system to achieve its nutrient target.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1. Temporal Dynamics, Seasonality, and Critical Time of Nutrients and *ChlaC* Concentrations in Sykes Creek/Barge Canal (WBID 3044B)

As is shown in **Table 2.1**, during the Cycle 2 Verified Period (January of 2004 through June of 2011), the annual average *ChlaC* concentration only exceeded the 11 µg/L assessment threshold in 2009 and 2010 (The 2011 water quality data were not available for the Cycle 2 water quality assessment). In all the other years in the verified period before these two years, the *ChlaC* concentration was lower than the 11 µg/L assessment threshold. As the goal of nutrient TMDLs is to reduce the nutrient loads from the drainage basin into the impaired waterbody so that the trophic state of the receiving water can meet the nutrient criteria, it is very important to determine whether the observed increase in the *ChlaC* concentration was caused by elevated nutrient loads from the drainage basin. To answer this question, the temporal dynamics of nutrient and *ChlaC* concentrations were examined against measured rainfall data to explore possible relationships between the water quality condition of the Sykes Creek and the hydrology of its drainage basin, based on the assumption that the rainfall condition drives the watershed nutrient loading. The higher the annual rainfall, the higher nutrient loads would be created from the watershed, and vise versa.

Water quality data collected from a water quality site – 21FLSJWMIRLSC03 were retrieved from Department's IWR database Run_44 for this analysis. This site has been maintained by SJRWMD and nutrient related samples have been collected since the fourth quarter of 1999. Because water quality trends on the annual time scale are part of the temporal analysis in this TMDL report (IWR listing process assesses nutrient condition on the annual basis), to ensure that the annual mean will not be biased toward any quarters with more data being collected, quarterly means were first calculated based on nutrient concentrations measured within each quarter before annual means were calculated based on quarterly means. Because nutrient related data were only collected from 21FLSJWMIRLSC03 in the fourth quarter, data from 1999 were excluded for the annual mean analysis. The annual trend analysis was conducted based on data collected in the period from 2000 through 2010. **Figure 5.1** shows the location of the water quality station in Sykes Creek/Barge Canal system.

5.1.1. Rainfall in the Sykes Creek, North IRL, and BRL Drainage Basins

One way to examine the relationship between the water quality condition and watershed hydrology is to compare nutrients and *ChlaC* concentrations to rainfall data. Rainfall data used for this analysis were collected from four weather stations, including two stations from the Southeast Regional Climate Center (SERCC)'s Climate Information Management and Operational Decision (CLIMOD) system (http://climod.meas.ncsu.edu/), and two weather stations maintained by the SJRWMD (http://webapub.sjrwmd.com/agws10/hdsnew/map.html). The two CLIMOD stations include one located in City of Titusville (StationID 88942) and one located in City of Melbourne (StationID 85612). The two stations maintained by SJRWMD include one located in the Kiwanis Park at Merritt Island (01500682) and one located at Ransom Road at NASA (015112758). The weather station located in the Kiwanis Park at Merritt Island was originally chosen for the water quality/hydrology comparison because it is located right next to the water quality station used in this analysis (21FLSJWMIRLSC03). If the local hydrology dictates the water quality condition in the Sykes Creek/Barge Canal system, relationship may be observed between observed nutrient and *ChlaC* concentrations and rainfall data collected from this station. The other three stations were chosen because they represent the regional hydrologic condition that drives the watershed nutrient loads into the north IRL and BRL. Because the Sykes Creek is hydrodynamically influenced by these sub-lagoon areas, regional hydrologic condition will provide insight on whether the elevated *ChlaC* concentration during the Cycle 2 Verified Period were caused by elevated nutrient loads from the drainage basins discharging into the north IRL and BRL mainstem lagoon segments. **Figure 5.1** shows the locations of these four weather stations.

Table 5.1 shows the annual total rainfall for the four weather stations included in this analysis in the period from 2000 through 2011 and their average annual rainfall for the period. As is shown by the table, the highest long-term average annual rainfall was observed at the Melbourne station, which was about 54 inches/year, while the lowest long-term average annual rainfall was at the Merritt Island station, which was about 44 inches/year. The long-term average annual rainfalls at the Titusville and NASA stations were the same. Both were about 50 inches. For the period from 2000 through 2011, the overall average long-term annual rainfall for all the four sites was 49 inches/year. The Merritt Island long-term average annual rainfall was about 5 inches lower than the regional average.

Annual rainfalls significantly higher than the long-term average appeared in 2001, 2005, and 2008 for all the four stations. Annual rainfalls higher than the long-term average also appeared in 2002 and 2004 for all the four stations.

Except for the Titusville station, the annual rainfall in 2009, 2010, and 2011 at all the other three stations were lower than the long-term average annual rainfall. At the Titusville station, the annual rainfall in 2009 and 2010 were lower than the long-term average annual rainfall. However, the annual rainfall in 2011 at this station was slightly higher than the long-term average. Overall, 2009 and 2010, during which increased *ChlaC* were observed, were two dry years in the general area.

Figure 5.2 shows the quarterly rainfall from the four weather stations for the period from 2000 through 2011. The general trends of the quarterly rainfall from the four stations were very similar. The highest quarterly rainfall typically appeared in the third quarter (July through September) of a year and the lowest quarterly rainfall appeared in the first (January through March) and fourth quarters (October through December). Relatively higher quarterly rainfalls were observed from the second through the fourth quarters in 2002 and 2005. Higher quarterly rainfalls were also observed in the second and third quarters in 2009 and in the first and third quarters in 2010.

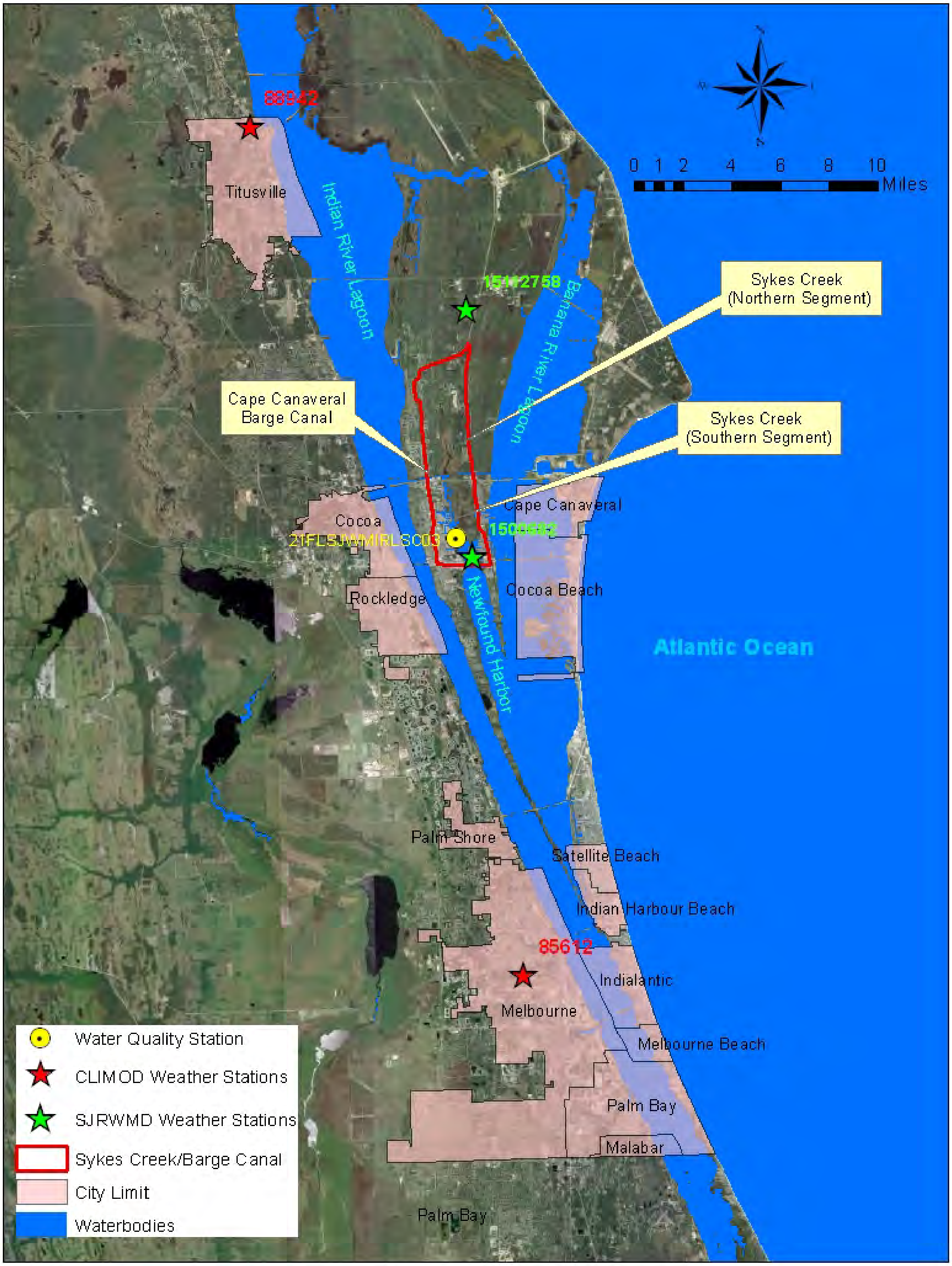

Figure 5.1. Location of a Water Quality Station (21FLSJWMIRLSC03) and CLIMOD and SJRWMD Weather Stations Used in this Analysis

Table 5.1. Annual Total Rainfall for the Four Weather Stations

Year	Titusville	NASA	Merritt Island	Melbourne
2000	32.7	20.9	34.3	43.2
2001	58.8	69.7	50.3	64.9
2002	53.9	58.3	50.6	55.4
2003	51.3	47.5	41.8	44.0
2004	57.8	59.4	44.9	57.1
2005	66.2	62.6	57.1	66.0
2006	47.5	36.0	27.0	42.2
2007	45.8	50.9	52.3	53.0
2008	50.8	64.1	57.0	76.1
2009	40.3	39.8	36.3	50.4
2010	37.5	43.6	32.3	41.6
2011	56.1	46.6	39.7	50.5
Mean	49.9	49.9	43.6	53.7

5.1.2. North IRL, BRL, and Sykes Creek/Barge Canal Hydrodynamics Are Controlled Primarily by Rainfall/Evaporation and Wind

The BRL and north IRL (IRL segments between Titusville and the Eau Gallie River) system, which are hydraulically connected to the Sykes Creek/Barge Canal system, are lagoon segments relatively isolated from astronomic tide activities because of the low astronomic height at the mouth of the ocean inlet, the narrow water path and the shallow water depth of the lagoon proper, and the relatively long-distance of the BRL and north IRL from the closest ocean inlet – the Sebastian Inlet (Woodward-Clyde, 1994). According to Evink (1980) and Dombrowski et al. (1987), the height of spring tide quickly decreased from about 2.2 ft at the mouth of the Sebastian Inlet to about 1 ft in the lagoon segments near the Sebastian River (about 1 mile north of the Sebastian Inlet), and to 0.2 ft in the lagoon segment between the Melbourne and Eau Gallie Causeways about 17 miles north of the inlet, indicating a rapid decrease of tidal amplitude within a short distance from the inlet. The astronomical tide was mostly absent in lagoon segments north of the Eau Gallie Causeway. This portion of the north IRL was described by Smith (1993) as the "tideless sub-regime." While the BRL is connected to the Atlantic Ocean through a boat lock on the Cape Canaveral Barge Canal, the impact of the boat lock on the hydrodynamics and water budget of the lagoon is very limited (Woodward-Clyde, 1994).

