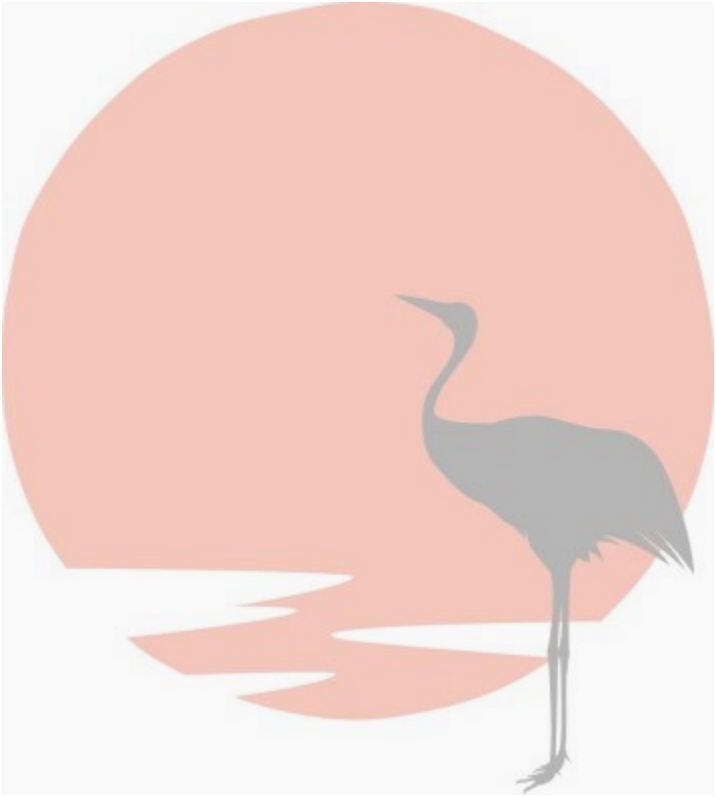
Appendix C
Water Quality



December 2012

Sarasota County | Southwest Florida Water Management District | Jones Edmunds | Janicki Environmental, Inc.

TABLE OF CONTENTS

1.0 WATER QUALITY IN SARASOTA BAY AND ITS WATERSHED 1-1
1.1 WATER QUALITY STATUS AND TRENDS 1-3
1.2 ESTUARINE WATER QUALITY 1-3
1.3 TRIBUTARY WATER QUALITY 1-4
1.4 CURRENT AND FUTURE POLLUTANT LOADINGS 1-6
1.5 SALINITY-FLOW RELATIONSHIPS 1-9
1.6 WATER QUALITY LEVELS OF SERVICE (LOS) 1-9

2.0 ESTUARINE WATER QUALITY STATUS AND TRENDS 2-1
2.1 OBJECTIVE 2-1
2.2 APPROACH 2-1
2.3 DATA USED 2-1
2.4 RESULTS 2-1
2.4.1 Temporal Variation – Monthly 2-1
2.4.2 Trend Analyses 2-11
2.4.3 Spatial Variation 2-12
2.4.4 Water Quality Status 2-19
2.4.5 Data Collection 2-23

3.0 TRIBUTARY WATER QUALITY STATUS AND TRENDS 3-1
3.1 OBJECTIVE 3-1
3.2 APPROACH 3-1
3.3 DATA USED 3-1
3.4 RESULTS 3-1
3.4.1 Temporal and Spatial Variation 3-3
3.4.2 Comparison of Freshwater Tributary Ambient Water Quality to FDEP NNC 3-22
3.4.3 Impaired WBIDs within the Sarasota Bay Watershed 3-24
3.4.4 Data Collection 3-27

4.0 CURRENT AND FUTURE POLLUTANT LOADINGS 4-1
4.1 OBJECTIVE 4-1
4.2 APPROACH 4-1
4.3 DATA USED 4-1
4.3.1 Current 4-1
4.3.2 Future 4-1
4.4 RESULTS 4-3
4.4.1 Comparison of Current and Future Nutrient Loads 4-3

5.0 WATER QUALITY LEVELS OF SERVICE 5-1

5.1 OBJECTIVE 5-1
5.2 APPROACH 5-1
5.3 DATA AND INFORMATION USED 5-3
5.4 RESULTS 5-4
5.4.1 Development of Seagrass LOS Targets 5-4
5.4.2 Development of Chlorophyll *a* LOS Targets 5-5
5.4.3 Development of the Nitrogen and Phosphorus LOS 5-7

6.0 DISSOLVED OXYGEN 6-1
6.1 INTRODUCTION 6-1
6.2 THE RESOURCE AND ITS FUNCTIONS 6-1
6.2.1 Estuary 6-3
6.2.2 Tributaries 6-4
6.3 OBJECTIVE 6-6
6.4 MONITORING PROGRAMS AND OTHER DATA SOURCE(S) 6-6
6.5 APPROACH 6-6
6.5.1 DO Relationships with Other Water Quality Parameters 6-6
6.5.2 Comparison of Ambient DO Levels in Sarasota Bay and its Tributaries to Current and Proposed FDEP DO Standards 6-7
6.6 RESULTS 6-9
6.6.1 DO Relationships with Other Estuarine Water Quality Parameters 6-9
6.6.2 DO Relationships with Other Tributary Water Quality Parameters 6-9
6.6.3 Comparison of Sarasota Bay and its Tributaries to Existing and Proposed FDEP DO Standards 6-10
6.7 RELATIONSHIP OF DISSOLVED OXYGEN WITH BIOTA IN TRIBUTARIES 6-12
6.8 CONCLUSIONS 6-15

7.0 SEDIMENT LEVELS OF SERVICE 7-1
7.1 INORGANIC SEDIMENT LOS 7-2
7.2 ORGANIC SEDIMENT LOS 7-3

8.0 WATER QUALITY IMPROVEMENTS 8-1
8.1 BACKGROUND INFORMATION 8-1
8.2 TMDL STATUS 8-1
8.3 WATER QUALITY IMPROVEMENT OPPORTUNITIES 8-2
8.3.1 Methodology 8-2
8.3.2 INVESTIGATION 8-4
8.4 ANALYSIS\RECOMMENDATIONS 8-12
8.4.1 Projects 8-12
8.4.2 Programs 8-41

9.0 CONCLUSION 9-1

10.0 APPENDIX—EXISTING DATA, STUDIES, AND INFORMATION 10-1

11.0 REFERENCES 11-1

LIST OF TABLES

Table 2-1 Number of DO Samples and the Number Less than 4 mg/L from Sarasota Bay by Year 2-20
Table 3-1 Annual Geometric Mean TN and TP Concentrations in Freshwater Sarasota Bay Tributaries 3-24
Table 3-2 Impaired Waterbodies in the Sarasota Bay Watershed using Impaired Waters Rule Criteria (FDEP, 2011) 3-25
Table 4-1 Acreage of Basins within the Sarasota Bay Watershed 4-18
Table 5-1 Comparison of Water Quality within North and South Sarasota Bay (Values Represent Medians for 1998–2009) 5-11
Table 5-2 TN and TP Loading Targets and Thresholds for Sarasota Bay Basins 5-20
Table 5-3 TN and TP Loading Targets and Thresholds for Sarasota Bay Basins 5-31
Table 5-4 Salinity Preferences for Selected Species (ppt) 5-36
Table 5-5 Summary of Water Quality LOS Targets and Thresholds for Sarasota Bay 5-39
Table 6-1 Summary of Relationships between DO and Explanatory Variables by Tributary and Class for Sarasota Bay Tributaries 6-10
Table 6-2 Sarasota Bay and Other Tributaries Not Meeting Proposed FDEP DO Standards 6-11
Table 6-3 FDEP Stream Conditions Index Sarasota Bay System Sites and Sample Results 6-13
Table 8-1 List of Potential Water Quality Improvement Project Sites 8-12
Table 9-1 List of Recommended Water Quality Improvement Project Sites 9-1

LIST OF FIGURES

Figure 1-1 Sarasota Bay and Watershed 1-2
Figure 1-2 Sarasota Bay Tributaries 1-5
Figure 1-3 Sarasota Bay Subbasins 1-8
Figure 2-1 Mean Monthly Salinity in Sarasota Bay 2-1
Figure 2-2 Mean Monthly Chlorophyll *a* Concentrations in Sarasota Bay 2-2
Figure 2-3 Mean Monthly TN Concentrations in Sarasota Bay 2-2
Figure 2-4 Mean Monthly TP Concentrations in Sarasota Bay 2-3
Figure 2-5 Mean Monthly TSS Concentrations in Sarasota Bay 2-3
Figure 2-6 Mean Monthly Turbidity Concentrations in Sarasota Bay 2-4

Figure 2-7 Mean Monthly K_d in Sarasota Bay 2-4
Figure 2-8 Within-Year Variation in Salinity in Sarasota Bay....2-5
Figure 2-9 Within-Year Variation in Chlorophyll *a* Concentrations in Sarasota Bay 2-6
Figure 2-10 Within-Year Variation in TN Concentrations in Sarasota Bay 2-7
Figure 2-11 Within-Year Variation in TP Concentrations in Sarasota Bay 2-8
Figure 2-12 Within-Year Variation in TSS Concentrations in Sarasota Bay 2-9
Figure 2-13 Within-Year Variation in Turbidity Concentrations in Sarasota Bay....2-10
Figure 2-14 Within-Year Variation in Light Attenuation in Sarasota Bay 2-11
Figure 2-15 Four Water Quality Strata within the Sarasota Bay Estuary....2-12
Figure 2-16 Comparison of Mean Monthly Salinity in the Four Strata of Sarasota Bay 2-13
Figure 2-17 Comparison of Mean Monthly Chlorophyll *a* in the Four Strata of Sarasota Bay 2-14
Figure 2-18 Comparison of Mean Monthly TN in the Four Strata of Sarasota Bay 2-15
Figure 2-19 Comparison of Mean Monthly TP in the Four Strata of Sarasota Bay....2-16
Figure 2-20 Comparison of Mean Monthly TSS concentrations in the Four Strata of Sarasota Bay....2-17
Figure 2-21 Comparison of Mean Monthly Turbidity in the Four Strata of Sarasota Bay 2-18
Figure 2-22 Comparison of Mean Monthly Light Attenuation in the Four Strata of Sarasota Bay....2-19
Figure 2-23 Comparison of Geometric Mean Chlorophyll *a* Concentrations to the SBEP Chlorophyll *a* Target (6.1 µg/L) and Threshold (5.2 µg/L) for Sarasota Bay....2-20
Figure 2-24 Comparison of Geometric Mean TN concentrations to the SBEP TN Numeric Criterion for Sarasota Bay. 2-21
Figure 2-25 Comparison of Geometric Mean TP concentrations to the SBEP TP Numeric Criterion for Sarasota Bay (0.19 mg/L) 2-22
Figure 2-26 Percentage of DO Samples <4 mg/L in Sarasota Bay by Calendar Month for 1998–2009....2-23
Figure 3-1 Locations of the Sarasota Bay Tributary Water Quality Sampling Stations 3-2
Figure 3-2 Conductivity (µS/cm) Observations from the Whitaker Bayou Water Quality Sampling Stations 3-4
Figure 3-3 Chlorophyll *a* (µg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations 3-5
Figure 3-4 TN (mg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations 3-6
Figure 3-5 TP (mg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations 3-7
Figure 3-6 DO (mg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations 3-8
Figure 3-7 Color (PtCo units) Observations from the Whitaker Bayou Water Quality Sampling Stations 3-9

Figure 3-8 Conductivity (µS/cm) Observations from the Hudson Bayou Water Quality Sampling Stations 3-11
Figure 3-9 Chlorophyll *a* (µg/L) concentrations from the Hudson Bayou Water Quality Sampling Stations 3-12
Figure 3-10 TN (mg/L) Concentrations from the Hudson Bayou Water Quality Sampling Stations 3-13
Figure 3-11 TP (mg/L) Concentrations from the Hudson Bayou Water Quality Sampling Stations 3-14
Figure 3-12 DO (mg/L) Concentrations from the Hudson Bayou Water Quality Sampling Stations 3-15
Figure 3-13 Color (PtCo units) Observations from the Hudson Bayou Water Quality Sampling Stations 3-16
Figure 3-14 Conductivity (µS/cm) Observations from the Bowless Creek Water Quality Sampling Station 3-17
Figure 3-15 Chlorophyll *a* (µg/L) Concentrations from the Bowless Creek Water Quality Sampling Station 3-18
Figure 3-16 TN (mg/L) Concentrations from the Bowless Creek Water Quality Sampling Station 3-19
Figure 3-17 TP (mg/L) Concentrations from the Bowless Creek Water Quality Sampling Station 3-20
Figure 3-18 DO (mg/L) Concentrations from the Bowless Creek Water Quality Sampling Station 3-21
Figure 3-19 Color (PtCo units) Observations from the Bowless Creek Water Quality Sampling Station 3-22
Figure 3-20 WBIDs Impaired for TN, TP, DO, or Fecal Coliform in the Sarasota Bay Watershed 3-23
Figure 4-1 Total Annual Hydrologic Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-3
Figure 4-2 Total Annual TN loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-4
Figure 4-3 Total Annual TP loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-4
Figure 4-4 Total Annual TSS Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-5
Figure 4-5 Within-Year Variation in Hydrologic Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-6
Figure 4-6 Within-Year Variation in TN loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-7
Figure 4-7 Within-Year Variation in TP Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-8
Figure 4-8 Within-Year Variation in TSS Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-9

Figure 4-9 Comparison of the Relative Contributions from Various Sources to Hydrologic Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-10
Figure 4-10 Comparison of the Relative Contributions from Various Sources to TN Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-11
Figure 4-11 Comparison of the Relative Contributions from Various Sources to TP Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-12
Figure 4-12 Comparison of the Relative Contributions from Various Sources to TSS Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008) 4-13
Figure 4-13 Comparison of Annual Hydrologic Loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008) 4-14
Figure 4-14 Comparison of Annual TN Loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008) 4-15
Figure 4-15 Comparison of Annual TP loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008) 4-16
Figure 4-16 Comparison of Annual TSS Loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008) 4-17
Figure 4-17 Comparison of Annual Hydrologic Loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989–2008) 4-19
Figure 4-18 Comparison of Annual TN Loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989-2008) 4-20
Figure 4-19 Comparison of Annual TP Loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989–2008) 4-21
Figure 4-20 Comparison of Annual TSS loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989–2008) 4-22
Figure 4-21 Comparison of Current Versus Future Unit-Area Annual TN loads to Sarasota Bay (1989–2008) 4-23
Figure 4-22 Comparison of Current Versus Future Unit-Area Annual TP loads to Sarasota Bay (1989–2008) 4-24
Figure 4-23 Comparison of Current Versus Future Unit-Area Annual TSS Loads to Sarasota Bay (1989–2008) 4-25
Figure 5-1 Nutrient Watershed Regions of Florida (FDEP, 2012a) 5-3
Figure 5-2 Seagrass Coverage (Acres) from Historical and Recent Surveys in Sarasota Bay with Target (7,269 Acres) Shown 5-5
Figure 5-3 Sarasota Bay Mean Monthly Chlorophyll *a* Concentrations with Trend Line (non-parametric Kendall-Tau) 5-6
Figure 5-4 Sarasota Bay Chlorophyll *a* Concentrations (Annual Arithmetic Means) with Threshold Line (6.1 µg/L) and Target (5.2 mg/L) 5-7
Figure 5-5 Mean Monthly TN Concentrations (mg/L) Observed in Sarasota Bay with Trend Line (non-parametric Kendall-Tau) 5-8

Figure 5-6 Box-and-Whisker Plots of the Monthly TN Concentrations (mg/L) Observed in Sarasota Bay 5-9
Figure 5-7 Relationship Between Monthly Average Chlorophyll *a* and TN Concentrations in Sarasota Bay 5-10
Figure 5-8 North and South Portions of the Sarasota Bay Segment....5-11
Figure 5-9 Predicted vs Observed Chlorophyll *a* Concentrations in Sarasota Bay (R^2 = 0.67) 5-12
Figure 5-10 Comparison of Observed Annual Geometric Mean TN Concentrations in Sarasota Bay to Year-Specific TN Thresholds (shown in the upper panel) and TN Target (shown in the lower panel) 5-13
Figure 5-11 Comparison of TP Concentration Threshold (0.19 mg/L) and Target (0.15 mg/L) for Sarasota Bay to the Annual Geometric Mean TP Concentrations from 1998–2008....5-14
Figure 5-12 Comparison of TN Load Threshold (237.2 tons/year) and Target (215.0 tons/year) for Sarasota Bay to Annual Loads (1998–2008)....5-15
Figure 5-13 Comparison of TP Load Threshold (35.2 tons/year) and Target (32.0 tons/year) for Sarasota Bay to Annual Loads (1998–2008)....5-16
Figure 5-14 Comparison of the Freshwater TN Threshold (1.65 mg/L) and Targets to TN Concentrations in Whitaker Bayou (top) and Hudson Bayou (bottom) 5-17
Figure 5-15 Comparison of the Freshwater TP Threshold (0.49 mg/L) and Targets to TP Concentrations in Whitaker Bayou (top) and Hudson Bayou (bottom)....5-18
Figure 5-16 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Canal Road Drain 5-21
Figure 5-17 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Sarasota Bay Coastal North....5-22
Figure 5-18 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Palma Sola Drain—Bayshore....5-23
Figure 5-19 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Cedar Hammock Creek 5-24
Figure 5-20 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Bowlees Creek....5-25
Figure 5-21 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Longboat/Lido Keys....5-26
Figure 5-22 Comparison of Mean Annual TN (Top) and TP (bottom) Loads to Basin Targets and Thresholds—Sarasota Bay Coastal South....5-27
Figure 5-23 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Whitaker Bayou....5-28
Figure 5-24 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Hudson Bayou 5-29
Figure 5-25 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Siesta Key....5-30
Figure 5-26 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Canal Road Drain 5-31

Figure 5-27 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Sarasota Bay Coastal North 5-32
Figure 5-28 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Palma Sola Drain—Bayshore 5-32
Figure 5-29 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Cedar Hammock Creek....5-33
Figure 5-30 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Bowlees Creek 5-33
Figure 5-31 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Longboat/Lido Keys 5-34
Figure 5-32 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Sarasota Bay Coastal South 5-34
Figure 5-33 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Whitaker Bayou 5-35
Figure 5-34 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Hudson Bayou 5-35
Figure 5-35 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Siesta Key 5-36
Figure 5-36 Comparison of Current and Historical Freshwater Inputs to Sarasota Bay 5-37
Figure 5-37 Comparison of Current and Historical Salinity Distributions in Sarasota Bay 5-38
Figure 6-1 Annual Frequency (percent) of DO Exceedances in Sarasota Bay Using Existing Criteria 6-8
Figure 6-2 Annual Frequency (percent) of DO Exceedances in Sarasota Bay Using Proposed Criteria of 41.7% Saturation 6-11
Figure 6-3 Biological Sampling Sites in Sarasota Bay Tributaries and Phillippi Creek 6-14
Figure 6-4 Sarasota County Tidal Creek Conditions Index Scores 2008 through 2011 6-15
Figure 8-1 Water Quality Improvement Opportunity Identification Methodology....8-3
Figure 8-2 Sarasota County Sarasota Bay Watershed Impaired WBIDs 8-5
Figure 8-3 Sarasota Bay Watershed SIMPLE Total Nitrogen Loading 8-6
Figure 8-4 Sarasota Bay Watershed SIMPLE Total Phosphorus 8-7
Figure 8-5 Sarasota Bay Watershed SIMPLE Total Suspended Solids (TSS)....8-8
Figure 8-6 Sarasota Bay Watershed SIMPLE Biological Oxygen Demand (BOD) 8-9
Figure 8-7 Sarasota Bay Watershed SIMPLE Fecal Coliform 8-10
Figure 8-8 Potential Water Quality Improvement Project Site Locations....8-11
Figure 8-9 Aerial View of Site 1 (SWFWMD, 2010) with Sarasota County Stormwater Inventory 8-13
Figure 8-10 Site 1 Pollutant Loads and Listed WBIDs 8-14
Figure 8-11 Site 1 Looking Downstream, West (A) and Upstream, East (B) 8-15
Figure 8-12 Aerial View of Site 2 (SWFWMD, 2010) with Sarasota County Stormwater Inventory 8-17
Figure 8-13 Site 2 Pollutant Loads and Listed WBIDs 8-17

Figure 8-14 Aerial View of Site 3 (SWFWMD, 2010) with Sarasota County Stormwater Inventory 8-18
Figure 8-15 Site 3 Pollutant Loads and Listed WBIDs 8-19
Figure 8-16 Aerial View of Site 4 (SWFWMD, 2010) with Sarasota County Stormwater Inventory 8-20
Figure 8-17 Site 4 Pollutant Loads and Listed WBIDs 8-21
Figure 8-18 Site 4 Storm Sewer System 8-22
Figure 8-19 47th Street (Source: Google Maps) (A) and 46th Street (B) 8-23
Figure 8-20 46th Street, Facing East Toward Proposed Wetland in Water Tower Park 8-24
Figure 8-21 Ditch Adjacent to Private Properties on the South Side of 47th Street 8-25
Figure 8-22 Aerial View of Site 5 (SWFWMD, 2010) with Sarasota County Stormwater Inventory 8-26
Figure 8-23 Site 5 Pollutant Loads and Listed WBIDs 8-27
Figure 8-24 Site 5 Retention Area at North Side of South Lot 8-28
Figure 8-25 Site 5 Outfall at North Side of South Lot 8-28
Figure 8-26 Aerial View of Site 6 (SWFWMD, 2010) with Sarasota County Stormwater Inventory 8-30
Figure 8-27 Site 6 Pollutant Loads and Listed WBIDs 8-30
Figure 8-28 Hatton Street Ditch, Facing East 8-31
Figure 8-29 Aerial View of Site 7 (SWFWMD, 2010) 8-32
Figure 8-30 Site 7 Pollutant Loads and Listed WBIDs 8-32
Figure 8-31 Van Wezel Parking Lot 8-33
Figure 8-32 10th Street Outfall 8-34
Figure 8-33 10th Street Boat Basin, Northeast Corner 8-34
Figure 8-34 Aerial View of Site 8 (SWFWMD, 2010) 8-36
Figure 8-35 Site 8 Pollutant Loads and Listed WBIDs 8-36
Figure 8-36 Aerial View of Site 9 (SWFWMD, 2010) with Sarasota County Stormwater Inventory 8-37
Figure 8-37 Site 9 Pollutant Loads and Listed WBIDs 8-38
Figure 8-38 Ditch to East Branch of Hudson Bayou, Facing South 8-39
Figure 8-39 Skimmer and Culvert to East Branch of Hudson Bayou, Facing Southwest 8-39
Figure 8-40 Bird's Eye View of Site 10 (Source: Bing Maps) 8-40
Figure 8-41 Site 10 Pollutant Loads and Listed WBIDs 8-41
Figure 8-42 Rain Barrel System 8-43
Figure 8-43 Rain Gutter Bubbler System 8-44

ATTACHMENTS

ATTACHMENT 1 BIVARIATE PLOTS OF DO VERSUS TN, TP, TEMPERATURE, TIME OF DAY, SALINITY, CONDUCTIVITY, CHLOROPHYLL A, TN LOADS, TP LOADS, AND BOD LOADS FOR SARASOTA BAY AND SARASOTA COUNTY TRIBUTARIES

1.0 WATER QUALITY IN SARASOTA BAY AND ITS WATERSHED

The value of the Sarasota Bay ecosystem (Figure 1-1) depends in great part on the prevailing quality of the estuarine waters of the bay. In turn, the bay water quality depends on the effective management of the anthropogenic activities that shape the Sarasota Bay watershed and the tributary waters that drain this watershed and eventually enter the bay.

Water quality is characterized by a number of parameters that can affect the suitability of the aquatic habitats for essential biologic elements of the estuarine ecosystem as well as other designated uses such as recreational and commercial activities. These parameters include:

- Salinity—A measure of the dissolved salts in bay waters. Spatial and temporal variations in salinity are driven by freshwater inputs and communication with the Gulf of Mexico. Salinity tolerances can vary significantly among different plant and animal taxa. Variation in salinity can, therefore, affect the spatial and temporal distributions of these organisms.
- Chlorophyll—A measure of the amount of algae in the water. Spatial and temporal distributions depend on nutrient loading and circulation (i.e., flushing). Chlorophyll affects water clarity and dissolved oxygen, and nuisance algal blooms can affect fishes and other biota.
- Water Clarity—A measure of the amount of light that reaches the bottom. Water clarity depends on chlorophyll, turbidity, water color, and suspended sediments and affects seagrass growth and reproduction.
- Dissolved Oxygen (DO)—A measure of the amount of O_2 dissolved in the water. Spatial and temporal DO distributions depend on water temperature, salinity, amount of algae and decomposing organic matter, and degree of vertical stratification in the water column. DO affects habitat suitability for fish and bottom-dwelling organisms (benthos).
- Nutrients—Typically nitrogen and phosphorus measured as concentrations, i.e., of the amount of nitrogen and phosphorus in the water or as loading (expressed as amount per unit time). Nutrient sources include atmospheric deposition, stormwater runoff from fertilizer, pet waste, and point sources. Nutrient over-enrichment drives algal growth and potential bloom conditions.

Figure 1-1 Sarasota Bay and Watershed

This appendix has been produced to provide critical insight into the water quality of Sarasota Bay and its tributaries. Informed decisions regarding management of the anthropogenic activities that mark the linkage between the bay and its watershed depend on a clear understanding of this linkage. Thus, this document provides the basis for the overall water quality management plan (WQMP) and addresses the following topics:

- The current status and temporal trends in water quality in the bay and its tributaries.
- The relationship between freshwater inputs and salinity in the bay.
- Estimation of current and future pollutant loadings to the bay.
- Identification of pollutant-loading "hot spots" in the Sarasota Bay watershed.
- Examination of the relationships between in-bay nutrient concentrations and watershed loadings with chlorophyll and DO concentrations in Sarasota Bay.
- Establishment of water quality levels of service for the bay and its tributaries.
- The review of recently proposed revisions to DO criteria and an examination of the factors that affect DO in the bay and its tributaries.

The following discussion presents some of the salient findings found in subsequent sections of the water quality appendix.

1.1 WATER QUALITY STATUS AND TRENDS

Knowledge of water quality status and trends is an essential element of a watershed management plan. Effective management is supported by the assessment of the current status in relation to existing regulatory standards/criteria and resource management targets. Early detection of negative trends in water quality can allow resource managers to respond before water quality conditions become unacceptably degraded. Assessment of the effectiveness of various water quality management strategies is often achieved by the detection of positive trends in water quality.

1.2 ESTUARINE WATER QUALITY

Achieving the water quality standards and targets within Sarasota Bay assures resource managers that key targets such as the seagrass targets established by the Sarasota Bay Estuary Program (SBEP) can be met. Suitable habitats for fishes and other biota can also be expected to be maintained.

Sarasota Bay is currently meeting all critical regulatory standards and resource management targets by which the estuary's water quality is assessed. These include:

- The chlorophyll target established by SBEP.
- The recently established estuarine numeric nutrient criteria (NNC) for both nitrogen and phosphorus.

- The recently proposed revisions to Florida DO standards for estuarine waters.

The period of record for water quality within Sarasota Bay is 1998–2009. The following temporal trends in water quality were detected:

- Significant decreasing trends were observed in the total phosphorus (TP), total suspended solids (TSS), and turbidity concentrations over the period of record.
- No significant trends in chlorophyll *a*, total nitrogen (TN), or water clarity were found over the period of record.

Additionally, no open water portions of the estuary have been deemed impaired under Florida's Impaired Waters Rule (IWR) (Chapter 62-303, FAC). Therefore, despite changes in the anthropogenic influences within its watershed, water quality within Sarasota Bay has been effectively protected by the management programs being implemented by Sarasota County and other stakeholders.

1.3 TRIBUTARY WATER QUALITY

Tributary streams are one of the major links between the estuary and its watershed. These tributaries convey both baseflow and stormwater runoff to the estuary. In the context of the estuarine ecosystem, these tributaries, therefore, influence bay water quality and circulation by delivering nutrients and freshwater to the estuary. Tributaries can be classified as either freshwater or tidal (marine waters with conductivity greater than 1,500 µS/cm). The tidal tributaries provide valuable nursery habitat for the early life stages of numerous fish as well as benthic invertebrates. There are four major tributaries to Sarasota Bay – Whitaker Bayou, Hudson Bayou, Bowlees Creek, and Cedar Hammock Creek (Figure 1-2).

Water quality data are collected at three freshwater stations in Whitaker Bayou. No temporal trends were found in any of the water quality parameters examined (salinity, chlorophyll *a*, TN, TP, or DO) in any of these stations. Despite the lack of trends, the marine segment of Whitaker Bayou has been deemed impaired by the Florida Department of Environmental Protection (FDEP) under the IWR (Chapter 62-303, FAC). Whitaker Bayou waterbody ID (WBID) 1936 impairments include fecal coliform, DO, and historical chlorophyll *a*; the latter two impairments are attributed to elevated nitrogen concentrations.

Figure 1-2 Sarasota Bay Tributaries

Water quality has been monitored at three sites in Hudson Bayou, including two freshwater and one tidal site. A modest increasing temporal trend was observed in TN concentrations at Hudson Bayou Station HB7 (the upstream-most site); a concomitant increase in DO concentrations at Station HB7 was observed over the same sampling period. Similar to WBID 1936 in Whitaker Bayou, impairments due to elevated fecal coliform, low DO, and elevated chlorophyll *a* concentrations have been documented in Hudson Bayou WBID 1953.

No temporal trends in either chlorophyll *a* or TN were evident in Bowlees Creek, but the overall concentrations were higher than in Whitaker Bayou or Hudson Bayou. TP concentrations were similar among all three tributaries. Despite high nutrients and chlorophyll *a*, Bowlees Creek generally maintained DO concentrations between 4 and 8 mg/L, but DO concentrations have been generally lower since 2007.

Water quality impairments have been documented by FDEP in other waterbodies within the Sarasota Bay watershed, including West Cedar Hammock WBID 1885 and Longboat Key WBID 1916, which have both been deemed impaired due to low DO conditions attributed to either high levels of TN or biochemical oxygen demand (BOD).

TN and TP concentrations for 2006–2010 from the three freshwater sampling sites in Whitaker Bayou and two freshwater sites in Hudson Bayou were compared to the FDEP NNC for the West Central Nutrient Watershed Region. Concentrations in both tributaries were well below the TN freshwater standard of 1.65 mg/L in all years. Whitaker Bayou was also well under the TP standard of 0.49 mg/L. Hudson Bayou had TP concentrations higher than 0.49 mg/L in 1 year; however, to not meet the standard the concentration must be exceeded in any 2 years within a consecutive 3-year period. Thus, both tributaries met the NNC.

DO levels for 2006–2011 in freshwater and tidal segments of Whitaker Bayou and Hudson Bayou were also compared to FDEP's recently proposed revised DO standards. Whitaker Bayou freshwater and marine segments both met the standards in all years. The Hudson Bayou freshwater segment did not meet the proposed standard in any year, and the marine segment did not meet the standard in 2006–2009.

1.4 CURRENT AND FUTURE POLLUTANT LOADINGS

Water quality problems in either the estuary or tributary coastal streams are frequently a function of pollutant inputs, or loadings, from the watershed. Thus, the source, location, and timing of these loadings must be identified to better manage resources in the streams and the estuary. The objective of the current and future pollutant loading analysis was to present the approach, data used, and summary of results associated with examining the current and future nutrient and suspended solids loads for the Sarasota Bay watershed.

The loading sources were estimated using the Sarasota Bay SIMPLE model developed by Jones Edmunds & Associates for Sarasota County and supported by SBEP. The sources include:

- Atmospheric deposition.
- Direct runoff (stormwater runoff).
- Baseflow (shallow groundwater).
- Irrigation.
- Septic tanks.
- Point sources.

Current loadings were estimated for 1989–2008 by subbasin (Figure 1-3). Future loadings were estimated by applying the same precipitation record as used for the current estimates to a future land use setting based on expected land use changes.

Significant results and conclusions from these estimates include:

- Current Loading Estimates:
  - The variability in total hydrologic load (freshwater inputs) to the bay is mainly a function of precipitation, which drives atmospheric deposition, stormwater runoff, and to a degree baseflow.
  - Similar to the pattern in annual precipitation, a slightly decreasing trend in TN load to the bay was observed over 1989–2008.
  - Because loading is largely driven by precipitation, that all loads are higher during the wet summer months is not surprising.
  - Atmospheric deposition (precipitation to the bay surface) is the major source of freshwater to the bay, accounting for over half of all freshwater inputs over the period of record for current and future conditions. This result is not surprising given that the area of the Sarasota Bay watershed is relatively small in relation to the area of the bay itself.
  - Direct runoff accounted for over half of TN loadings to the bay from 1989 through 2008. Atmospheric deposition contributed approximately 30% and baseflow (shallow groundwater) contributed approximately 15–17% of the TN load during that period.
  - Direct runoff is responsible for just over half of all TP loadings to the bay, and baseflow contributes another 27–29%.
  - Almost 90% of TSS loads to the bay originate from direct runoff.
  - Other sources (point sources, septic tanks, and irrigation) collectively account for less than 20% of any current loading estimate.
  - Eleven basins are within the Sarasota Bay watershed. Unit area loadings (UAL) were estimated by dividing the annual watershed loading (i.e., direct runoff + baseflow) by the area of a basin to allow comparison of the watershed loadings from basins with widely varying areas. The largest TN and TP UALs were found for the Cedar Hammock Creek, Whitaker Bayou, and Hudson Bayou basins.

Figure 1-3 Sarasota Bay Subbasins

- Future Loading Estimates:
  - The estimated increase in loadings from the current to the future conditions can be mainly attributed to land use change because the same precipitation was used for current and future loadings.

1.5 SALINITY-FLOW RELATIONSHIPS

Another critical element of the linkage between an estuary and its watershed is the timing and magnitude of freshwater delivery to the estuary. Freshwater inputs are an important determinant of the eventual spatial and temporal patterns of estuarine circulation and salinity. Salinity influences habitat suitability, as estuarine biota display a wide range of preferences and tolerances for inherently variable salinity regimes. Salinity also affects circulation in the bay. Water density increases with increasing salt content, which can result in vertical stratification of the water column and affect the degree to which reaeration of bottom waters occurs. Estuarine circulation also influences responses of the estuary to pollutant loadings by determining estuarine residence times.

Freshwater inputs to Sarasota Bay for current and historical conditions were estimated using the Sarasota Bay SIMPLE model. The relationship between freshwater inputs and ambient salinity within Sarasota Bay was examined by plotting the mean monthly estuarine salinity against the current month's inputs and a series of cumulative freshwater inputs. As expected, the relationship between salinity and freshwater inputs is inverse, i.e., salinity in the bay decreases as freshwater inputs from the watershed increase. Salinity displayed the strongest relationship with the 3-month cumulative freshwater inputs.

Questions have arisen as to whether changes in the freshwater inputs from historical levels have significantly altered the salinity regime in Sarasota Bay. The historical and current freshwater flow regimes are similar at the inputs less than the 30th percentile, i.e., at the lower flows. The greatest differences between the historical and current inflows are found at the higher flows. Since these higher flows most commonly occur during the summer months, current estuarine salinities are likely lower than those during the summer months in the historical period. However, these differences are relatively small and do not significantly affect Sarasota Bay.

1.6 WATER QUALITY LEVELS OF SERVICE (LOS)

Effective management of water quality in Sarasota Bay and its tributaries can be achieved by clearly understanding how these waters respond to changes in water quality. This knowledge allows water quality levels of service (LOS) to be established. Levels of service can be preventative and *elicit* management responses when exceeded, or regulatory that *require* specific management actions. Both types of water quality LOS have been recommended for Sarasota Bay and its tributaries.

2.0 ESTUARINE WATER QUALITY STATUS AND TRENDS

2.1 OBJECTIVE

This section presents the approach, data used, and summary of results associated with examining the water quality status and trends in the Sarasota Bay estuary.

2.2 APPROACH

Ambient water quality data were examined to identify any significant temporal or spatial trends in Sarasota Bay. Seasonal Kendall Tau trend tests were used to identify significant temporal trends. Spatial trends were examined using graphical plotting techniques.

2.3 DATA USED

- Ambient water quality data provided by Sarasota and Manatee Counties.
- SBEP water quality targets and NNC.

2.4 RESULTS

2.4.1 Temporal Variation – Monthly

Figures 2-1 through 2-7 plot the mean monthly water quality data. Mean monthly salinity for Sarasota Bay as a whole for 1998 through 2010 ranged from approximately 30 parts per thousand (ppt) to over 40 ppt (Figure 2-1). Salinity, like several other parameters in an estuary including nutrients and chlorophyll *a*, are influenced by the magnitude of freshwater inputs. Higher freshwater inputs result in higher pollutant loading to the estuary. Also, estuarine circulation and residence times are affected by freshwater inputs.