Because of the insignificant impact from tidal activities, the water budget of the BRL and north IRL lagoon segments are primarily influenced by the rainfall and evaporation. The circulation pattern and mixing of these lagoon segments can be significantly influenced by the wind. Also because of the insignificant ocean impact, the salinity of these lagoon segments, including the salinity of Sykes Creek, are primarily determined by the relationship between rainfall and evaporation. **Figure 5.3** shows pan evaporation measurements obtained from a weather station located in Vero Beach (retrieved from the CLIMOD system. Station ID is 89219) for the period 1990 through 2000 (the evaporation records of the station stopped at 2001). There appears to be a sudden decrease of the value of evaporation measurements at the station in 1999 and 2000 after a period of no records in 1998. Other than the evaporation measurements in 1999 and 2000, the seasonal pattern of evaporation appears to be very consistent in the period from 1990 through 1997. Based on this observation, long-term average quarterly evaporations were calculated based on the quarterly evaporations in the period from 1990 through 1997. In

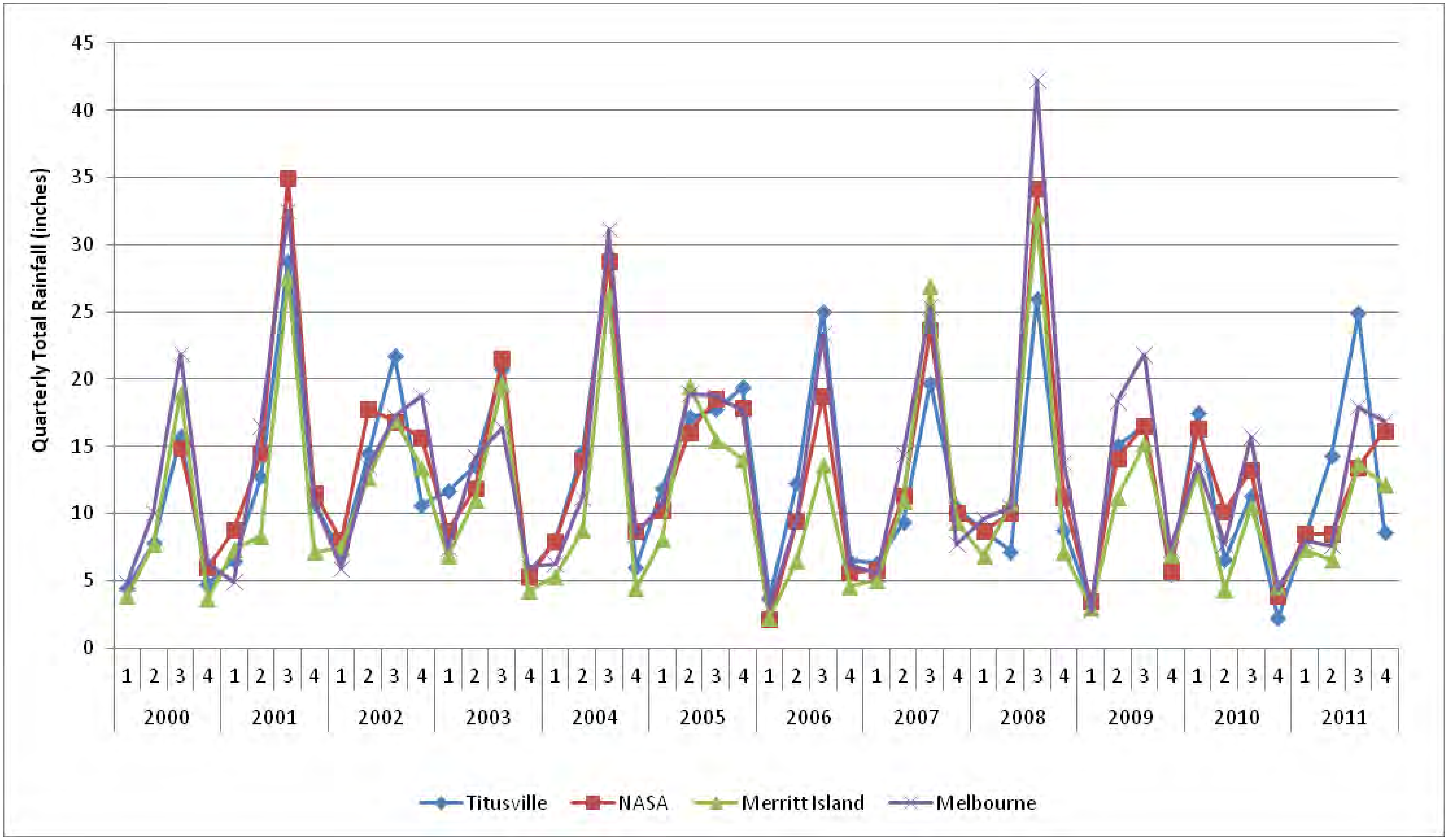

Figure 5.2. Quarterly Rainfall from the Four Weather Stations Used in this Analysis

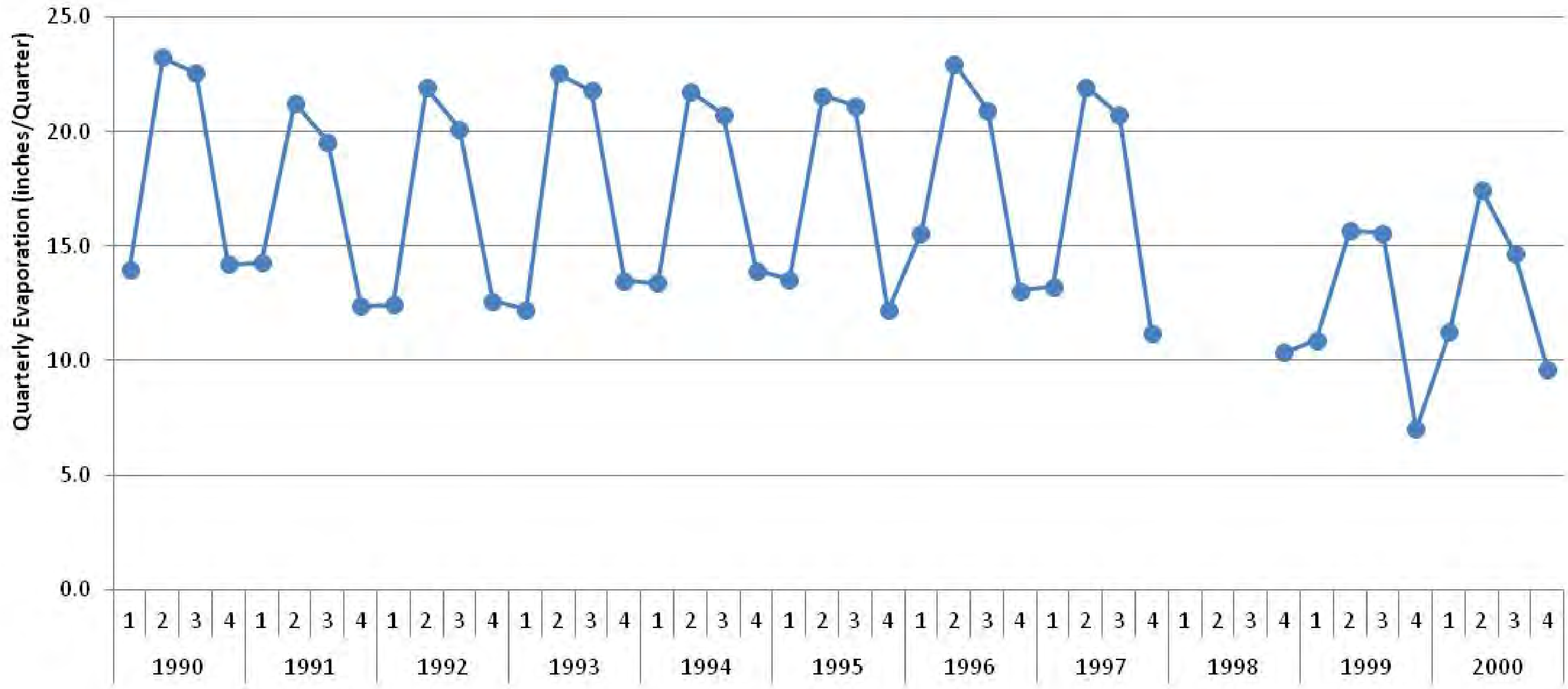

Figure 5.3. Quarterly Evaporation from a Weather Station Located in Vero Beach

addition, because the drainage basin in the north IRL and BRL areas are relatively small compared to the lagoon surface area, it is assumed that the rainfall directly onto the lagoon surface area is more important on the water budget and salinity dynamics than the drainage basin runoff. This assumption is only applied to the salinity measurement, which reflects the relatively conservative salt content of the water. It does not apply to materials such as nutrients, which can be taken up by aquatic organisms, especially submerged aquatic vegetation and associated epiphyte, and therefore be quickly removed from the water column. Based on these assumptions, net quarterly rainfalls were calculated as the total quarterly rainfalls minus quarterly evaporations. In this analysis, long-term average quarterly evaporations were calculated based on the evaporation data measured in the period from 1990 through 1997 and applied to the period from 2000 through 2010, assuming the quarterly evaporation in the 2000 through 2010 period is the same as the long-term average quarterly evaporation. Because the evaporation measurements directly obtained from the Vero Beach Station represent pan evaporations, which are commonly considered higher than the actual lagoon evaporations, a pan evaporation coefficient of 0.78 (Woodward-Clyde, 1994) was multiplied to the pan evaporation measurements to calculate the actual lagoon evaporation rates. **Table 5.2** shows the long-term average quarterly pan evaporation rates and pan evaporation coefficient (0.78) adjusted long-term average quarterly evaporation rates for the lagoon.

Table 5.2. Long-term Average Quarterly Pan Evaporation Rates and Long-term Average Quarterly Evaporation Rates Adjusted with the Pan Evaporation Coefficient (inches)

Quarter	Long-term Average Quarterly Pan Evaporation	Long-term Average Quarterly Evaporation Adjusted with the Pan Evaporation Coefficient (0.78)
1st Quarter	13.6	10.6
2nd Quarter	22.2	17.3
3rd Quarter	20.9	16.3
4th Quarter	12.9	10.1
Annual	69.6	54.3

Based on **Table 5.2**, the long-term average annual evaporation rate adjusted with the pan evaporation coefficient is about 54 inches for the period from 2000 through 2010, which is similar to the long-term annual rainfall at the Melbourne weather station, but is higher than long-term annual rainfalls from the other weather stations included in this report. While this finding is consistent with the historic observation (Woodward-Clyde, 1994), it also has the caveats that the drainage basin runoff was not taking into consideration.

Figure 5.4 shows the long-term temporal dynamics of net quarterly rainfall (total quarterly rainfall obtained from the Merritt Island weather station minus quarterly evaporation) and quarterly average salinity in Sykes Creek at the water quality sampling site of 21FLSJWMIRLSC03. As the figure shows, there is a general inverse trend between the quarterly salinity and quarterly net rainfalls in the period from 2000 through 2010. However, in 2009 and 2010, salinity appeared not to respond to the change of the net rainfall.

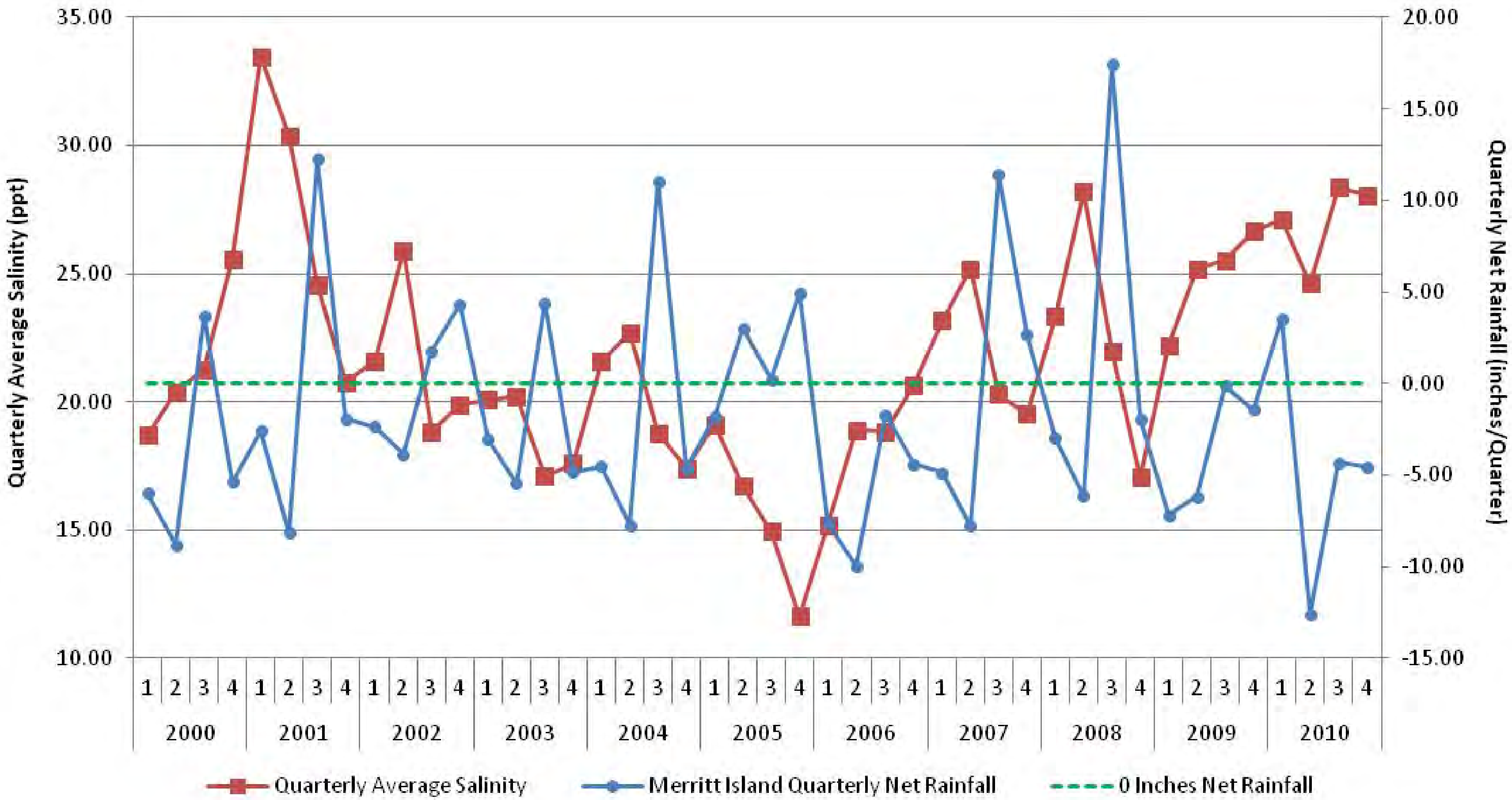

Figure 5.4. Long-term Temporal Dynamics of Quarterly Average Salinity and Quarterly Net Rainfall

To interpret this observation, the relationship between the net rainfall and salinity in the 2000-2010 period were re-examined. Three periods in which there was a consistent increase of salinity across multiple seasons were identified. The first period was from the first quarter of 2000 through the first quarter of 2001. Within this five quarter period, the quarterly average salinity consistently increased from about 19 ppt to about 35 ppt without responding to the change of the net quarterly rainfall. The second period was from the fourth quarter of 2005 through the second quarter of 2007. The quarterly average salinity consistently increased through the seven-quarter period from 11 ppt to about 25 ppt without responding to the change of net rainfall. The third period was from the fourth quarter of 2008 through the fourth quarter of 2010. Except for a slight decrease of salinity in the second quarter of 2010, the salinity consistently increased from 17 ppt to about 28 ppt without responding to the change of net rainfall. A common observation from all these three periods was that the net quarterly rainfall amounts in the vast majority of quarters in these periods were negative. In other words, as long as the evaporation exceeded the rainfall, salinity of the system will increase. The salinity will not decrease due to a reduced net rainfall debt (smaller negative net rainfall). The salinity will only decrease if the net rainfall became a non-negative value.

Based on the above observation and discussions, there appear to be a very good relationship between the variation of salinity in Sykes Creek/Barge Canal and the regional rainfall – the salinity is primarily determined by the regional rainfall condition. The observed elevation of the salinity in 2009 and 2010 were primarily due to the fact that, in most of this period, the evaporation exceeded the rainfall and the concentration effect caused the salinity to increase.

5.1.3. Temporal Dynamics of ChlaC, TN, and TP Concentrations in the Sykes Creek/Barge Canal System

Figure 5.5 shows the long-term temporal dynamics of quarterly average *ChlaC* concentration in Sykes Creek. As the figure shows, the period from 2000 through 2010 can be divided into three sub-periods that had different *ChlaC* concentration patterns. The first period is from 2000 through 2002. Quarterly mean *ChlaC* concentrations higher than 10 µg/L were common. In fact, the average quarterly mean *ChlaC* concentration for the period was about 11.3 µg/L. The second period was from 2003 through 2008, during which the vast majority of quarterly mean *ChlaC* concentrations were lower than 10 µg/L. The average quarterly mean *ChlaC* concentration for the period was about 5 µg/L. The third period was 2009 and 2010. During this period, except for the second and fourth quarters in 2009, the other quarterly mean *ChlaC* concentrations were all higher than 10 µg/L. The average quarterly mean *ChlaC* concentration for this period was about 14.3 µg/L.

This temporal pattern of *ChlaC* concentration appeared to be consistent with the temporal pattern of salinity. As is shown in **Figure 5.4**, in the 2000-2002 period, the long-term average quarterly mean salinity was about 23 ppt. In the period from 2003 through 2008, the long-term average quarterly mean salinity was about 19 ppt. The long-term average quarterly mean salinity for the period from 2009 through 2010 was 26 ppt. The long-term average quarterly mean *ChlaC* appeared to be positively correlated to the long-term salinity pattern in the Sykes Creek/Barge Canal system.

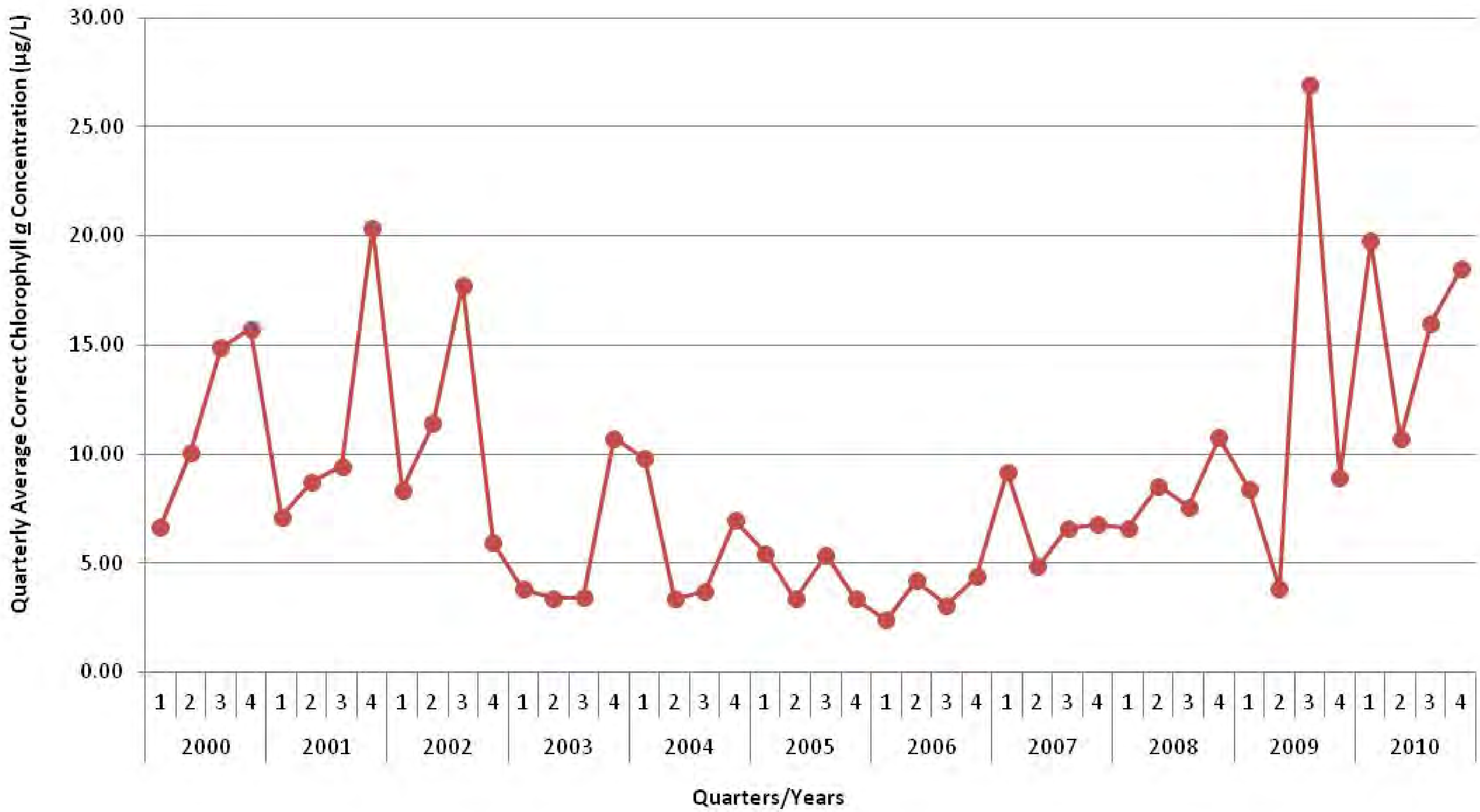

Figure 5.5. Long-term Temporal Dynamics of Chlorophyll a Concentration in Sykes Creek

Seasonally, the highest *ChlaC* concentrations mostly appeared either in the third quarter (July through September) or fourth quarterly (October through December) or both. The peak *ChlaC* concentrations were also observed in the first quarterly (January through March) in 2004, 2005, and 2007). The seasonal pattern of *ChlaC* concentration may reflect the fact that phytoplankton in the creek favor warm water temperature. Phlips et al. (2002) found that the highest phytoplankton standing crops in IRL typically occurred in the warmer months of the year, i.e. May to November. Although the location of the IRL makes the seasonal variation of water temperature relatively modest compared to waterbodies located in the temperate zones, many warm water taxa appear in these lagoon areas favor the warm water weather. Studies showed that a potentially toxic dinofllagellate species – *Pyrodinium bahamense* mostly bloom in warm months of the year in this part of the lagoon (Landsberg et al., 2002; Philips et al., 2004). The seasonal variation of the *ChlaC* concentrations suggests that temperature could be one of the major factors responsible for the intra-annual variation of phytoplankton biomass.

While the long-term temporal dynamics of *ChlaC* concentration clearly showed a three-period pattern, similar patterns were observed with TN and TP concentrations, but to a lesser extent. **Figures 5.6** and **5.7** show the long-term temporal dynamics of TN and TP concentrations in Sykes Creek for the period from 2000 through 2010, respectively. In the 2000 through 2002 period, most TN concentrations were above 1.50 mg/L and many TP concentrations were above 0.05 mg/L. The long-term average quarterly mean TN and TP concentrations for this period were 1.60 mg/L and 0.05 mg/L, respectively. In the period from 2003 through 2008, most quarterly average TN concentrations were lower than 1.50 mg/L, and most quarterly average TP concentrations were lower than 0.05 mg/L. The long-term average quarterly mean TN and TP concentrations for this period were 1.39 mg/L and 0.04 mg/L, respectively. In the 2009 and 2010 period, both quarterly average TN and TP concentration showed consistent increase. In 2010, all quarterly average TN were around or higher than 1.50 mg/L and all quarterly average TP were higher than 0.05 mg/L. The long-term average quarterly mean TN and TP concentrations for the period were 1.52 mg/L and 0.06 mg/L, respectively.

No clear seasonal patterns could be identified for the quarterly average TN and TP concentrations.

5.1.4. Potential Factors That May Influence the ChlaC Concentration

To explore possible factors that may influence the *ChlaC* concentration in the Sykes Creek/Barge Canal system, parameters included in **Table 5.3** were retrieved from Department's IWR Database Run_44 for the period from 2000 through 2010. Because nutrient impairment is typically assessed at the annual average time-scale using the IWR listing process, annual average values of these parameters were calculated in this analysis. To ensure that annual average values for these parameters were not biaed toward any given months that had more data than others, quarterly averages of these parameters were first calculated based on raw data. Annual means were then calculated based on quarterly means. To examine possible relationship between *ChlaC* concentration to these parameters, single correlation analyses were conducted between annual mean *ChlaC* concentrations and annual means of each of these parameters using the ordinary least square method. **Table 5.3** shows the correlation coefficients (R^2) and the probability at which the slope of the correlation curve is zero (P). **Table 5.4** lists annual means of the parameters used in this analysis.