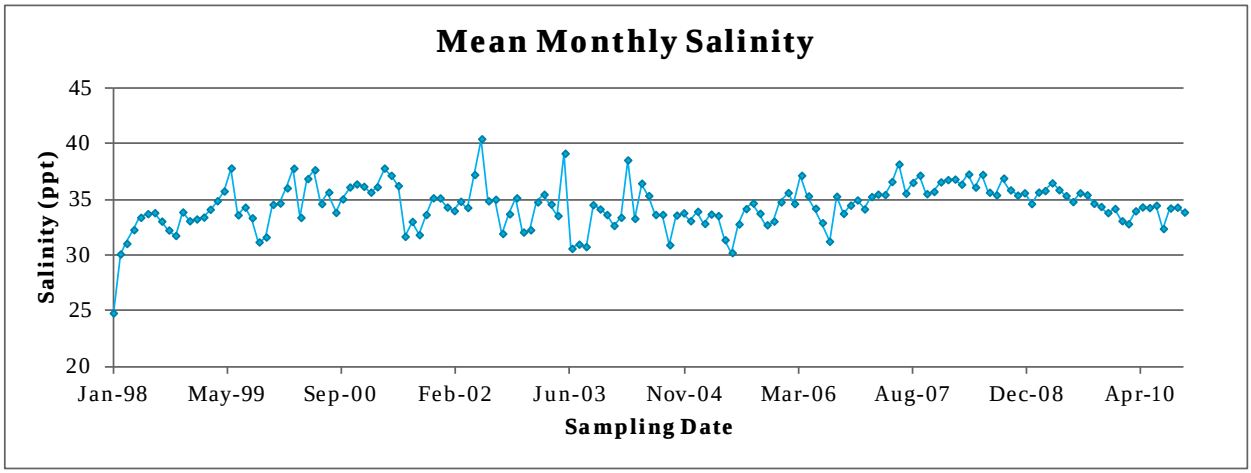


Figure 2-1 Mean Monthly Salinity in Sarasota Bay

Figure 2-2 presents mean monthly chlorophyll *a* concentrations for Sarasota Bay for 1998 through 2010. Values exceeding 10 µg/L occurred during 10 months, reaching a maximum of close to 16 µg/L in summer 2001. No significant trend in the monthly chlorophyll *a* concentrations occurred over the period of record.

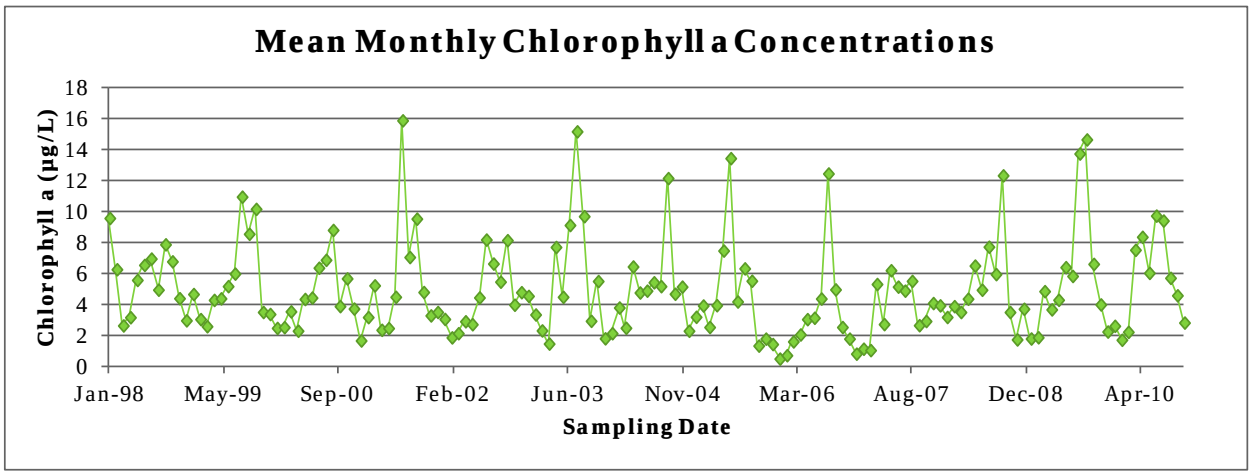


Figure 2-2 Mean Monthly Chlorophyll *a* Concentrations in Sarasota Bay

Figure 2-3 shows Sarasota Bay mean monthly TN concentrations for the same period. The great majority of TN concentrations fall between 0.2 and 0.5 mg/L. Only four monthly values exceeded 0.6 mg/L, with the maximum exceeding 1.0 mg/L in 2004. No significant trend in the monthly TN concentrations occurred over the period of record.

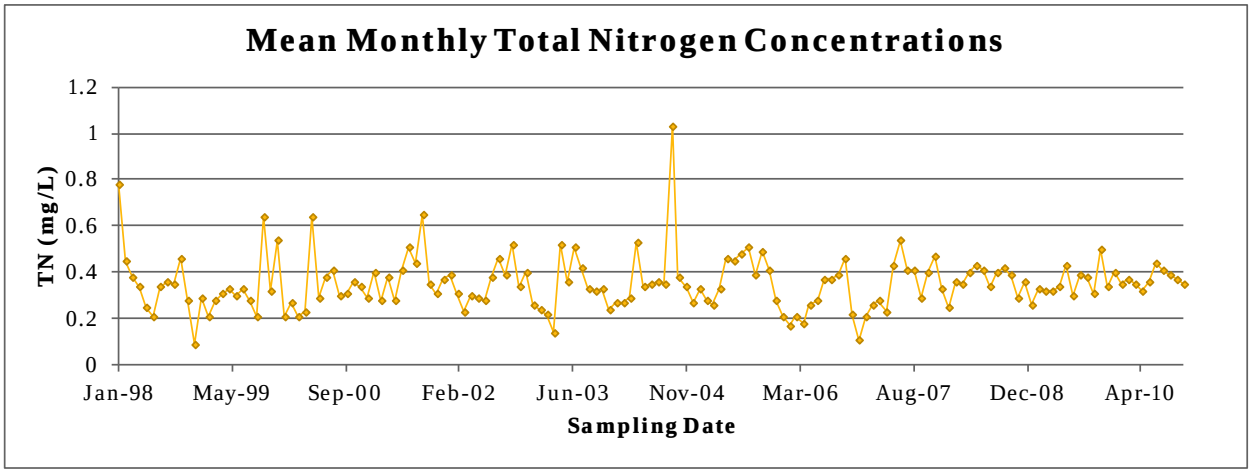


Figure 2-3 Mean Monthly TN Concentrations in Sarasota Bay

Figure 2-4 shows TP values for Sarasota Bay. The monthly concentrations were less variable than TN, with most values between 0.08 and 0.18 mg/L. Six monthly values exceeded 0.25 mg/L, and only one exceeded 0.3 mg/L. A maximum monthly value of over 0.8 mg/L occurred in summer 2002. A significant decreasing trend in the monthly TP concentrations occurred over the period of record.

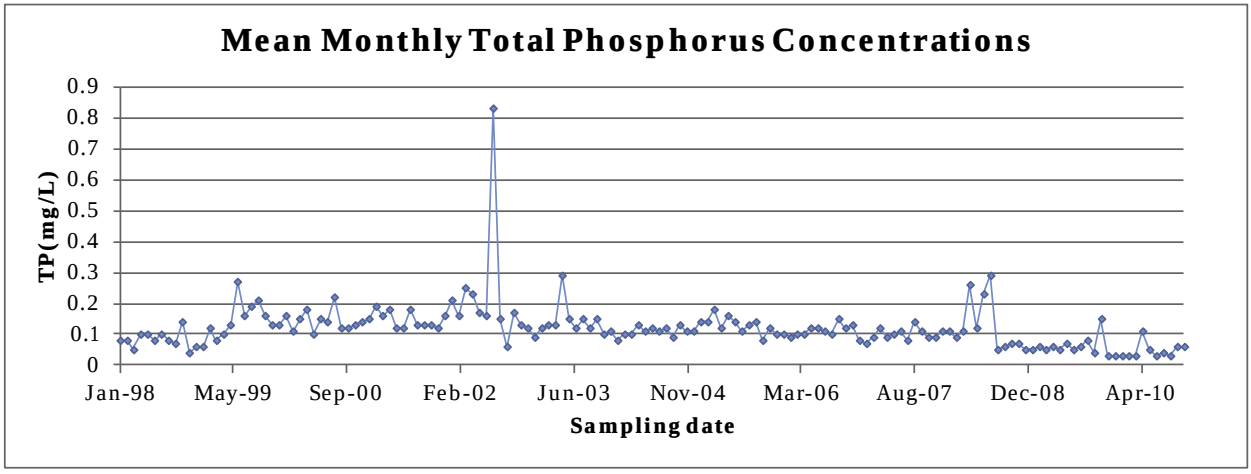


Figure 2-4 Mean Monthly TP Concentrations in Sarasota Bay

Figure 2-5 presents monthly TSS values for Sarasota Bay. These data reflect a reduction in the temporal variation in TSS over the period of record, particularly after 2003. TSS concentrations have varied less since the occurrence of the highest concentration (0.69 mg/L) in 2006. In general, TSS concentrations varied between 7 and 25 mg/L. A significant decreasing trend in the monthly TSS concentrations occurred over the period of record.

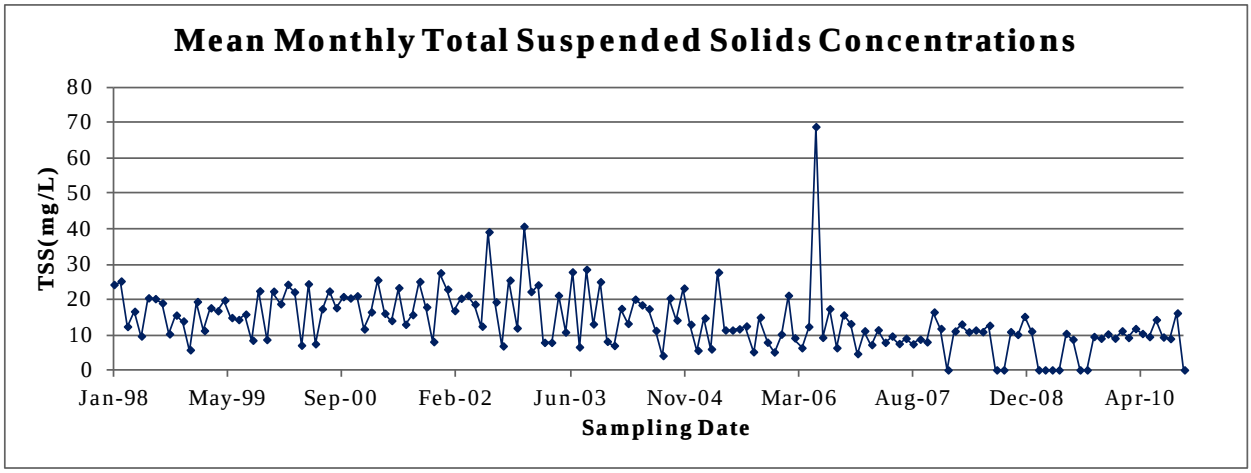


Figure 2-5 Mean Monthly TSS Concentrations in Sarasota Bay

Figure 2-6 shows turbidity concentrations in Sarasota Bay. The majority of monthly means were less than 5 NTU. Values occasionally spiked above 6 NTU and reached a maximum of approximately 13 NTU in 2001. Similar to TP and TSS, a significant decreasing trend in monthly turbidity concentrations occurred over the period of record.

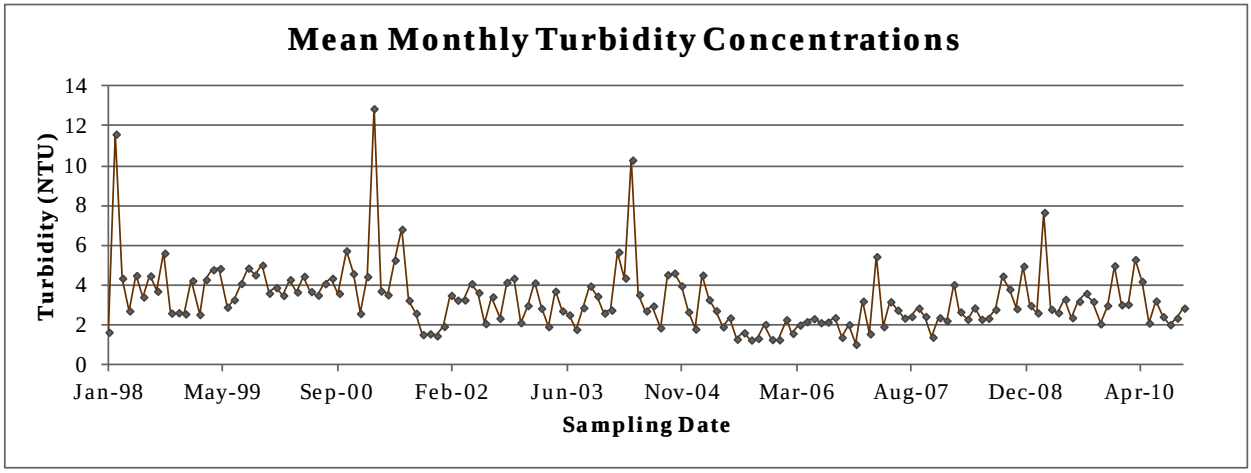


Figure 2-6 Mean Monthly Turbidity Concentrations in Sarasota Bay

Figure 2-7 presents light attenuation coefficient (K_d) values for Sarasota Bay. K_d is a measure of light attenuation in a water column. Higher K_d values indicate greater light attenuation, i.e., less light reaches the bottom waters. K_d values varied between 0.33 to over 1.4 as measured in 1/meter, or m^{-1}. No statistically significant trend in K_d values occurred.

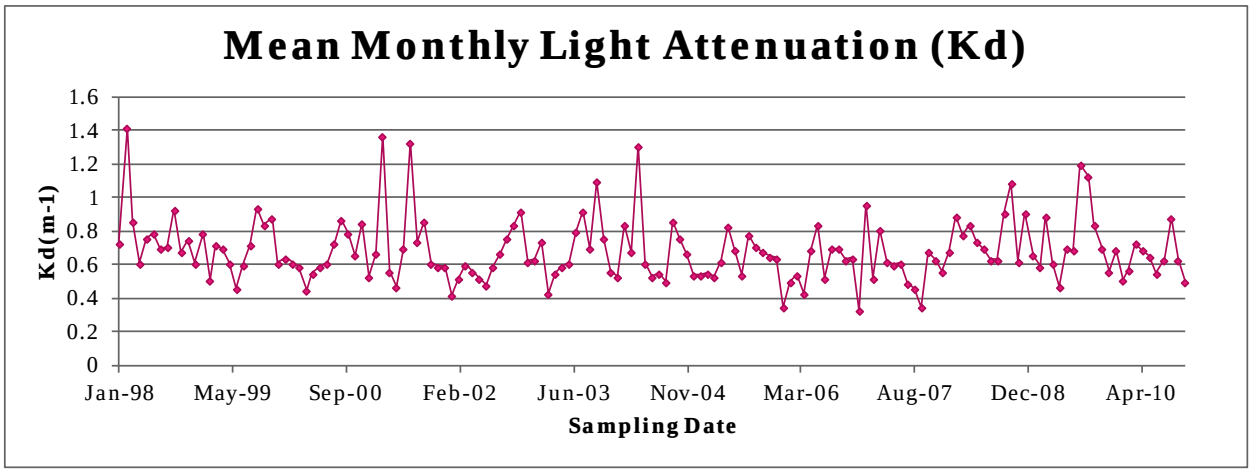


Figure 2-7 Mean Monthly K_d in Sarasota Bay

Figures 2-8 through 2-14 present within-year variation in the various water quality parameters in Sarasota Bay. The box-and-whisker plots present the variation within each calendar month and across calendar months from 1998 through 2009. The line in the middle of the box is the mean, and the top and bottom edges of the box represent the 75th and 25th percentiles of monthly values, respectively. The whisker top and bottom are the 95th and 5th percentiles, respectively. The crosses represent extreme single measurements.

Figure 2-8 shows within-year variation in salinity for Sarasota Bay. Clearly, low salinity values (33–34 ppt) generally occurred during the wet summer months (June–September) and higher salinities (35–36+ ppt) during the dry season when freshwater inputs are lowest.

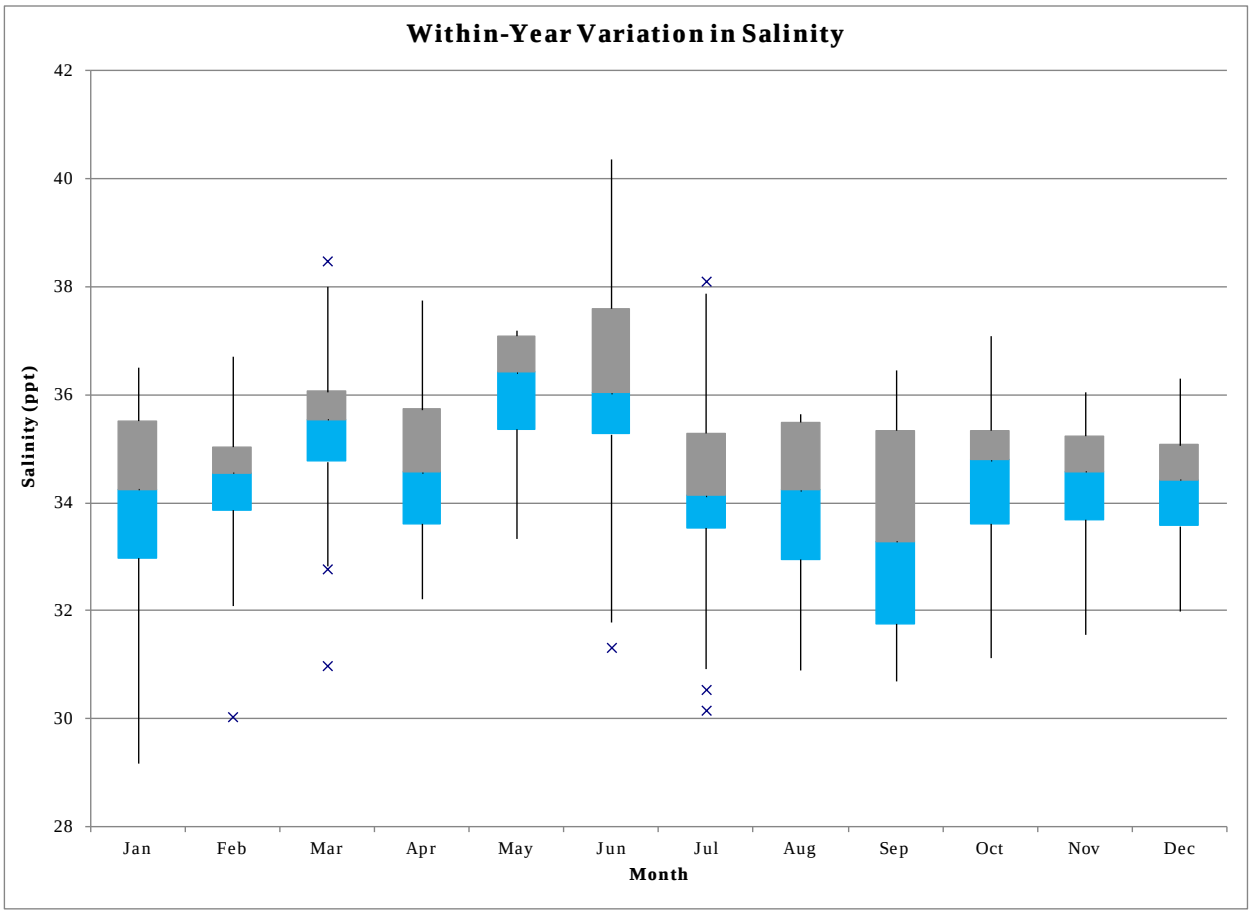


Figure 2-8 Within-Year Variation in Salinity in Sarasota Bay

Figures 2-9 shows within-year variation in chlorophyll *a* for Sarasota Bay. Higher mean chlorophyll *a* concentrations (to over 8 µg/L) occurred July through October when water temperatures, solar illumination, and nutrient loading are high. Dry season mean values remain between 2 and 4 µg/L. The variation within a calendar month was also greater during the summer months.

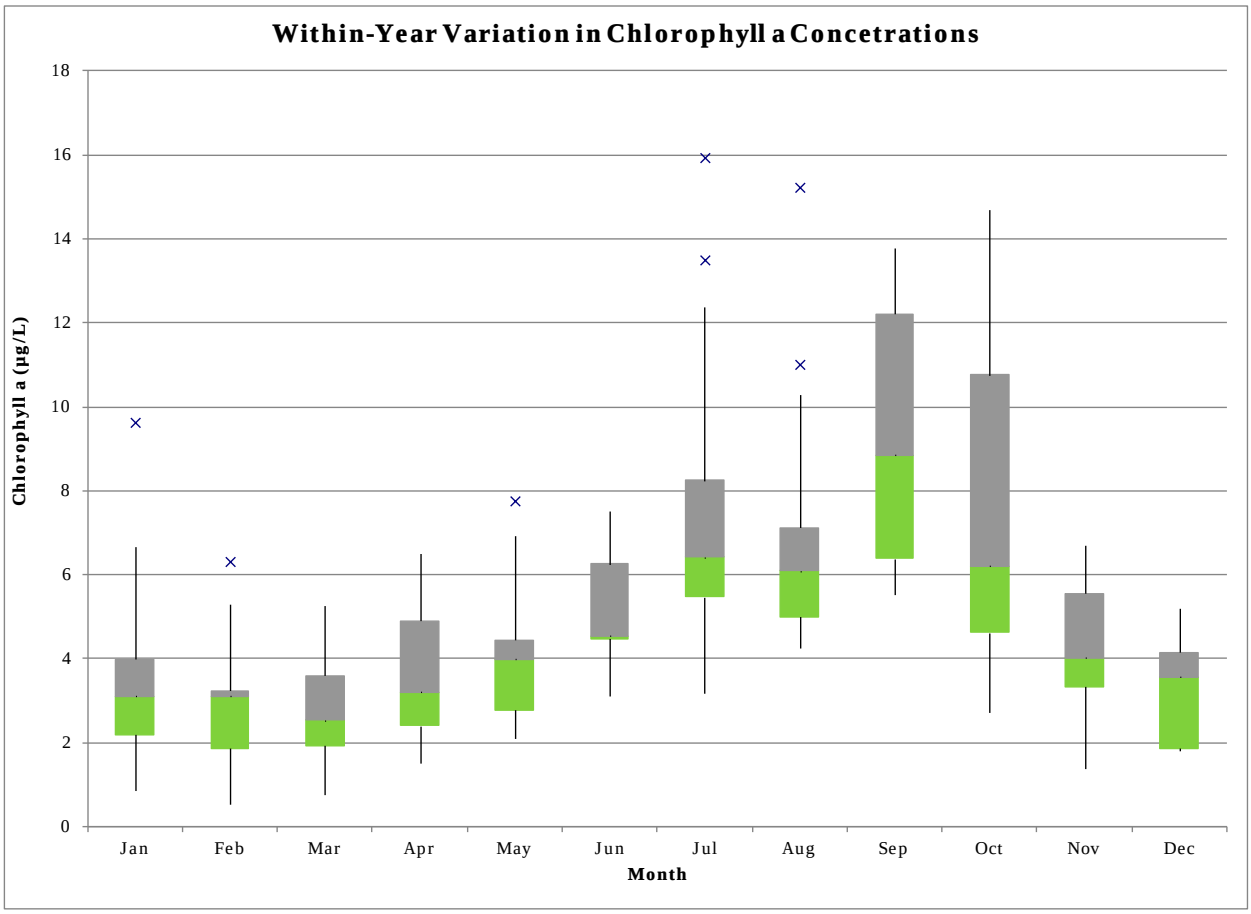


Figure 2-9 Within-Year Variation in Chlorophyll *a* Concentrations in Sarasota Bay

Figure 2-10 shows the within-year variation in TN concentrations for Sarasota Bay. Generally, little variation in TN concentrations was observed across months. Somewhat higher concentrations, above 0.35 mg/L, were observed during the summer months, with dry season concentrations typically between 0.25 and 0.35 mg/L.

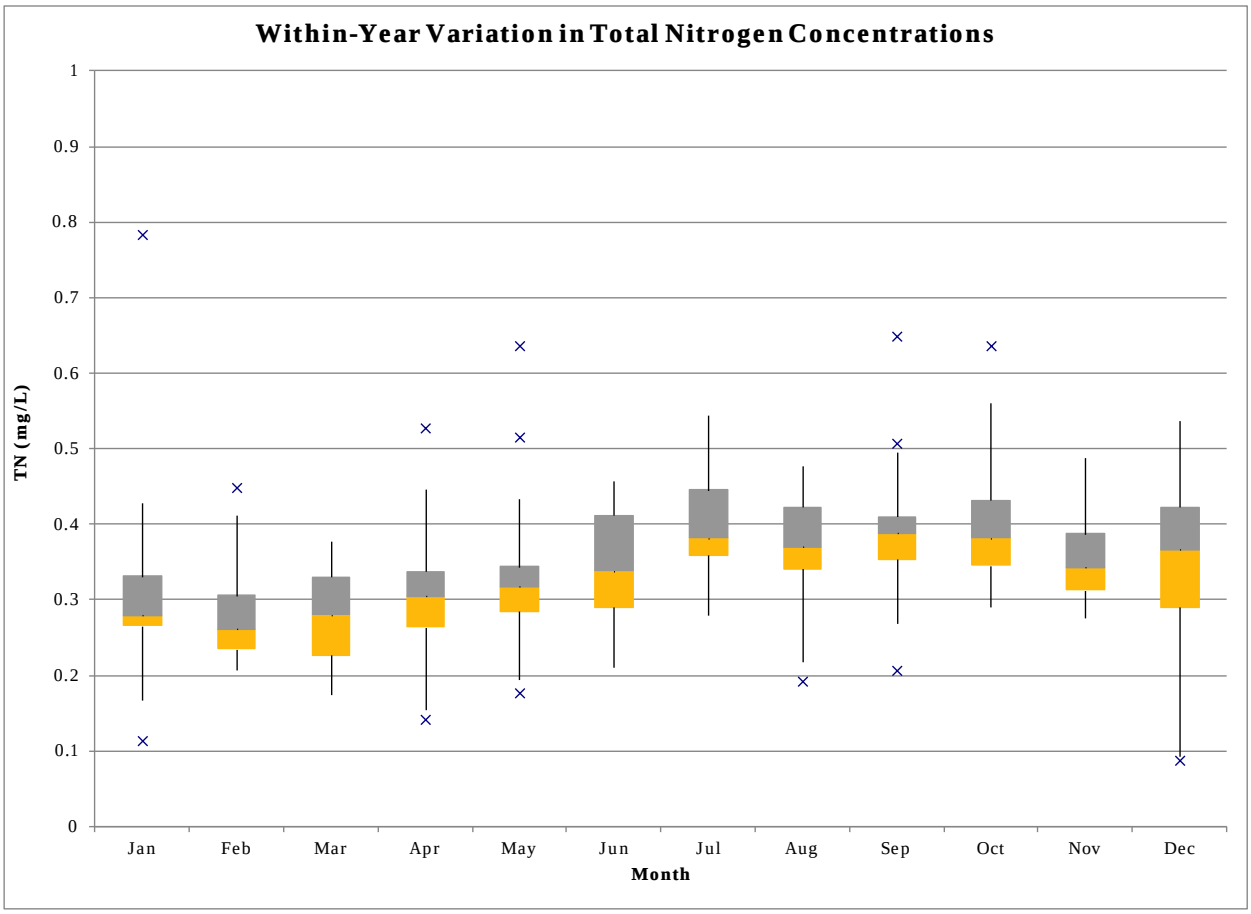


Figure 2-10 Within-Year Variation in TN Concentrations in Sarasota Bay

Figure 2-11 shows the within-year variation in TP concentrations for Sarasota Bay. Similar to the TN concentrations, little variation in TP concentrations was observed across all months.

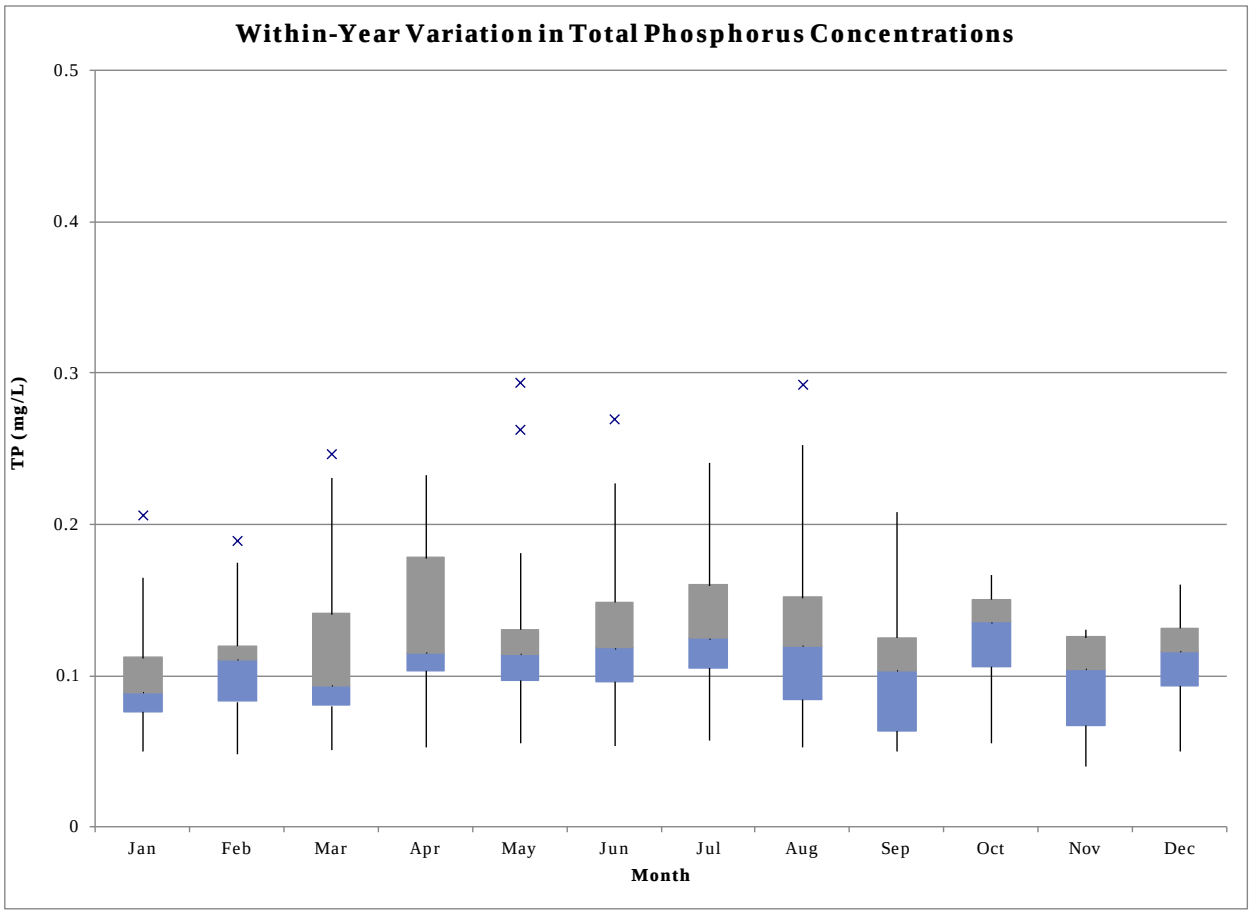


Figure 2-11 Within-Year Variation in TP Concentrations in Sarasota Bay

Figure 2-12 presents the within-year variation in TSS concentrations for Sarasota Bay. Again, little variation in TSS concentrations was observed across all months. The greatest within-month variation was observed during July.

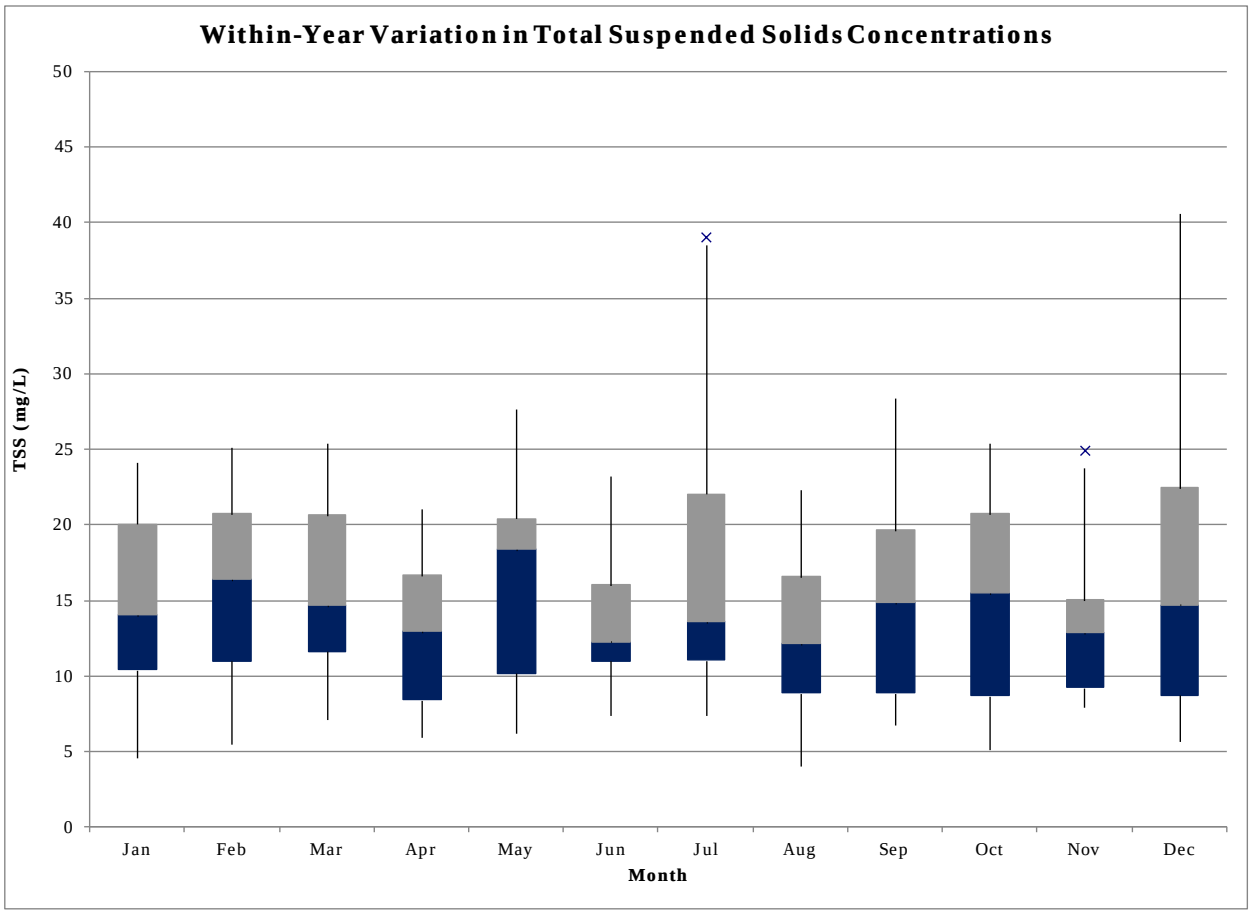


Figure 2-12 Within-Year Variation in TSS Concentrations in Sarasota Bay

Figure 2-13 presents the within-year variation in turbidity for Sarasota Bay. Similar to TN, TP, and TSS concentrations, little within-year variation in the turbidity was observed in Sarasota Bay. The within-month variation in turbidity was greatest from January through April.

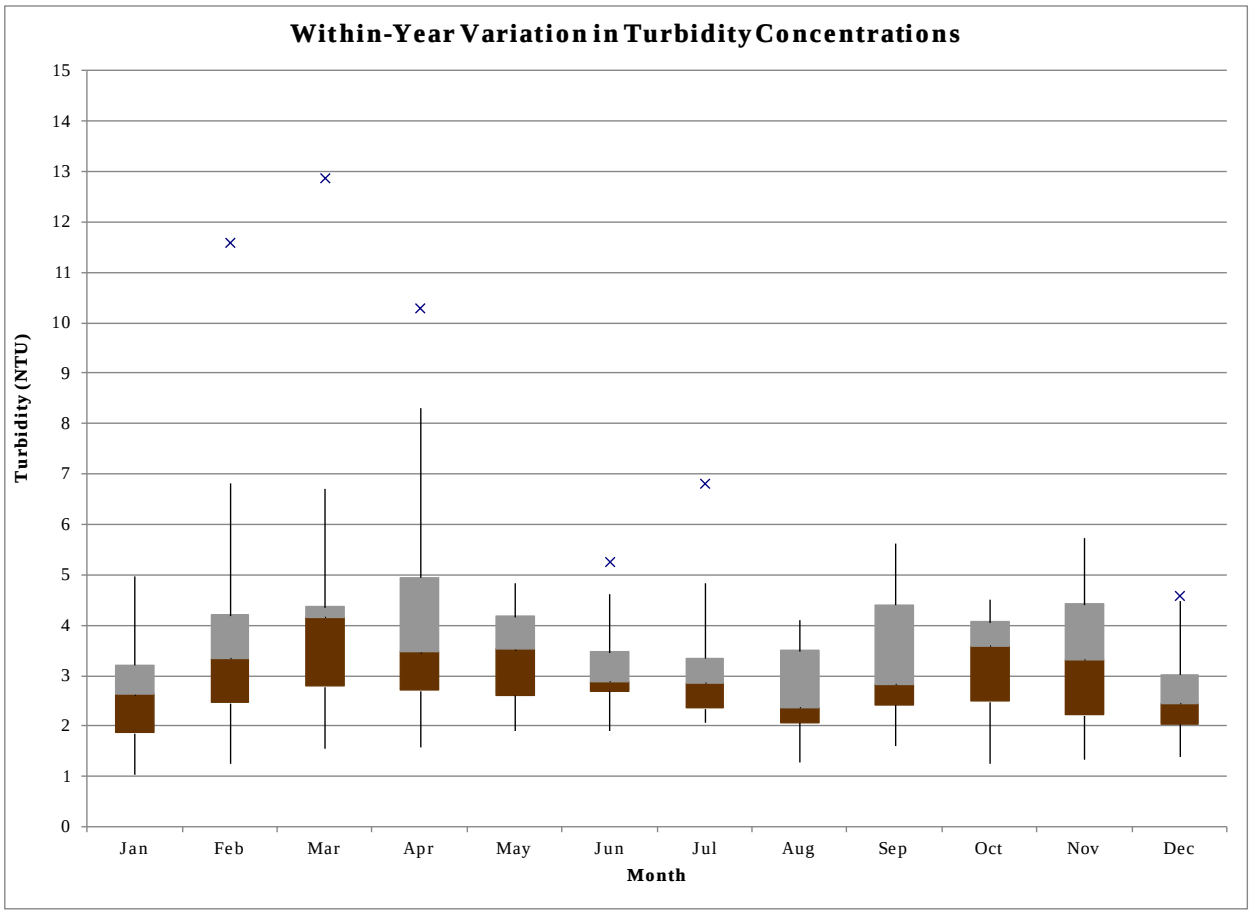


Figure 2-13 Within-Year Variation in Turbidity Concentrations in Sarasota Bay

Figure 2-14 presents the intra-annual variation in Kd. Relatively little variation in light attenuation was observed across months. The greatest light attenuation was observed during September through November. Within-month variation was generally greater during April, September, and October.