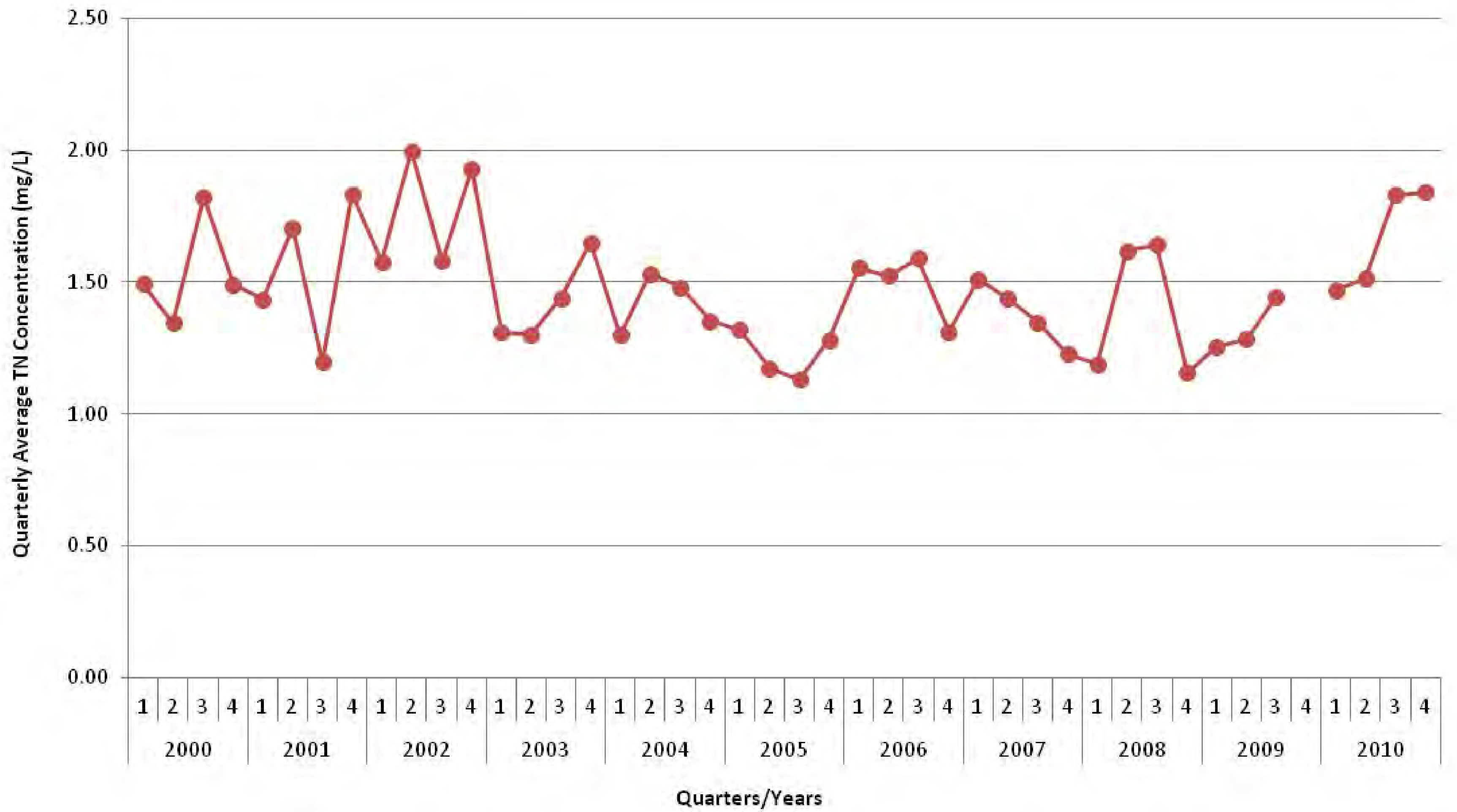

Figure 5.6. Long-term Temporal Dynamics of TN Concentration in Sykes Creek

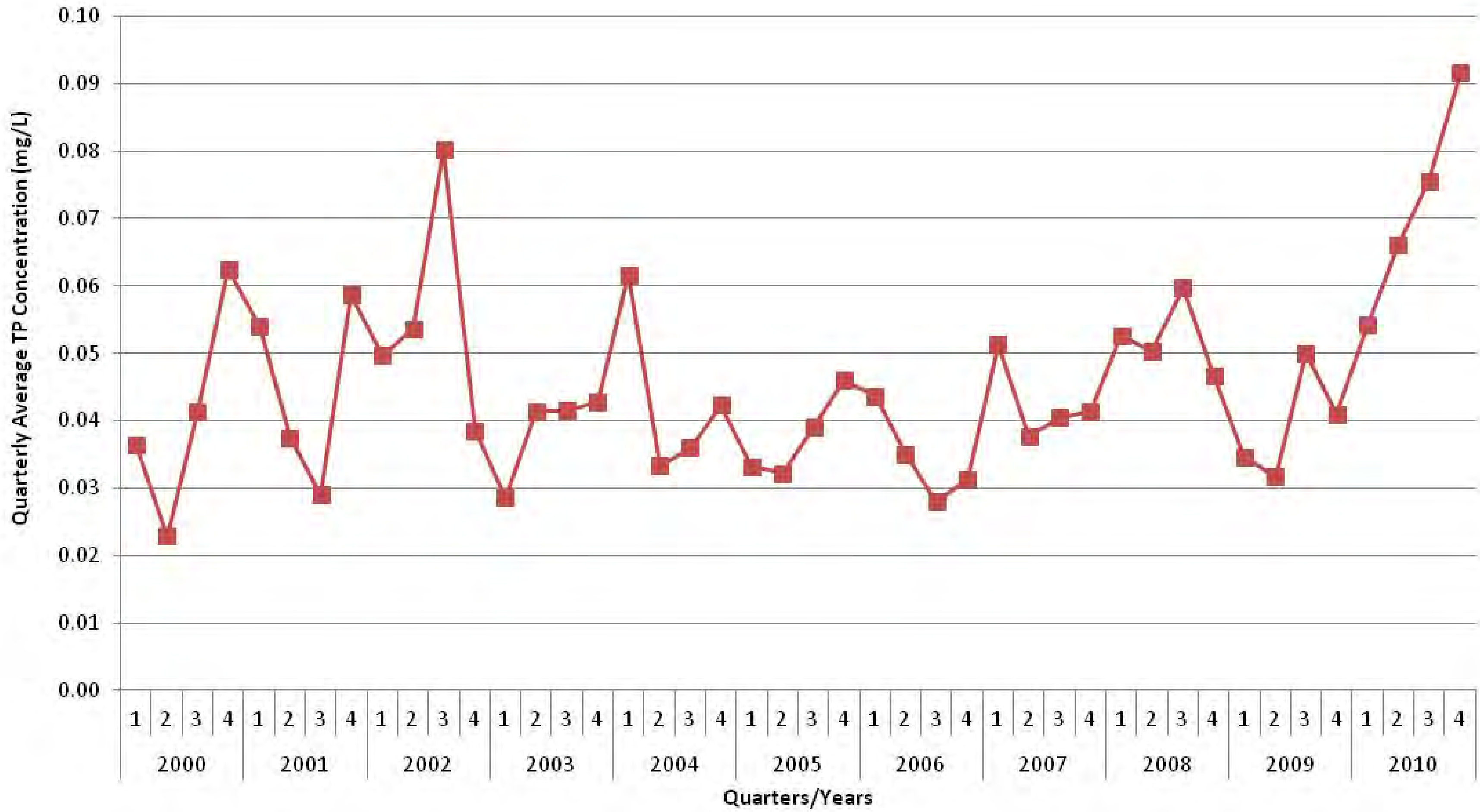

Figure 5.7. Long-term Temporal Dynamics of TP Concentration in Sykes Creek

Table 5.3. Correlation between Annual Mean Corrected Chla and Annual Means of Some Water Parameters

Parameter	R^2	Coefficient	Intercept	F Ratio	P > (F)	Equation
TN	0.34	14.64	-12.6	5.2	0.046	Chla = -12.6 + 14.67 * TN
TKN	0.31	15.09	-12.88	4.57	0.058	Chla = -12.9 + 15.1 * TKN
NH_4	0.57	-136.39	17.12	8.1	0.029	Chla = 17.1 - 136.3 * NH4
No_x	0.36	-361.56	15.66	5.58	0.04	Chla = 15.7 - 361.6 * Nox
TP	0.42	231.9	-1.49	7.12	0.024	Chla = -1.49 + 231.9 * TP
PO_4	0.06	-493.5	13.88	0.66	0.437	Chla = 13.9 - 493.5 * PO4
Conductivity	0.68	0.0006	-12.58	20.89	0.001	Chla = -12.6 + 0.0006 * Cond
Salinity	0.68	0.896	-10.5	20.97	0.001	Chla = -10.5 + 0.90 * Salinity
Turbidity	0.08	1.31	5.19	0.9	0.36	Chla = 5.19 + 1.3 * Turbidity
TSS	0.12	0.41	4.49	1.38	0.27	Chla = 4.49 + 0.41 * TSS
Color	0.36	-0.47	17.66	5.75	0.03	Chla = 17.65 + 0.47 * Color
Temp	0.12	2.18	-45.77	1.37	0.269	Chla = -45.8 + 2.2 * Temp
TOC	0.02	-0.27	13.34	0.2	0.662	Chla = 13.3 - 0.27 * TOC

Note: Green highlighted correlations are statistically significant.

Based on **Table 5.3**, it is obvious that *ChlaC* concentration has the highest correlation with conductivity and salinity. The variance of conductivity and salinity explained close to 70% of the variance in *ChlaC* concentration. Second to the correlation between *ChlaC* concentration and conductivity/salinity is the correlation between *ChlaC* concentration and nutrients. The correlation coefficients between *ChlaC* concentration and TP and TN are 0.42 and 0.34, respectively. All these correlations show positive slopes, which suggest stimulation effects of conductive/salinity and TN/TP to the growth of algae.

Negative slope correlations were also observed in the correlation analyses. For example, the correlation between *ChlaC* concentration and color showed a negative slope. This is expected because the color-induced light attenuation may cause light limitation on algal growth. For this analysis, the variance of color explains about 36% of the variance of *ChlaC* concentration. Negative correlations were also observed between *ChlaC* concentration and NH_4 and NO_x concentrations. This seems counterintuitive because increase of inorganic nutrients is expected to stimulate the growth of phytoplankton and therefore cause the *ChlaC* concentration to increase. However, the negative correlation between *ChlaC* concentration and NH_4/NO_x may simply reflect a reverse relationship between phytoplankton and the availability of NH_4/NO_x, i.e. the more phytoplankton biomass existed in the water column, the more NH_4/NO_x was taken up, and therefore less NH_4/NO_x existed in the water column.

In addition to conductivity/salinity, TN/TP, NH_4/NO_x, and color, other factors that may potentially influence the *ChlaC* concentration were also examined in this analysis. These included Turbidity/TSS, water temperature, and TOC. It is expected that the variance of turbidity/TSS may influence the light availability in the water column, and in turn influence the *ChlaC* concentration. However, based on this analysis, no significant correlations were observed between *ChlaC* concentration and turbidity/TSS. No significant correlation was observed between the annual average *ChlaC* concentration and annual average water temperature either.

The original intention of examining the relationship between *ChlaC* and water temperature is to see whether increase of water temperature in low rainfall years (maybe due to decreased water volumes in the lagoon) may stimulate the growth of phytoplankton in this part of the lagoon system. However, based on the water temperature data collected at 21FLSJWMIRLSC03, the long-term average annual mean water temperatures for Sykes Creek was about 25.05^{0}C with a standard deviation of 0.60^{0}C during the period from 2000 through 2010 (**Table 5.4**). The annual mean water temperature for 2009 and 2010 were 25.39^{0}C and 25.07^{0}C, which were not significantly different from the long-term average. Therefore, variance of annual average water temperature does not explain the observed elevation of annual average *ChlaC* concentration in these years.

No correlation was observed between *ChlaC* and TOC concentrations. Possible correlation between these two parameters was examined because organic carbon is the food source for bacterioplankton, which compete against phytoplankton for nutrients. Decrease of the organic carbon input from the watershed under the low rainfall condition in 2009 and 2010 may depress bacterioplankton's growth and therefore make nutrients more available to phytoplankton and cause the increase of *ChlaC* concentration. This hypothesis was not supported by the results of the correlation analysis.

In summary, when examining data on an annual average time scale, the elevated *ChlaC* concentration in the Sykes Creek/Barge Canal system in 2009 and 2010 appeared to be more related to the elevated conductivity/salinity than any other water quality parameters measured in these same years. This conclusion is supported by the overall strong correlation between the annual average *ChlaC* concentration and the annual average conductivity/salinity for the entire period record from 2000 through 2010 (R^2 = 0.68, P=0.001 < 0.05). The *ChlaC* concentration was also related to nutrient concentrations, particularly, TN and TP concentrations. However, compared to the correlation between *ChlaC* and conductivity/salinity, the correlation between *ChlaC* and nutrients appeared to be secondary. The variance of TN and TP concentrations only explained about 34% and 42% of the variance of *ChlaC*, respectively. Although color variation also explained about 36% of the *ChlaC* variation, compared to other years in the period from 2000 through 2010, the decrease of color in 2009 and 2010 was relatively minor (**Table 5.4**).

Interpreting the elevated *ChlaC* concentration against elevated conductivity/salinity can be complicated because variation of conductivity/salinity could cause or be caused by other environmental factors that may influence phytoplankton abundance. For example, studies have pointed out that, due to the large variation of salinity in the north IRL area (from 10 to 35 ppt), most of the dominant phytoplankton species, including those of dinoflagellates, diatom, and blue-green algae, are mostly euryhaline, which have high tolerance to the salinity variation. However, most of these dominant species reach their biomass peaks at mid-range salinity (20 to 30 ppt) (Phlips, et al. 2011). Based on the data shown in **Figure 5.4**, the quarterly average salinity at 21FLSJWMRLSC03 fell within the range between 20 and 30 ppt in 2009 and 2010, which provided a favorable salinity environment for the phytoplankton to reach their growth potential. This is consistent with the strong correlation between salinity and *ChlaC* concentration observed based on the correlation analysis.

Elevated conductivity/salinity in the north IRL and Banana River Lagoon segments can also mean increased water residence time, which provides longer time for algal biomass to accumulate in these lagoon segments and causes *ChlaC* concentration to increase. While this is a theoretical possibility, studies have indicated that the water residence time in the north IRL and Banana River Lagoon segments are normally long, which generally ranges from several months to one year (Sheng and Davis, 2003; Steward et al., 2005), while the general

Table 5.4. Annual Means of Water Quality Parameters Used in the Correlation Analyses

Year	Chla (µg/L)	TN (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3O2 (mg/L)	TP (mg/L)	PO4 (mg/L)	Conduct (UMHOS/CM)	Salinity (PPT)	Turbidity (NTU)	TSS (mg/L)	Color (pcu)	Water Temp (^{0}C)	DO (mg/L)	TOC (mg/L)
2000	11.84	1.54	1.53	---	0.011	0.041	0.007	34185	21.5	1.86	14.1	11.7	25.69	6.9	14.2
2001	11.22	1.54	1.52	---	0.017	0.044	0.011	42232	27.2	2.92	14.9	10.0	25.45	6.5	14.7
2002	10.87	1.78	1.73	---	0.031	0.056	0.007	34328	21.6	4.18	11.6	18.8	25.06	7.1	20.6
2003	5.62	1.42	1.40	---	0.021	0.039	0.012	30159	18.7	3.22	15.9	18.8	24.90	6.8	15.4
2004	5.96	1.42	1.40	0.08	0.018	0.043	0.012	32234	20.1	2.84	5.9	19.2	23.68	7.0	15.8
2005	4.40	1.22	1.20	0.07	0.023	0.038	0.010	25577	15.6	2.39	6.8	26.0	25.45	7.0	14.9
2006	3.51	1.49	1.47	0.11	0.023	0.035	0.010	29732	18.4	2.10	8.5	21.7	24.87	6.2	17.3
2007	6.86	1.38	1.36	0.05	0.023	0.043	0.010	34960	22.0	2.51	9.9	20.4	25.64	7.2	18.4
2008	8.37	1.40	1.38	0.05	0.018	0.052	0.010	35768	22.6	4.17	12.3	22.5	24.36	7.3	17.0
2009	12.02	1.33	1.31	0.06	0.014	0.039	0.010	39032	24.9	3.27	10.2	20.4	25.39	7.2	14.0
2010	15.82	1.67	1.59	0.04	0.010	0.073	0.012	42464	27.3	3.84	9.3	17.3	25.07	7.2	16.6
Mean	**8.77**	**1.47**	**1.45**	**0.06**	**0.02**	**0.05**	**0.01**	**34607**	**21.82**	**3.03**	**10.83**	**18.79**	**25.05**	**6.94**	**16.27**
Stdev	**3.85**	**0.16**	**0.15**	**0.02**	**0.01**	**0.01**	**0.00**	**5214**	**3.65**	**0.80**	**3.25**	**4.59**	**0.60**	**0.34**	**1.98**

phytoplankton doubling time is in days. Therefore, even without the dry period in 2009 and 2010, water residence time may not be a limiting factor in controlling the overall *ChlaC* concentration in the north IRL and Banana River Lagoon segments. Longer water residence times, in this case, may not explain the dramatic increase of the *ChlaC* concentration observed in 2009 and 2010.

Elevated conductivity/salinity may also mean shallow water depth due to the relatively stable evaporation and reduced rainfall. Vertical mixing, which is caused by wind and can bring benthic algae back into the water column and cause water column *ChlaC* concentrations to increase (Phlips et al., 2002), might become more significant under the shallow water depth condition. At the time when this TMDL was developed, no information regarding the benthic algal species in the water column in 2009 and 2010 was available. Therefore, it is impossible to judge whether elevated *ChlaC* concentration in 2009 and 2010 was caused by elevated benthic algae in the water column. If wind mixing caused resuspension is a major factor in the north IRL and Banana River Lagoon segments, and in Sykes Creek system, elevated turbidity and TSS should have been observed in these years. Based on **Table 5.4**, turbidity and TSS indeed increased in 2009 and 2010, compared to 2004, 2005, and 2006. The latter years were characterized with low turbidity and TSS, as well as low *ChlaC* concentration. This appears to be consistent with the hypothesis that certain portion of elevated water column *ChlaC* concentration may be due to the resuspension of benthic algae. However, over the period from 2000 through 2010, the correlation between turbidity/TSS and *ChlaC* is not significant. Therefore, even if benthic algae resuspension may be a contributor to the water column *ChlaC* concentration, the contribution may not be very significant.

Could the conductivity/salinity increase caused nutrient concentrations to increase, which, in turn, stimulate the growth of phytoplankton and therefore cause the *ChlaC* concentration? If this is the case, nutrients should be the primary factors that control the *ChlaC* concentration in the Sykes Creek system and correlations between *ChlaC* and nutrients should be stronger than the correlation between *ChlaC* and turbidity/salinity. Apparently, this is inconsistent with the findings from the correlation analyses. Another interesting observation associated with nutrient dynamics in the lagoon is that, based on Phlips (2011), nutrient concentrations, especially the TN concentration, tended to increase with the increased rainfall. However, based on data analysis conducted in this TMDL, during consecutive dry years, reduced rainfall not only did not significantly reduce the nutrient concentration, in fact, nutrient concentrations were elevated in those dry years. This is especially true for the periods of 2000 – 2002 and 2008 – 2010. The increase of TP concentration during these dry periods appears more obvious than the increase of TN concentration (**Figures 5.6 and 5.7**). This could be caused by the concentration effect due to the low net rainfall, but the possible contribution from the internal loading may also be an important contributor to the elevated nutrient concentrations during the dry periods.

There are other possible explanations for the elevated nutrient concentrations in 2009 and 2010. The 2009 to 2010 winter was a very cold winter. The low water temperature could have caused the die-off of drifting macro algae in the lagoon system, which released nutrients into the lagoon water column and increased nutrient concentrations. At the same time, zooplankton numbers significantly decreased, most likely also due to the low winter water temperature. Although there are no data available to show the status of benthic filter feeders during this time, low water temperature could also depressed their feeding capability. Therefore, when temperature increase in the spring, phytoplankton had more nutrients available for their growth and, at the same time, were faced with a significant lower grazing pressure compared to previous year, which caused rapid increase in phytoplankton biomass and *ChlaC* concentration

(Dr. Edward Phlips and Mr. Joel Steward, personal communication). According to Dr. Phlips, also observed in late 2010 and 2011 was a switch of phytoplankton community species composition from being dominated by dinoflagellates and diatoms to green algae and blue-green algae picoplankton. Because of the dying-off of macro-algae, large amounts of organic nutrients were released into the water column. Many picoplankton species have the capability to use inorganic nutrient, as well as organic nutrients to grow and therefore enjoyed the competition advantage over dinoflagellates and diatoms, which mostly rely on inorganic nutrients. These picoplankton species typically have higher chlorophyll content to cell volume ratio. The same amount of algal biomass of these green and blue-green algal species typically has higher chlorophyll content than dinoflagellates and diatoms. This could be another reason resulted in the elevated *ChlaC* concentration in the IRL and BRL segments since 2009, and especially in 2011.

In summary, based on the available data and correlation analyses, and results from past and recent studies by Dr. Phlips and other researchers, the elevated *ChlaC* concentration observed in 2009 and 2010, which extended into 2011, appeared to be more related to changes within the lagoon system caused by the change of the climate condition, than being caused by increased nutrient loads from the watershed. The observed elevation in *ChlaC* concentration could be a combined result of a cold-winter killing of macro-algae, zooplankton, and benthic filter feeders, which provide phytoplankton with more nutrient and reduced the grazing pressure on phytoplankton, switching of phytoplankton species composition from being dominated by dinoflagellates and diatoms to more chlorophyll-rich green and blue-green picoplankton, which further caused the *ChlaC* in the system to hike, and also, the consecutive low rainfall condition causing salinity in the north IRL and BRL to increase to the range that favored the growth of dominate phytoplankton species.

On the long-term basis, especially for Sykes Creek, the strongest correlation was found between conductivity/salinity and *ChlaC* concentration. Nutrients also positively correlated to the *ChlaC* concentration, but appeared to be secondary compared to the influence of conductivity. Without the change of the climate condition, even during the hurricane years when large amount of nutrients were brought into the system, for example, in 2004 through 2008, annual *ChlaC* concentration did not exceeded the 11 µg/L assessment threshold. Therefore, maintaining the existing nutrient loads from the watershed should be sufficient to keep the *ChlaC* concentration below the impairment threshold under most weather conditions. However, as the Sykes Creek watershed is part of the drainage basin that contributes nutrients to the Banana River Lagoon, which has nutrient loading targets that protect seagrass, the percent nutrient reductions that apply to the other parts of the Banana River Lagoon basin should also be applicable to the Sykes Creek watershed. In addition to restore the mainstem seagrass distribution, this reduction will also help lower the *ChlaC* concentration in Sykes Creek further more so that the *ChlaC* concentration will less likely to exceed the ChlaC impairment threshold even under the extreme weather condition.

5.2. Areal Nutrient Loading Targets for the Seagrass Restoration in The Indian River lagoon and Banana River Lagoon

In 2009, the Department adopted a set of nutrient TMDLs for mainstem water segments of the IRL and BRL. These TMDLs were developed based on the Pollutant Load Reduction Goals (PLRGs) created by SJRWMD to restore the seagrass distribution in IRL and BRL segments. These PLRGs were established based on seagrass distribution targets, which were represented by the seagrass depth-limit in different lagoon segments. Different seagrass depth-limit targets were established for 15 lagoon segments, including four segments for the BRL sub-lagoon, six segments for the North IRL sub-lagoon, and five for the Central IRL sub-lagoon, through analyzing the seagrass mapping results created in 1943, 1986, 1989, 1992, 1994, 1996, and 1999 and the lagoon bathymetry established by Coastal Planning and Engineering, Inc., in 1996 (Steward et al. 2005). **Figure 5.8** shows the segmentation of the IRL and BRL system used by the mainstem seagrass nutrient TMDLs. **Table 5.5** shows the range of the median values of maximum achievable seagrass depth-limit targets for each sub-lagoon. The final TMDL depth-limit targets were established by allowing a 10 percent departure (shallower) from the maximum achievable depth-limit targets because the applicable State Surface Water Quality Standard for light transmission (Chapter 62-302, F.A.C.) allows a decrease of depth of the compensation point by no more than 10 percent from the natural background condition.

Table 5.5. Range of Seagrass Median Maximum Achievable Depth-Limit Targets for the Three Sublagoons

Sublagoon	Median Maximum Achievable Seagrass Depth-Limit Target (meters)
North IRL	1.5 – 1.8
Central IRL	1.2 – 1.7
Banana River Lagoon	1.4 – 1.8

In order to derive nutrient targets from the seagrass depth-limit targets, relationships between watershed nutrient loadings and seagrass depth-limits were established for the three sub-lagoons by the SJRWMD (Steward and Green 2006 and 2007). Nutrient loadings from lagoon segments' drainage basins were estimated for years that both land use information and seagrass depth-limit measurements were available using either the Pollutant Loading Screening Model (PLSM) or Hydrologic Simulation Program – Fortran (HSPF). As discussed in Chapter 4, the estimation of total nutrient loads discharged into each lagoon segment took into consideration of the nutrient loads from point source dischargers, nonpoint source human land use areas, and nutrient removal effects from the best management practices (BMPs) associated with the construction built after 1984 when the state stormwater rule was implemented. Areal nutrient loadings into each lagoon segments were calculated by dividing the drainage basin loadings by the drainage basin area. Areal nutrient loadings for different years were then log-transformed and regressed against the percent deviation of seagrass depth-limit from the target seagrass depth-limit. The final TMDL nutrient target loadings for each sub-lagoon were then derived as the nutrient loadings that resulted in not more than a ten percent (10%) deviation (shallower) of the seagrass depth-limit from the maximum achievable seagrass depth. **Table 5.6** lists the per acre TN and TP nutrient loading targets for all the three sub-lagoons.