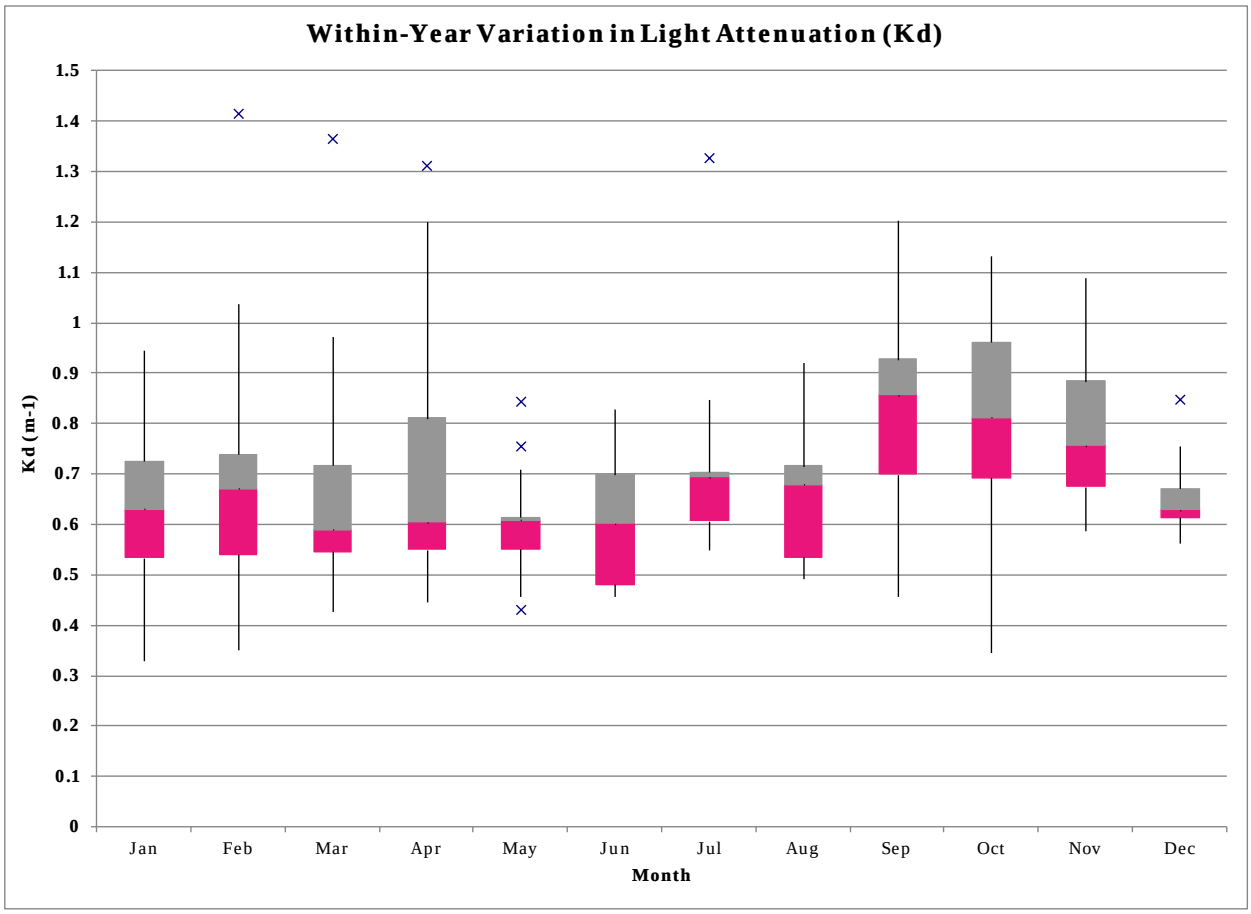


Figure 2-14 Within-Year Variation in Light Attenuation in Sarasota Bay

2.4.2 Trend Analyses

The results of the trend analyses are as follows:

- Salinity—no significant trend.
- Chlorophyll *a*—no significant trend.
- TN—no significant trend.
- TP—significant decreasing trend.
- TSS—significant decreasing trend.
- Turbidity—significant decreasing trend.
- Light attenuation (K*d*)—no significant trend.

2.4.3 Spatial Variation

Figure 2-15 is a map of the four water quality strata within Sarasota Bay. The strata are based on a bay segmentation scheme developed for SBEP (Estevez and Palmer, 1990) to enhance the analysis of surface water quality data collected by Sarasota County and others. Stratum MC contains the north portion of Sarasota Bay and is bounded to the south by the Sarasota County-Manatee County boundary. Given its location, the MC stratum can be influenced by flows from the Manatee River. Stratum SCUS is the upper stratum within Sarasota County and includes areas distant from Big Pass and New Pass that facilitate tidal interactions with the Gulf of Mexico. SC10 and SC11 are in lower Sarasota Bay adjacent to Roberts Bay North and potentially affected by Philippi Creek.

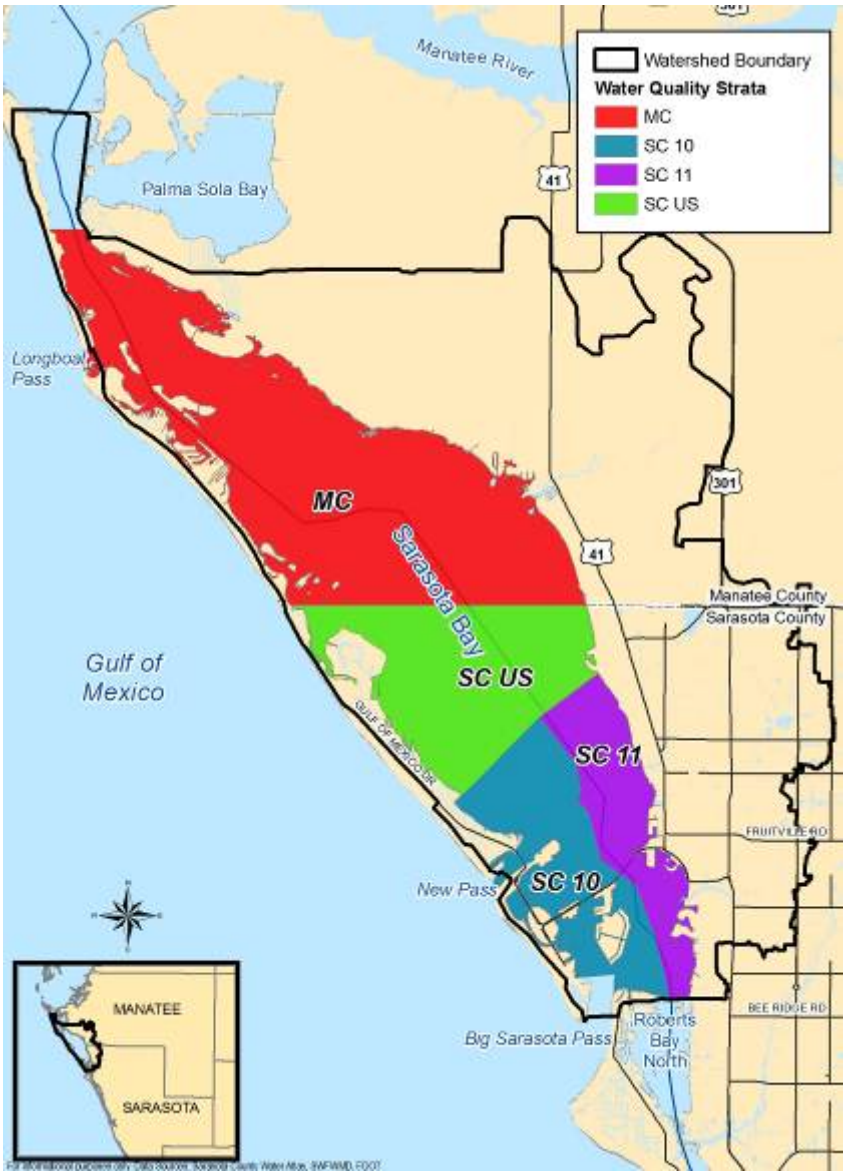


Figure 2-15 Four Water Quality Strata within the Sarasota Bay Estuary

Figures 2-16 through 2-22 present the distributions of water quality data observed in each of the four water quality strata. These plots allow examination of the variation across strata. Also, the within-stratum variation displayed reflects the temporal variation over the period of record within each stratum.

Figure 2-16 shows the within-stratum variation in monthly salinities across the four Sarasota Bay strata. Salinities were typically lower and displayed the greatest within-stratum variation in Stratum MC, likely reflecting the influence of flows from the Manatee River. Salinities were generally similar among the SC10, SC11, and SCUS strata, including the within-stratum variation.

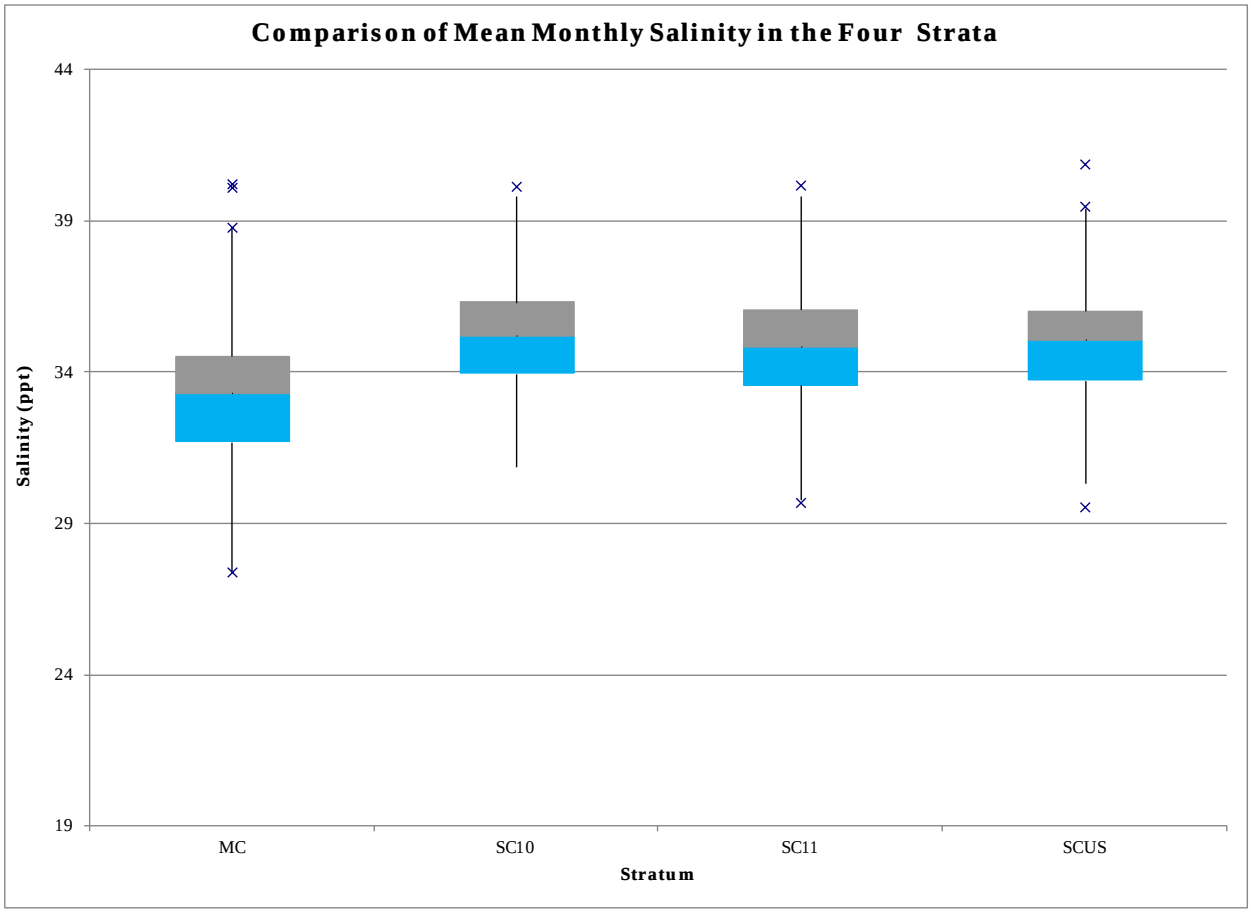


Figure 2-16 Comparison of Mean Monthly Salinity in the Four Strata of Sarasota Bay

Figure 2-17 shows the within-stratum variation in monthly chlorophyll *a* concentrations across the four Sarasota Bay strata. These data indicate relatively little variation in the chlorophyll *a* concentrations in Sarasota Bay. The chlorophyll *a* concentrations in SC10 tend to be somewhat lower and may reflect the influence of the circulation of Gulf of Mexico waters through New Pass.

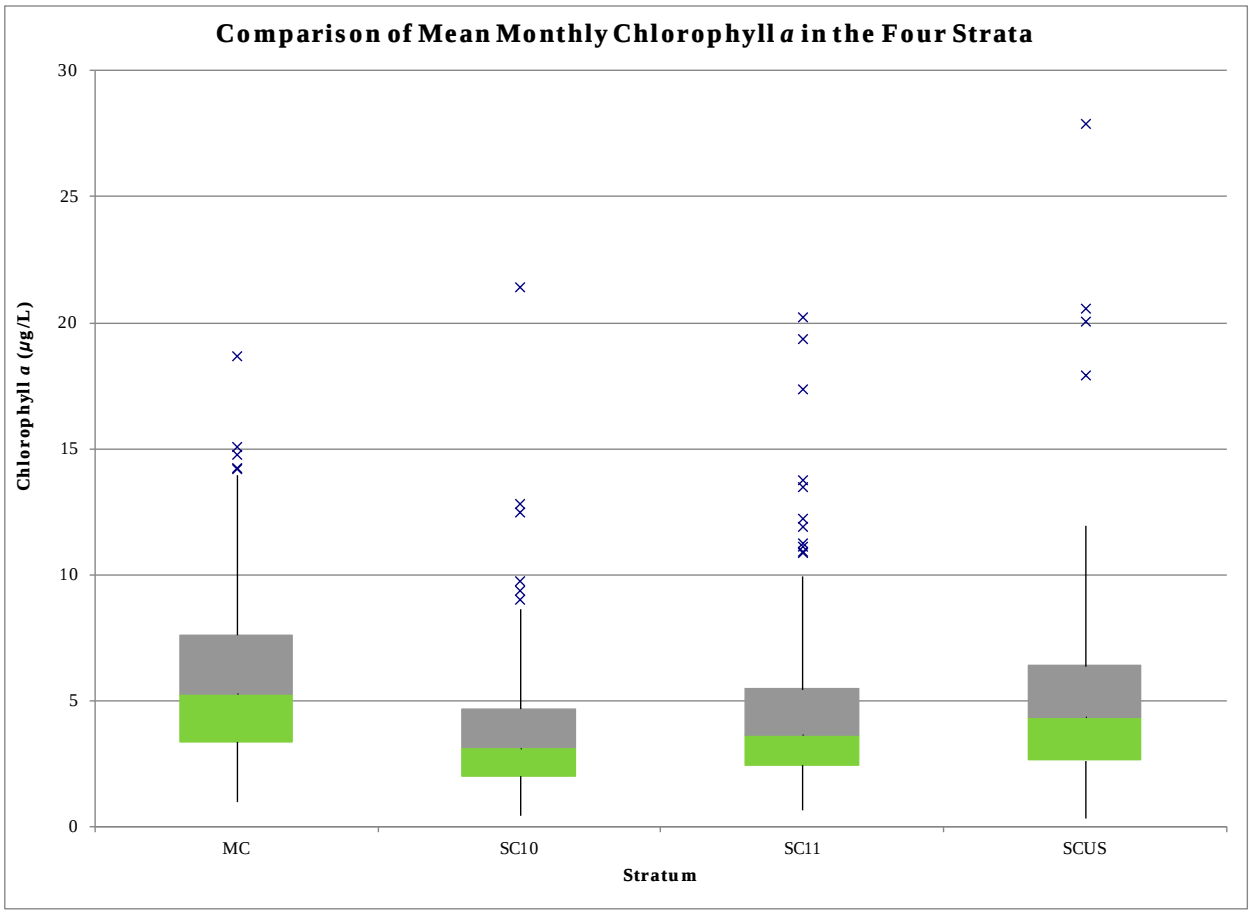


Figure 2-17 Comparison of Mean Monthly Chlorophyll *a* in the Four Strata of Sarasota Bay

Figure 2-18 illustrates the within-stratum variation in monthly TN concentrations across the four Sarasota Bay strata. The TN concentrations were clearly highest in Stratum MC with a mean value of approximately 0.6 mg/L. The within-stratum variation in TN concentrations was also much greater in Stratum MC. The TN concentrations were similar within the SCUS, SC10, and SC11 strata where the mean TN concentrations were approximately 0.3 mg/L.

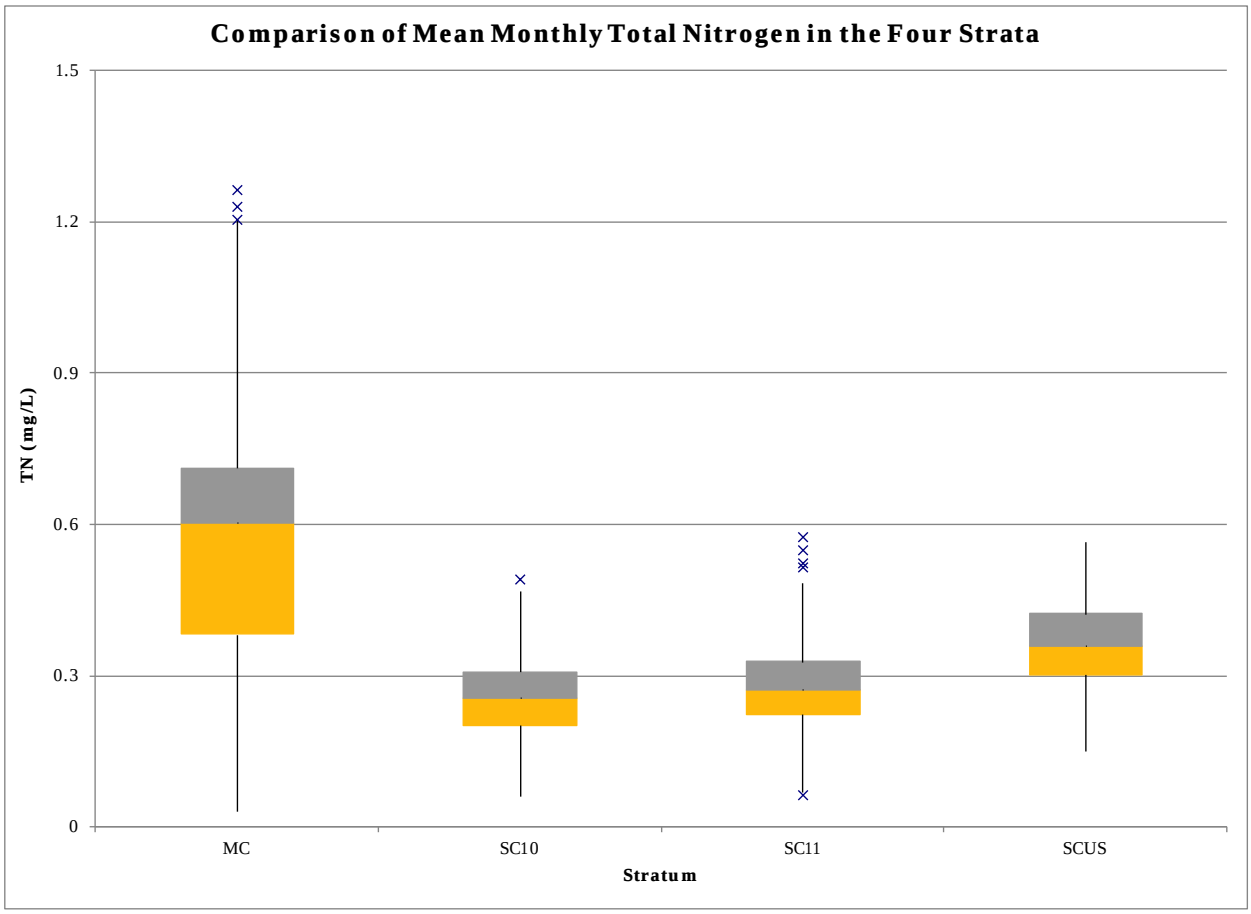


Figure 2-18 Comparison of Mean Monthly TN in the Four Strata of Sarasota Bay

Figure 2-19 shows a very different pattern for TP concentrations across the four Sarasota Bay strata. The TP concentrations were relatively similar across all strata, and the most apparent difference was observed in Stratum MC where the within-stratum variation was greatest.

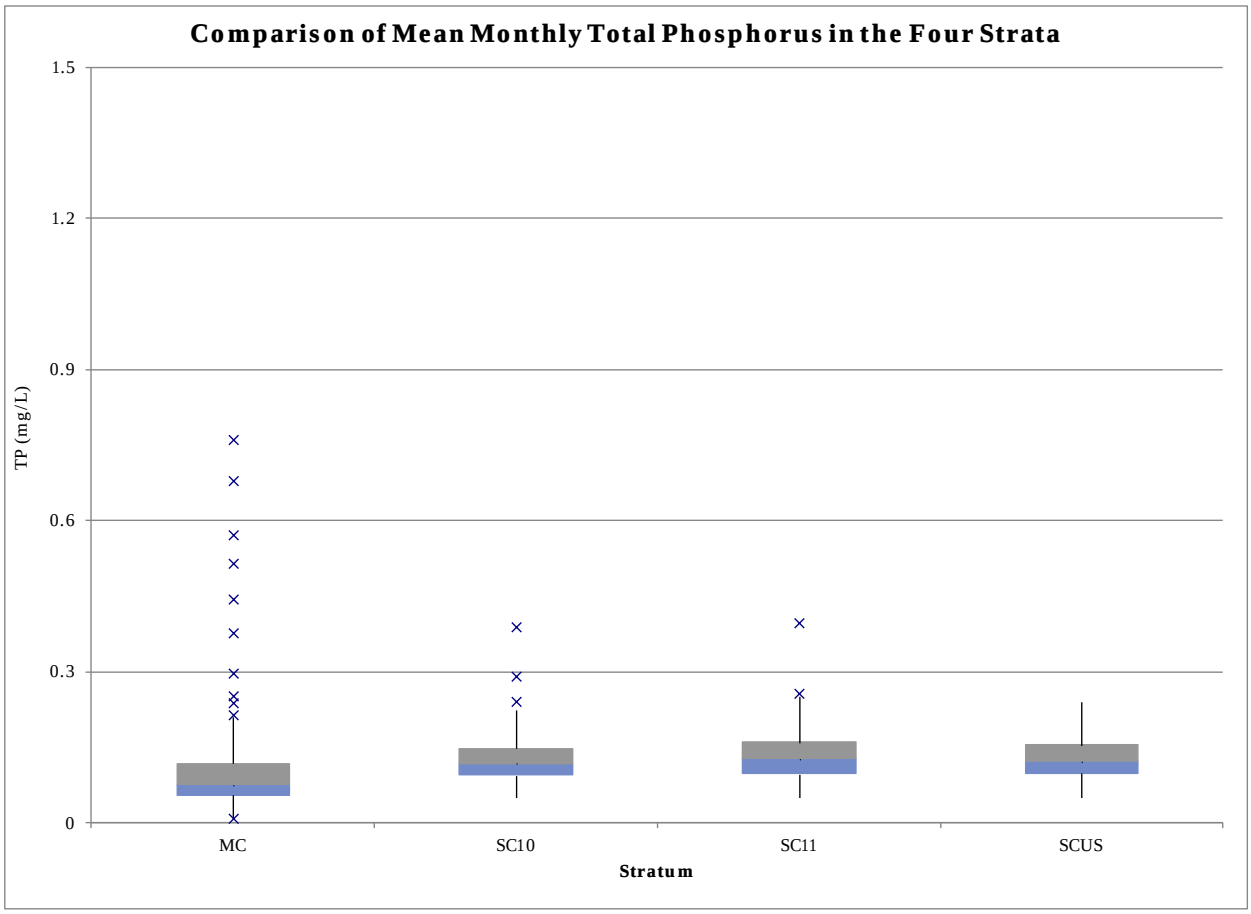


Figure 2-19 Comparison of Mean Monthly TP in the Four Strata of Sarasota Bay

Figure 2-20 presents the within-stratum variation in TSS concentrations across the four strata. A pattern similar to that observed for TP concentrations is apparent. The TSS concentrations in Stratum MC were clearly greatest, including the within-stratum variation.

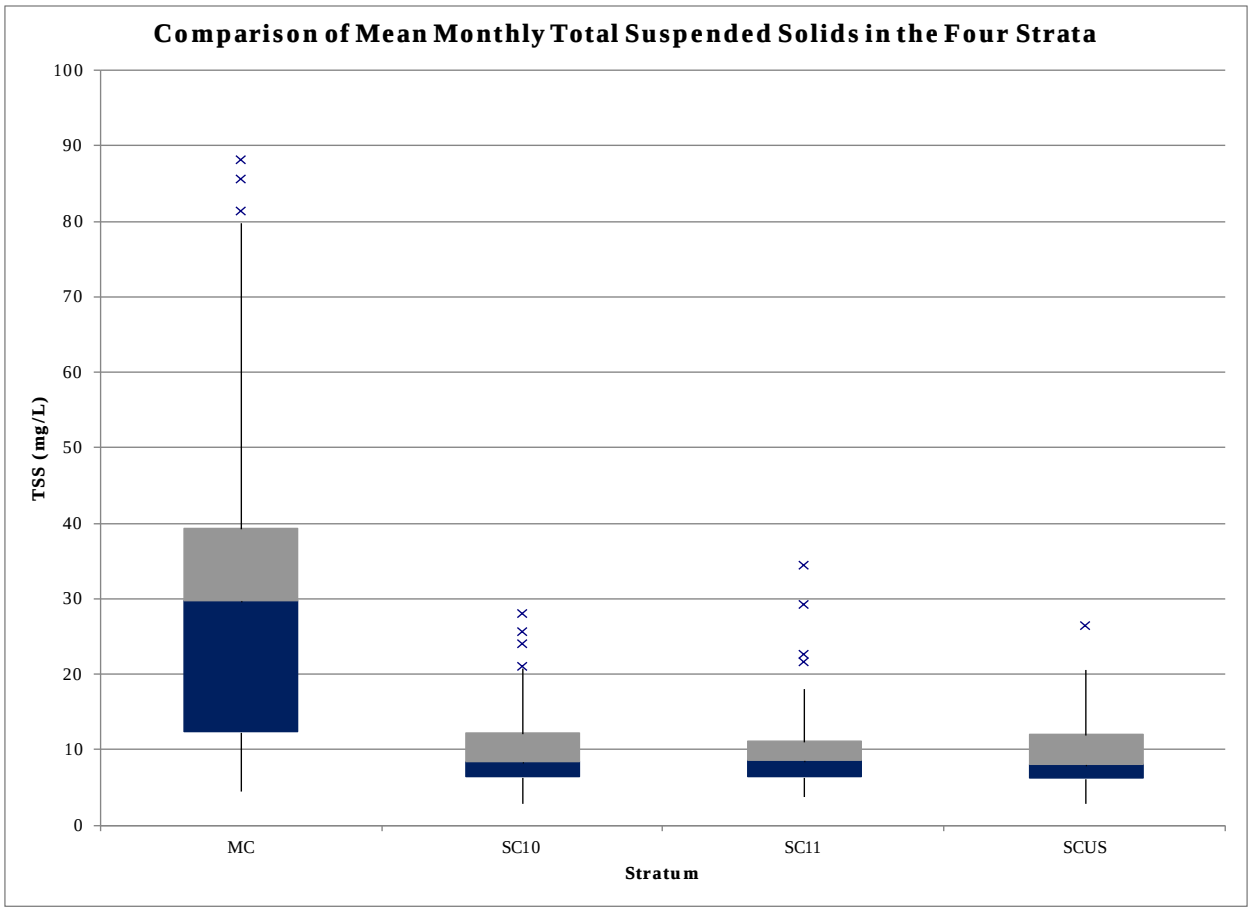


Figure 2-20 Comparison of Mean Monthly TSS concentrations in the Four Strata of Sarasota Bay

Figure 2-21 compares mean monthly turbidity for the four strata. No significant differences was noted, with mean turbidity values between 2 and 3 NTUs.

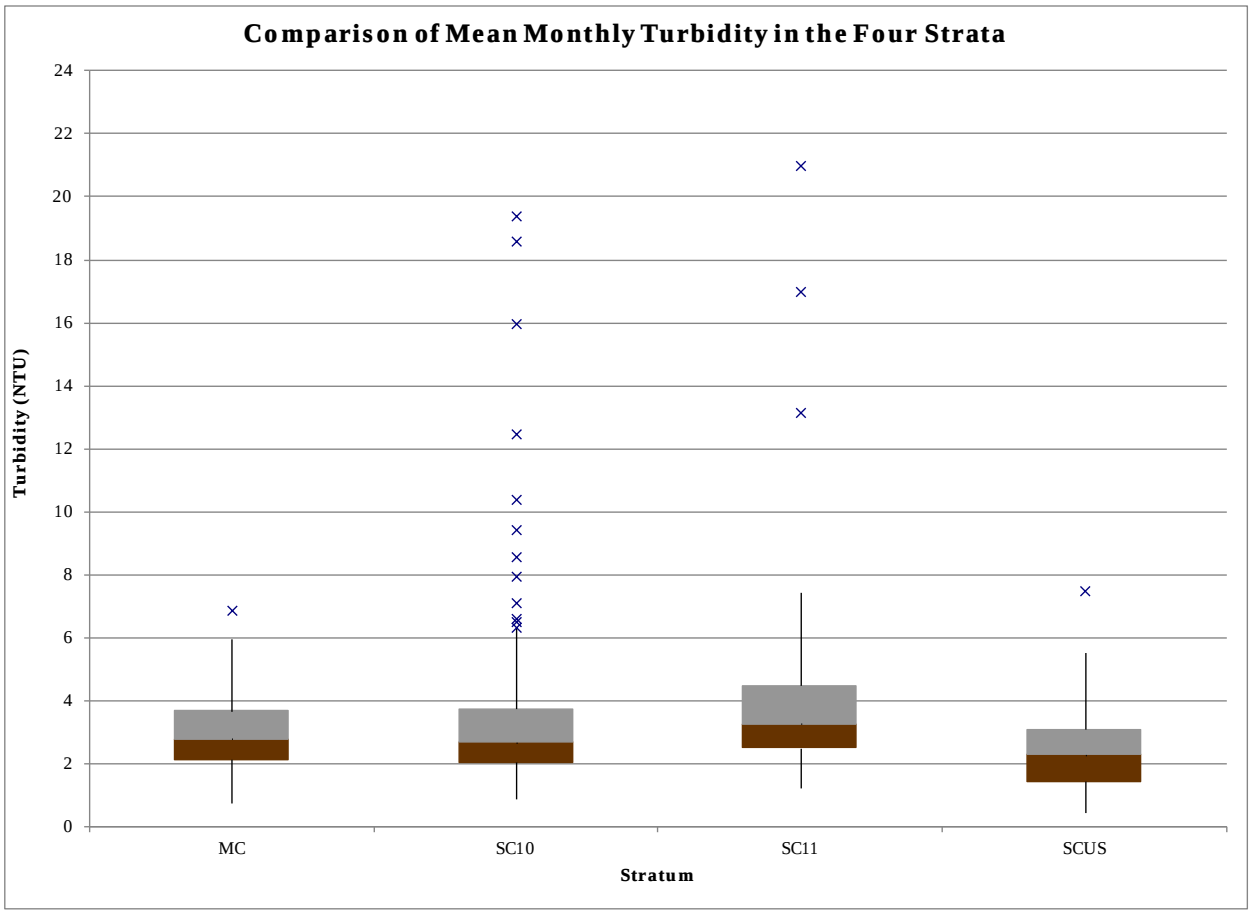


Figure 2-21 Comparison of Mean Monthly Turbidity in the Four Strata of Sarasota Bay

Figure 2-22 similarly show similar light attenuation means across the four strata. Mean values are all in the range of 0.6 to 0.7 m^{-1}.

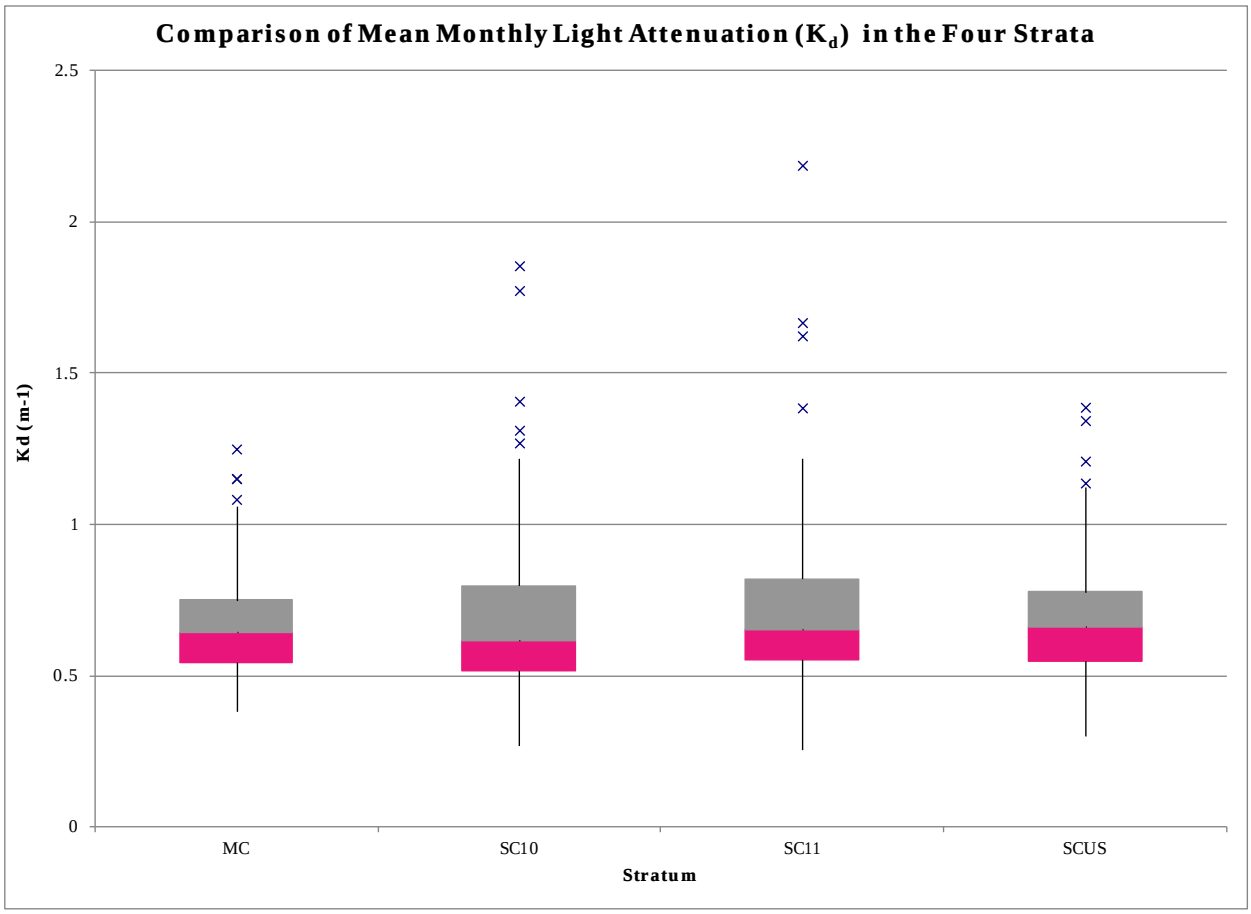


Figure 2-22 Comparison of Mean Monthly Light Attenuation in the Four Strata of Sarasota Bay

2.4.4 Water Quality Status

Water quality status is assessed relative to several endpoints—the chlorophyll *a* target, threshold, and NNC adopted by SBEP (January 15 and June 4, 2010, respectively) and the current State standard for DO in marine waters. These targets are further discussed below in Section 5.4 and Section 6.6.3.

The status of water quality in Sarasota Bay relative to the SBEP chlorophyll *a* target, threshold, and NNC has been examined. Figures 2-23 through 2-26 and Table 2-1 present the results.

Table 2-1 Number of DO Samples and the Number Less than 4 mg/L from Sarasota Bay by Year

Year	Number of DO Samples	Number of DO Samples < 4 mg/L
1995	9	0
1996	56	0
1997	53	0
1998	161	0
1999	180	0
2000	169	0
2001	228	0
2002	237	0
2003	222	2
2004	185	0
2005	235	2
2006	235	1
2007	234	1
2008	236	0
2009	220	0

Figure 2-23 compares the annual geometric mean chlorophyll *concentrations* to the SBEP chlorophyll *a* target and threshold for Sarasota Bay. The target concentration of 5.2 µg/L represents an upper limit of desirable levels of chlorophyll *a* for the bay. The threshold of 6.1 µg/L is the minimum concentration above which adverse impacts to the bay's ecology may become evident. As can be seen, annual chlorophyll *a* concentrations for 1998 through 2010 have been consistently lower than the target, i.e., within the range of desirable levels.