As the Sykes Creek – Newfound Harbor system is located in the Banana River Lagoon basin, the TN and TP targets established for the Banana River Lagoon also apply to the Sykes Creek – Newfound Harbor watershed. The areal nutrient targets applicable to the Banana River Lagoon basin include 2.18 lbs/ac/year of TN and 0.374 lbs/ac/year of TP. A 66% reduction of TN and 70% reduction of TP are needed to be implemented in the Sykes Creek – Newfound Harbor watershed in order to achieve these areal nutrient loading targets. These needed percent reductions are defined in the IRL main stem TMDLs adopted by the Department in 2009 (FDEP, 2009).

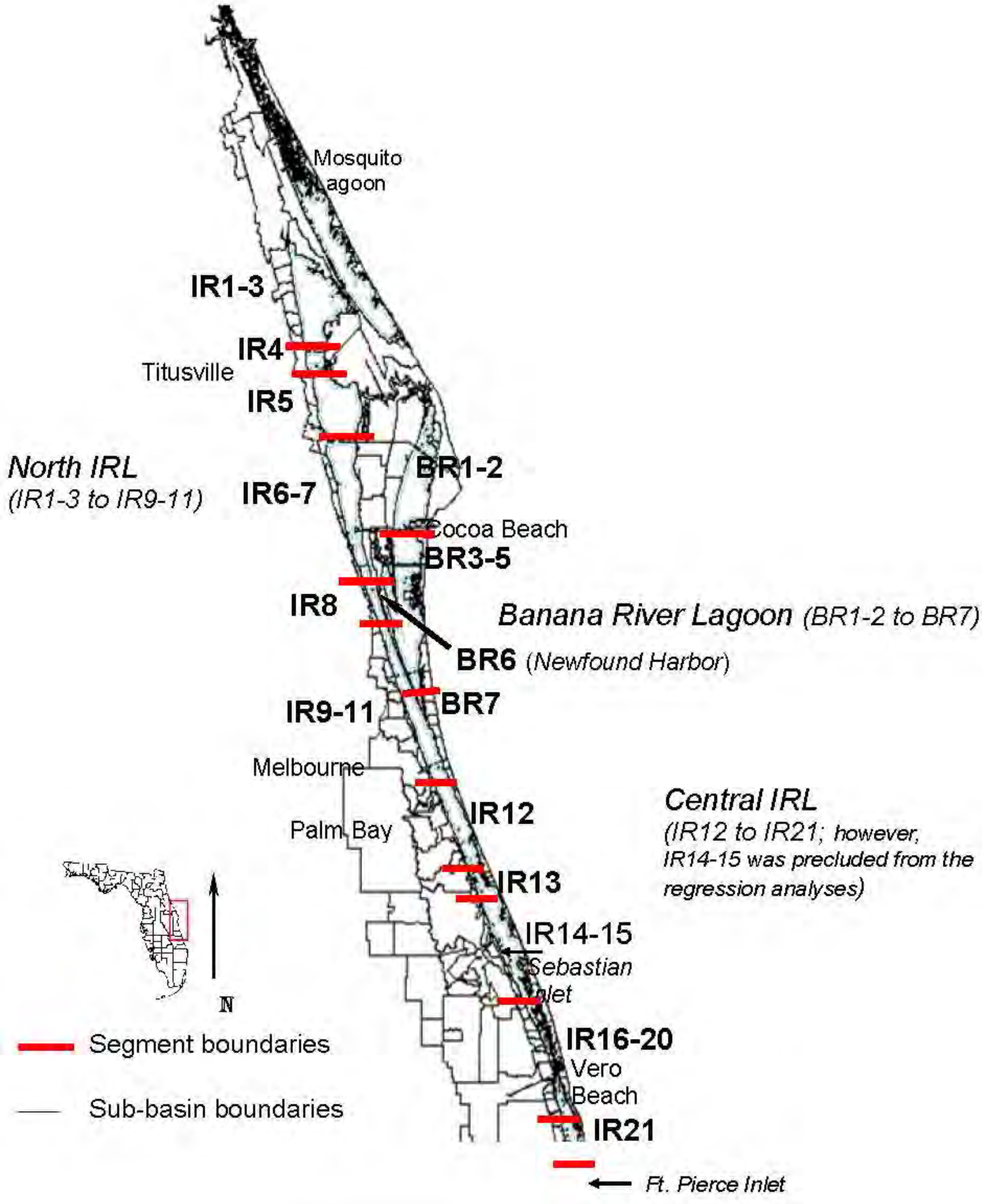

Figure 5.8. Location of the North IRL, Central IRL, and BRL, and Further Segmentation of the IRL and Banana River Lagoon Systems (Steward and Green 2006)

Table 5.6. Nutrient Loading Targets for Surface Water Nonpoint and Point Sources Lagoonwide, and for the Three Sublagoon Systems (Steward and Green 2006)

Lagoonwide - (IRL and Banana River Lagoon combined; excludes Sebastian Segment IR14-15)

PLSM Regressions	TN target loading (pounds per acre per year [lbs/ac/yr])	TP target loading (lbs/ac/yr)
Years included in the analyses: 1943, 1996, 1999, and 2001 data	3.34 $R^2 = 0.49$, $p < 0.001$	0.546 $R^2 = 0.53$, $p < 0.001$

North IRL

PLSM Regressions	TN target loading (lbs/ac/yr)	TP target loading (lbs/ac/yr)
Years included in the analyses: 1943, 1996, and 1999 data	2.88 $R^2 = 0.43$, $p = 0.006$	
HSPF Regressions		
Years included in the analyses: 1943, 1996, and 1999 data		0.368 $R^2 = 0.47$, $p = 0.003$

Central IRL (excludes Sebastian Segment IR14-15)

PLSM Regressions	TN target loading (lbs/ac/yr)	TP target loading (lbs/ac/yr)
Years included in the analyses: 1996, 1999, and 2001 data	2.90 $R^2 = 0.87$, $p<0.001$	0.574 $R^2 = 0.65$, $p = 0.001$

Banana River Lagoon

PLSM Regressions	TN target loading (lbs/ac/yr)	TP target loading (lbs/ac/yr)
Years included in the analyses: 1943, 1996, and 1999 data	2.18 $R^2 = 0.74$, $p = 0.001$	0.374 $R^2 = 0.72$, $p = 0.001$

5.3. Sufficiency of Applying Nutrient Reductions Needed to Restore IRL Seagrass to Sykes Creek

As the needed percent nutrient reductions were established to restore the seagrass growth in the BRL lagoon proper, which includes Newfound Harbor, a legitimate question is whether achieving the seagrass nutrient targets for the mainstem segments of the lagoon, including Newfound Harbor, will also bring the similar water quality condition to Sykes Creek. In order to answer this question, annual average *ChlaC*, TN, and TP concentrations, and conductance collected from long-term stations located in Sykes Creek (21FLSJWMIRLSC03) and Newfound Harbor (21FLSJWMIRLNFH01) in the period from 2000 through 2010 were compared to examine whether they share a similar distribution. To conduct the comparison, *ChlaC*, TN, TP, and conductance data from all sampling events were first aggregated into quarterly means and then into annual means. **Figures 5.9a**, **5.9b**, **5.9c**, and **5.9d** show the results of these comparisons. **Figure 5.10** shows the location of the sampling stations used for these analyses.

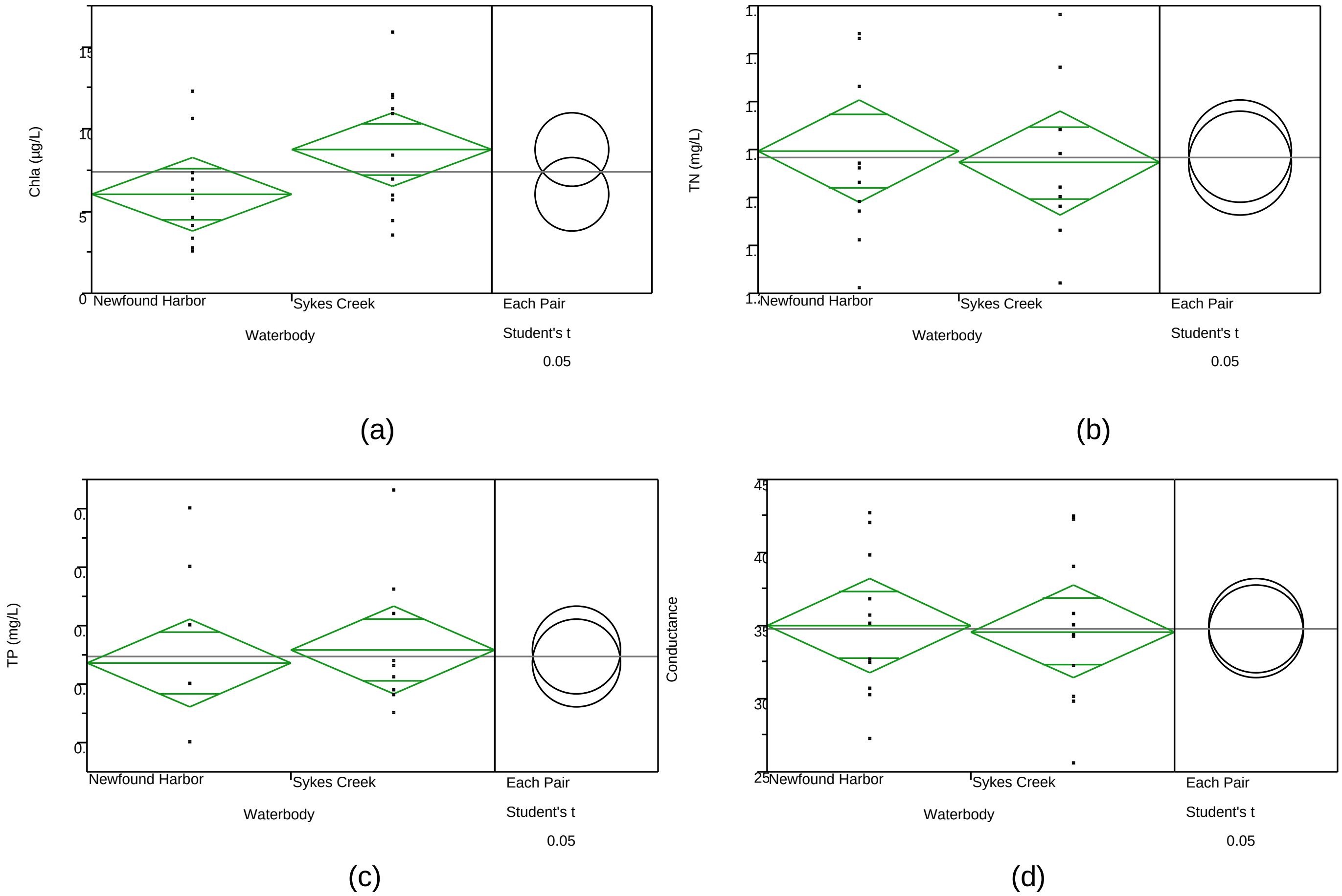

Figure 5.9. Comparison of Annual Average *ChlaC* (a), TN (b), TP (c), and conductance (d) in Sykes Creek and Newfound Harbor

Based on **Figures 5.9a**, **5.9b, 5.9c**, and **5.9d**, annual average TN, TP, and conductance values from Sykes Creek were very similar to those from Newfound Harbor in the period from 2000 through 2010. The annual average *ChlaC* from Sykes Creek was slightly higher than the annual average *ChlaC* from Newfound Harbor. However, the Student T Test result shows that the difference of *ChlaC* between the two sites was not statistically significant. The similarity of the water quality conditions in Sykes Creek and Newfound Harbor could primarily be caused by the hydrodynamic interaction between the two water segments. It could also mean that the water quality conditions of these two water segments are controlled by similar sources. Achieving the nutrient targets of the Newfound Harbor, which is part of the Banana River Lagoon seagrass restoration TMDLs, should result in a similar nutrient condition improvement in Sykes Creek.