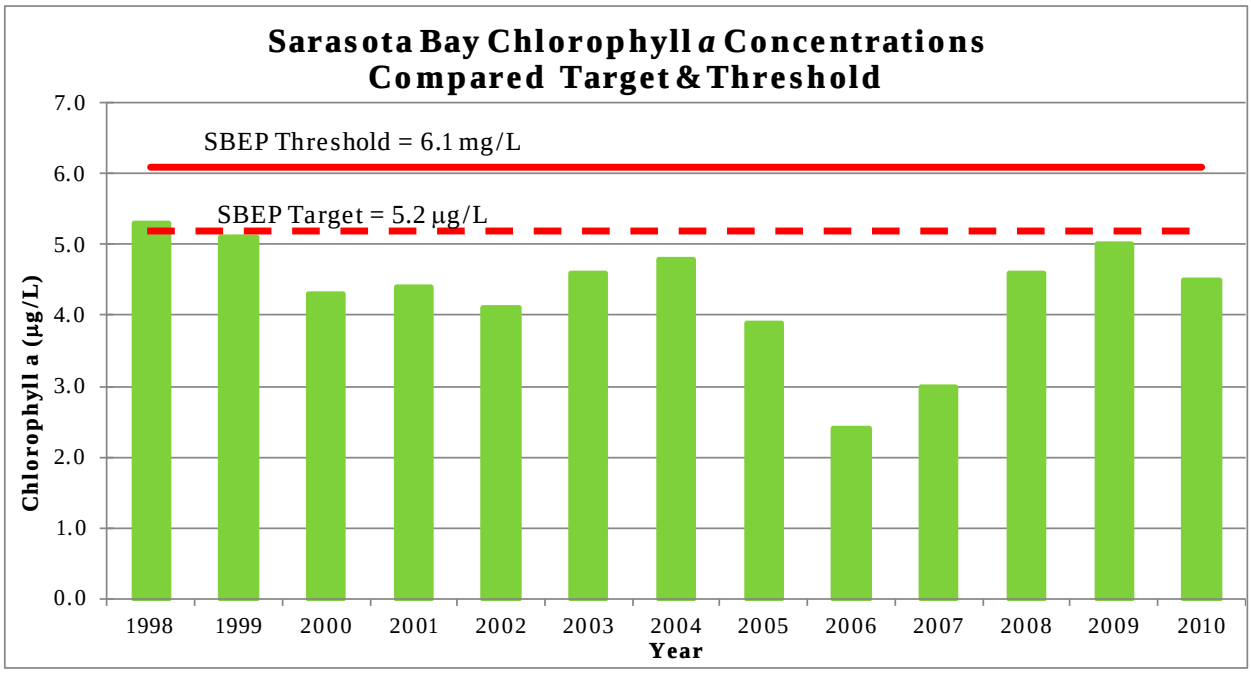


Figure 2-23 Comparison of Geometric Mean Chlorophyll *a* Concentrations to the SBEP Chlorophyll *a* Target (6.1 µg/L) and Threshold (5.2 µg/L) for Sarasota Bay

Figure 2-24 compares the annual geometric mean TN concentrations to the TN numeric criterion developed by SBEP for Sarasota Bay. Ambient TN mean concentrations are below the criterion for all years except 2008. Ambient TN concentrations range from 0.25 to under 0.4 mg/L. The TN criterion, which is calculated each year, is over 0.6 mg/L for all years except 2008.

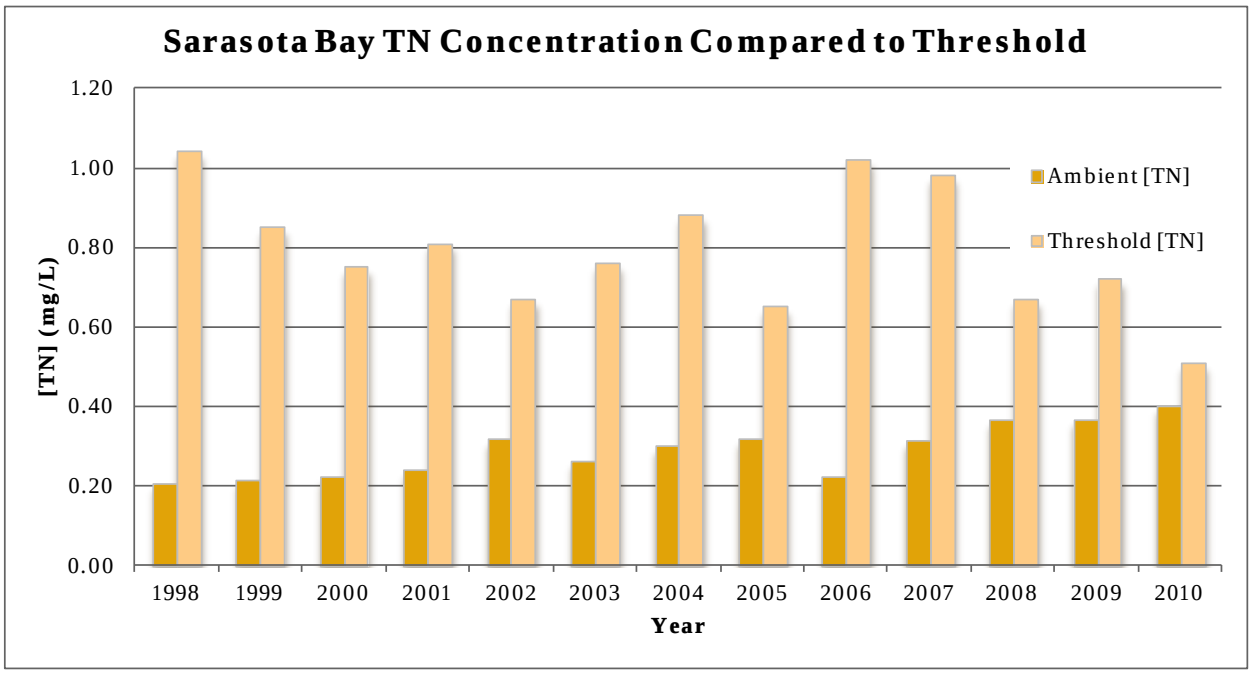


Figure 2-24 Comparison of Geometric Mean TN concentrations to the SBEP TN Numeric Criterion for Sarasota Bay.
TN criterion is calculated annually.

Figure 2-25 compares the annual geometric mean TP concentrations to the TP numeric criterion developed by SBEP for Sarasota Bay (0.19 mg/L). Ambient annual mean TP concentrations do not exceed the numeric criterion. Ambient concentrations remain under 0.18 mg/L and in all but 2 years are below 0.15 mg/L.

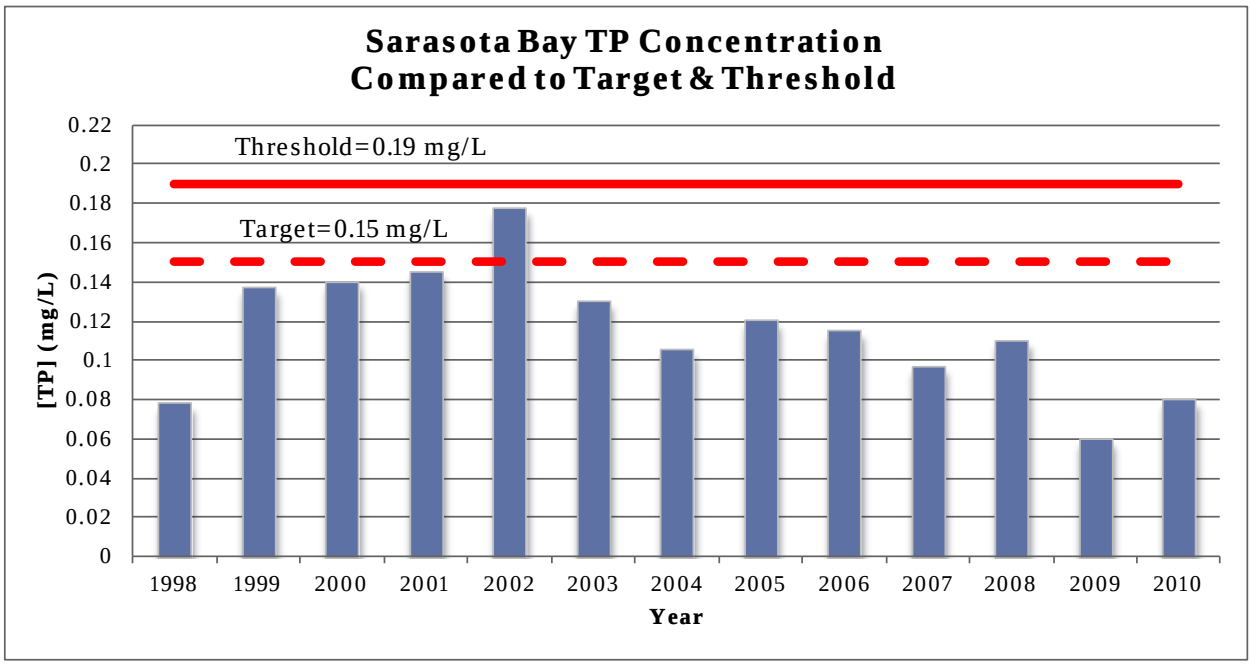


Figure 2-25 Comparison of Geometric Mean TP concentrations to the SBEP TP Numeric Criterion for Sarasota Bay (0.19 mg/L)

The State standard for DO in Class 3 marine waters is 4 mg/L at all places and all times. Generally, the IWR identifies a waterbody as being impaired if the percentage of samples less than 4 mg/L exceeds 10%. Table 2-1 presents the number of DO samples in Sarasota Bay less than 4 mg/L for 1998–2009. The maximum percent of samples not meeting the DO criterion for any year was 0.9%, which occurred in 2003. Thus, the vast majority of samples in Sarasota Bay met the State standard during 1998–2009.

Figure 2-26 summarizes the percentage of DO samples less than 4 mg/L by calendar month in Sarasota Bay for 1998–2009. The percentage of samples less than 4 mg/L never exceeded 2 percent; therefore, at a minimum 98 percent of all DO samples taken in Sarasota Bay within all calendar months met the State standard.

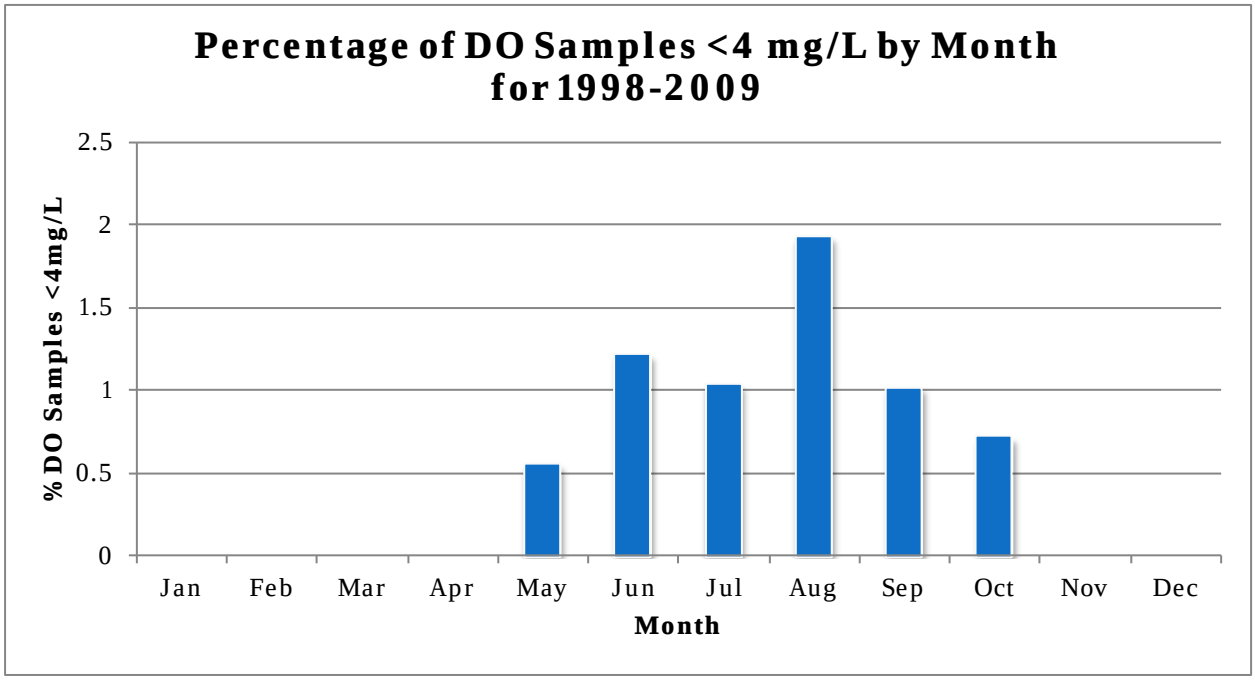


Figure 2-26 Percentage of DO Samples <4 mg/L in Sarasota Bay by Calendar Month for 1998–2009

2.4.5 Data Collection

No data gaps were found during this analysis. Therefore, we do not recommend additional monitoring or data collection.

3.0 TRIBUTARY WATER QUALITY STATUS AND TRENDS

3.1 OBJECTIVE

This section presents the approach, data used, and summary of results associated with examining the water quality status and trends in the Sarasota Bay tributaries.

3.2 APPROACH

Ambient water quality data were examined to identify any significant temporal or spatial trends in Sarasota Bay tributaries. Temporal trends were visually examined because none of the time series is of adequate length to analyze statistically. Spatial trends were examined graphically. The freshwater numeric criteria for TN and TP developed by FDEP were compared to the ambient water quality data from the freshwater portions of these tributaries. Lastly, the statuses of the Sarasota Bay tributaries with regard to the IWR were summarized.

3.3 DATA USED

- Ambient water quality data provided by Sarasota and Manatee Counties and additional data obtained from the IWR database.
- Draft revised Rule Chapter 62-302, FAC Surface Water Quality Standards. November 1, 2011 (FDEP, 2011a).
- NNC briefing for Environmental Regulatory Commission. November 3, 2011 (FDEP, 2011b).
- Impaired Waters Rule Chapter 62-303. FAC (FDEP, 2011c).

3.4 RESULTS

Figure 3-1 shows the Sarasota Bay tributaries and ambient water quality sampling stations. Tributaries include Hudson Bayou to the south; Whitaker Bayou to the north; and Bowlees Creek, the northernmost tributary to the estuary, in Manatee County.

- Whitaker Bayou has three sampling stations (WB10, WB11, and WB12). FDEP identified all three as freshwater stations.
- Hudson Bayou has three sampling stations (HB6, HB7, and HB8). FDEP identified HB6 as tidal and HB7 and HB8 as freshwater.
- Bowlees Creek has one sampling station (BC1). FDEP identified BC1 as tidal.

Figure 3-1 Locations of the Sarasota Bay Tributary Water Quality Sampling Stations

3.4.1 Temporal and Spatial Variation

3.4.1.1 Whitaker Bayou

Figures 3-2 through 3-7 present variation over time in conductivity, chlorophyll *a*, TN, TP, DO, and color in Whitaker Bayou. Figure 3-2 shows conductivity at the three sampling stations. With very few exceptions, conductivity remained under 1,000 µS/cm, which is less than 2 parts per thousand salinity. All three stations had a single excursion in 1998, with concentrations significantly higher than normal. The downstream station, WB10, also had an extremely high value of 33,000 µS/cm in 2000. Visual inspection of the time series revealed no temporal trend at any station.

Figure 3-3 shows chlorophyll *a* concentrations from the three Whitaker Bayou stations. The downstream station, WB10, had the lowest concentrations of the three stations, with concentrations of 2 µg/L or less with two exceptions. Station WB11 had higher concentrations, with most concentrations between 1 and 4.5 µg/L and two concentrations over 8 µg/L. Chlorophyll *a* concentrations from Station WB12 generally ranged from less than 1 µg/L to 5 µg/L, with three concentrations over 15 µg/L. Visual inspection of the time series revealed no temporal trend at any station.

Figure 3-4 shows TN concentrations for Whitaker Bayou. Stations WB10 and WB11 generally remained less than 1.0 mg/L, while Station WB12 had more frequent concentrations between 1.0 and 1.6 mg/L. Visual inspection of the time series revealed no temporal trend at any station. Generally, the temporal variation in TN concentrations was similar among the three stations, perhaps due to changes in precipitation and subsequent streamflow.

Figure 3-5 shows TP concentrations for Whitaker Bayou. Station WB10 generally ranged from 0.15 to 0.4 mg/L, with a maximum of 0.64 mg/L. TP concentrations from Stations WB11 and WB12 were in the same range, with very few concentrations greater than 0.5 mg/L. Visual inspection of the time series revealed no temporal trend at any station.

Figure 3-6 shows DO concentrations in Whitaker Bayou. The data record was discontinuous but indicates that DO concentrations from Station WB10 usually remained above the 4.0-mg/L State standard, with two measurements reported below. DO concentrations from Stations WB11 and WB12 had more low concentrations, but all have the majority of samples above 4.0 mg/L. Visual inspection of the time series revealed no temporal trend at any station.

Figure 3-7 shows color at the three Whitaker Bayou stations. A visual inspection of Station WB10 data showed an increasing trend, with concentrations rising from 40 to 60 PtCo units to 60 to 100 PtCo units. A shift in color appeared to have occurred in 1999, although the period of record is too short to draw firm conclusions. Station WB11 had color concentrations in a similar range, but color at Station WB12 was higher, typically between 70 and 120 PtCo units.

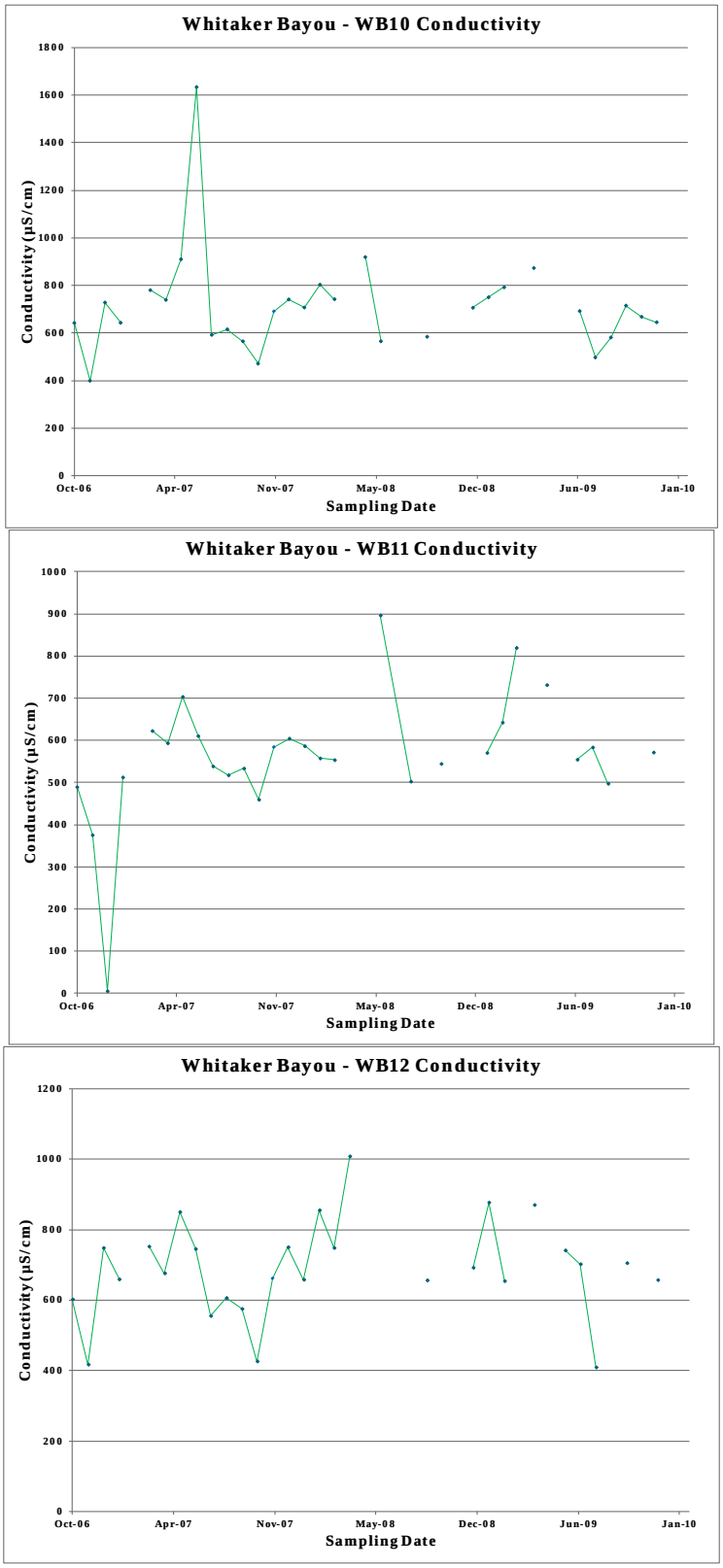


Figure 3-2 Conductivity (µS/cm) Observations from the Whitaker Bayou Water Quality Sampling Stations

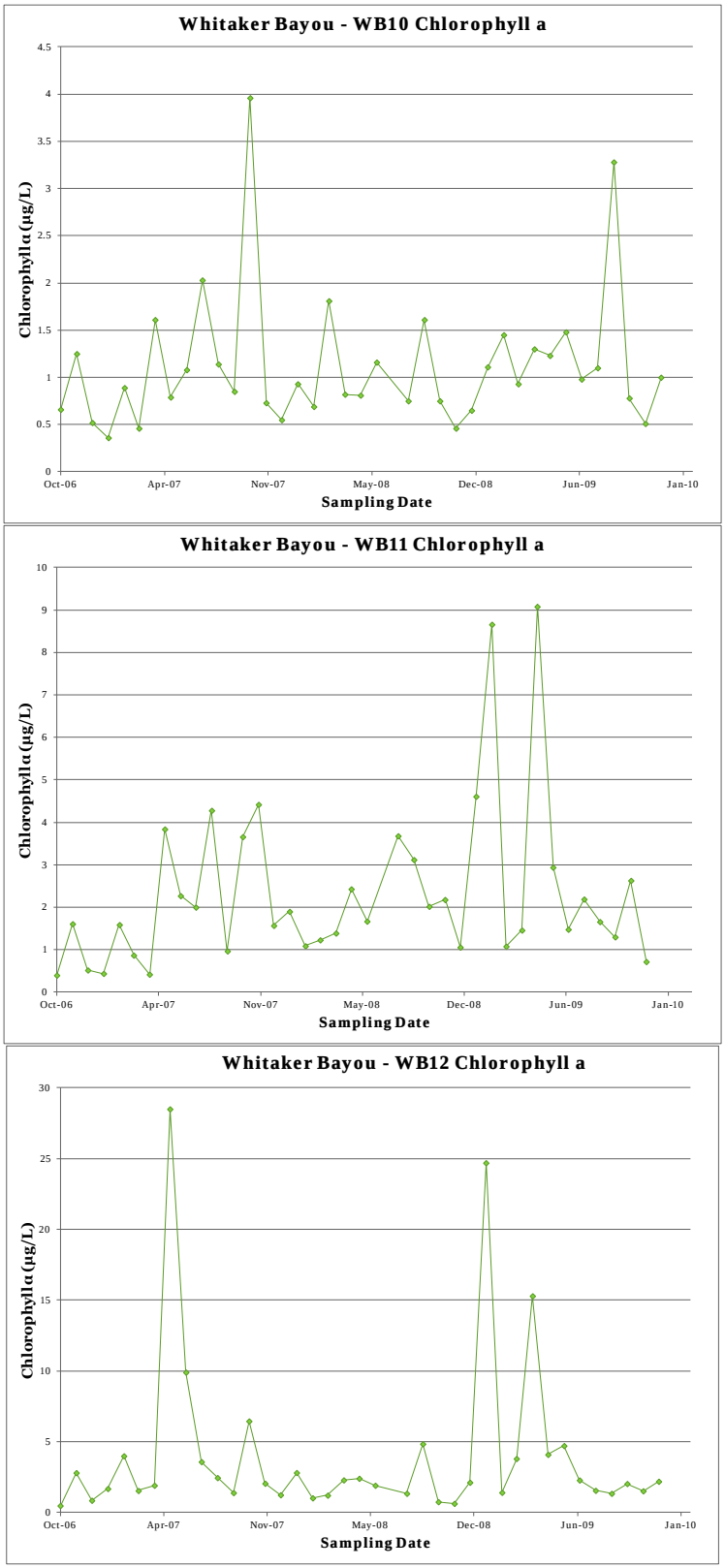


Figure 3-3 Chlorophyll *a* (µg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations

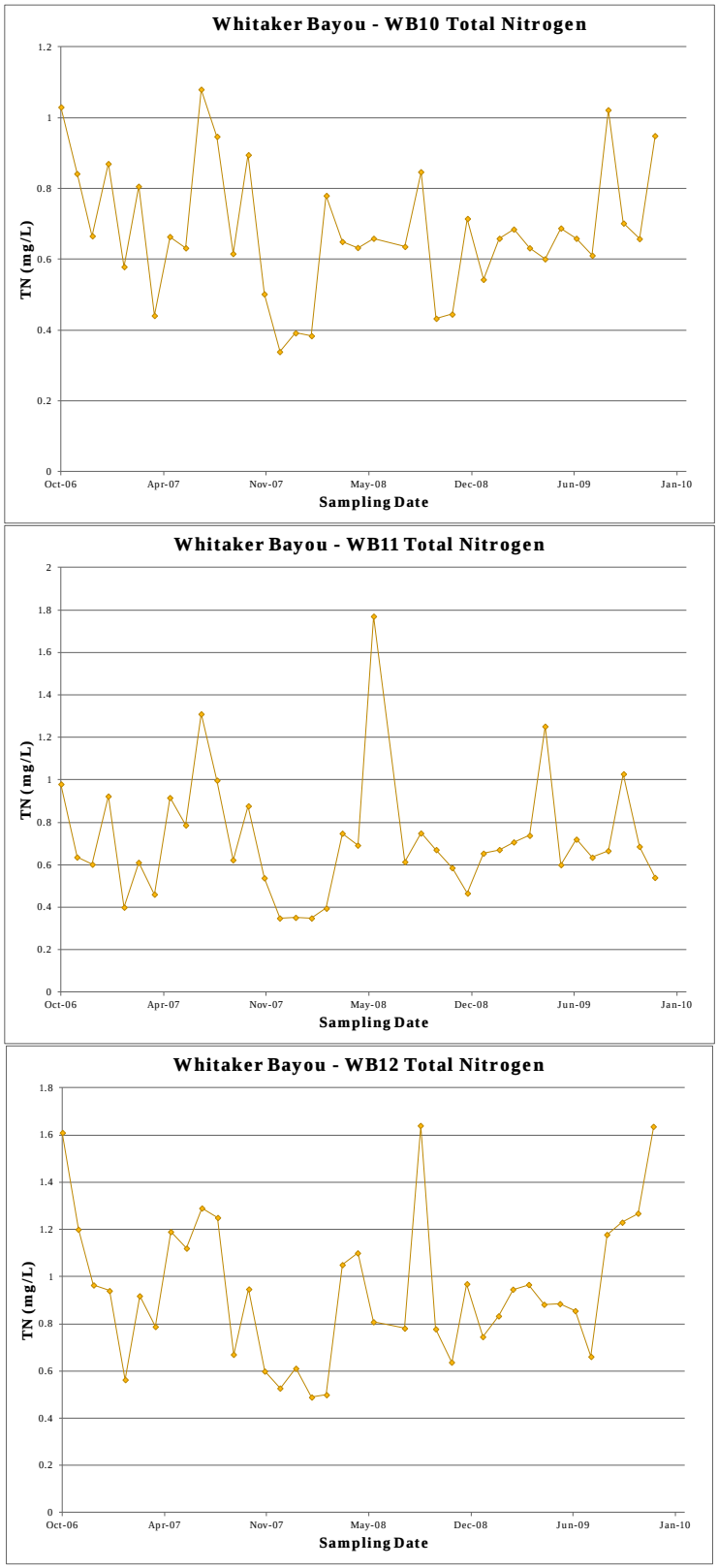


Figure 3-4 TN (mg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations

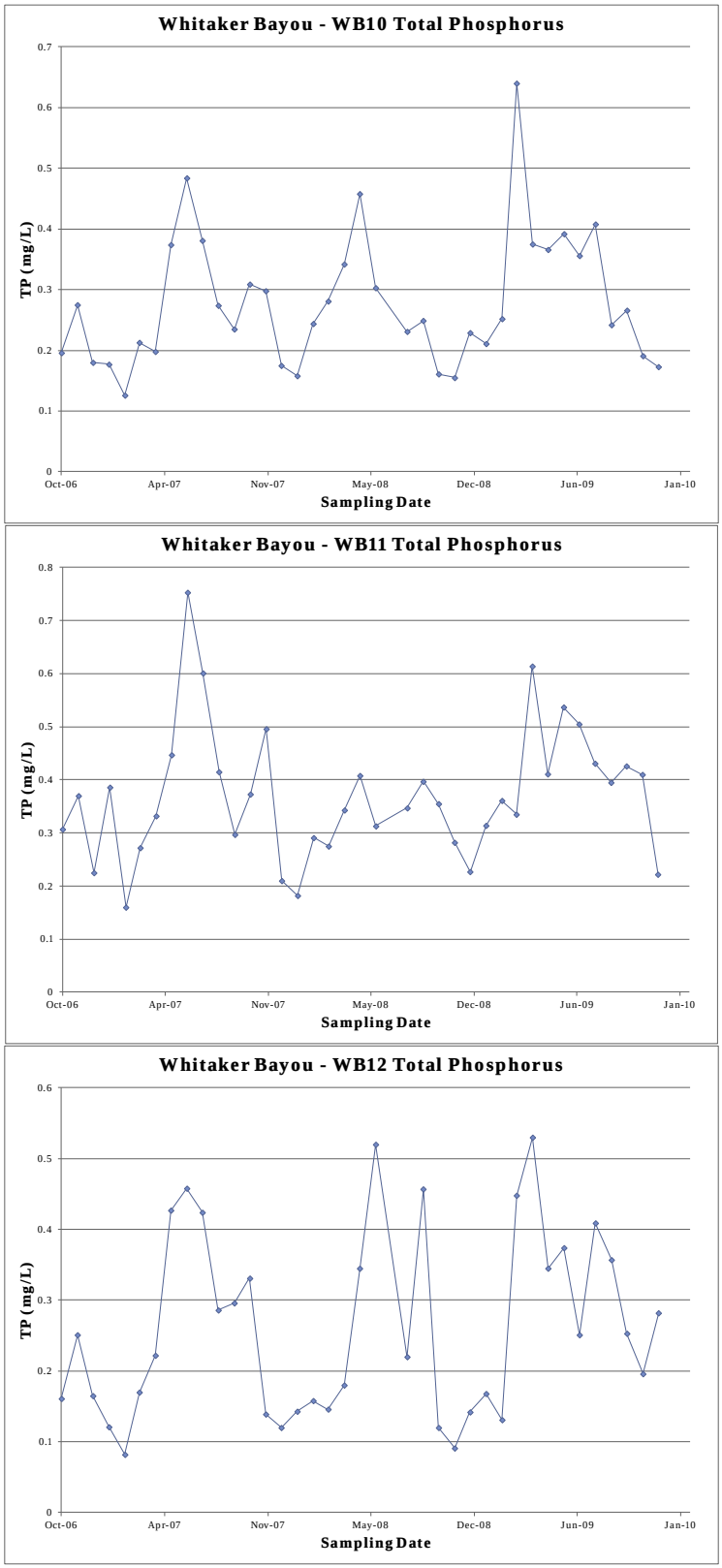


Figure 3-5 TP (mg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations

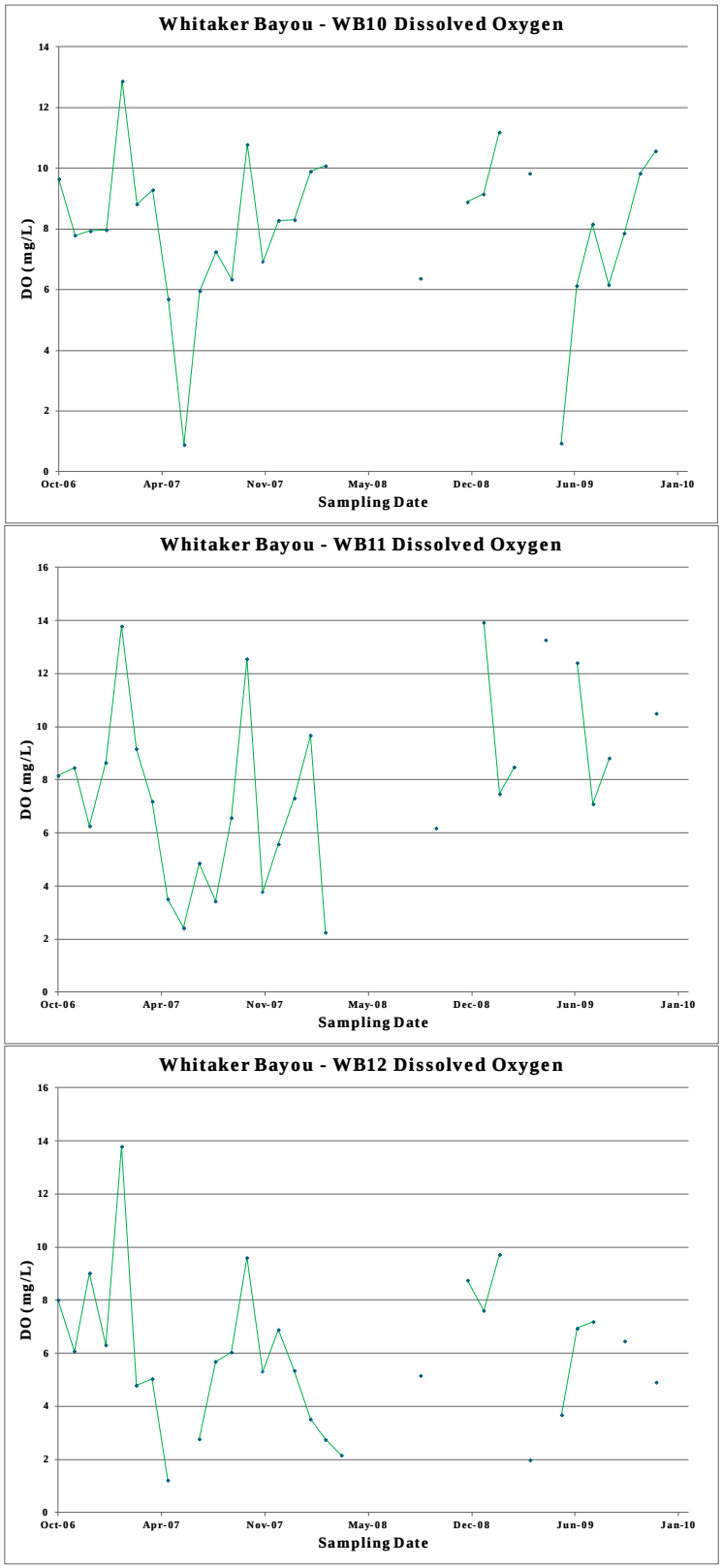


Figure 3-6 DO (mg/L) Concentrations from the Whitaker Bayou Water Quality Sampling Stations

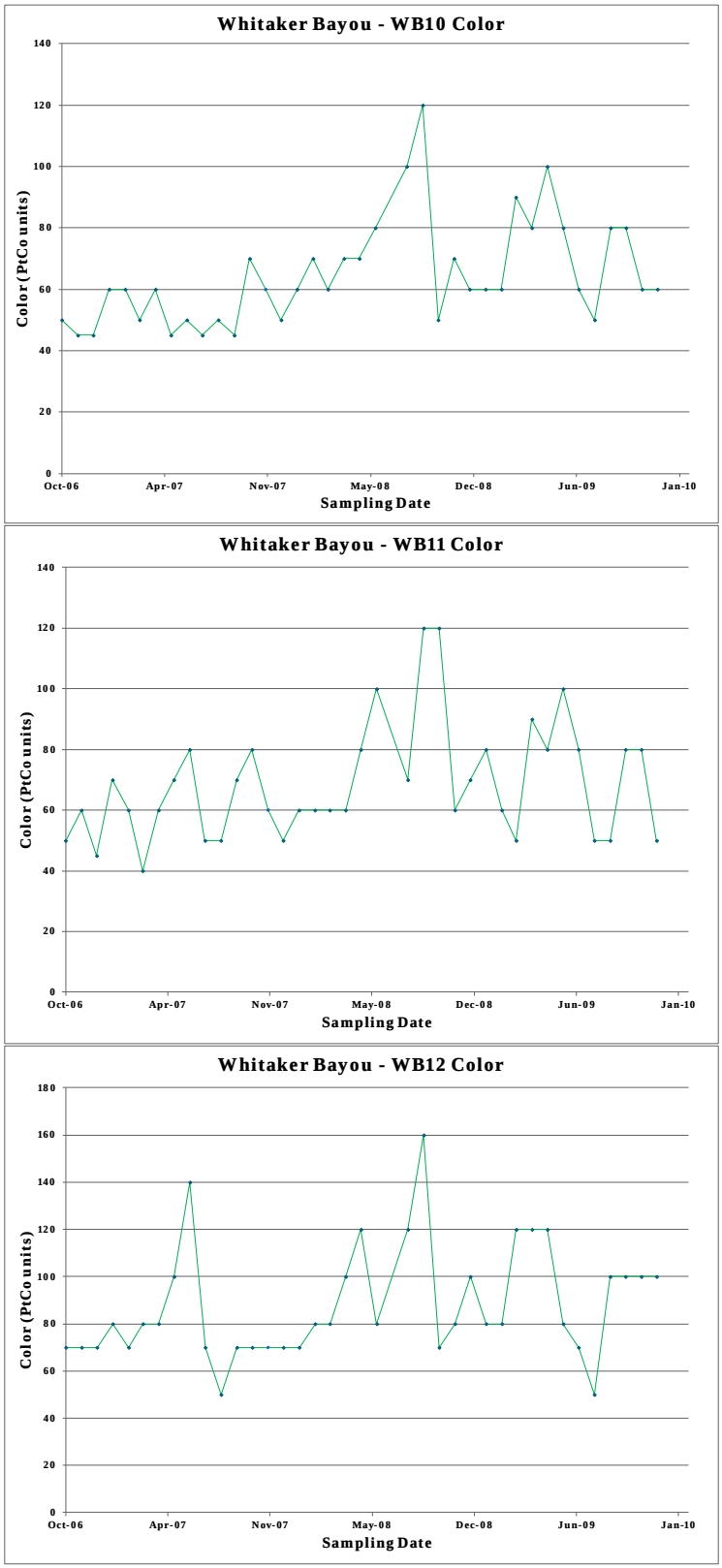


Figure 3-7 Color (PtCo units) Observations from the Whitaker Bayou Water Quality Sampling Stations

3.4.1.2 Hudson Bayou

Figures 3-8 through 3-13 show variation over time in conductivity, chlorophyll *a*, TN, TP, DO, and color in Hudson Bayou.

Figure 3-8 shows conductivity at the three sampling stations. Station HB6, a tidal station, had conductivity consistent with that designation, with most concentrations between 10,000 and 40,000 µS/cm. A wide range of conductivities were observed over time at Station HB6 that likely reflects the influence of time-varying freshwater inputs from the upstream watershed. Except for two events, the conductivities at Stations HB7 and HB8 were typically less than 1,000 µS/cm.

Figure 3-9 presents chlorophyll *a* concentrations from the Hudson Bayou stations. Station HB6 concentrations were generally less than 8 µg/L until 2000. The temporal patterns at Stations HB7 and HB8 were similar to that observed at HB6, with generally low concentrations of chlorophyll *a* until a marked increase in 2000.

Figure 3-10 shows TN concentrations in Hudson Bayou. TN concentration from Stations HB6 and HB8 were generally in the range of 0.6 to 1.2 mg/L, while those observed from Station HB7 were lower. A slight increasing temporal trend in TN concentrations appeared to occur at Station HB7.

Figure 3-11 shows TP concentrations from Hudson Bayou. HB7 had lower concentrations, generally less than 0.5 mg/L, while HB6 and HB8 were higher typically between 0.35 to 0.65 mg/L and 0.45 to 0.90 mg/L, respectively.

Figure 3-12 shows Hudson Bayou DO concentrations. Although the record was discontinuous, DO concentrations from Station HB7 appeared to have an increasing trend over the sampling period with most of the most recent concentrations above 4 mg/L. DO concentrations less than 2 mg/L were frequently observed at Stations HB6 and HB8.

Figure 3-13 shows that color concentrations at all three stations on Hudson Bayou appeared to have a modest increasing trend. Color at Station HB7 was typically lower than that at Stations HB6 and HB8.

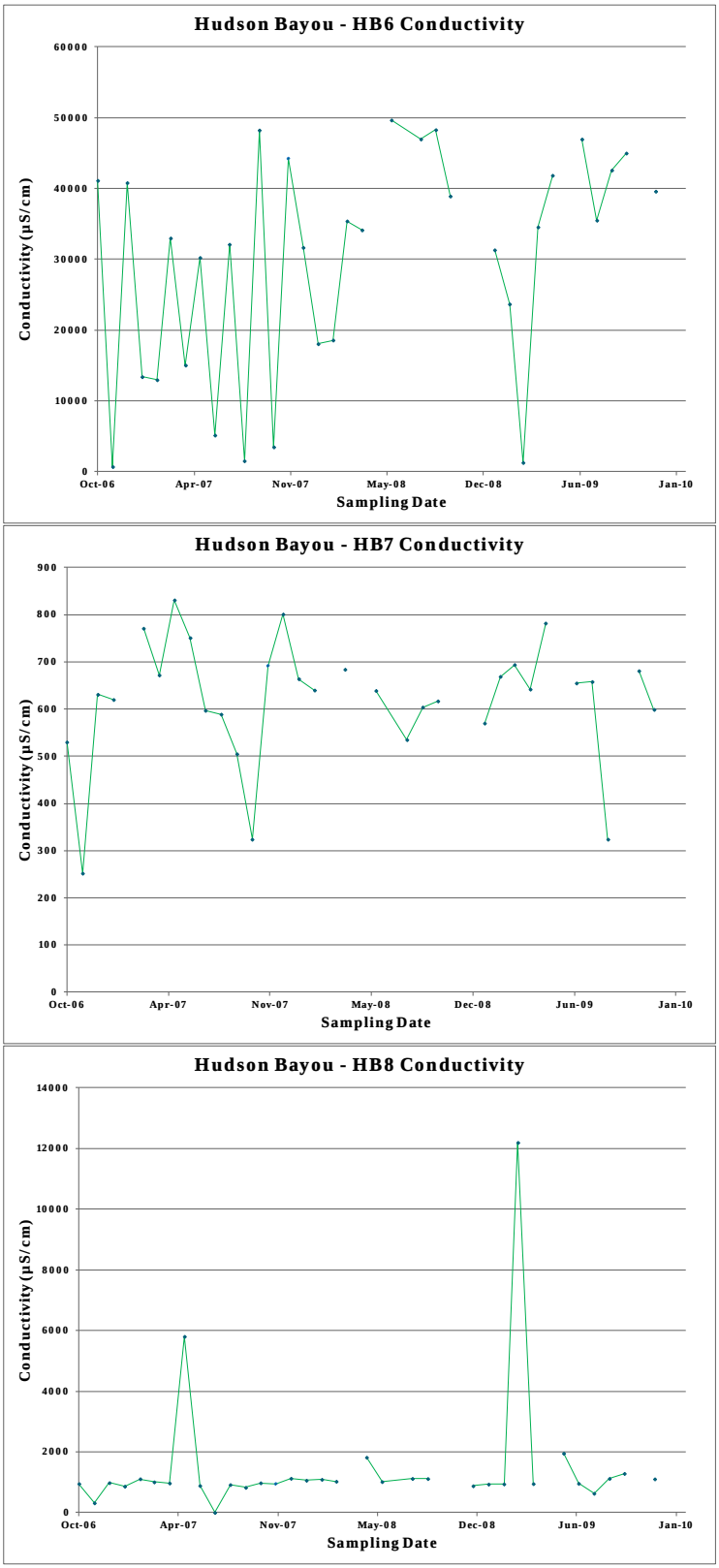


Figure 3-8 Conductivity (µS/cm) Observations from the Hudson Bayou Water Quality Sampling Stations

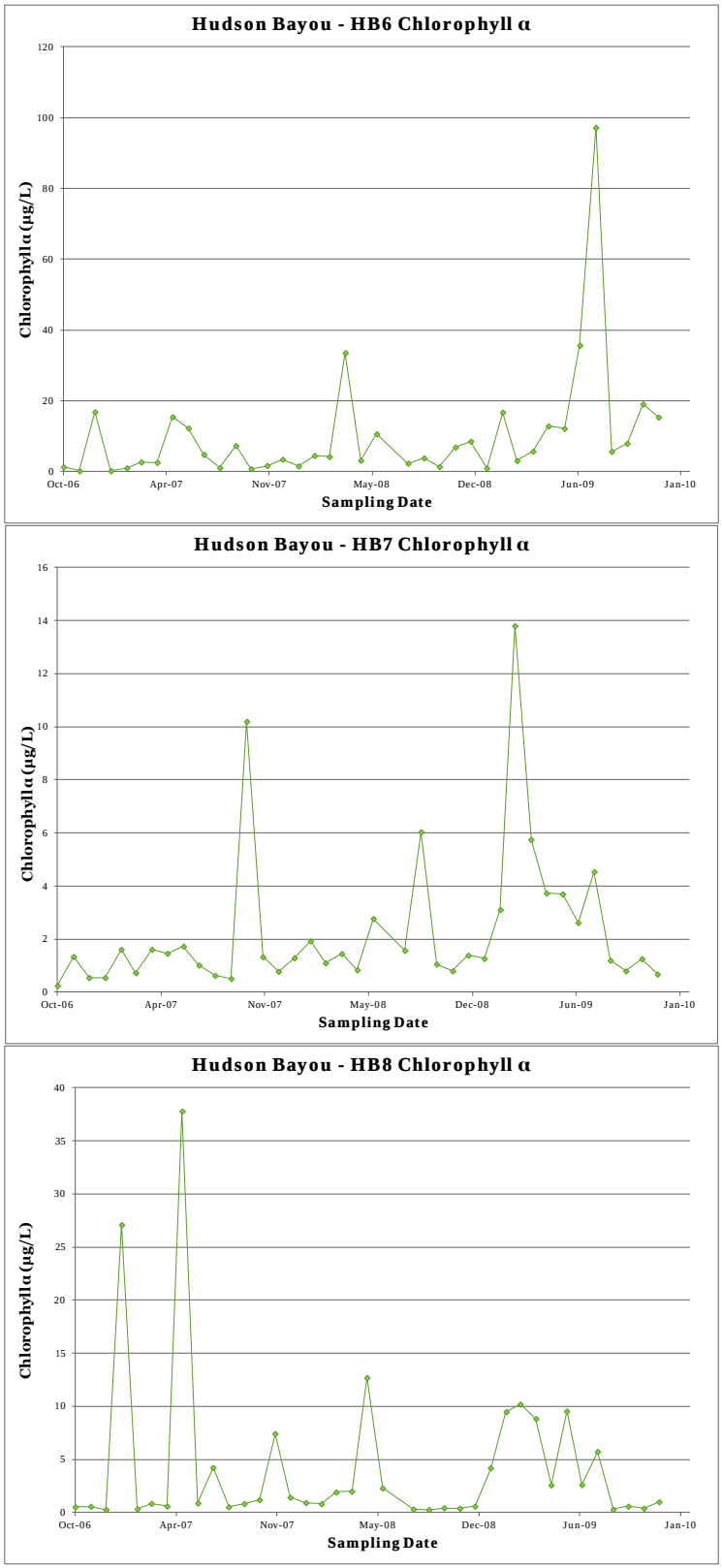


Figure 3-9 Chlorophyll *a* (µg/L) concentrations from the Hudson Bayou Water Quality Sampling Stations

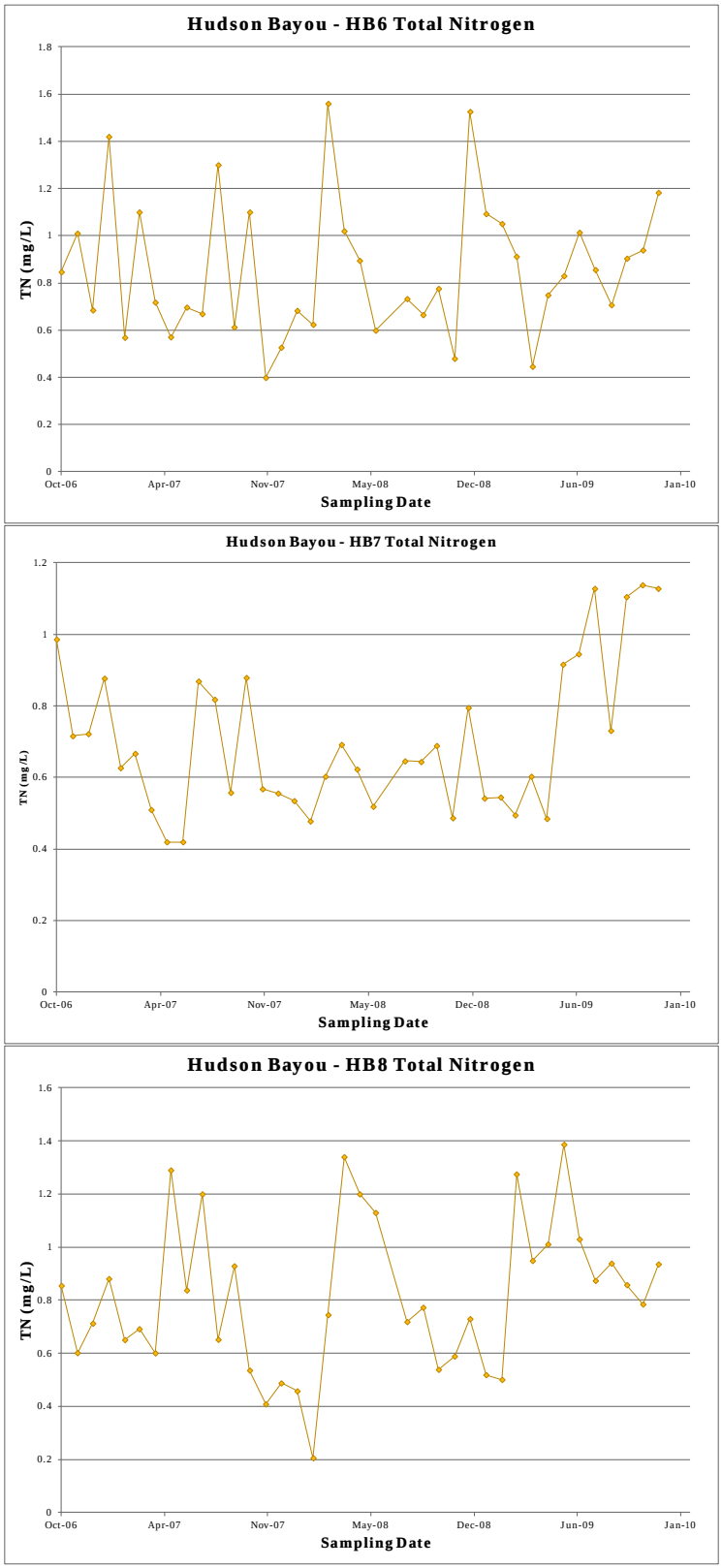


Figure 3-10 TN (mg/L) Concentrations from the Hudson Bayou Water Quality Sampling Stations

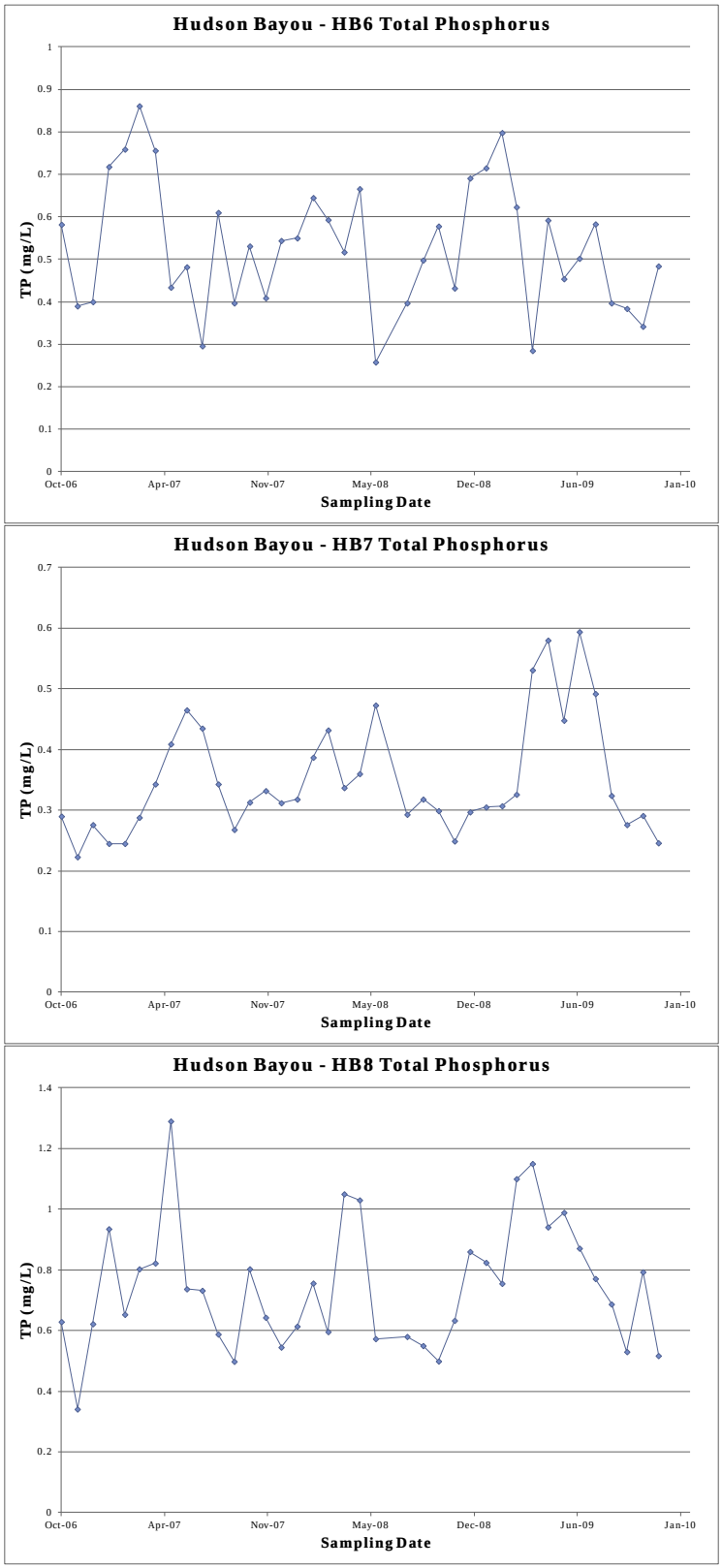


Figure 3-11 TP (mg/L) Concentrations from the Hudson Bayou Water Quality Sampling Stations

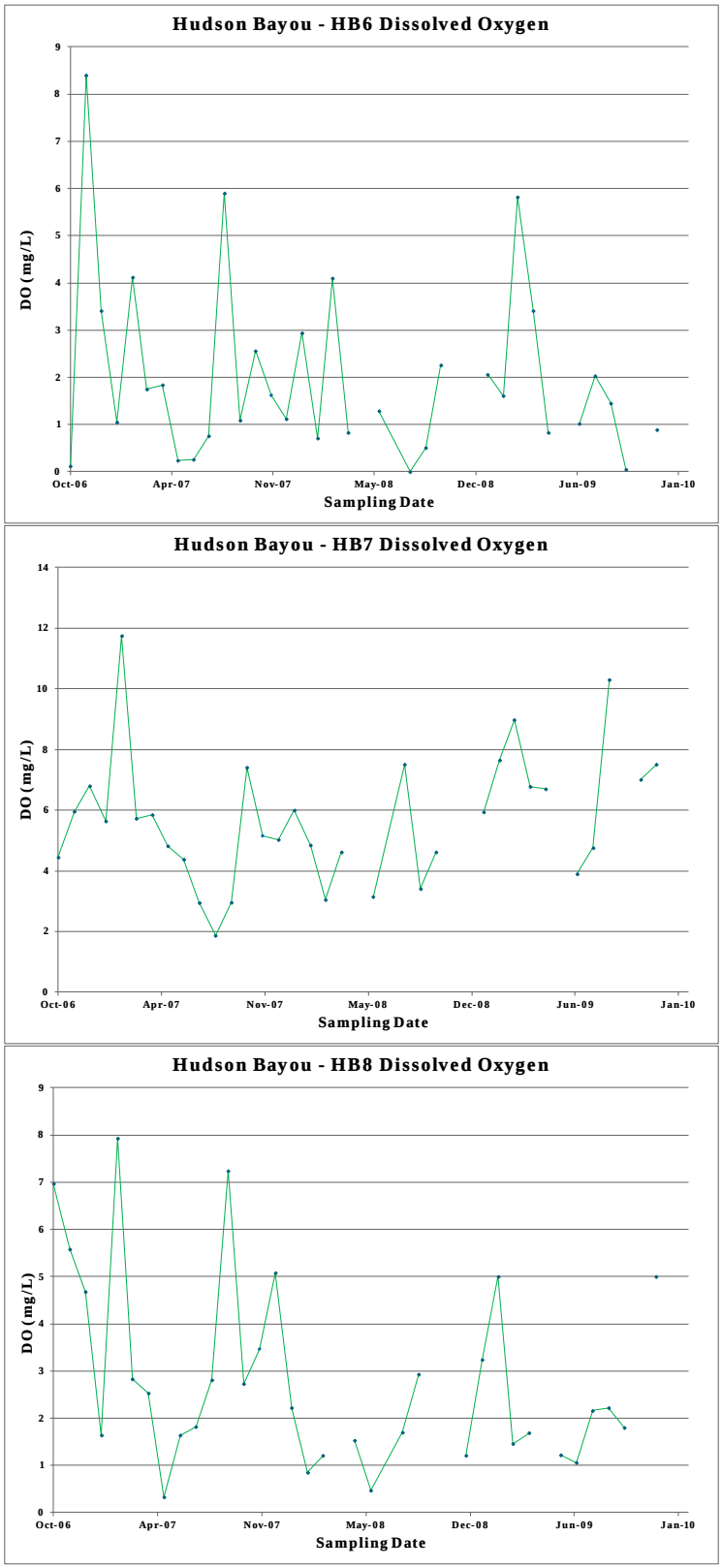


Figure 3-12 DO (mg/L) Concentrations from the Hudson Bayou Water Quality Sampling Stations

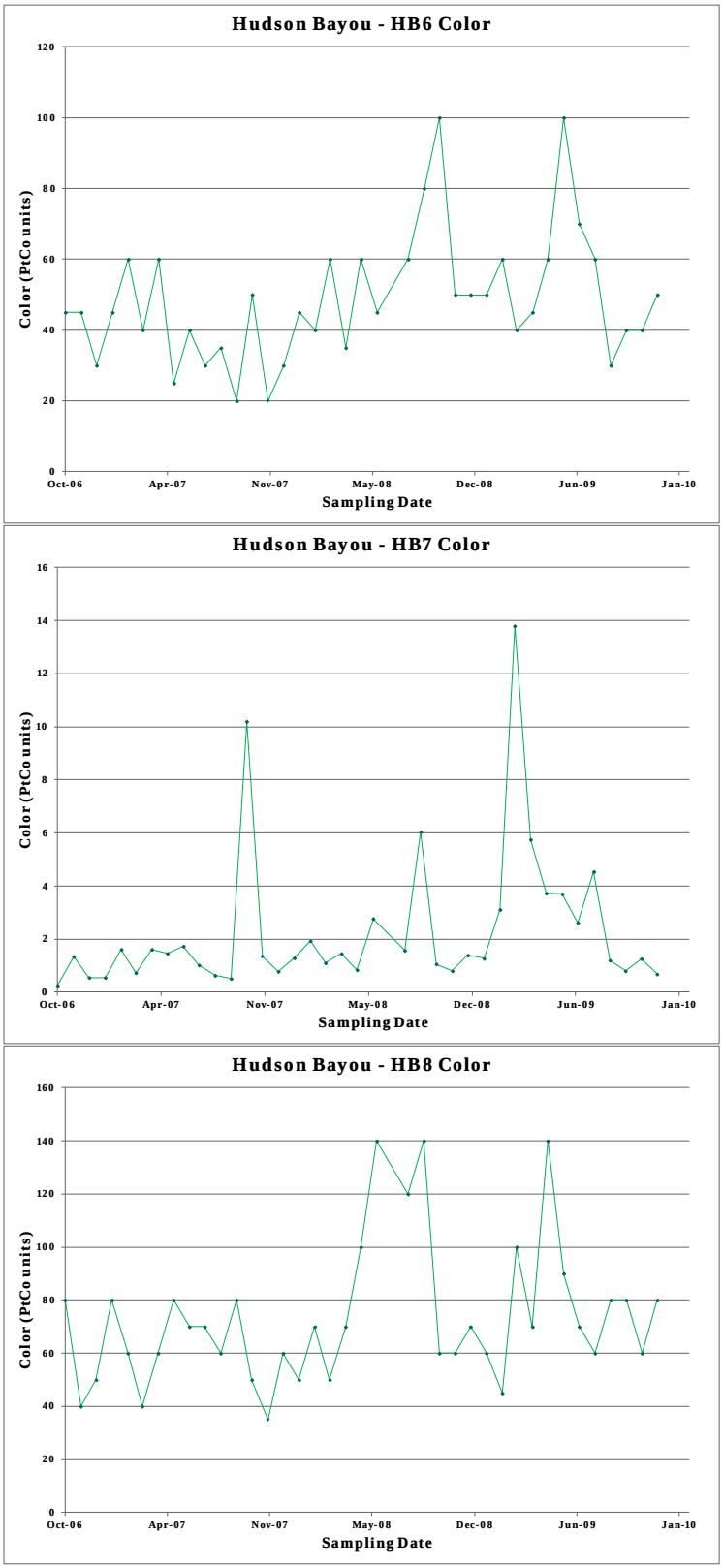


Figure 3-13 Color (PtCo units) Observations from the Hudson Bayou Water Quality Sampling Stations

3.4.1.3 Bowlees Creek

Figures 3-14 through 3-19 present water quality data for Bowlees Creek Station BC1, which is designated as tidal. The period of record for Bowlees Creek was 10 years, which is significantly longer than that of Hudson or Whitaker Bayous.

Conductivity concentrations at BC1 reflect its tidal designation (Figure 3-14). No temporal trend was evident.

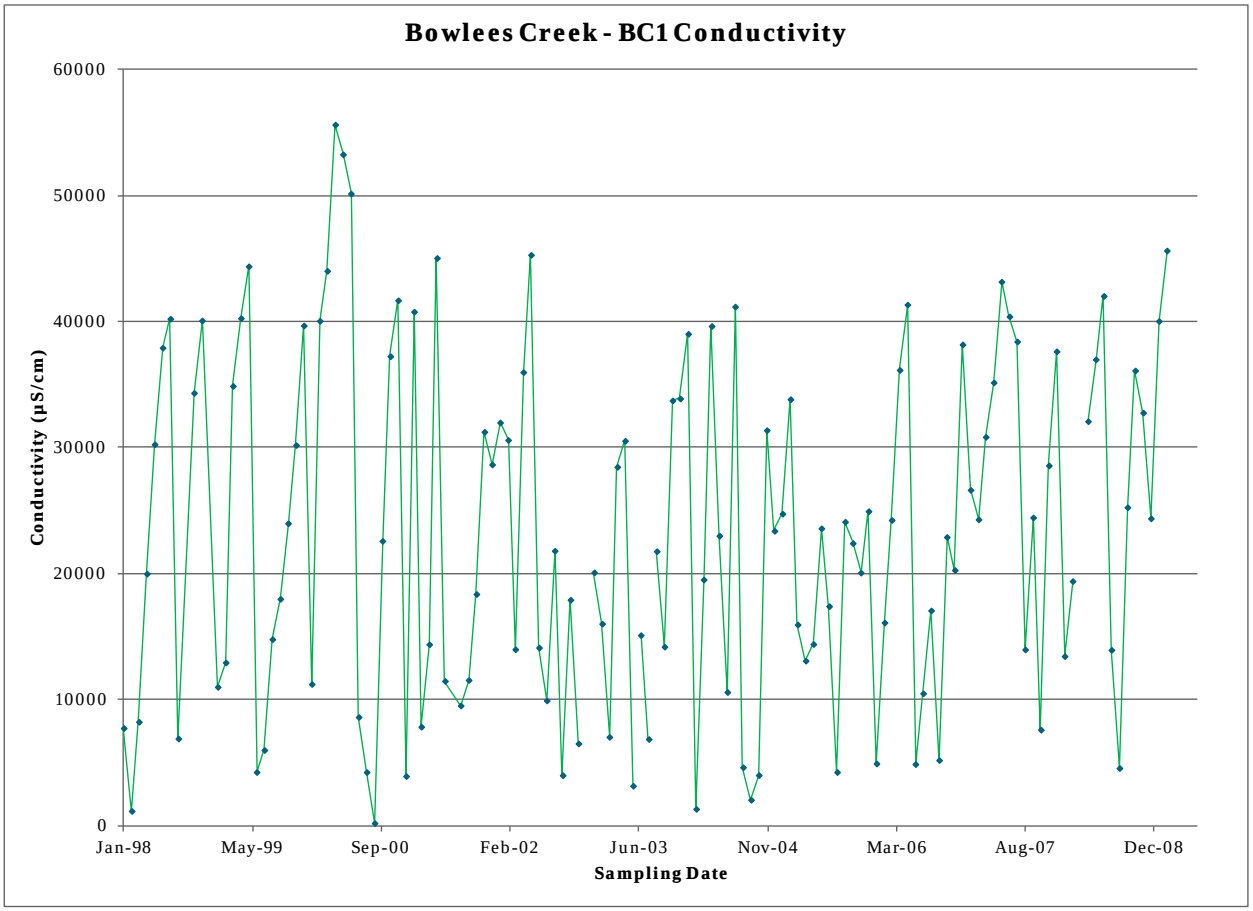


Figure 3-14 Conductivity (µS/cm) Observations from the Bowless Creek Water Quality Sampling Station

Figure 3-15 presents chlorophyll *a* concentrations for Bowlees Creek. These concentrations were significantly higher than those observed from either Whitaker Bayou or Hudson Bayou. Many of the concentrations were between 4 and 20 µg/L, with numerous observations greater than 20 µg/L.

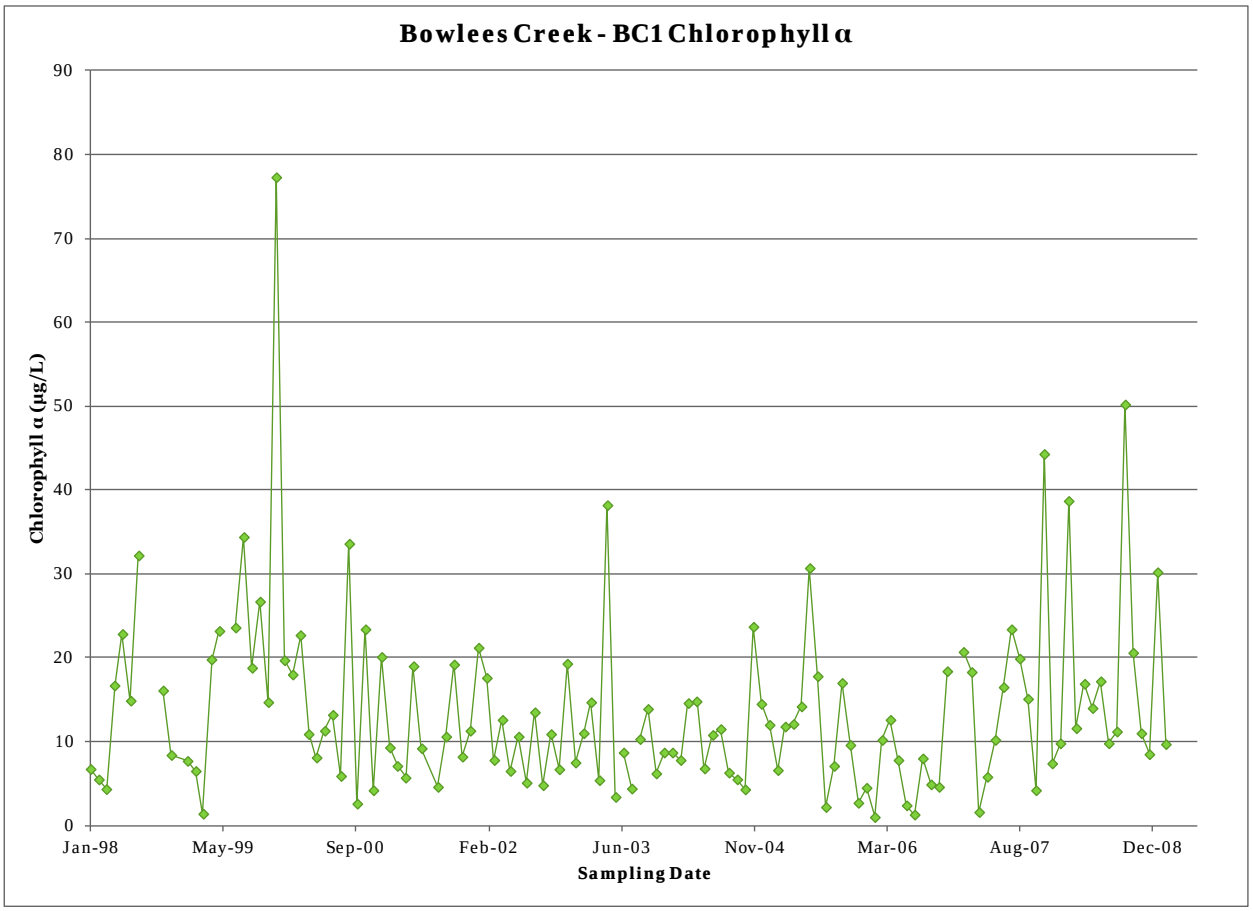


Figure 3-15 Chlorophyll *a* (µg/L) Concentrations from the Bowless Creek Water Quality Sampling Station

Figure 3-16 shows TN concentrations in Bowlees Creek. Most of the concentrations were between 0.6 and 2.0 mg/L, which was also higher than either Whitaker or Hudson Bayous. TN concentrations have been lower since some elevated concentrations were observed at the end of 2005/beginning of 2006. Since that period, the TN concentrations have typically been less than 1.5 mg/L.

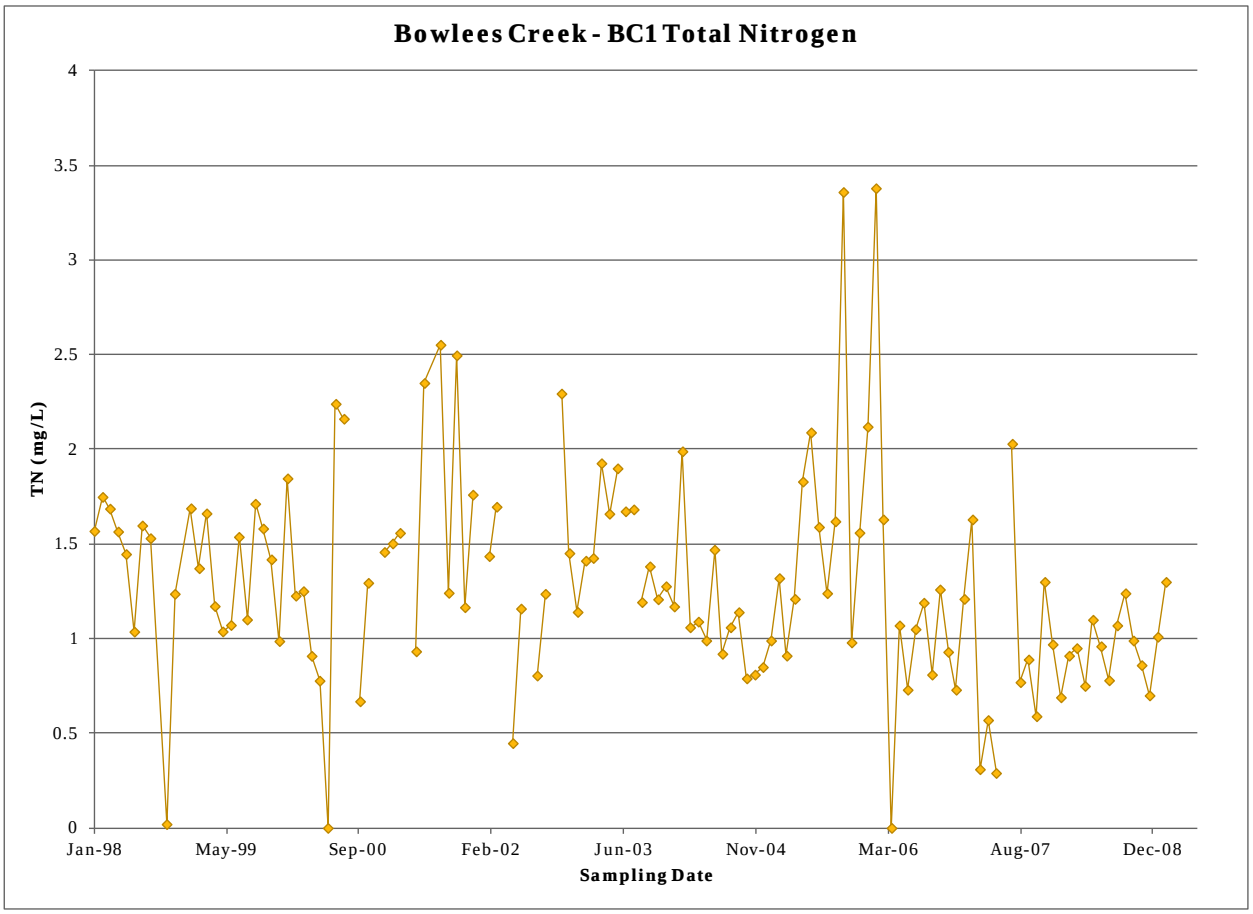


Figure 3-16 TN (mg/L) Concentrations from the Bowless Creek Water Quality Sampling Station

Figure 3-17 shows TP concentrations for Bowlees Creek. These TP concentrations were similar to those observed from Whitaker and Hudson Bayous, with the exception of higher extreme concentrations, with five samples over 1.0 mg/L, from Bowlees Creek. No temporal trend in TP concentrations was evident.