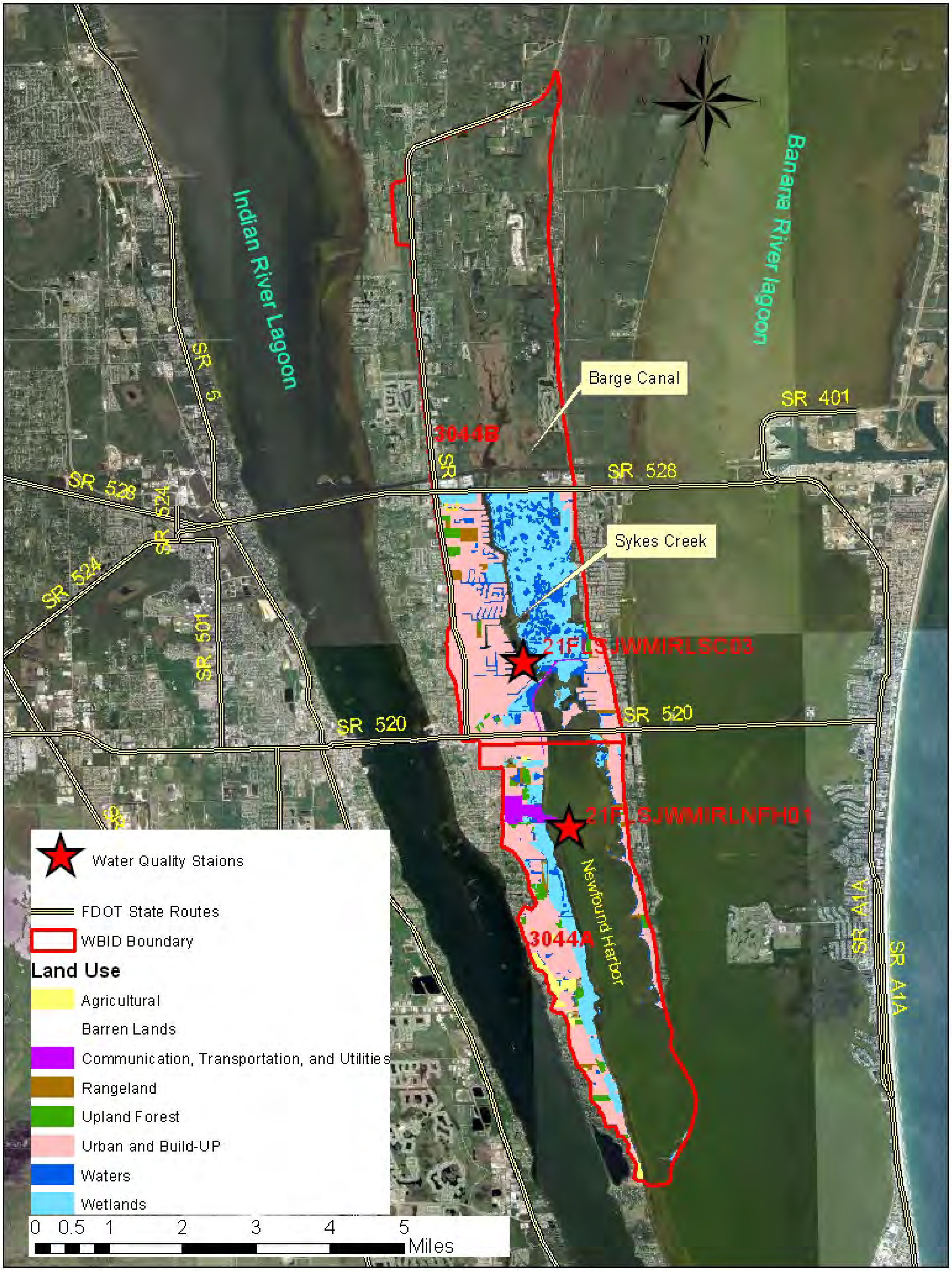

Figure 5.10. Water Quality Stations Used in this Analysis

Because no water quality model was established specifically for the Sykes Creek and Newfound Harbor system, it is infeasible to estimate, once the main stem nutrient TMDL target is achieved in the Banana River Lagoon , what the *ChlaC* concentration would be for the Sykes Creek – Newfound Harbor system. However, during the estuary numeric nutrient criteria development process, the SJRWMD analyzed the *ChlaC* concentration and TN and TP concentrations for those segments and years that seagrass depth-limit targets have been achieved, based on the assumption that the *ChlaC* and nutrient concentrations in these segment-years reflects the target *ChlaC* and nutrient concentrations. The annual median *ChlaC*, TN, and TP concentrations from segments located in the Banana River Lagoon, based on these analyses, were 2.7 µg/L, 1.32 mg/L, and 0.029 mg/L, respectively (Steward et al., 2010). The SJRWMD also used multivariate optical models that linked the target light extinguish coefficients with water column turbidity, *ChlaC*, and color to estimate possible targets of *ChlaC* concentration when the target light extinguish coefficients are achieved (Steward, et al. 2010). Based on the optical model established for the Banana River Lagoon, the target annual median *ChlaC* concentration will be 4.7 µg/L. Based on these results, it appears that, when the Banana River Lagoon main stem seagrass nutrient target is achieved, the *ChlaC* concentration for the Banana River Lagoon should be below 5.0 µg/L, likely being as low as 2.7µg/L. Moreover, once the TN and TP target loads are achieved for the Banana River main stem, the trophic condition for the lagoon would be around the mesotrophic, which means these nutrient targets are reasonable targets for the lagoon restoration. Because Sykes Creek is hydrodynamically linked to the Banana River Lagoon through Newfound Harbor, which is also part of the Banana River Lagoon seagrass segment, and the Sykes Creek *ChlaC*, TN, and TP concentrations are similar to those of Newfound Harbor, it is expected that *ChlaC*, TN, and TP levels will also be achieved in the Sykes Creek, which will restore the system to a mesotrophic system.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of 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 takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

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

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

It should be noted that 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 the 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 BMPs.

This approach is consistent with federal regulations (40 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. TMDLs for Sykes Creek are expressed in terms of lbs/yr, lbs/day, and percent reduction of TN and TP, and represent the long-term average TN and TP loadings that the creek can assimilate and maintain balanced aquatic flora and fauna.

According to the analysis conducted in **Chapter 4** of this report, the total existing loads of TN and TP from the immediate Sykes Creek – Newfound Harbor watershed are 42,958 lbs/year of TN and 9,472 lbs/year of TP. Applying the 66% reduction on TN and 70% reduction on TP gives target watershed loads of 14,606 lbs/year of TN and 2,842 lbs/year of TP from the watershed. In addition, there are 15,424 lbs/year of TN and 332 lbs/year of TP falling directly onto the surface of the Sykes Creek – Newfound Harbor system. As the TMDL is a Clean Water Act requirement and currently does not have a direct mechanism to regulate air-originated nutrient loads. Therefore, no percent reduction is applied to the atmospheric loads.

This brings the total allowable loads, i.e. TMDLs to 14,606 + 15,424 = 30,030 lbs/year of TN and 2,842 + 332 = 3,174 lbs/year of TP for the Sykes Creek – Newfound Harbor system (**Table 6.1**).

Based on an EPA memorandum (2006), daily loads of TN and TP from point and nonpoint sources were also calculated. These daily loads were calculated by dividing the annual loads by 365 days/yr and were about 82 lbs/day of TN and 9 lbs/day of TP. It should be noted that these daily loading numbers are only provided in this report for informational purposes. The implementation of the TMDLs covered in this TMDL report should be carried out using an annual time scale.

Table 6.1. Nutrient TMDL Components for Sykes Creek – Newfound Harbor system

WBID	Parameter	TMDL (lbs/yr)	$WLA_{NPDES\ wastewater}$ (lbs/yr)	$WLA_{NPDES\ Stormwater}$ *	LA (lbs/yr)	MOS
The portion of WBID 3044 B South of State Route 528 and WBID 3044A	TN	30,030	N/A	66%*	66%*	Implicit
The portion of WBID 3044 B South of State Route 528 and WBID 3044A	TP	3,174	N/A	70%*	70%*	Implicit

N/A – Not applicable.
* The required percent reductions for $WLA_{NPDES\ Stormwater}$ and LA only apply to the existing watershed loads. No percent reduction is required for the atmospheric deposition loadings.

6.2 Load Allocation

As discussed in **Section 6.1**, the existing nutrient loads into the Sykes Creek – Newfound Harbor system include two parts: loads from the immediate watershed and loads from the atmospheric deposition. The required percent reductions defined in the main stem nutrient TMDL for Segment BR6 (FDEP, 2009), which include 66% reduction of TN and 70% reduction of TP, only apply to the existing nutrient loads from the immediate Sykes Creek – Newfound Harbor watershed, which are 42,958 lbs/year of TN and 9,472 lbs/year of TP.

6.3 Wasteload Allocation

6.3.1 NPDES Wastewater Discharges

There were no NPDES permitted facilities located in the immediate Sykes Creek – Newfound Harbor watershed. Therefore, no WLA was assigned to any wastewater facilities.

6.3.2 NPDES Stormwater Discharges

As discussed in **Chapter 4**, the Sykes Creek watershed is covered by a Phase II MS4 permit issued to the Brevard County (FLR04E052) and a Phase II MS4 permit held by FDOT (FLR04E024). Because no information was available to the Department at the time this analysis was conducted regarding the boundaries and locations of these NPDES stormwater dischargers, the exact stormwater TN and TP loadings from MS4 areas could not be explicitly estimated. The wasteload allocations to the MS4s areas are therefore considered the same percent TN and TP reductions required for the LA assigned to the nonpoint sources in the Sykes Creek – Newfound Harbor watershed. It should be noted that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads in its jurisdiction.

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department, 2001), an implicit MOS was used in the development of this TMDL. An implicit MOS was provided by the conservative decisions associated with a number of modeling assumptions, the development of site-specific alternative water quality targets, and the development of assimilative capacity.

The Sykes Creek nutrient TMDL was developed using an implicit MOS. The water segment was listed for nutrient impairment based on the observation that the annual average corrected Chla concentration exceeding the 11 µg/L assessment threshold. This TMDL required the Sykes Creek – Newfound Harbor watershed to meet the same nutrient reduction required by the BRL main stem seagrass restoration target, which, based on SJRWMD's *ChlaC* analysis on those segments and years that seagrass distribution met the depth-limit target as well as an optical model analysis, the expected *ChlaC* concentration that may result from achieving the seagrass target would be below 5 µg/L and likely to be as low as 2.7 µg/L. This is certainly significantly lower than the 11 µg/L assessment threshold and adds to the margin of safety. However, it should be pointed out that reducing the watershed nutrient loading reduces the long-term *ChlaC* concentration in the lagoon. Short-term *ChlaC* elevations caused by extreme weather condition, such as elongated draught condition or cold temperature caused nutrient release from internal storage pool such as macro-algae, may still be an issue in the future. However, as the watershed nutrient loading gradually reduces, the scale of the problem is also expected to decline.

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Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the Department will determine the best course of action regarding its implementation. Depending upon the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. Basin Management Action Plans are the primary mechanism through which TMDLs are implemented in Florida [see Subsection 403.067(7) F.S.]. A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies.

If the Department determines a BMAP is needed to support the implementation of this TMDL, a BMAP will be developed through a transparent stakeholder-driven process intended to result in a plan that is cost-effective, technically feasible, and meets the restoration needs of the applicable waterbodies. Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and municipal stormwater permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- *Water quality goals (based directly on the TMDL);*
- *Refined source identification;*
- *Load reduction requirements for stakeholders (quantitative detailed allocations, if technically feasible);*
- *A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach;*
- *A description of further research, data collection, or source identification needed in order to achieve the TMDL;*
- *Timetables for implementation;*
- *Implementation funding mechanisms;*
- *An evaluation of future increases in pollutant loading due to population growth;*
- *Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures; and*
- *Stakeholder statements of commitment (typically a local government resolution).*

BMAPs are updated through annual meetings and may be officially revised every five years. Completed BMAPs in the state have improved communication and cooperation among local stakeholders and state agencies; improved internal communication within local governments; applied high-quality science and local information in managing water resources; clarified obligations of wastewater point source, MS4, and non-MS4 stakeholders in TMDL implementation; enhanced transparency in Department decision making; and built strong relationships between the Department and local stakeholders that have benefited other program areas.

Nutrient TMDLs were previously developed by the Department for main stem segments of Indian River Lagoon (IRL) and Banana River Lagoon (BRL). These TMDLs have been adopted into Chapter 62-304.520, Florida Administrative Code. The Department is now working closely with the SJRWMD, counties, cities, and other local stakeholders to develop Basin Management Action Plans to implement these TMDLs. As proposed Sykes Creek/Barge Canal TMDL targets are the same as those established for their main stem drainage basin areas in the BRL basin, the implementation strategies of these newly proposed TMDLs should be consistent with those being adopted for the BRL basin. The Sykes Creek watershed is part of the BRL main stem drainage basin and is already included in a BMAP under development. If the receiving segments of the BRL main stem meet the previously adopted TMDLs, Sykes Creek will have met its targets as well and the Department will not request that the target percent reductions of nutrient be applied specifically to the Sykes Creek watershed.

7.2 Other TMDL Implementation Tools

However, in some basins, and for some parameters, particularly those with fecal coliform impairments, the development of a BMAP using the process described above will not be the most efficient way to restore a waterbody, such that it meets its designated uses. This is because fecal coliform impairments result from the cumulative effects of a multitude of potential sources, both natural and anthropogenic. Addressing these problems requires good old-fashioned detective work that is best done by those in the area.