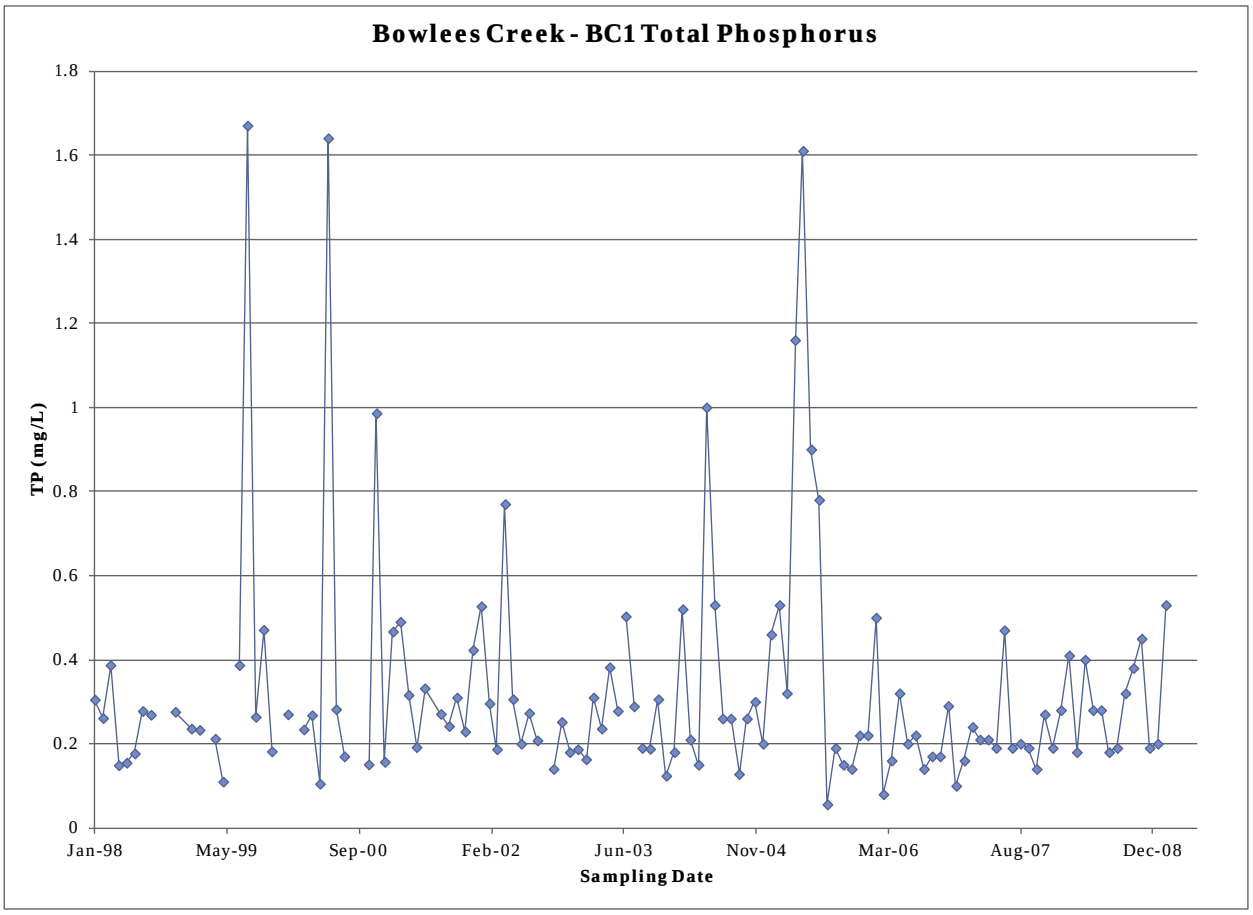


Figure 3-17 TP (mg/L) Concentrations from the Bowless Creek Water Quality Sampling Station

Figure 3-18 shows DO concentrations in Bowless Creek. Despite high nutrients and chlorophyll *a*, Bowlees Creek generally maintained DO concentrations between 4 mg/L and 8 mg/L. Since 2007, DO concentrations were generally lower, with frequent observations less than 4 mg/L.

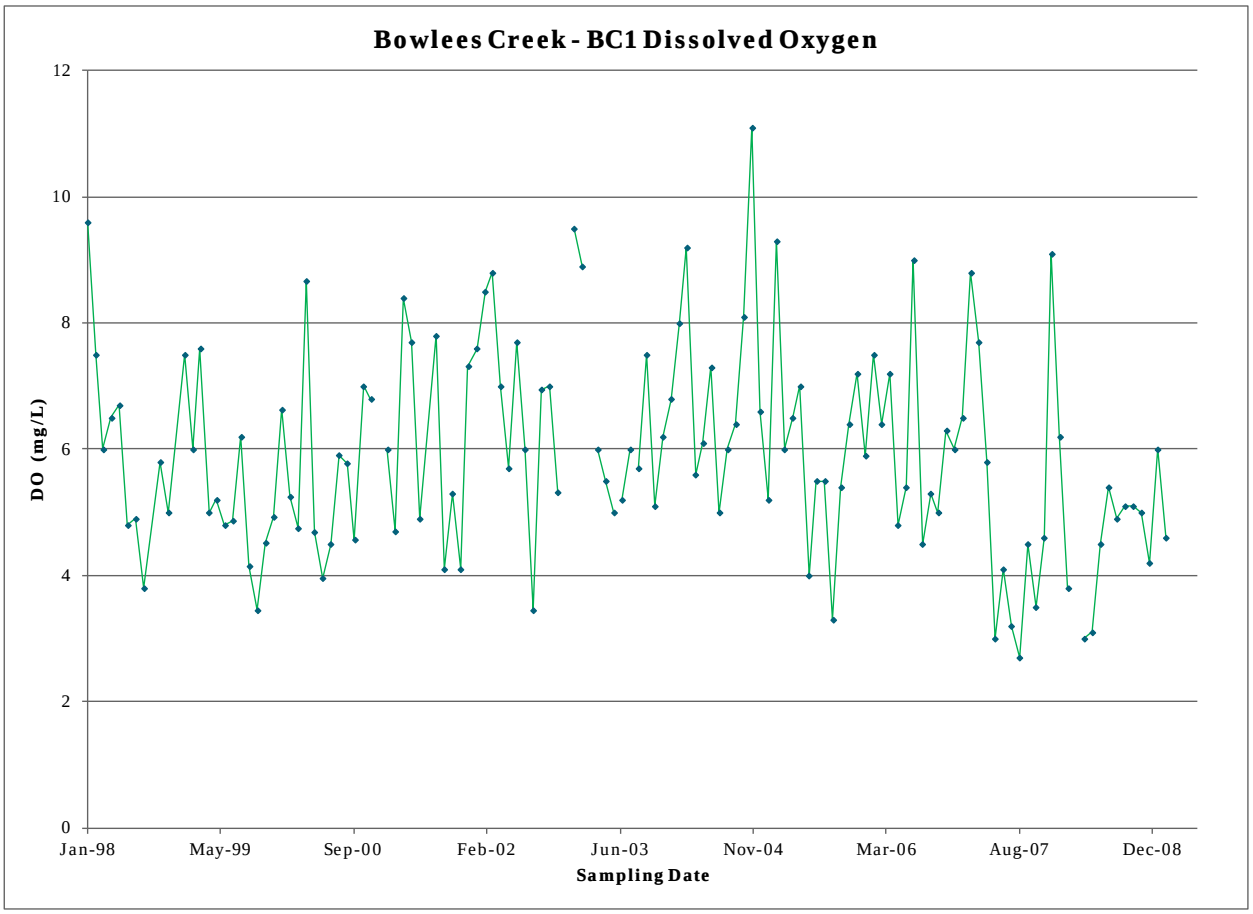


Figure 3-18 DO (mg/L) Concentrations from the Bowless Creek Water Quality Sampling Station

Figure 3-19 shows color in Bowlees Creek. Concentrations were generally between 50 PtCo units and 120 PtCo units, except for the lower color observed during 2004–2005.

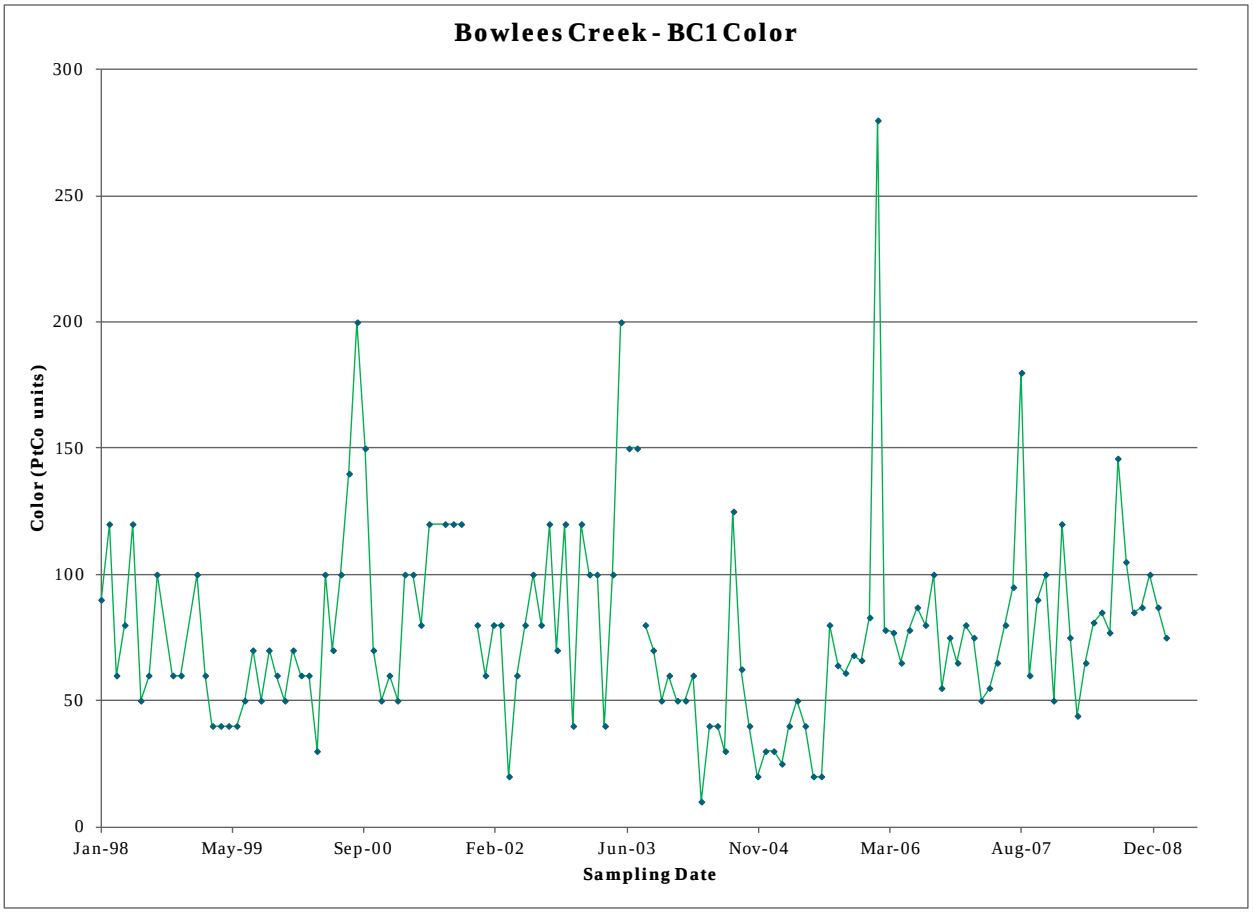


Figure 3-19 Color (PtCo units) Observations from the Bowless Creek Water Quality Sampling Station

3.4.2 Comparison of Freshwater Tributary Ambient Water Quality to FDEP NNC

NNC have been adopted for freshwater streams by FDEP (2012c). Draft TN thresholds for streams were developed based on water quality characteristics of "nutrient watershed regions" within the State. Sarasota Bay tributaries are assigned to the West Central region, shown in Figure 3-20, which has a TN nutrient threshold of 1.65 mg/L and a TP threshold of 0.49 mg/L. To meet the criteria, the annual geometric mean of ambient concentrations may not exceed the criteria more than once in a 3-calendar-year period.

The criteria are applicable for freshwater streams in the Sarasota Bay watershed, specifically the reaches containing sampling stations WB10, WB11, and WB12 in Whitaker Bayou and HB7 and HB8 in Hudson Bayou. Bowlees Creek is tidal and thus is not subject to the freshwater criteria.

Figure 3-20 WBIDs Impaired for TN, TP, DO, or Fecal Coliform in the Sarasota Bay Watershed

3.4.2.1 TN

Table 3-1 shows the annual geometric means of TN for the freshwater reach of Whitaker Bayou, which includes sampling sites WB 10, WB 11, and WB12. The means are below the criterion of 1.65 mg/L for all years (2007 through 2010). Whitaker Bayou was also sampled in 2006 but only for October–December. The geometric mean for that 3-month period is 0.9 mg/L but would not be used to determine conformance with the criterion. Calculating an annual geometric mean for TN or TP using the FDEP (2012a) protocol requires at least four temporally independent samples per year with at least one sample taken between May 1 and September 30 and at least one sample taken during the other months of the calendar year.

Table 3-1 also presents annual geometric means for the freshwater portion of Hudson Bayou, which includes sampling sites HB7 and HB8. The values all meet the proposed threshold.

Table 3-1 Annual Geometric Mean TN and TP Concentrations in Freshwater Sarasota Bay Tributaries

Waterbody	Year	TN (mg/L)	TP (mg/L
Whitaker Bayou	2007	0.73	0.27
	2008	0.65	0.25
	2009	0.79	0.32
	2010	0.01	0.29
Hudson Bayou	2007	0.68	0.49
	2008	0.63	0.47
	2009	0.86	0.55
	2010	1.02	0.49
FDEP NNC		*1.65*	*0.49*

3.4.2.2 TP

Table 3-1 shows that the freshwater portion of Whitaker Bayou meets the TP threshold of 0.49 mg/L. However, the annual geometric mean for freshwater Hudson Bayou equaled the threshold in 2007 and 2010 and exceeded the threshold in 2009 (0.55 mg/L). Because the FDEP (2012a) protocol states that the threshold would not be met if it is exceeded (not equaled) more than once in a 3-year period, Hudson Bayou would meet the threshold.

3.4.3 Impaired WBIDs within the Sarasota Bay Watershed

Although several Total Maximum Daily Loads (TMDLs) have been proposed or adopted for Sarasota County's WBIDs, no TMDLs have been proposed for Sarasota Bay proper or its tributaries. However, several WBIDs within the Sarasota Bay watershed have been identified as impaired, as indicated by the IWR criteria (FDEP, 2011c). Figure 3-20 and Table 3-2 present the WBIDs within the Sarasota Bay watershed that were designated as impaired for TN, TP, DO, or fecal coliform.

Table 3-2 Impaired Waterbodies in the Sarasota Bay Watershed using Impaired Waters Rule Criteria (FDEP, 2011)

WBID	Water Segment Name and County	Waterbody Class	Parameters Assessed	DO / Biology Pollutant of Concern	Pollutant of Concern Median Concentrations (mg/L)	Concentration of Criterion or Threshold Not Met	Priority for TMDL Development	Verified Period (no. exceedances / no. samples)[6]	Comments
1885	West Cedar Hammock Manatee	Class 3 Marine	Dissolved Oxygen (Nutrients)	TN, TP, BOD	TN =1.07 (n=40) TP =0.27 (n=42) BOD =2.3 (n=33)	≥ 4.0 mg/L	Medium	9/40	Impaired with TN, TP, and BOD identified as the causative pollutants.
1885	West Cedar Hammock Manatee	Class 3 Marine	Fecal Coliform			≤ 400 Counts / 100 mL	Low	36/39	Impaired based on the number of exceedances.
1916	Longboat Key Manatee/ Sarasota	Class 3 Marine	Dissolved Oxygen	BOD	TN =0.766 (n=5) TP =0.049 (n=5) BOD =2.9 (n=21)	≥ 4.0 mg/L	Medium	9/21	Impaired with BOD identified as the causative pollutant.
1936	Whitaker Bayou (Tidal) Sarasota	Class 3 Marine	Nutrients (Chlorophyll a)		TN =1.166 (n=14) TP =0.275 (n=14) BOD =2.9 (n=14)	≤ 11 µg/L	High	2008 (39.0 µg/l)	Impaired because annual average Chl-*a* concentrations exceeded 11 µg/L in 2008. Nitrogen is the limiting nutrient based on the TN/TP ratio median of 4.11 mg/L.
1936	Whitaker Bayou (Tidal) Sarasota	Class 3 Marine	Dissolved Oxygen (Nutrients)	TN, TP, BOD	TN =1.166 (n=14) TP =0.275 (n=14) BOD =2.9 (n=14)	≥ 4.0 mg/L	High	7/16	Impaired with TN, TP, and BOD identified as the causative pollutants.

Table 3-2 Impaired Waterbodies in the Sarasota Bay Watershed using Impaired Waters Rule Criteria (FDEP, 2011)

WBID	Water Segment Name and County	Waterbody Class	Parameters Assessed	DO / Biology Pollutant of Concern	Pollutant of Concern Median Concentrations (mg/L)	Concentration of Criterion or Threshold Not Met	Priority for TMDL Development	Verified Period (no. exceedances / no. samples)[6]	Comments
1936	Whitaker Bayou (Tidal) Sarasota	Class 3 Marine	Fecal Coliform			≤ 400 Counts / 100 mL	Low	14/24	Impaired based on the number of exceedances.
1953	Hudson Bayou Tidal Sarasota	Class 3 Marine	Dissolved Oxygen	BOD	TN =0.734 (n=18) TP =0.13 (n=17) BOD =2.2 (n=18)	≥ 4.0 mg/L	Medium	11/21	Impaired with BOD identified as the causative pollutant.
1953	Hudson Bayou Tidal Sarasota	Class 3 Marine	Fecal Coliform			≤ 400 Counts / 100 mL	Low	7/20	Impaired based on the number of exceedances.

Hudson Bayou WBID 1953, Whitaker Bayou WBID 1936, and West Cedar Hammock WBID 1885 have been deemed impaired for fecal coliform based on exceedances of the fecal coliform standard of 400 counts/100 milliliters as shown in Table 3-2.

Hudson Bayou WBID 1953, Whitaker Bayou WBID 1936, West Cedar Hammock WBID 1885, and Longboat Key WBID 1916 have all been deemed impaired for DO. The Hudson Bayou impairment was identified as being caused by elevated BOD concentrations. The Whitaker Bayou and West Cedar Hammock impairments were attributed to elevated BOD, TN, and TP concentrations. BOD was identified as the causative agent for the Longboat Key impairment.

Whitaker Bayou was also identified as impaired for nutrients (TN) because of elevated chlorophyll *a* concentrations. The chlorophyll *a* threshold for marine waters is 11 µg/L. Chlorophyll *a* in samples from Whitaker Bayou exceeded that value by a factor of three in 2008, leading to the impairment determination.

3.4.4 Data Collection

No data gaps were found during this analysis. Therefore, we do not recommend additional monitoring or data collection.

4.0 CURRENT AND FUTURE POLLUTANT LOADINGS

4.1 OBJECTIVE

This section presents the approach, data used, and summary of results associated with examining the current and future nutrient and suspended solids loads for Sarasota Bay.

4.2 APPROACH

The SIMPLE model has a number of modules that estimate hydrologic and pollutant loads from a number of sources. The SIMPLE model was used to estimate hydrologic and nutrient inputs from the following sources:

- Atmospheric deposition (direct precipitation to the open water estuary).
- Baseflow.
- Direct runoff.
- Irrigation.
- Point sources.
- Septic tanks.

The analyses of these data included examining and comparing the spatial and temporal variation in nutrient loads to Sarasota Bay.

4.3 DATA USED

4.3.1 Current

The current nutrient-loading estimates were provided by a SIMPLE model for 1989 through 2008. The modeling was completed for a project funded by SBEP ("Numeric Nutrient Criteria for Sarasota Bay" prepared by Janicki Environmental, Inc. (Janicki Environmental, 2010a). Sources of data and methodologies for current conditions loadings are documented in the report.

4.3.2 Future

A Decision Memorandum defined the methods used to estimate the future nutrient loadings. The future conditions scenario was not defined according to a specific time frame but was developed to incorporate the following assumptions:

- Future land use followed the Jones Edmunds' approach used for the Roberts Bay North Plan in which undeveloped uplands were converted to medium-density residential.

- Future stormwater management assumed that loads from all new medium-density residential lands were reduced by an efficiency consistent with a wet detention pond.
- Stormwater event mean concentrations (EMCs) were the same as those used for the current conditions model runs.
- Rainfall and evapotranspiration estimates were the same as those used for the historical and current conditions model runs.
- Soil coverage was the same as that used for the historical and current conditions model runs.
- The City of Sarasota wastewater treatment plant was the only point source within the Sarasota Bay watershed. This facility disposes of treated effluent via deep-well injection during the wet season (June–September) and distribution to reuse during the dry season. The City of Sarasota was contacted to obtain data to use in estimating future loading rates. Although the plant's direct discharge to Whitaker Bayou is proposed to be taken offline in the future, there is no definitive schedule. Based on population projections, the change in point-source flows over the next decades is projected to be small; therefore, the point-source loads were kept the same as for existing conditions.
- Septic tank GIS-based coverage was the same as current conditions; however, the number of units was adjusted to reflect changing wastewater service areas.
- Atmospheric deposition loadings reflect the 38% future emissions reductions for TN estimated by EPA as a result of power plant cleanups and cleaner automobiles. These load-reduction estimates have been developed by EPA only recently and were not used in estimating loading for the Roberts North Bay or Lemon Bay Watershed Management Plans.

4.4 RESULTS

4.4.1 Comparison of Current and Future Nutrient Loads

4.4.1.1 Annual

Figure 4-1 shows total annual hydrologic loads for current and future conditions. Hydrologic loads during both periods range from approximately 100 to 210 million m^3/year. Except for a slight increase in hydrologic loads under future conditions, very little difference was observed between current and future conditions.

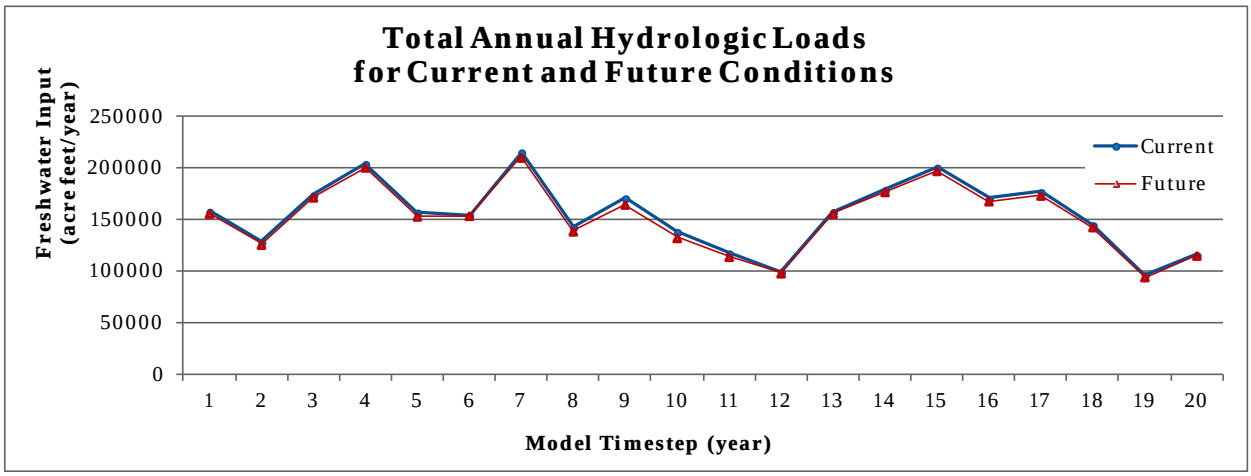


Figure 4-1 Total Annual Hydrologic Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-2 shows annual TN loads for current and future conditions. Comparing the trend in TN loads in Figure 4-2 with hydrologic loads in Figure 4-1 demonstrates the relationship between hydrologic and nutrient loads. TN loads during both periods range from approximately 110 to 250–280 tons/year and are lower under future conditions compared to current estimates as a result of the removal of direct point-source discharges and reductions in emissions expected to lower loads from atmospheric deposition.

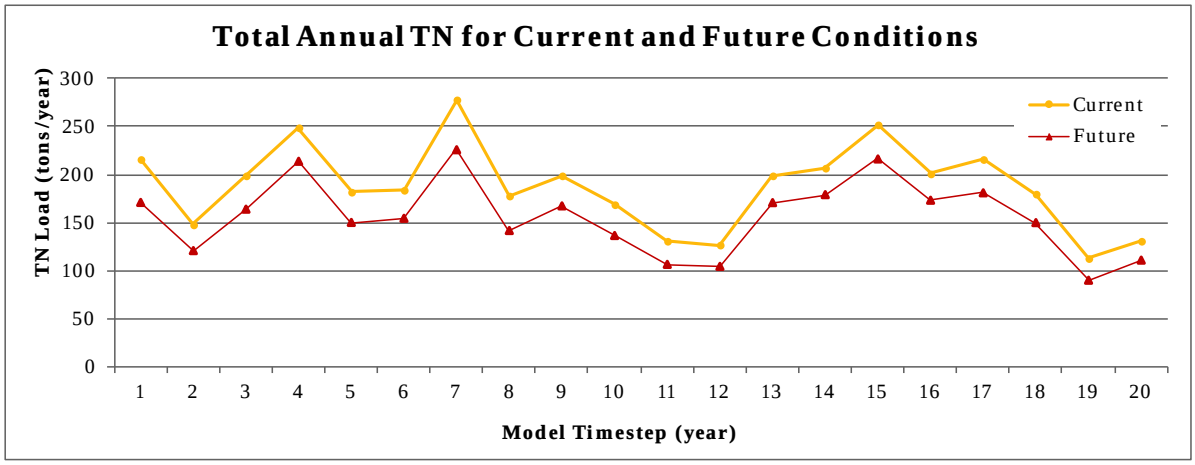


Figure 4-2 Total Annual TN loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-3 shows annual TP loads for current and future conditions. Comparing the trend in TP loads in Figure 4-3 with hydrologic loads in Figure 4-1 demonstrates the relationship between hydrologic and nutrient loads. TP loads range from approximately 18–38 tons/year and are nearly identical for current and future watershed conditions. The relatively small change in TN and TP loading estimates from current to future conditions can be interpreted as reflecting the influence of atmospheric deposition and the current nearly "built-out" state of the Sarasota Bay watershed, which provides low potential for future urban development and associated increased land-based loadings.

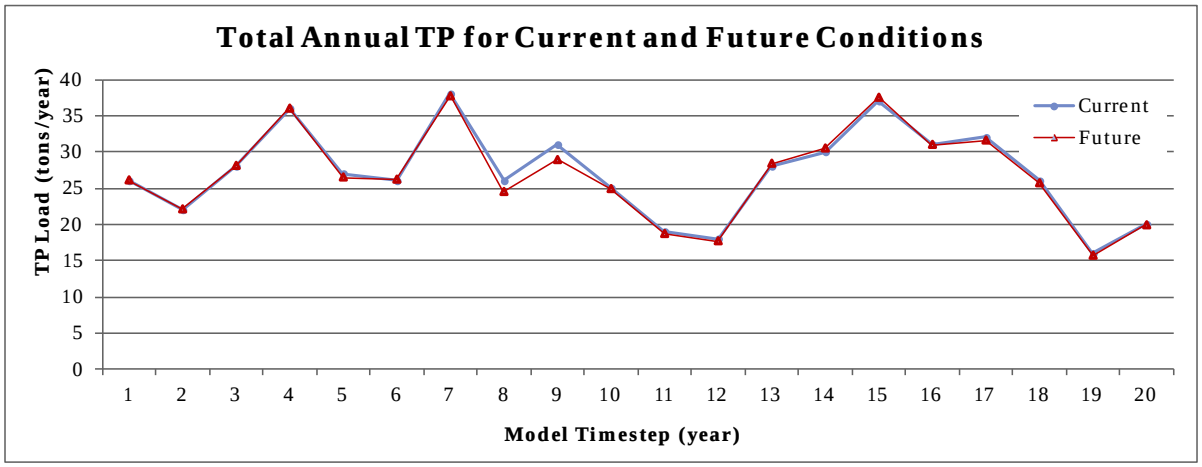


Figure 4-3 Total Annual TP loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-4 shows annual TSS loads for current and future conditions. TSS loads range from approximately 1,500–4,000 tons/year. TSS loads differ very little between current and future conditions. Because TSS loadings are largely a function of watershed land use and soils, the relatively small change in nutrient-loading estimates from current to future conditions can be attributed to the relatively small increase in urban land under future conditions.

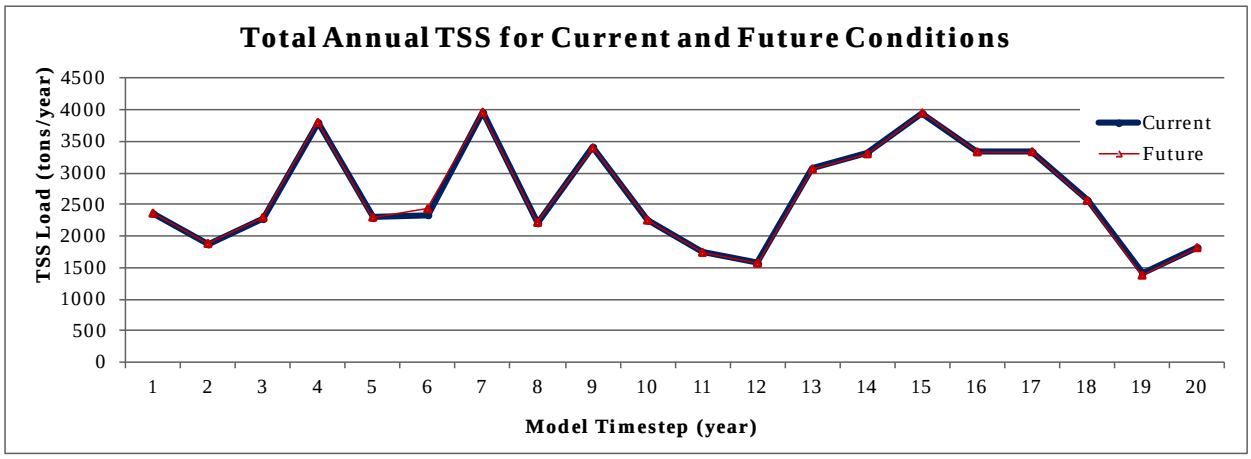


Figure 4-4 Total Annual TSS Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

4.4.1.2 Seasonal

Figure 4-5 shows the seasonal variability in hydrologic inputs under current and future conditions. This figure illustrates the similar wet-dry pattern for both periods, as would be expected since both scenarios used the same precipitation record. June has the most extreme events, but later months during the wet season have higher median hydrologic loads. Monthly hydrologic loads vary nearly two-fold between the wet season (June–October) and the dry season (November–May). No zero-flow months were observed because precipitation-independent sources such as baseflow contribute to hydrologic inputs each month.

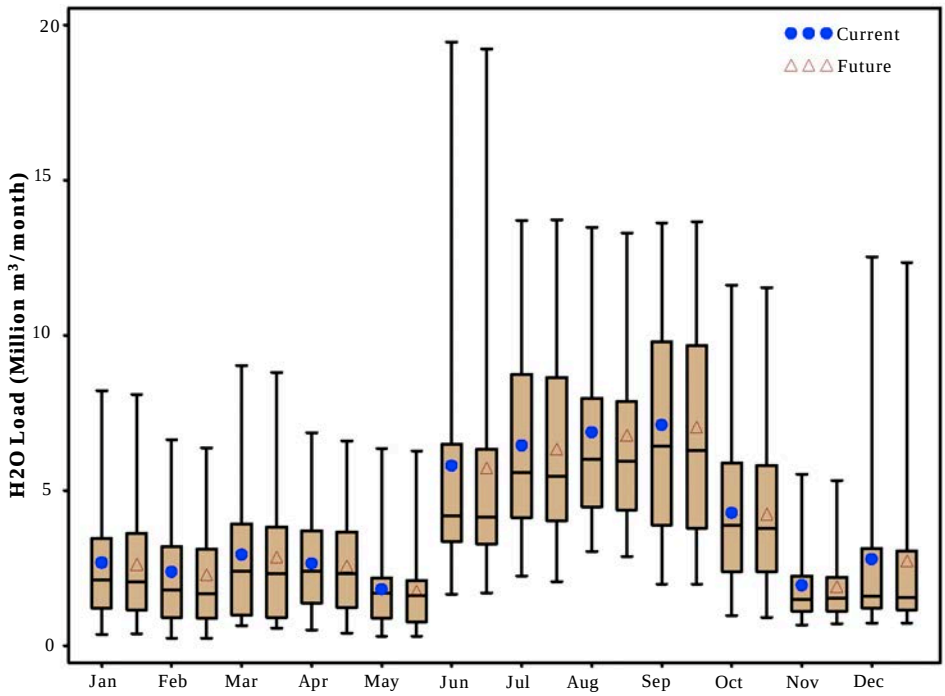


Figure 4-5 Within-Year Variation in Hydrologic Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-6 shows the seasonal variability in TN loads under current and future conditions. Seasonal patterns in TN loads reflect the seasonality in hydrologic inputs shown in Figure 4-6. As with hydrologic inputs, June has the most variable TN loadings, but the highest TN loads are from July through September. Wet season TN loadings are nearly twice as high as those during the dry season. A reduction in TN loads is apparent from the current to the future watershed condition, particularly during the wet months (June–September) as a result of no direct point-source discharge, lowered emissions, and less TN from atmospheric deposition.

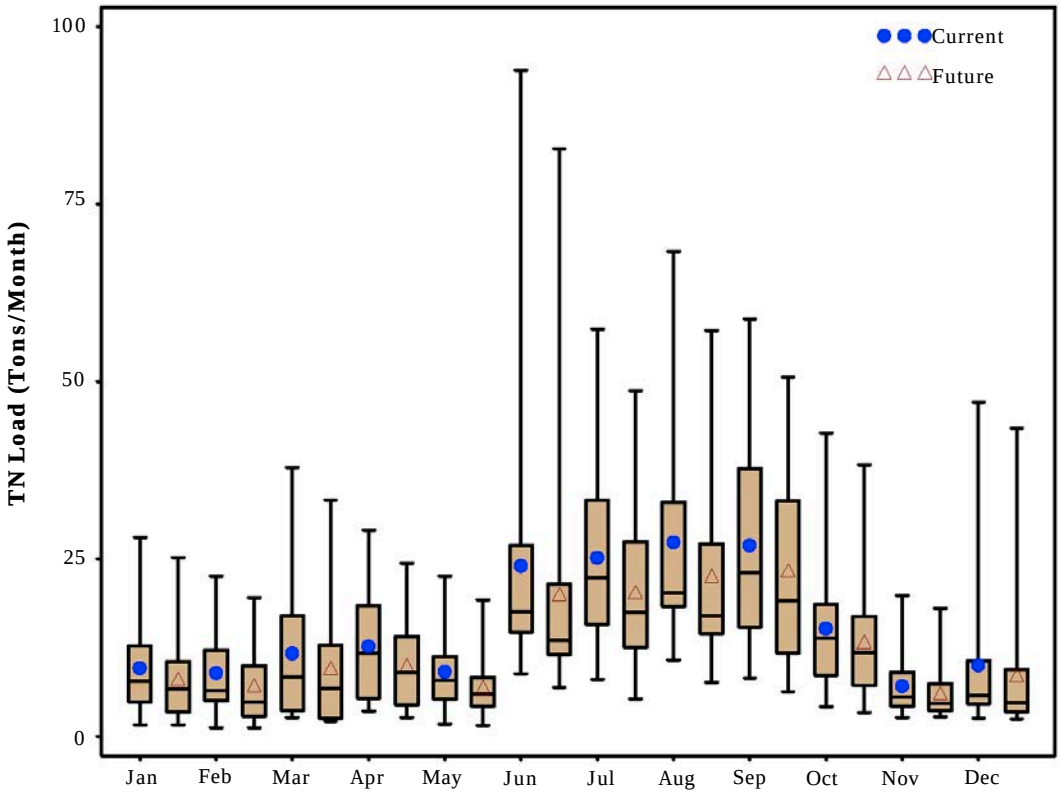


Figure 4-6 Within-Year Variation in TN loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-7 shows seasonal variation in TP loads under current and future conditions. As with TN loads, the monthly variability in TP loads is largely a function of hydrologic inputs. Seasonality is apparent for TP loads, with a nearly two-fold increase in TP load from the dry season to the wet season. TP loadings are nearly identical between the current and future watershed conditions.

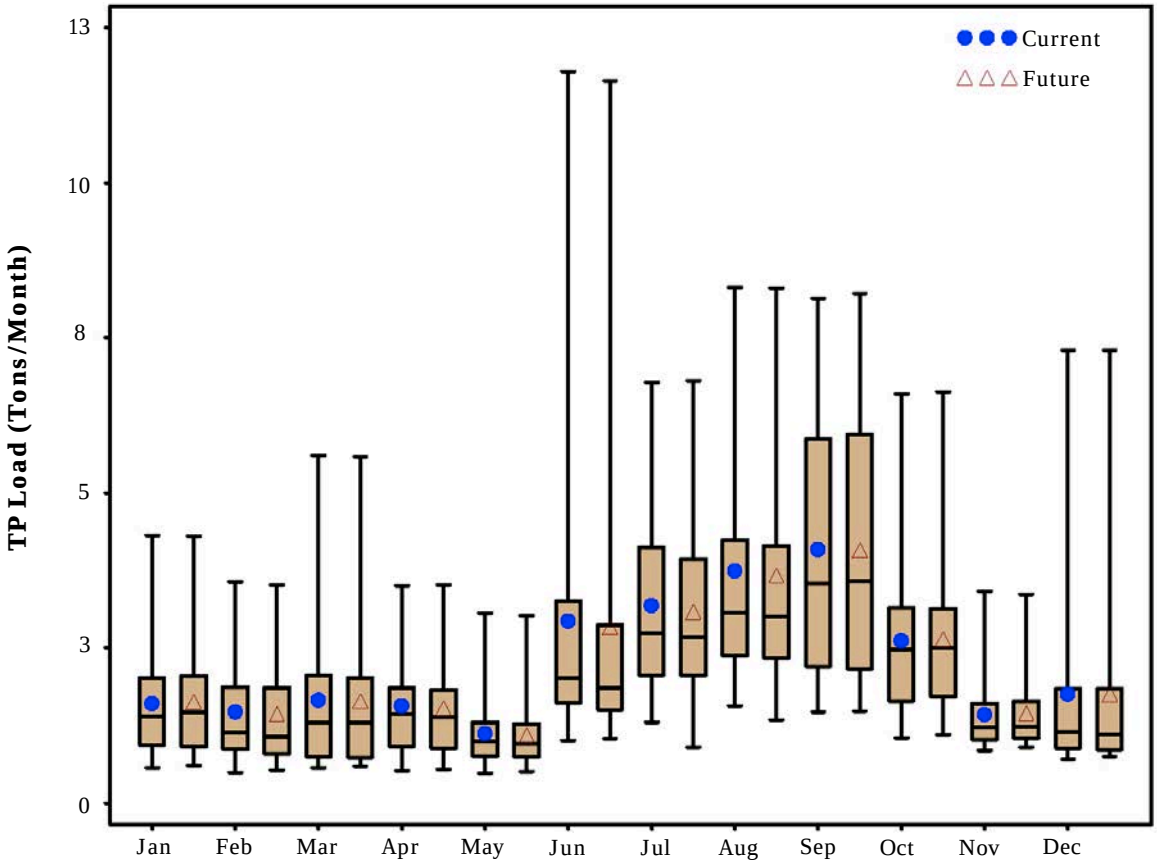


Figure 4-7 Within-Year Variation in TP Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-8 shows seasonal variation in total TSS loads under current and future conditions. Loadings of TSS are higher and more variable during the wet season from June through October under current and future conditions. Very little change in TSS loadings was observed, however, from the current to future watershed condition.

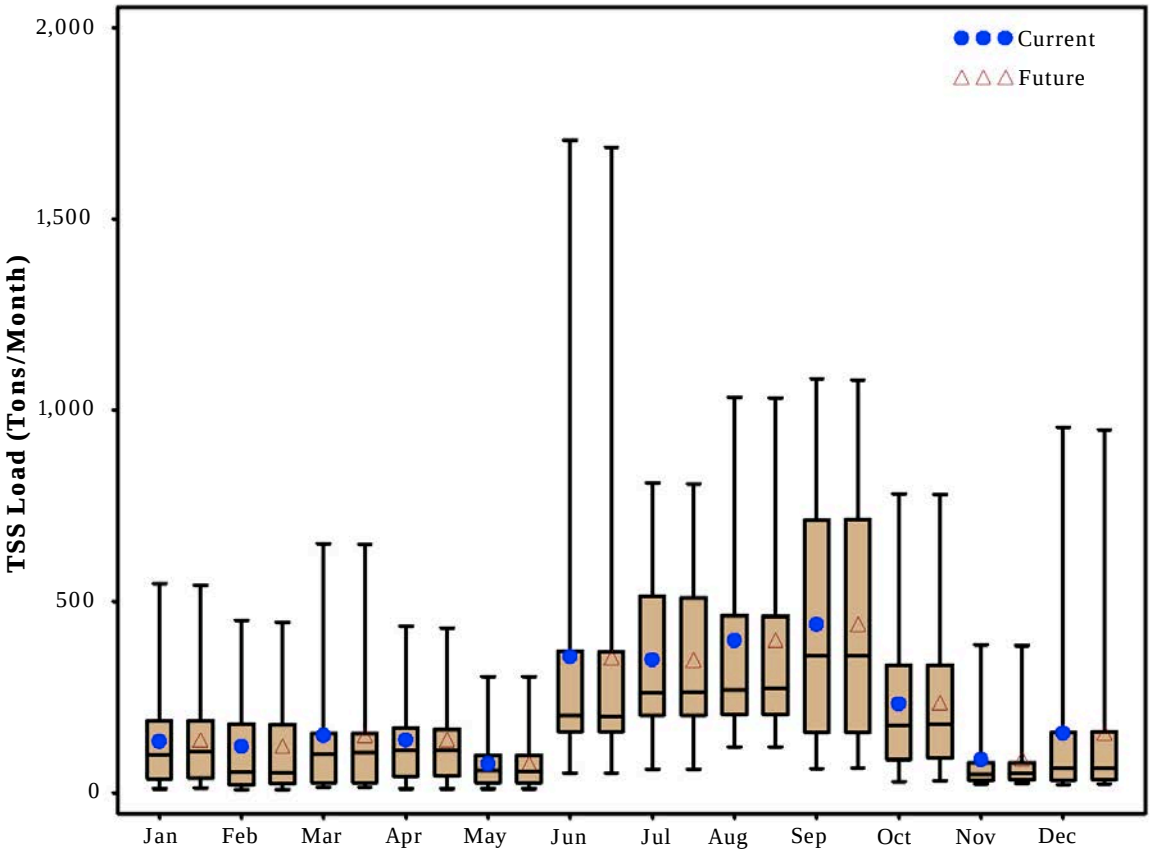


Figure 4-8 Within-Year Variation in TSS Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

4.4.1.3 Source Allocation

A. Overall

Figure 4-9 compares the hydrologic inputs from each of the sources during current and future watershed conditions. The major difference in the relative contribution of each source type between current and future conditions is the lack of direct point-source discharges in the future conditions. Because point-source discharges are in current conditions but not future, the relative percent contribution of the remaining sources appears quite different in some cases, even though the total load may be the same or less. Slight increases in hydrologic load from baseflow, direct runoff, and atmospheric deposition can be observed. In both scenarios, atmospheric deposition is the largest source of hydrologic inputs to the estuary, accounting for greater than half of the total hydrologic load. This is a reflection of the relatively large surface area of the estuary compared to the watershed's land area. Direct rainfall on the bay is a larger source of freshwater loading, even though inland areas average almost 9 more inches of precipitation than the bay annually. Direct runoff and baseflow also contributed significant hydrologic loads at approximately 20% each. Septic tanks and irrigation loads were minor sources.

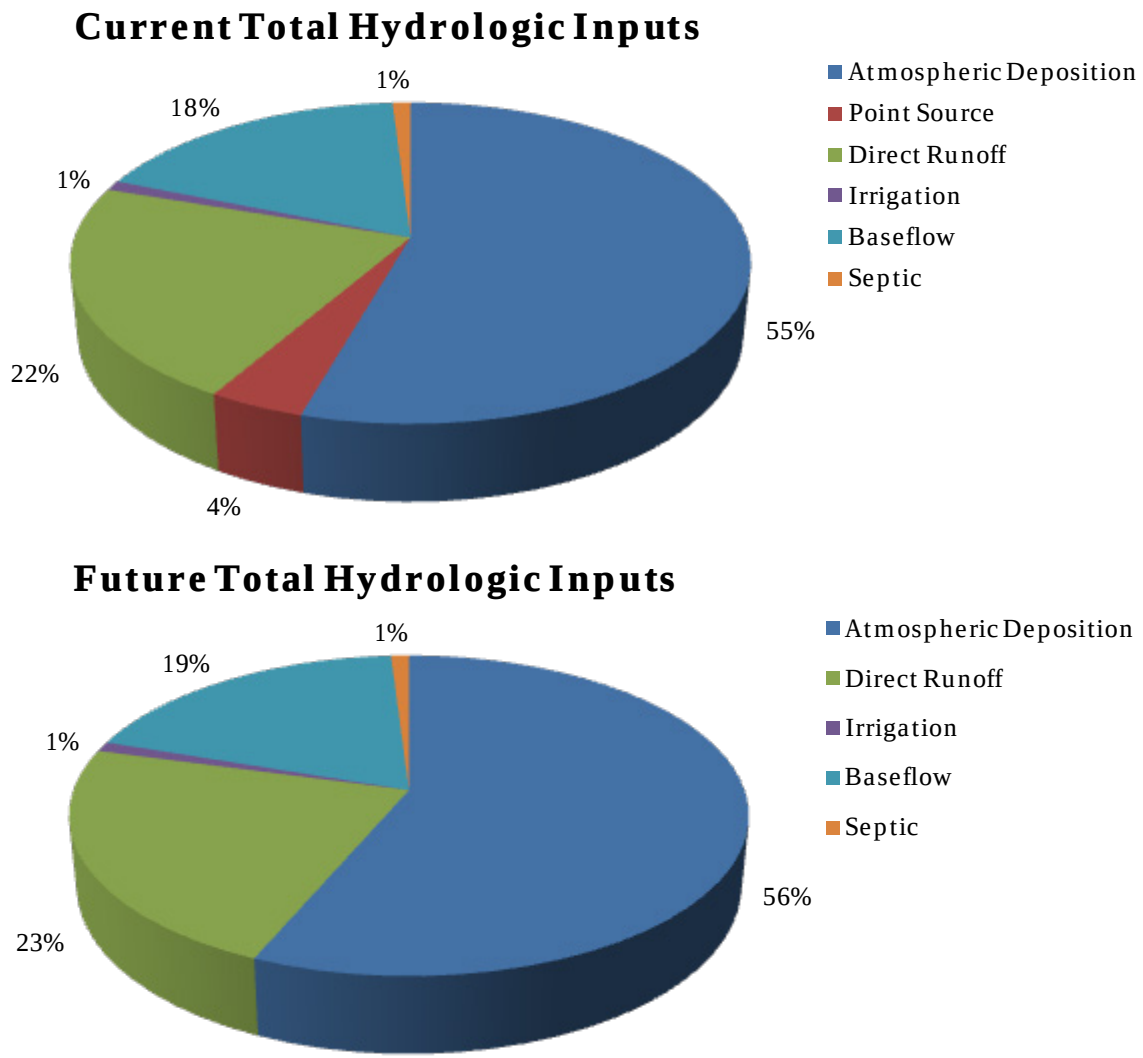


Figure 4-9 Comparison of the Relative Contributions from Various Sources to Hydrologic Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-10 compares TN loads by source for current and future watershed conditions. In both conditions, direct runoff accounted for the largest contribution of estimated current and future TN loads (45% and 48%, respectively). Atmospheric deposition was a significant source of TN, contributing nearly one-third of the total TN load. A reduction in the contribution of TN loads derived from point sources from 7% to 0% can be seen and results in changes to the relative contributions of remaining sources. Baseflow was a significant but smaller source of TN to the estuary. The smallest TN loads originated from septic tank and irrigation sources in future conditions and combined represented 4% of the total TN load.

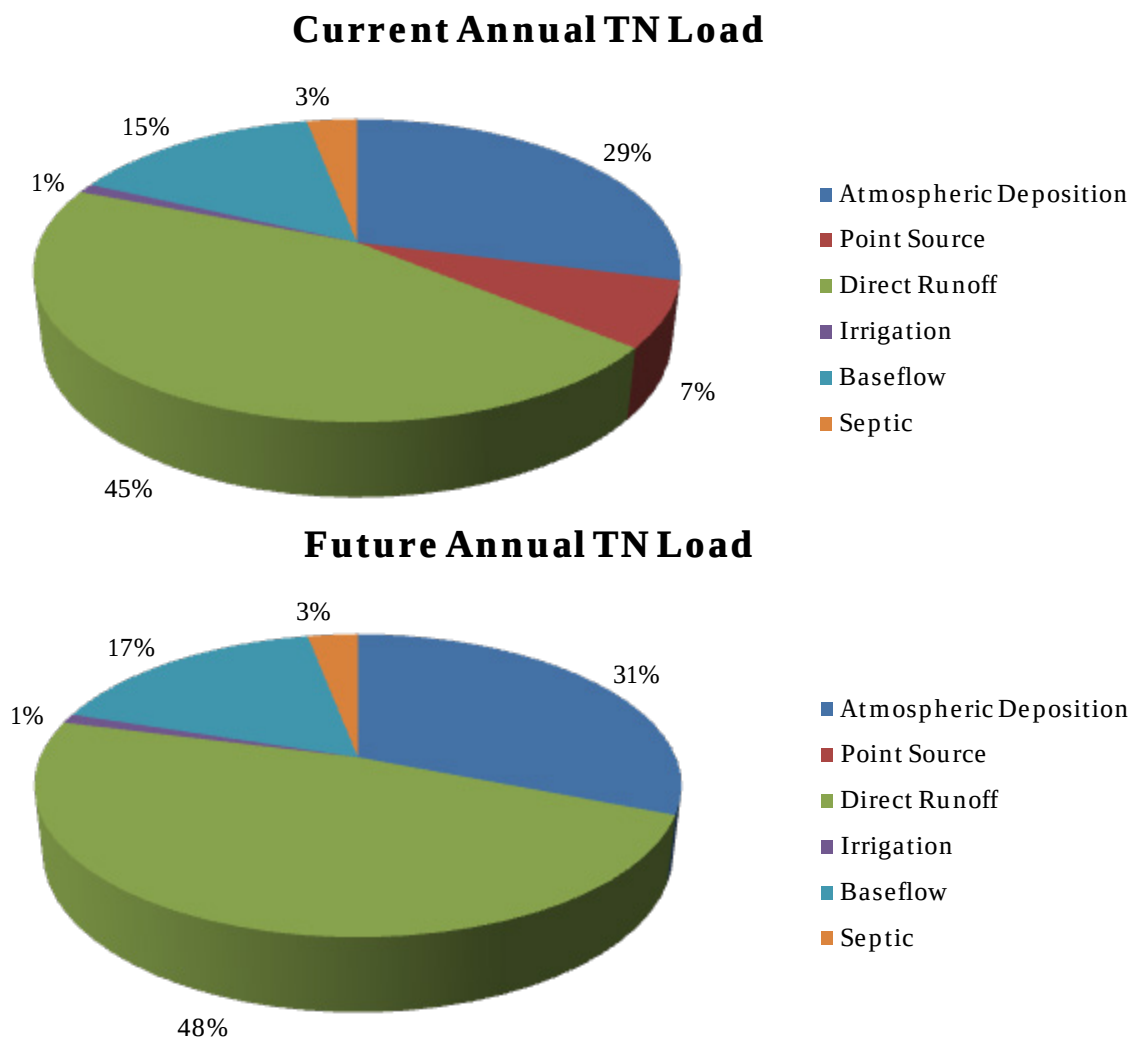


Figure 4-10 Comparison of the Relative Contributions from Various Sources to TN Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-11 compares the TP loads from each source during current and future watershed conditions. Increases in TP loadings from baseflow (2%) and irrigation (1%) can be observed as well as the elimination of point-source TP loads. Direct runoff was by far the largest source of TP loads in both conditions and represented half of the total TP loadings to Sarasota Bay. Considerable TP loads were also contributed via baseflow (almost 30%) with much smaller contributions from irrigation, septic tanks, and atmospheric deposition.

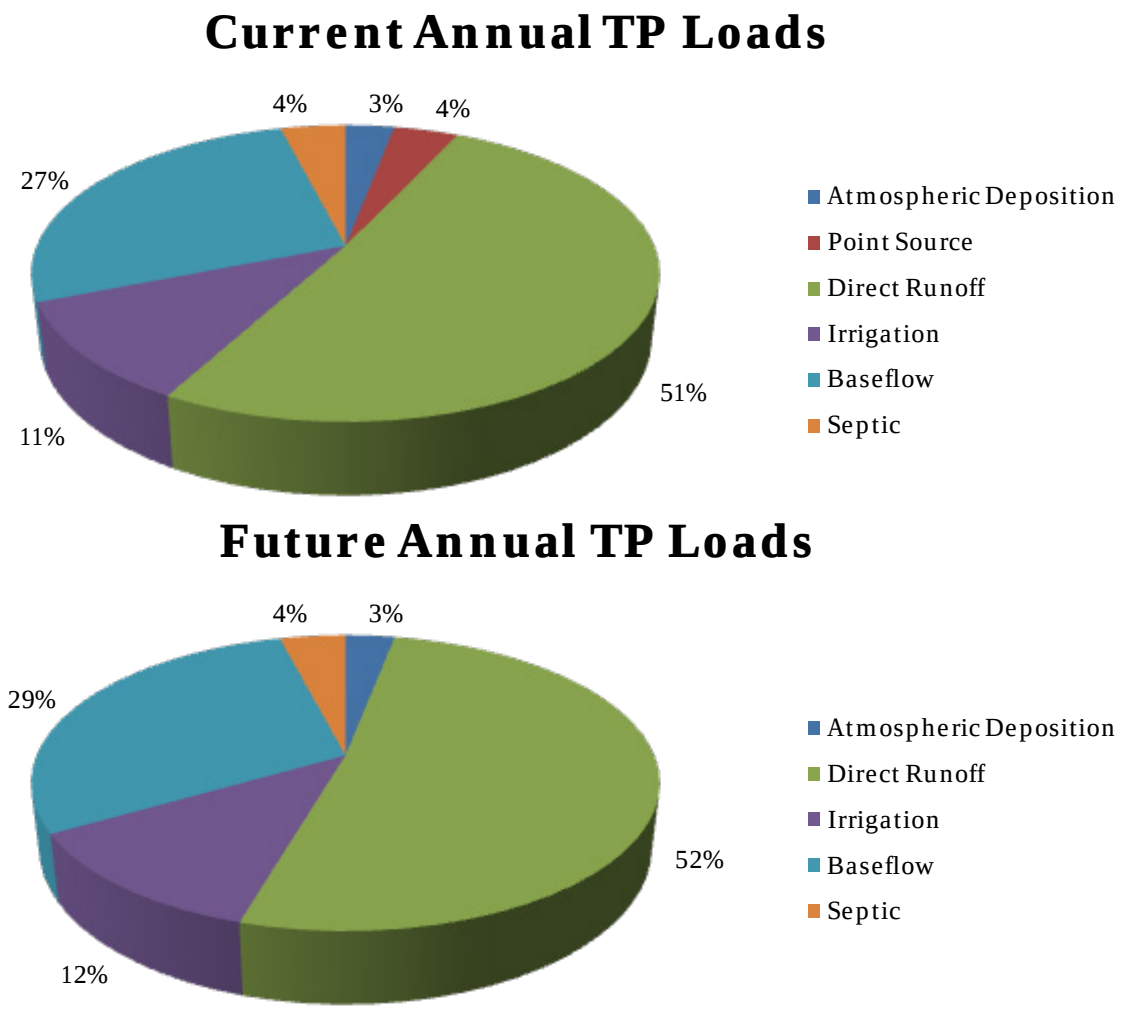


Figure 4-11 Comparison of the Relative Contributions from Various Sources to TP Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

Figure 4-12 compares the TSS loads from each source during current and future watershed conditions. Differences in the relative contribution of TSS loads from each source for current and future conditions are negligible. A slight increase in TSS loads from baseflow is suggested (1%), as well as slight decreases in TSS from direct runoff (1%) and septic sources (<1%). The majority of TSS originated from direct runoff (nearly 90%) with an additional 10% derived from baseflow.

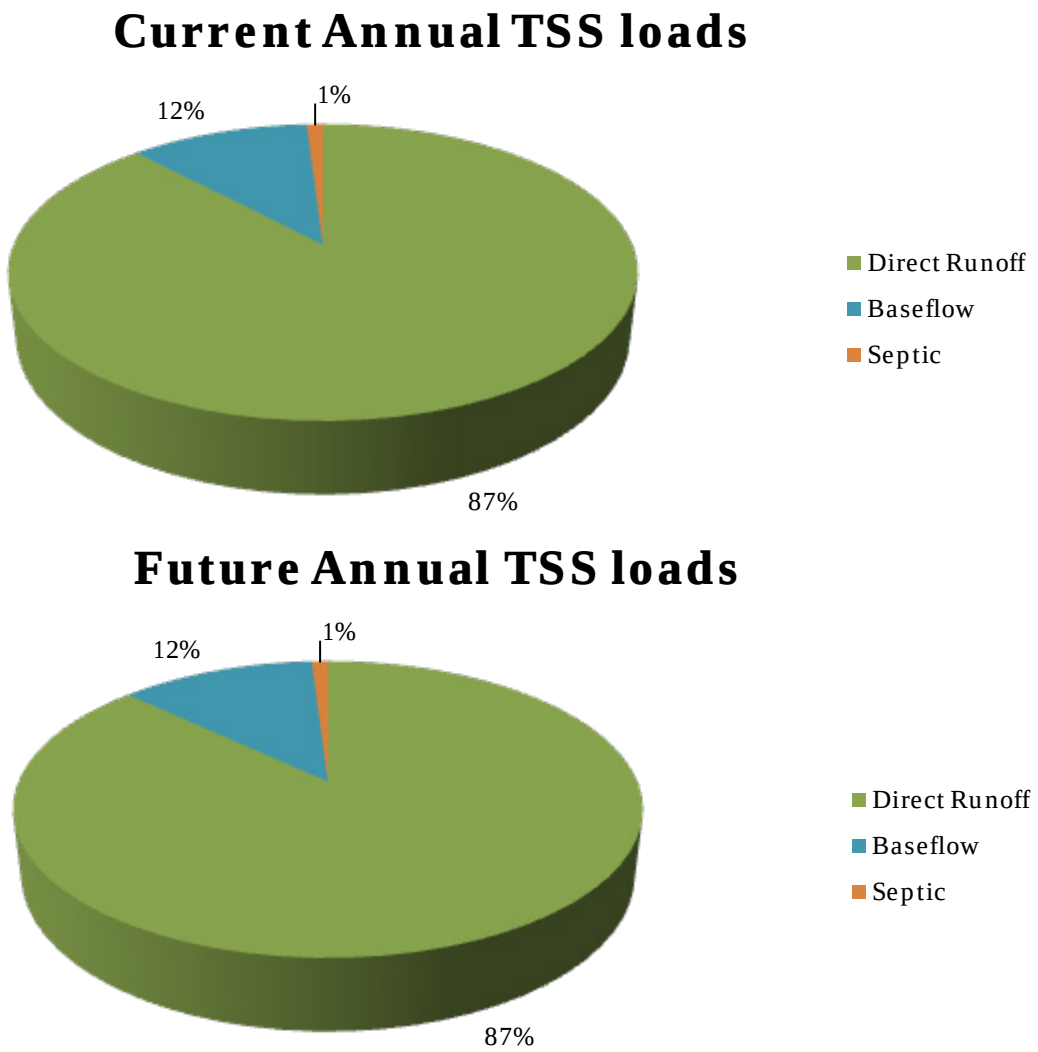


Figure 4-12 Comparison of the Relative Contributions from Various Sources to TSS Loads to Sarasota Bay for Current and Future Watershed Conditions (1989–2008)

B. Annual Variation

Figure 4-13 compares annual hydrologic loads by source for current and future conditions. The relative contribution of annual hydrologic loads by source is very similar for current and future watershed conditions, with the exception of point-source discharges. Very slight increases in baseflow are apparent in the future condition and are consistent across years.

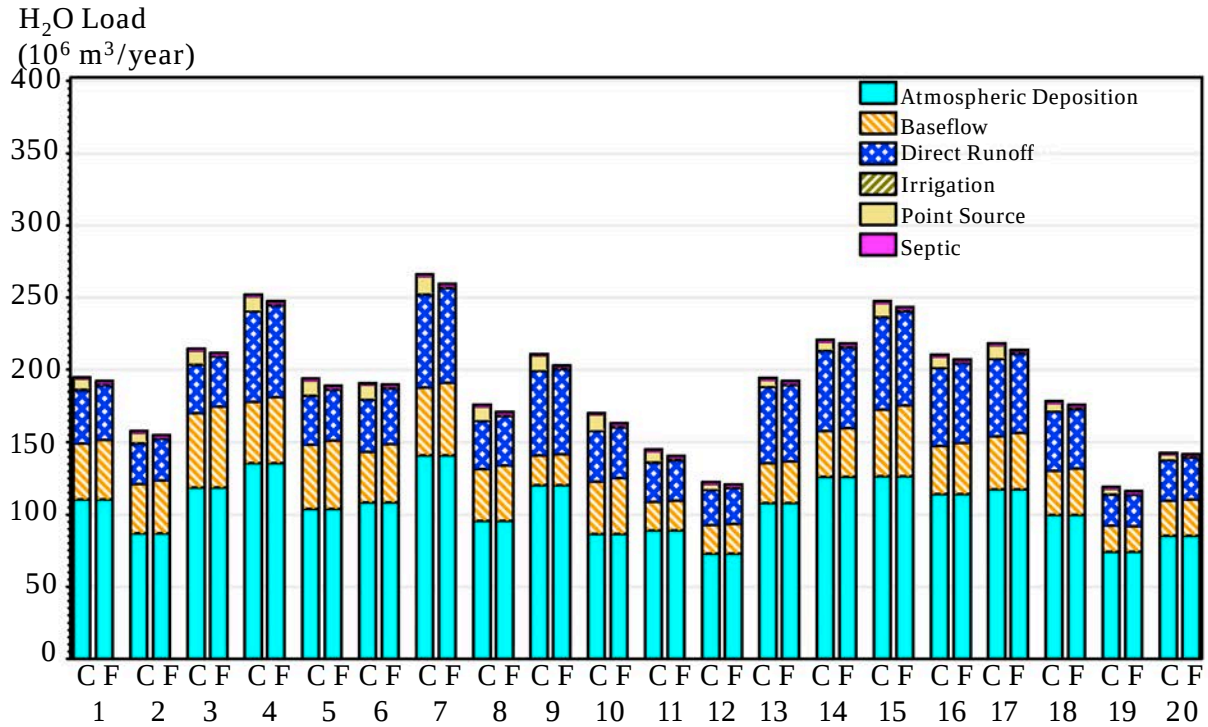


Figure 4-13 Comparison of Annual Hydrologic Loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008)

Figure 4-14 compares annual TN loads by source for current and future conditions. No point-source loads are in the future conditions, and a small reduction in the relative contribution of TN loads by source occurs between current and future watershed conditions as a result of lower TN loads from atmospheric deposition. Small increases in TN loadings from baseflow and direct runoff sources are also apparent among years under the future condition.

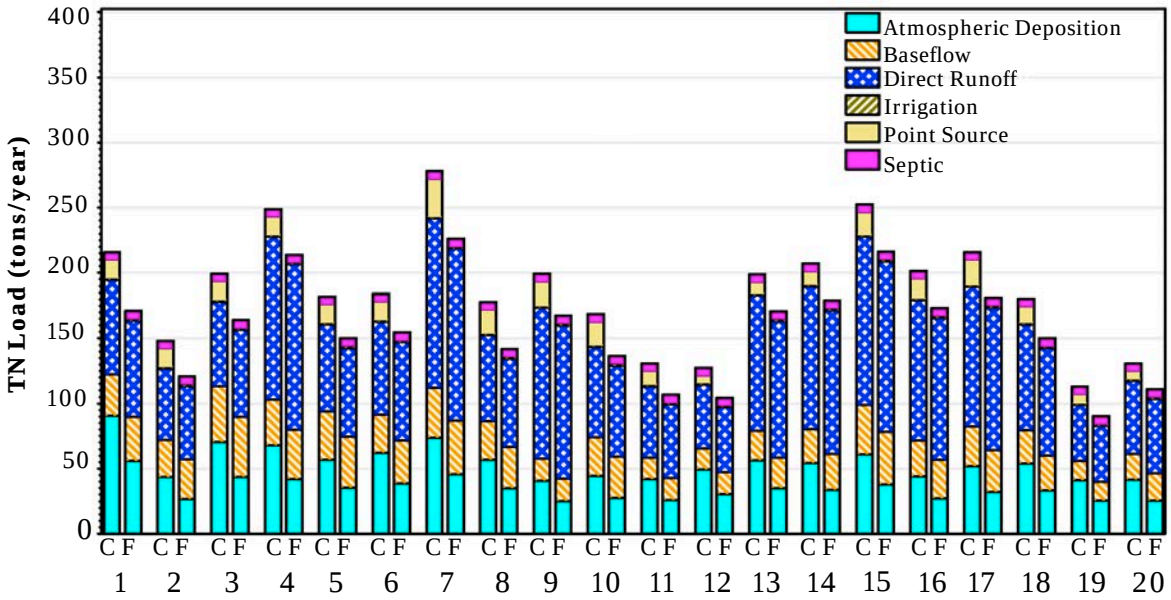


Figure 4-14 Comparison of Annual TN Loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008)

Figure 4-15 compares annual TP loads by source for current and future conditions. Baseflow and irrigation appear to be responsible for the slight increase in TP loadings during years in which future TP loads are greater than current loading estimates. During several years, a slight reduction in TP loads results from the elimination of point-source loads.

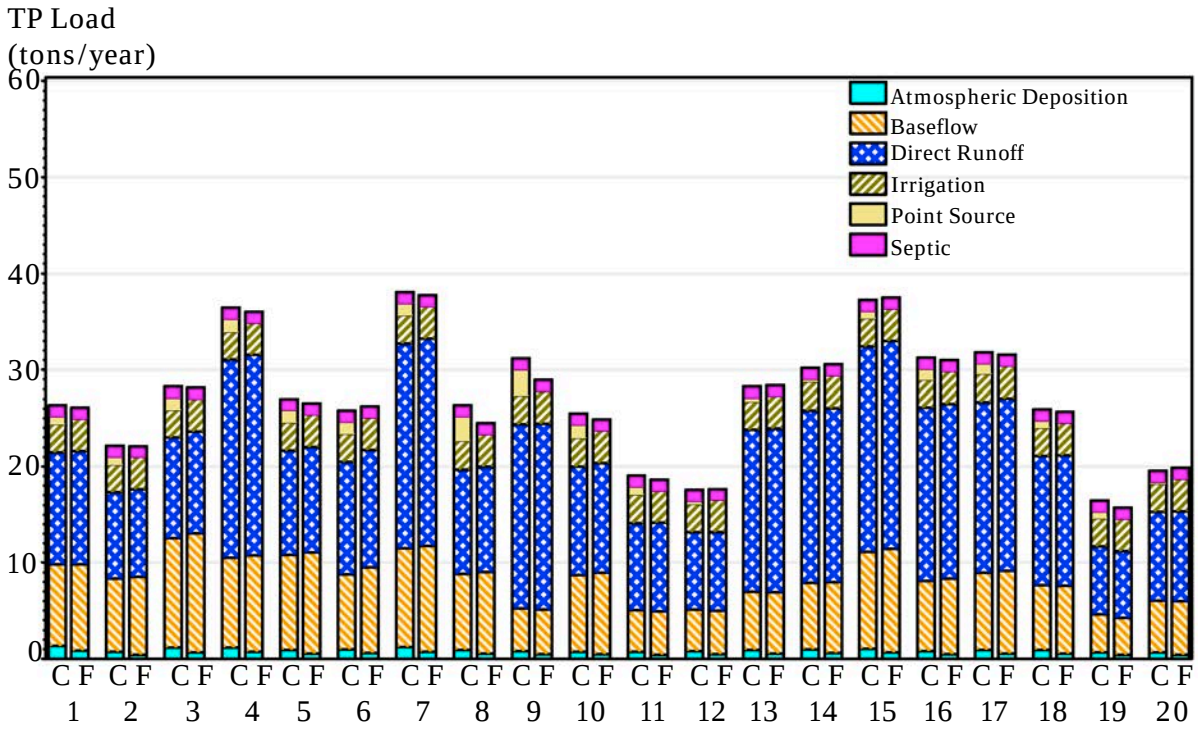


Figure 4-15 Comparison of Annual TP loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008)

Figure 4-16 compares annual TSS loads by source for current and future conditions. The majority of TSS loads originate from direct runoff in all years with little change in TSS loads from any of the sources between current and future watershed conditions.

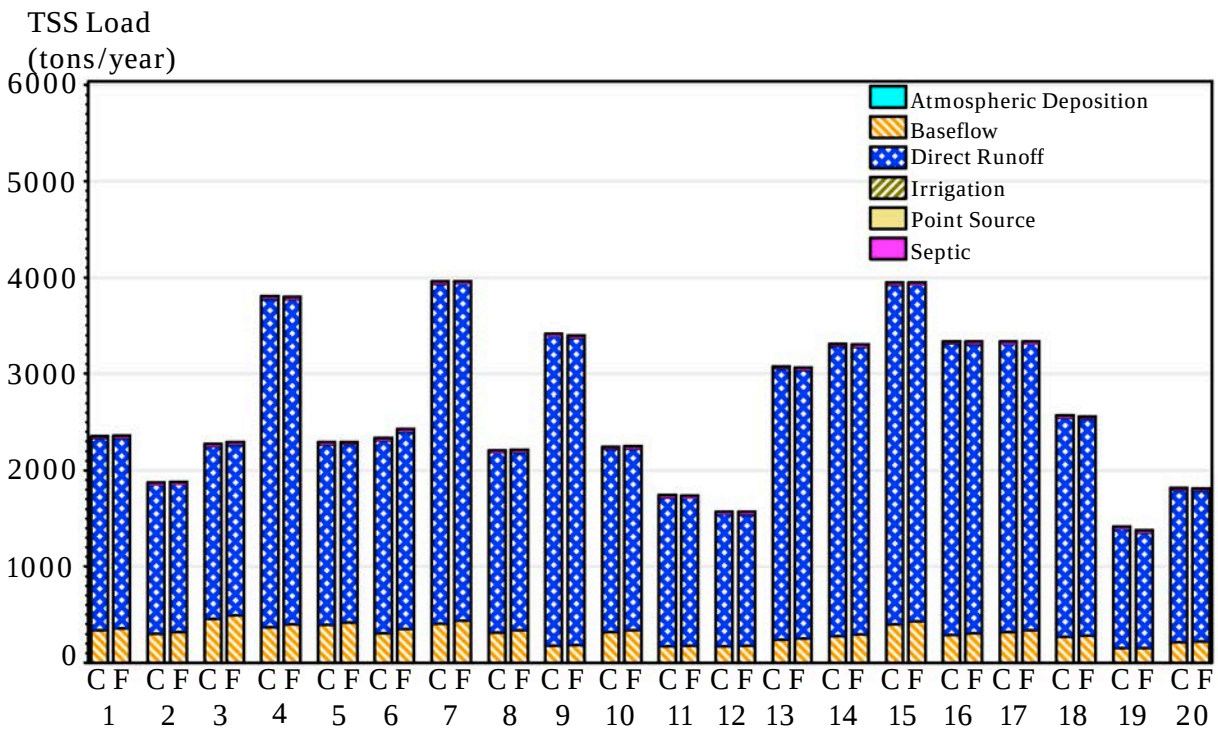


Figure 4-16 Comparison of Annual TSS Loads to Sarasota Bay by Source for Current and Future Watershed Conditions (1989–2008)

C. Spatial

The 10 basins within the Sarasota Bay watershed range in size from 83 to 5,783 acres (Table 4-1). Basin names provided by Sarasota and Manatee Counties were used. Sub-basin identification numbers shown correspond to figures at the end of this Appendix. The largest basins in the watershed—Bowlees Creek, Sarasota Bay Coastal North, and Whitaker Bayou—cover just over half of the watershed (57%), while the Longboat/Lido Key, Cedar Hammock Creek, and Hudson Bayou basins are only half the size of the largest basins and occupy nearly one-third (29%) of the watershed. The Sarasota Bay Coastal South and Cortez Drain basins each drain approximately 5% of the total watershed area. The three smallest basins drained <2% each. One of those basins—the north portion of Siesta Key—drains to Sarasota Bay (83 acres), but the majority of the key drains to Roberts Bay and Little Sarasota Bay to the southeast.

Table 4-1 Acreage of Basins within the Sarasota Bay Watershed

Basin	Sub-basins	Area (acres)
Canal Road Drain	38,115	378
Sarasota Bay Coastal North	98	4,784
Palma Sola Drain – Bayshore	90	1,397
Cedar Hammock Creek	91,92,95	2,718
Bowlees Creek	93,94,96,97	5,783
Longboat/Lido Key	117	2,816
Sarasota Bay Coastal South	100, 101	1,711
Whitaker Bayou	99,110-114,116	5,219
Hudson Bayou	102-109	2,406
Siesta Key	118	83

Figure 4-17 compares annual average hydrologic loads by source from each Sarasota Bay basin under current and future conditions. In both scenarios, the largest total hydrologic loads are contributed by the largest basins: Whitaker Bayou and Bowlees Creek. The greatest increase from current to future conditions in total hydrologic loads is observed in the Sarasota Bay Coastal North basin as a result of increased contributions from baseflow and direct runoff sources. This increase reflects the conversion of undeveloped areas in the current condition to urban lands in the future. Also notable is the reduction in hydrologic loads from septic tanks in the Longboat/Lido Key and Whitaker Bayou basins following the removal of septic tanks in the future condition.

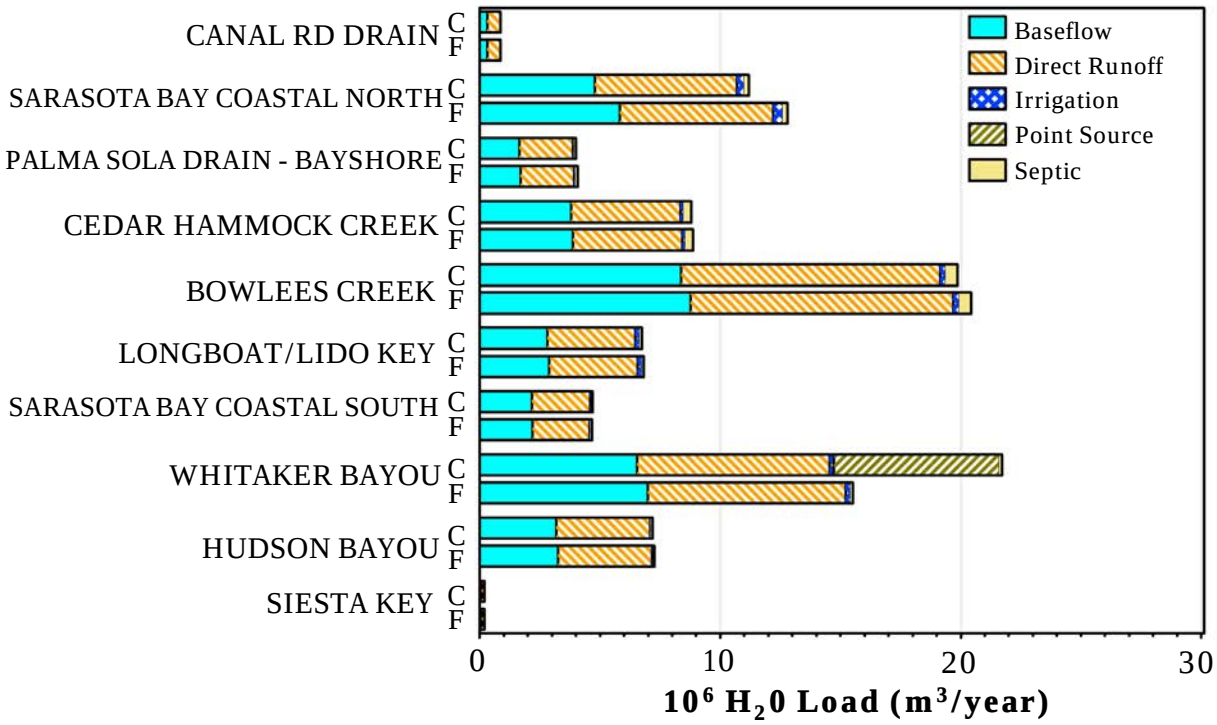


Figure 4-17 Comparison of Annual Hydrologic Loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989–2008)

Figure 4-18 compares annual average TN loads by source from each Sarasota Bay basin under current and future conditions. As with hydrologic loads, Whitaker Bayou and Bowlees Creek contributed the greatest TN loads under both conditions. Only small changes in TN loads (1–2 tons) are observed between the current and future conditions. Reductions in septic loads of TN are apparent for Longboat/Lido Key and Whitaker Bayou as a result of septic tank removal. In contrast, increases in septic loads resulted from aging septic tanks in several other basins, including Bowlees Creek. Slight increases in TN loads from baseflow and direct runoff appear to be the result of changes in land use as undeveloped land is converted to urban land uses.