Many assessment tools are available to assist local governments and interested stakeholders in this work. The tools range from the simple (such as Walk the WBIDs and GIS mapping) to the complex (such as bacteria source tracking). Department staff will provide technical assistance, guidance, and oversight of local efforts to identify and minimize fecal coliform sources of pollution. Based on work in the Lower St Johns River Tributaries and Hillsborough Basins, the Department and local stakeholders have developed a logical process and tools to serve as a foundation for this detective work.

In the near future, the Department will be releasing these tools to assist local stakeholders with the development of local implementation plans to address fecal coliform impairments. In such cases, the Department will rely on these local initiatives as a more cost-effective and simplified approach to identify the actions needed to put in place a road map for restoration activities, while still meeting the requirements of Subsection 403.067(7), F.S.

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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 that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, the Department's stormwater treatment requirements were integrated with the stormwater flood control requirements of the state's water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations.

Chapter 62-40, F.A.C., also requires the water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG had been developed for Newnans Lake when this report was published.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act 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. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific standard industrial classification (SIC) codes, construction sites disturbing 5 or more acres of land, and the master drainage systems of local governments with a population above 100,000, which are better known as MS4s. However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the Florida Department of Transportation throughout the 15 counties meeting the population criteria. EPA authorized the Department to implement the NPDES Stormwater Program (with the exception of Indian lands) in October 2000.

An important difference between the federal NPDES and the state's stormwater/environmental resource permitting programs is that the NPDES Program covers both new and existing discharges, while the state's program focuses on new discharges only. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between 1 and 5 acres, and to local governments with as few as 1,000 people. These revised rules require that these additional activities obtain permits by 2003.

While these urban stormwater discharges are now 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 all 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: Public Comments and FDEP Responses

Comments from Brevard County

BREVARD County
BOARD OF COUNTY COMMISSIONERS
FLORIDA'S SPACE COAST

NATURAL RESOURCES MANAGEMENT OFFICE
2725 Judge Fran Jamieson Way, Building A-219, Viera, FL 32940

October 5, 2012

Jan Mandrup-Poulsen, Environmental Administrator
Watershed Evaluation and TMDL Section
Florida Department of Environmental Protection, MS 3555
2600 Blair Stone Road
Tallahassee, FL 32399-2400

RE: Comments on FDEP's Draft TMDLs for portions of the Indian River Lagoon Basin - Sykes Creek/Barge Canal (WBID 3044B) and Goat Creek Marine Segment (WBID 3107A)

Dear Mr. Mandrup Poulsen:

We appreciate this opportunity to provide comments to FDEP on the proposed TMDLs for WBIDs 3044B and 3107A within the IRL Basin. In reviewing the listing data for these WBIDs and their upstream and downstream counterparts, Brevard County was encouraged to see progress toward lowering TN and TP concentrations over the 1998 to 2008 timeframe. Despite this decade of progress in nutrient concentrations, chlorophyll a impairments were documented in the IRL mainstem and multiple marine segments of IRL tributaries in 2009 and 2010. While we concur and commend FDEP for the technical aspects and logic of their analyses, we disagree with the recommendation that a TMDL is needed and we disagree on how to apply the downstream TMDLs to the upstream WBIDs.

- We concur with FDEP's conclusion that there is no apparent causal linkage between the recent chlorophyl a impairments in these WBIDs and changes in loading from the immediate or upstream drainage areas (as landuse changes, drought, and upstream ambient measurements do not indicate elevated loadings).

- We concur that measured chlorophyl a impairments do appear to be influenced by factors in the hydrologically connected IRL segments located immediately dowustream.

- We concur with FDEP's conclusion that adequate reduction of nutrient loads to the IRL mainstem should reduce total loading to the adjacent marine segments of tributaries and thereby improve the health of these marine segments of tributaries.

- We concur with the Department's recommendation not to request any further nutrient reductions beyond those already being enforced through the TMDLs and BMAPs for the mainstem of the IRL (and Banana) system.

- We disagree with applying the average allowable load per acre for the adjacent IRL segment (assimilative capacity of the IRL) to determine specific load reductions required within the drainage area of the impaired WBID. While we agree this is one way to allocate load reductions required for the IRL and provide a Measure of Safety for the impaired WBID, it will not lead to the most effective siting of load reducing BMPs and may not be feasible to implement. In fact, the TN reduction calculated for Goat Creek using this method exceeds the estimated load from all urbanized land in the Goat Creek watershed. Since the reports state that the WBID watershed loads are not responsible for the impairments, it seems unlikely that further reductions within these WBIDs will result in the water quality standard being achieved within the tributaries. To the contrary, wouldn't BMPs be more effective for both the IRL and the impaired tributaries if sited outside the tributary watershed in an area where the BMPs could intercept more problematic (higher) load concentrations entering the IRL mainstem? Siting BMPs where they are most feasible within the IRL basin is consistent with the draft BMAPs and should minimize the risk of IRL impairments extending from the IRL up the tributaries.

- We disagree with the current TMDLs adopted for the IRL and are currently developing an updated model to provide to FDEP for updating the TMDLs for the IRL. Is it possible to craft the tributary TMDLs in such a way that if the mainstem TMDLs change, the tributary TMDLs will automatically update by reference? Or is it possible to avoid numerical limits for the tributaries and simply state that if the IRL TMDLs (as amended) are met, the tributary TMDLs will also be satisfied?

In addition to the points of agreement and concurrence stated above, we are unsure regarding the measure of success. The draft IRL BMAPs measure success, not by changes in estimates of watershed loading, but in measured performance of the biological indicator that was the basis of the original impairment listing – seagrass. If target seagrass depths are achieved, the BMAP/TMDL is satisfied. It would seem consistent that if the impairment in the tributaries is addressed, then the tributary TMDL would be satisfied, but there is no measure in the proposal other than numerical standards that are derived from old model estimates of watershed load.

Thank you for this opportunity to provide comments on the proposed TMDLs for WBIDs 3044B and 3107A within the IRL Basin. In sum, and consistent with our comments to FDEP at the time of listing, we concur that the standards for chlorophyll a have been exceeded, and that the causative pollutant does not appear to be TN or TP from within the WBID watershed, therefore we maintain that development of nutrient TMDLs for these tributaries does not seem appropriate. More detailed concerns are provided in the staff comments that follow. Nonetheless, Brevard County remains committed to implementing stormwater BMPs to further reduce nutrient loadings to our locally and nationally treasured waters. If you have any questions about our comments, please do not hesitate to call me at 321-633-2016.

Sincerely,

Virginia Barker

Virginia Barker, Watershed Program Manager
Natural Resources Management Office

Response from the Florida Department of Environmental Protection

March 6, 2013

Ms. Virginia Barker, Watershed Program Manager
Natural Resource Management Office
2725 Judge Fran Jamieson Way, Building A-219,
Viera, FL 32940

Dear Virginia,

Thanks again for your letter dated October 5, 2012, regarding the nutrient TMDLs for Sykes Creek and Goat Creek that the Florida Department of Environmental Protection (FDEP) presented at the August 30, 2012 public workshop. We responded to your comments on October 5, 2012 through an email. As you mentioned in your returning email, our responses addressed most of the concerns from Brevard County regarding these two TMDLs. This letter is provided as our formal response to your comments.

You raised primarily three concerns in your summary comments:

(1) Because the elevated chlorophyll a concentration observed in these two creeks in 2009 and 2010 were not caused by the elevation of nutrient loads in the watershed, and the nutrient targets proposed by the FDEP was to follow the Indian River Lagoon (IRL) and Banana River Lagoon (BRL) mainstem nutrient TMDLs to protect the seagrass communities in the mainstem system, the local stakeholders should have the flexibility to decide where in the IRL and BRL basins nutrient controls and best management practices (BMPs) can be implemented most efficiently. The FDEP should not make it an obligation that local stakeholders have to implement BMPs in the watersheds of Sykes Creek and Goat Creek.
(2) As there are on-going efforts led by Brevard County to refine the IRL mainstem nutrient TMDLs, the FDEP should not use the watershed loading models that the FDEP used previously to develop the mainstem nutrient TMDL.
(3) There is not a specific measure (biological response factor) being established in Sykes Creek and Goat Creek TMDLs to evaluate the implementation success.

Reading through your detailed technical comments, we also realized that you and your staff have another concern. If the FDEP claimed that the elevated chlorophyll a concentrations observed in these two creeks were not caused by the elevation of nutrient loadings from the watershed, why does the FDEP still propose nutrient reductions and have the belief that the nutrient reductions will help the water quality condition of these tributaries?

These are all thoughtful comments and questions. While reports of Sykes Creek and Goat Creek TMDLs indicated that the observed elevation of chlorophyll a concentrations in these waters were not caused by elevated nutrient loadings from watershed of these impaired waters, the results from our analyses support the conclusion that the elevation of chlorophyll a concentration in these impaired segments was related to the lagoon processes that are influenced by nutrients. Therefore, reducing watershed nutrient loadings to the lagoon system will reduce the probability and intensity of the phytoplankton growth in the lagoon system, which will, in turn, benefit the nutrient condition of these impaired tributary segments that are closely related to their corresponding lagoon segments.

While it is only fair that nutrient loadings created anywhere in the drainage basin should be treated equally in order to level the playing field, we understand that, in practice, applying BMPs in different parts of the drainage basin can have different efficiencies in controlling the amount of nutrient eventually reach the lagoon. Therefore, although the nutrient targets were set up for the watershed of these impaired water segments, we agree with you that these targets are in reality set up to protect the lagoon system, which will in turn benefit these two impaired segments. As the watersheds of these impaired water segments are part of the larger lagoon drainage basin, if the nutrient goals set up for the larger drainage basin are achieved, we will not specifically request that nutrient reduction be applied to the watersheds of these impaired tributary segments. In fact, we have already included the following language into Chapter 7 of revised reports of these TMDLs:

> *Nutrient TMDLs were previously developed by the Department for mainstem segments of Indian River Lagoon and Banana River Lagoon basins. These TMDLs have been adopted into Chapter 62-304.520, Florida Administrative Code. The Department is now working closely with the SJRWMD, counties, cities, and other local stakeholders to develop Basin Management Action Plans to implement these TMDLs. As the proposed Sykes Creek and Goat Creek TMDL targets are the same as those established for their corresponding mainstem drainage basin areas in the Indian River Lagoon and Banana River Lagoon basins, the implementation strategies of these newly proposed TMDLs should be consistent with those being adopted for the corresponding mainstem drainage basins. The watersheds of Sykes Creek and Goat Creek are parts of the larger corresponding mainstem drainage basins and are already included in the developing BMAPs. If the receiving segments of the mainstem meet the previously adopted TMDLs, Sykes Creek and Goat Creek will have met their targets as well and the Department will not request that the target percent reductions of nutrient be applied specifically to Sykes Creek and Goat Creek watersheds.*

The FDEP remains committed to work with the County and its consultants as part of the ongoing efforts to refine the water quality targets and loading models that the FDEP used previously to develop the mainstem nutrient TMDLs. In fact, it is FDEP's long-term policy that the adopted TMDLs can be adaptive targets and may be refined or modified when new data and information become available. If the TMDL refinement products from Brevard County and consultants show a significant improvement compared to the mainstem nutrient TMDLs previously adopted for the mainstem segments, revising the mainstem nutrient TMDLs will certainly be considered by the FDEP. At this time, as the SJRWMD's PLSM model (and the associated HSPF model) and the nutrient targets derived from the seagrass depth-limit targets are still the only set of established tools available to us for developing loading targets, the FDEP intends to use these tools until a significantly improved set of tools become established. Doing this makes the potential revision of TMDLs in the future easier because we know the pros and cons of the existing methodology. Should we decide to revise the adopted TMDLs, we only need to address whatever the same set of improvements needed for all nutrient TMDLs adopted in the IRL basin, instead of analyzing many TMDLs developed using many different tools.

Regarding the measurement needed to evaluate the effect of TMDL implementation, because Sykes Creek and Goat Creek were primarily verified for nutrient impairment based on the elevated chlorophyll a concentration in 2009 and 2010, which, based on the analyses conducted by the FDEP, were associated with the receiving water processes taking place in the lagoon mainstem, the FDEP believes that, as long as the water quality condition of the IRL and BRL mainstem segments associated with these two creeks meets the established seagrass depth-limit bench mark, the nutrient condition of these two creeks should be considered meeting the water quality target.

Once again, we appreciate the effort from you to help us improve the quality of our work. We are looking forward to continuously working with you to improve the water quality conditions of the valuable water resources in the Indian River Lagoon basin.

Sincerely,

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