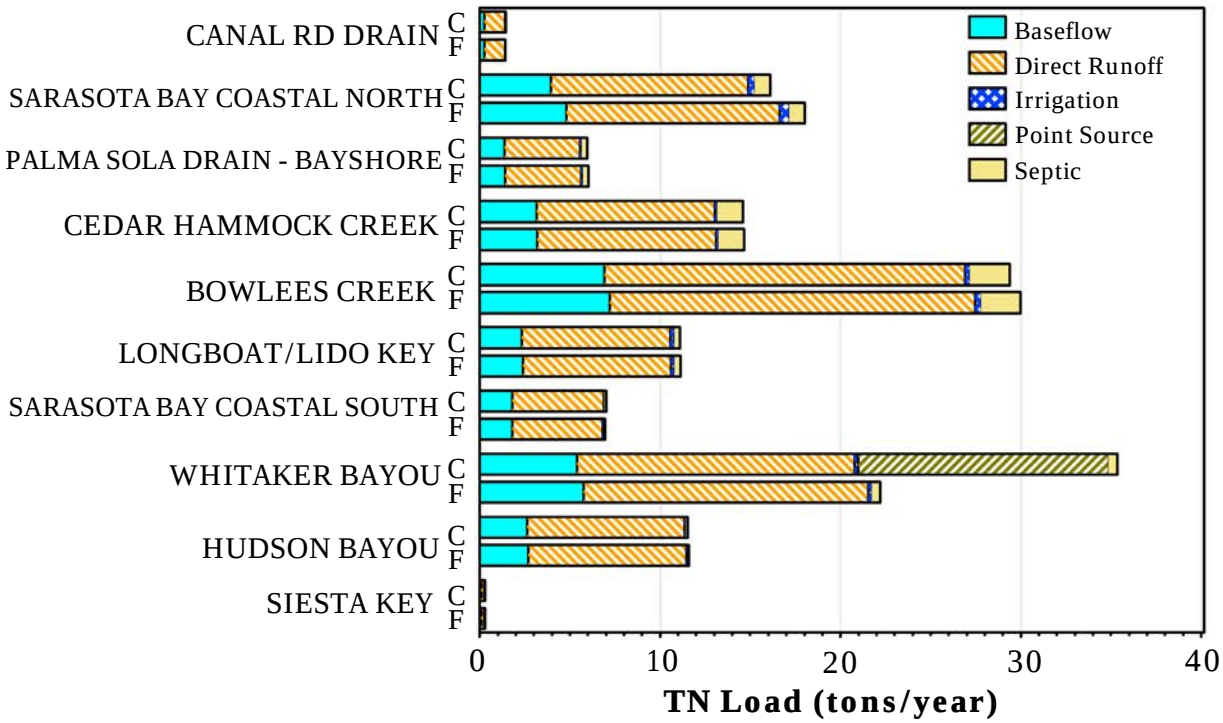


Figure 4-18 Comparison of Annual TN Loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989-2008)

Figure 4-19 compares annual average TP loads by source from each Sarasota Bay basin under current and future conditions. The greatest contributions of TP loads are from the largest basins—Whitaker Bayou and Bowlees Creek—though the change in total TP loadings to Sarasota Bay is relatively small from current to future estimates. In general, future TP loadings from a specific source did not change relative to current loading estimates. Slight increases were observed for baseflow and direct runoff, particularly for the Sarasota Bay North, which is presently one of the least developed basins in the watershed. As a result, this basin has the greatest potential to be developed, thus increasing the impervious surface for runoff. Reductions in TP loads from septic tanks are observed for the Longboat/Lido Key and Whitaker Bayou basins as a result of septic tank removal. Increases in TP loads from septic sources are apparent for the Cedar Hammock Creek, Sarasota Bay North, and Bowlees Creek basins as a result of failing septic tanks and potentially from increased baseflows in these basins.

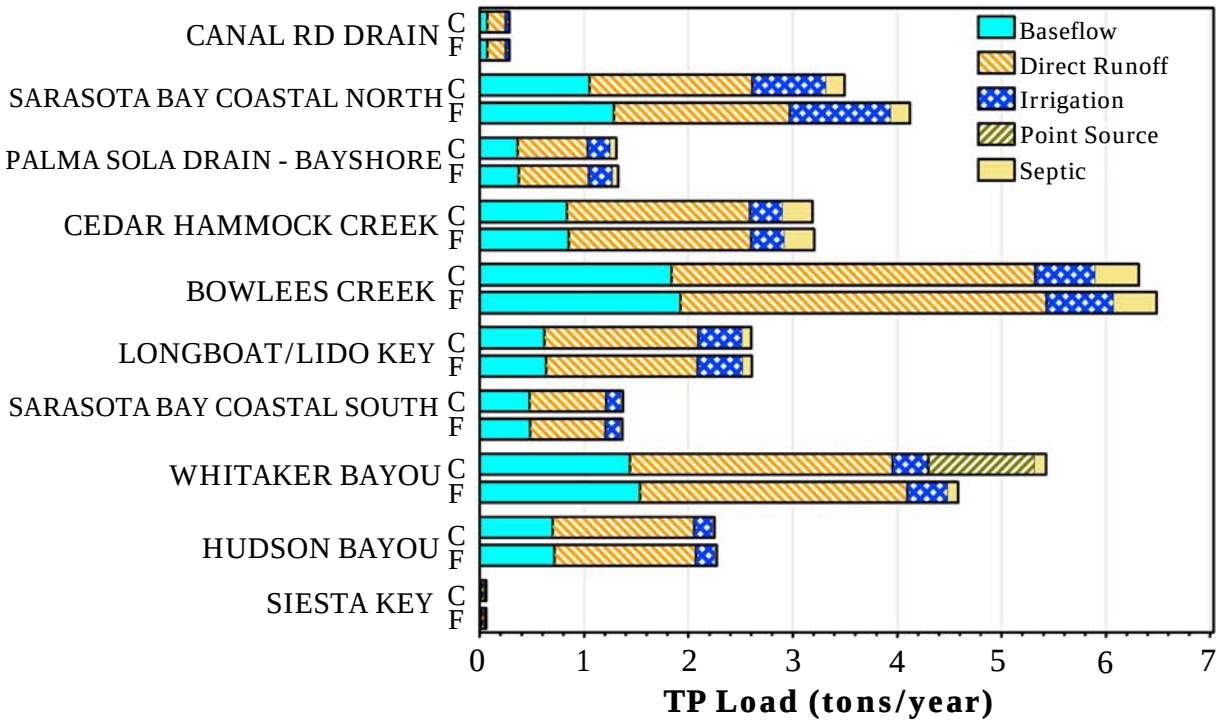


Figure 4-19 Comparison of Annual TP Loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989–2008)

Figure 4-20 compares annual average TSS loads by source from each Sarasota Bay basin under current and future conditions. In general, very little change in TSS loads was observed under future watershed conditions, though a slight increase in baseflow-derived TSS is apparent for the Sarasota Bay Coastal North basin and is likely a result of the greater potential for increased urban land uses in this basin.

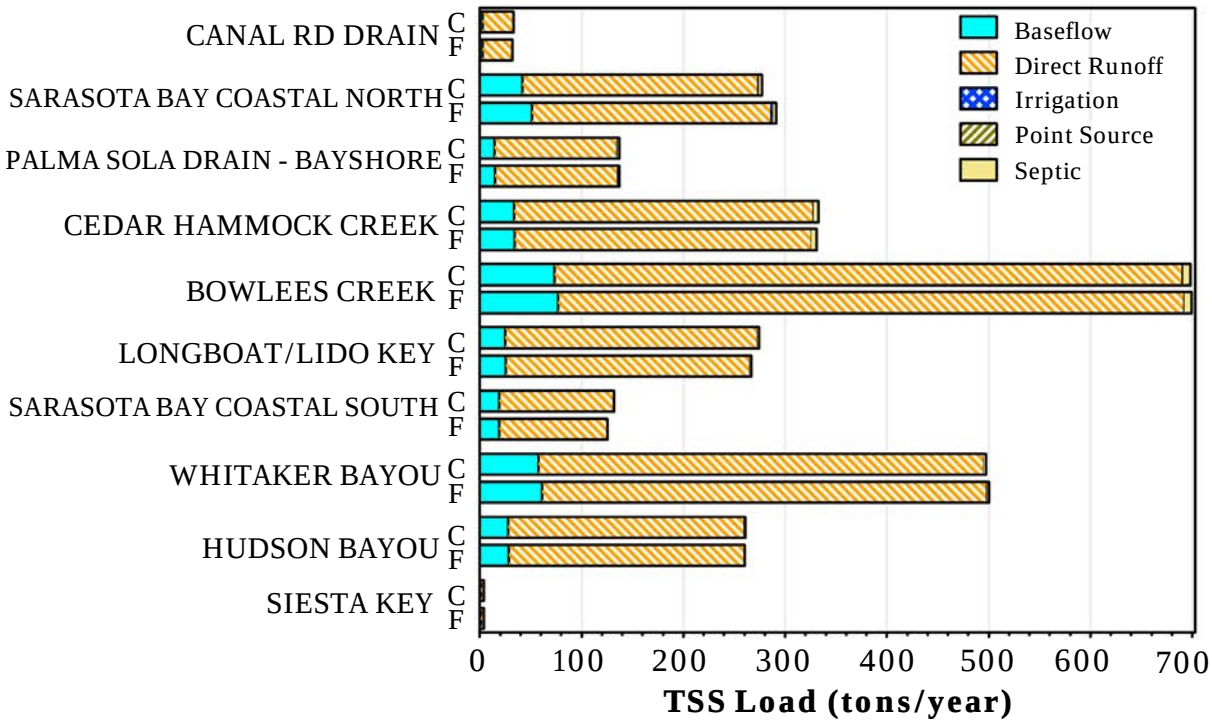


Figure 4-20 Comparison of Annual TSS loads to Sarasota Bay by Basin and Source for Current and Future Watershed Conditions (1989–2008)

Figure 4-21 shows the spatial distribution of unit-area TN loads by sub-basin. Sub-basin numbers correspond to the basin names in Table 4-1. TN loads from the majority of sub-basins remain relatively constant from the current to future conditions. Slight increases are apparent for the Longboat/Lido Key, Sarasota Bay Coastal North, Cedar Hammock Creek, and Bowlees Creek basins. A significant four-fold reduction in TN loads was estimated for Sub-basin 116 in the Whitaker Bayou basin and was the result of a large reduction in septic tank loads in this sub-basin.

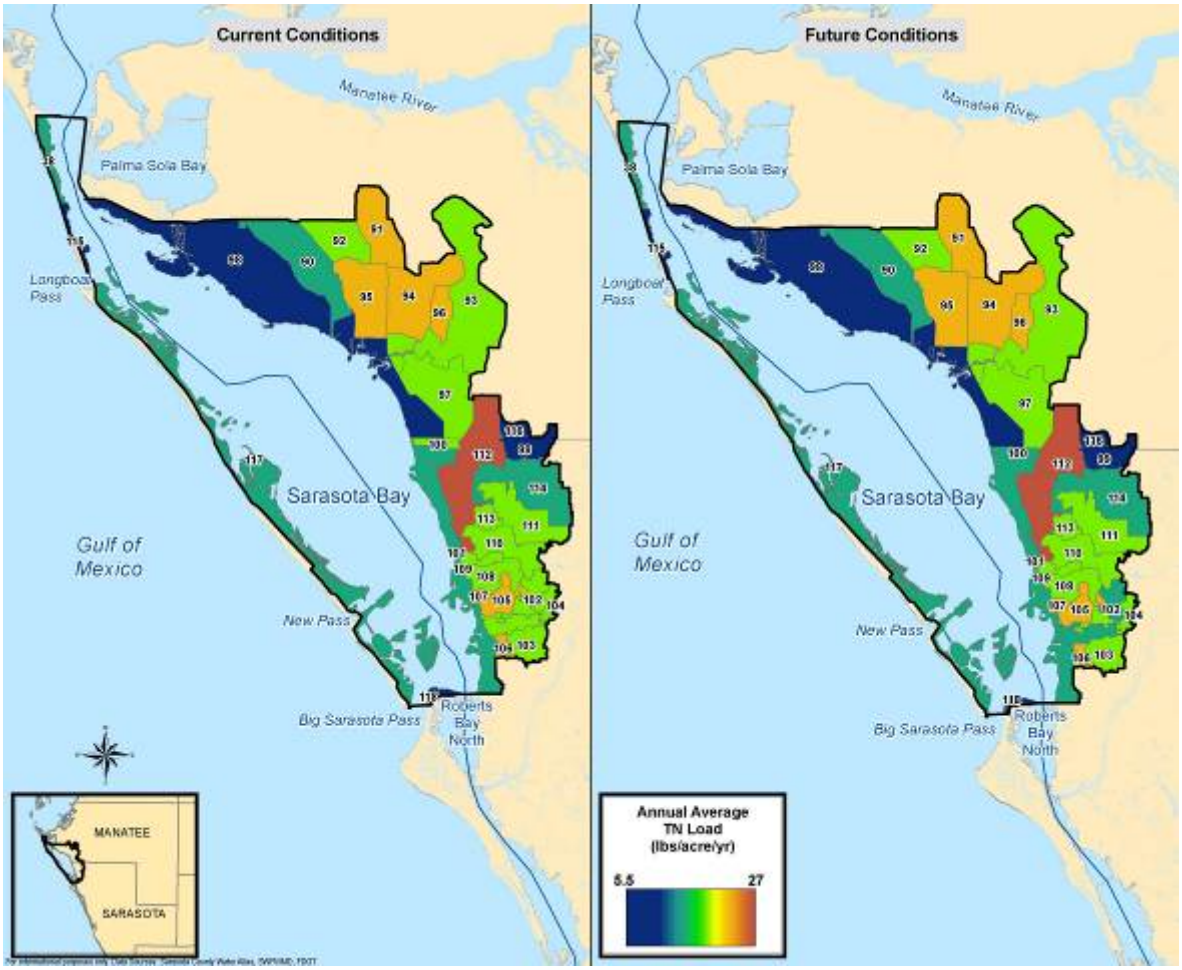


Figure 4-21 Comparison of Current Versus Future Unit-Area Annual TN loads to Sarasota Bay (1989–2008)
Sub-basin numbers correspond to basin names in Table 4-1.

Figure 4-22 depicts the spatial distribution of unit-area TP loads by sub-basin. Sub-basin numbers correspond to the basin names in Table 4-1. As with TN loads, small increases in TP loads were observed in the Longboat/Lido Key, Sarasota Bay Coastal North, Cedar Hammock Creek, and Bowlees Creek basins. TP loads were reduced greatly in Sub-basin 116 of Whitaker Bayou as a result of greatly reduced septic tank loads. Otherwise, TP loadings from most of the Sarasota Bay watershed were relatively consistent from the current to future conditions.

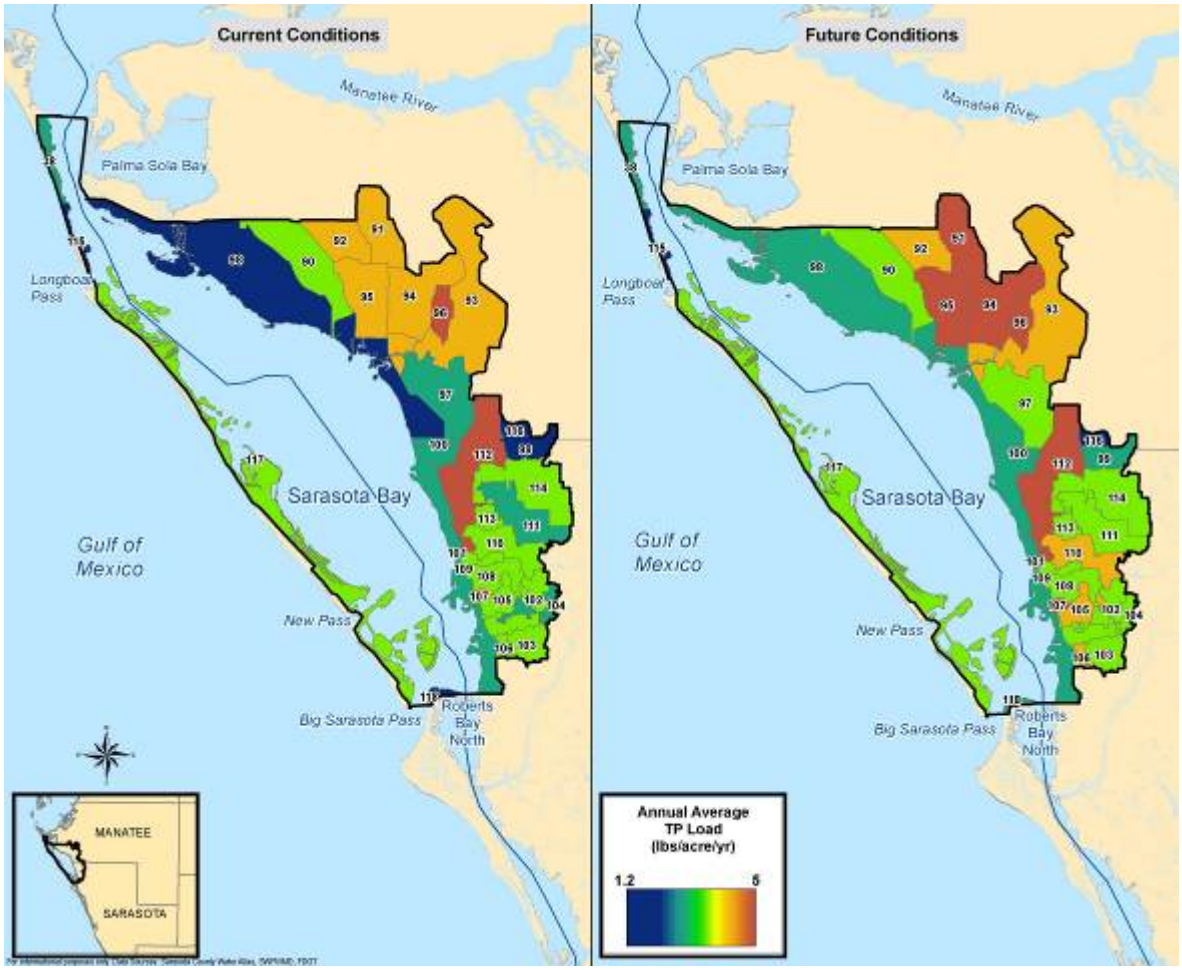


Figure 4-22 Comparison of Current Versus Future Unit-Area Annual TP loads to Sarasota Bay (1989–2008)

Sub-basin numbers correspond to basin names in Table 4-1.

Figure 4-23 shows the spatial distribution of unit-area TSS loads by sub-basin. TSS loads are similar from current to future conditions with little significant change in any of the sub-basins. The largest annual TSS loads per acre are primarily found in the Bowlees Creek, Cedar Hammock Creek, Hudson Bayou, and Whitaker Bayou basins. Reductions in TSS loads are apparent for Sub-basin 116 in Whitaker Bayou as a result of a large decrease in septic tank loads.

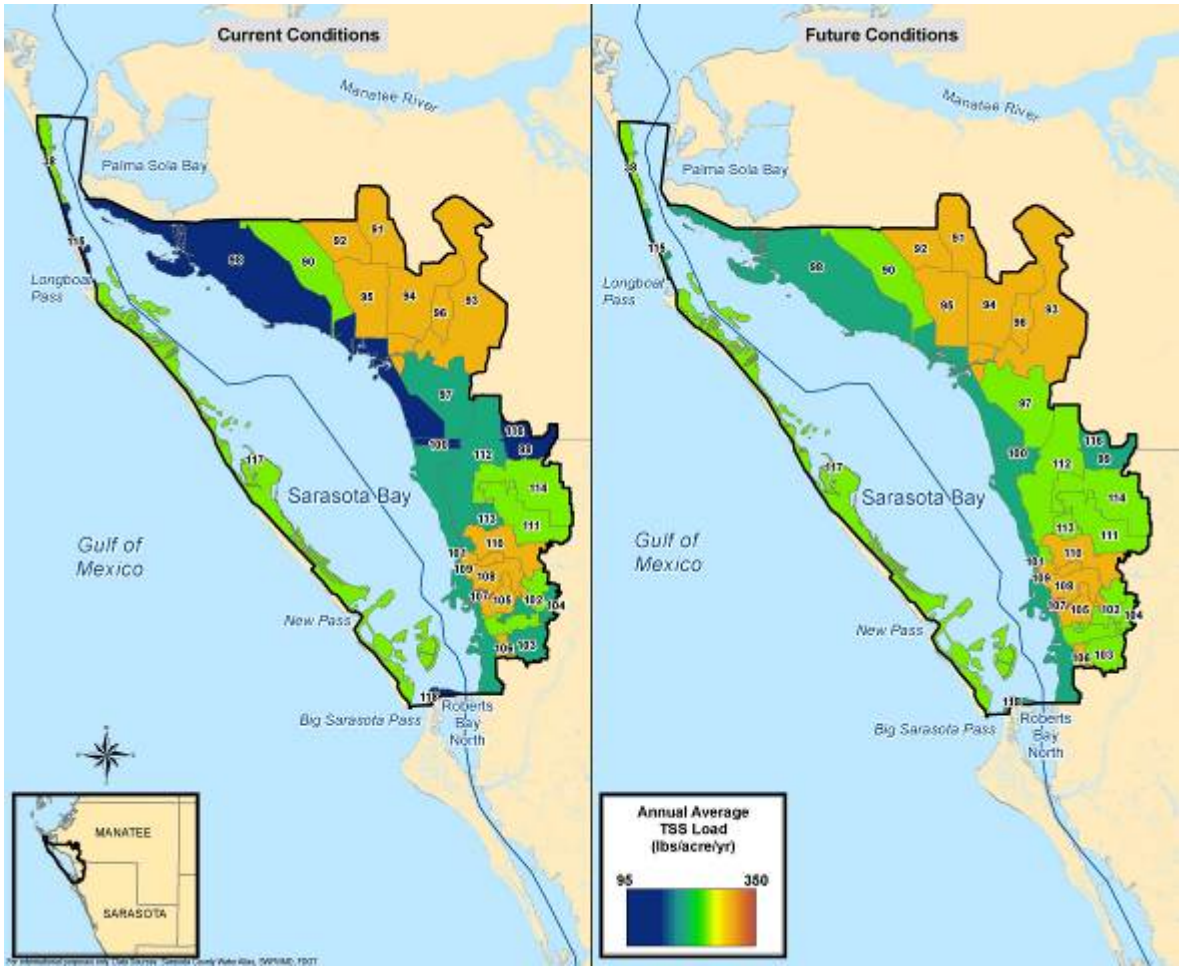


Figure 4-23 Comparison of Current Versus Future Unit-Area Annual TSS Loads to Sarasota Bay (1989–2008)

Sub-basin numbers correspond to basin names in Table 4-1.

5.0 WATER QUALITY LEVELS OF SERVICE

5.1 OBJECTIVE

This section presents the approach, information, and data used for and summarizes the results associated with developing water quality LOS criteria for the Sarasota Bay estuary and associated freshwater tributaries. The information provided in this section will be used to identify potential management actions for the Sarasota Bay WQMP.

5.2 APPROACH

Setting resource protection LOS is one of the most important elements of an effective watershed management plan. An overall approach for protecting Sarasota Bay's resources has recently been established through the work of SBEP, Southwest Florida Water Management District (SWFWMD), Sarasota County, other local governments, FDEP, and other interested parties.

The development of water quality LOS is based on a paradigm that distinguishes targets from thresholds, i.e., that distinguishes water quality management levels from regulatory levels. A **target** is a desired water quality condition and can be used as an "early warning" of undesirable change in water quality. Water quality targets, e.g., chlorophyll *a* concentrations, have been defined by SBEP as the annual mean of the reference period, i.e., the period that was deemed to be protective of desired water quality conditions. There may be years in which water quality targets may be exceeded without causing significant changes in the receiving waterbody. Therefore, some allowable amount of variation should not elicit a significant degradation in water quality and, in the case of Sarasota Bay proper, therefore seagrass coverage. SBEP defined this level of variation as the standard deviation around the mean annual water quality conditions in each segment for the entire period of record. Thresholds have often been set to meet the need for a regulatory level. Where these regulatory levels have not been established, there remains the need for a second water quality management level that elicits significant responses to the target exceedances. Therefore, for the Sarasota Bay WQMP, a **threshold** has been operationally defined as the sum of the annual mean conditions and this standard deviation. A distinction is made between a target, i.e., a desired water quality condition, and a threshold, i.e., a water quality level above which undesirable conditions exist.

The SBEP Management and Policy Boards unanimously approved chlorophyll *a* targets (presented in Section 5.4.2) at their January 15, 2010 meeting. At the June 4, 2010 meeting, both boards delegated authority to the SBEP Technical Advisory Committee for submitting draft NNC using the nutrient targets presented below to FDEP and EPA.

The SBEP approach is based on protecting seagrasses, an extremely important natural resource for Sarasota Bay. The control of loadings on a bay-wide scale is the most effective approach to protect seagrasses and other natural resources. Unless specific localized problems are identified,

a bay-wide approach to managing nutrient inputs, as opposed to managing on a basin or catchment scale, is recommended.

The adopted water quality LOS criteria for seagrass, chlorophyll *a*, and nutrients were reviewed and assessed to ensure their appropriateness. The general methodology and the results are described below. A detailed description of the methods is provided in Janicki Environmental, Inc. (2010a, b; 2011a). The relationships between pollutant loading and estuarine water quality, freshwater stream water quality, basin loadings, and freshwater inflow and salinity in the estuary are also discussed below in Section 5.4.3.

DO is another important parameter for assessing the ecological health of aquatic systems. Florida's current standard for DO in Class II and Class III marine waters, which include Sarasota Bay, states that DO "shall not average less than 5.0 mg/L in a 24-hour period and shall never be less than 4.0 mg/L" (Chapter 62-302.530, FAC, Criteria for Surface Water Quality Classifications). This standard was deemed inadequate by FDEP because it did not recognize seasonal and diurnal variability in DO that may cause DO levels to be naturally below the standard.

FDEP proposed a revised methodology for setting DO standards for fresh and marine waters. FDEP's proposed methods, described in FDEP's technical support manual for the derivation of dissolved oxygen criteria (FDEP, 2012a), is under peer review. DO in the estuary and tributaries is compared to existing and proposed criteria in Section 5.4.

NNC have been adopted for freshwater streams by FDEP (2011a). TN NNC for streams were developed based on water quality characteristics of "nutrient watershed regions." Sarasota Bay tributaries are assigned to the West Central region shown in Figure 5-1; this region has a TN nutrient threshold of 1.65 mg/L and a TP threshold of 0.49 mg/L. Ambient nutrient concentrations in Whitaker Bayou and Hudson Bayou were compared to these thresholds.

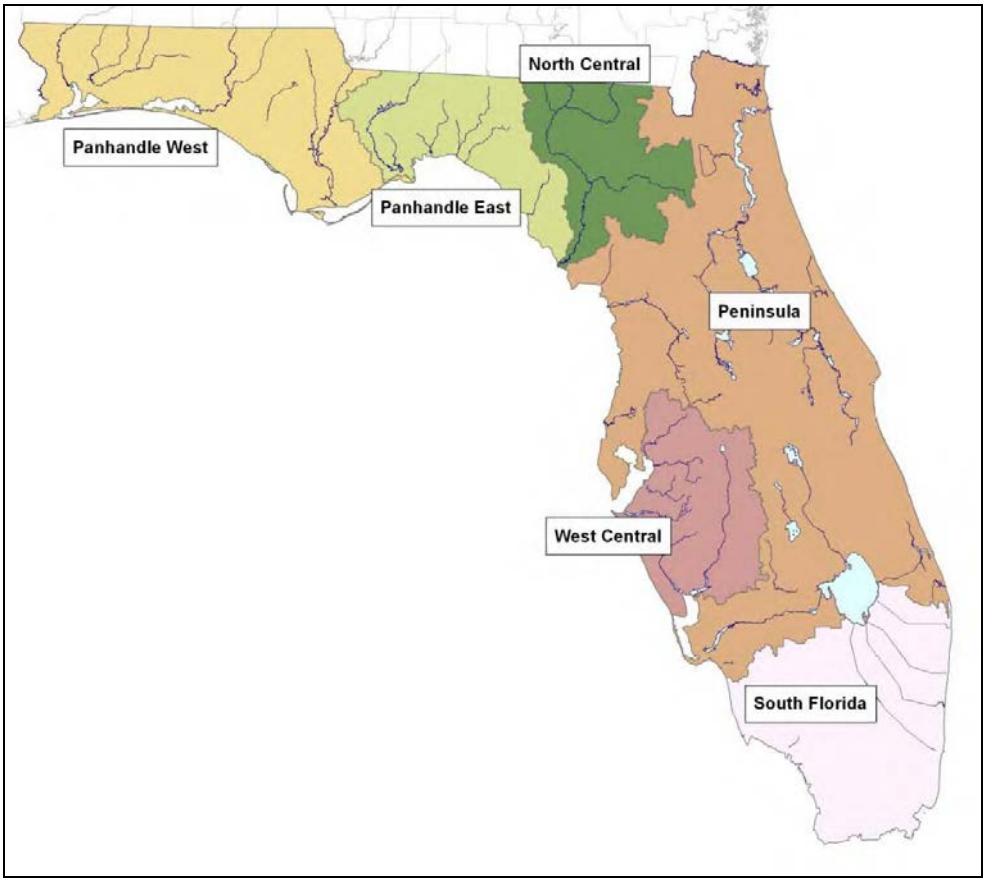


Figure 5-1 Nutrient Watershed Regions of Florida (FDEP, 2012a)

5.3 DATA AND INFORMATION USED

- TN loading and TP concentration and loading criteria as developed for SBEP from *Sarasota Bay Numeric Nutrient Criteria Task 1 – TN and TP Concentration and Loading Based Criteria*, March 17, 2011 (Janicki Environmental, 2011a).
- NNC for TN concentrations for Sarasota Bay as developed for SBEP from *Numeric Nutrient Criteria for Sarasota Bay* (Janicki Environmental, Inc., 2010a).
- Methodologies for developing NNCs [from Empirical Approaches to Establishing Numeric Nutrient Criteria for Southwest Florida Estuaries (Janicki Environmental, Inc., 2010b).
- Methods and Approaches for Deriving Numeric Criteria for Nitrogen/Phosphorus Pollution in Florida's Estuaries, Coastal Waters, and Southern Inland Flowing Waters (EPA, 2010).
- Draft revised Rule Chapter 62-302, FAC, Surface Water Quality Standards. November 1, 2011 (FDEP, 2011a).
- NNC briefing for Environmental Regulatory Commission. November 3, 2011 (FDEP, 2011b).
- Seagrass survey data for Sarasota Bay (1950, 1988, 1994, 1999, 2001, 2004, 2006, 2008, and 2010) provided by SWFWMD (2011).

- Ambient water quality data provided by Sarasota County (2012) and Manatee County (2012).
- TN, TP, and TSS loading estimates from the Sarasota SIMPLE-Monthly model (Janicki Environmental, Inc. (2010a).

5.4 RESULTS

5.4.1 Development of Seagrass LOS Targets

Setting water quality targets based on the requirements for the growth and reproduction of seagrasses helps ensure that the entire bay community remains sustainable. Seagrasses serve several important functions including stabilizing the benthic environment by trapping and holding fine-grained particles and sediment in their root systems and removing dissolved nutrients from the water column. Sequestering sediments and nutrients improves water clarity, which is beneficial to the entire system. Seagrasses also provide critical habitat, serving as nurseries for fish, crustaceans, and shellfish, including many commercially and recreationally important species. Seagrasses are also a food source for organisms that live in and on them and for mammals such as manatees.

Human activities can adversely affect seagrasses by physically disturbing them and by introducing excess levels of chemicals that originate in the watershed and enter the bay via stormwater runoff. Excess nutrients in the water can lead to algae blooms that impact water clarity and reduce the magnitude and areal extent of light availability at levels that seagrasses need to survive. If seagrasses are healthy and widespread in a waterbody, then the natural community as a whole is likely healthy.

As stated above, SBEP has set seagrass LOS targets for the entire Sarasota Bay system, including Sarasota Bay proper. The target-setting process was based on comparing historical seagrass coverage that was developed by photo-interpretation of historical (ca. 1950) aerial photographs to recent seagrass surveys conducted by SWFWMD. SBEP defined the seagrass target as the larger areal extent of seagrass coverage under either historical (less areas that have since been filled or dredged) or current conditions. Figure 5-2 presents the seagrass coverage data used to establish the target for Sarasota Bay. The LOS target is 7,269 acres, which represents the 1950 coverage, less areas that have been filled or dredged and are unrestorable. During target-setting, data from 2004 to 2006 were used to represent recent conditions. The 2008 and 2010 surveys indicate that seagrass coverage has been above the LOS target acreage.

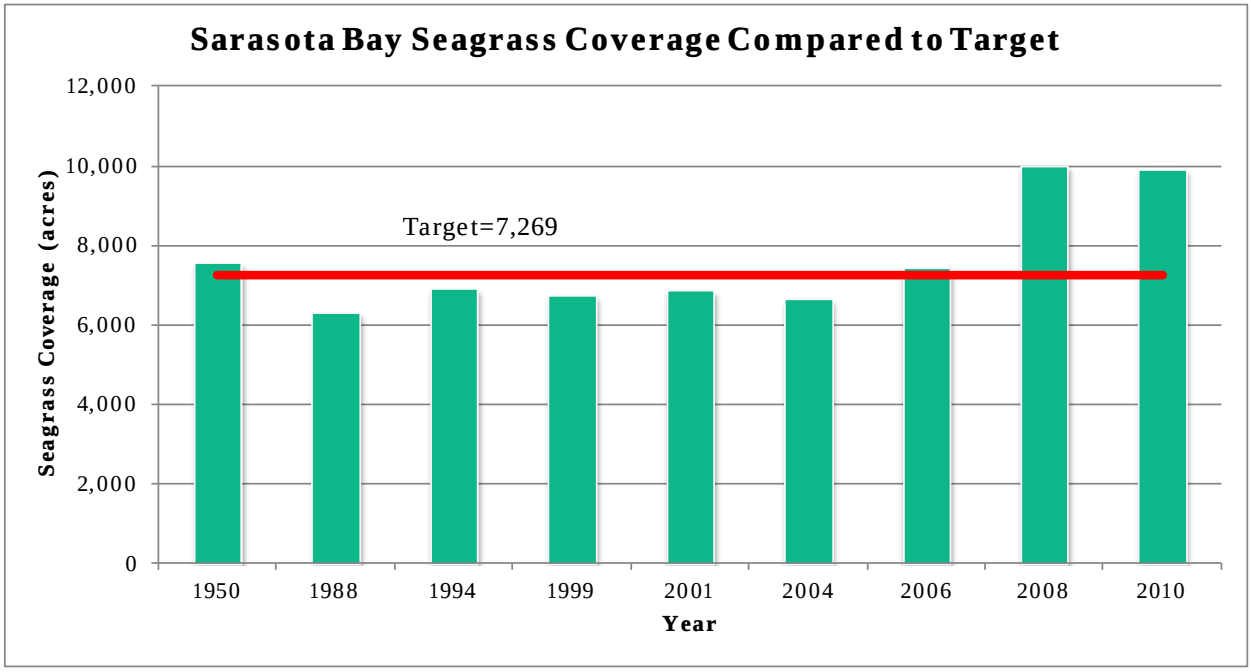


Figure 5-2 Seagrass Coverage (Acres) from Historical and Recent Surveys in Sarasota Bay with Target (7,269 Acres) Shown

5.4.2 Development of Chlorophyll *a* LOS Targets

Improving and maintaining water clarity are fundamental to restoring and protecting seagrass populations. Controlling chlorophyll *a* concentrations in the water column is a primary means of maintaining sufficient water clarity for seagrass restoration and maintenance. Recent data from ambient water quality monitoring programs indicate that chlorophyll *a* concentrations in Sarasota Bay declined from 1998 to 2009. Further analysis of the chlorophyll concentration data using non-parametric trend tests (Kendall-Tau) showed a significant decreasing trend ($p<0.03$) in chlorophyll in the bay (Figure 5-3). This finding, in conjunction with the increased seagrass acreage, provides strong evidence that the current management efforts of Sarasota County, SBEP, and others are successful and resulted in improved water quality and increased seagrass abundance.

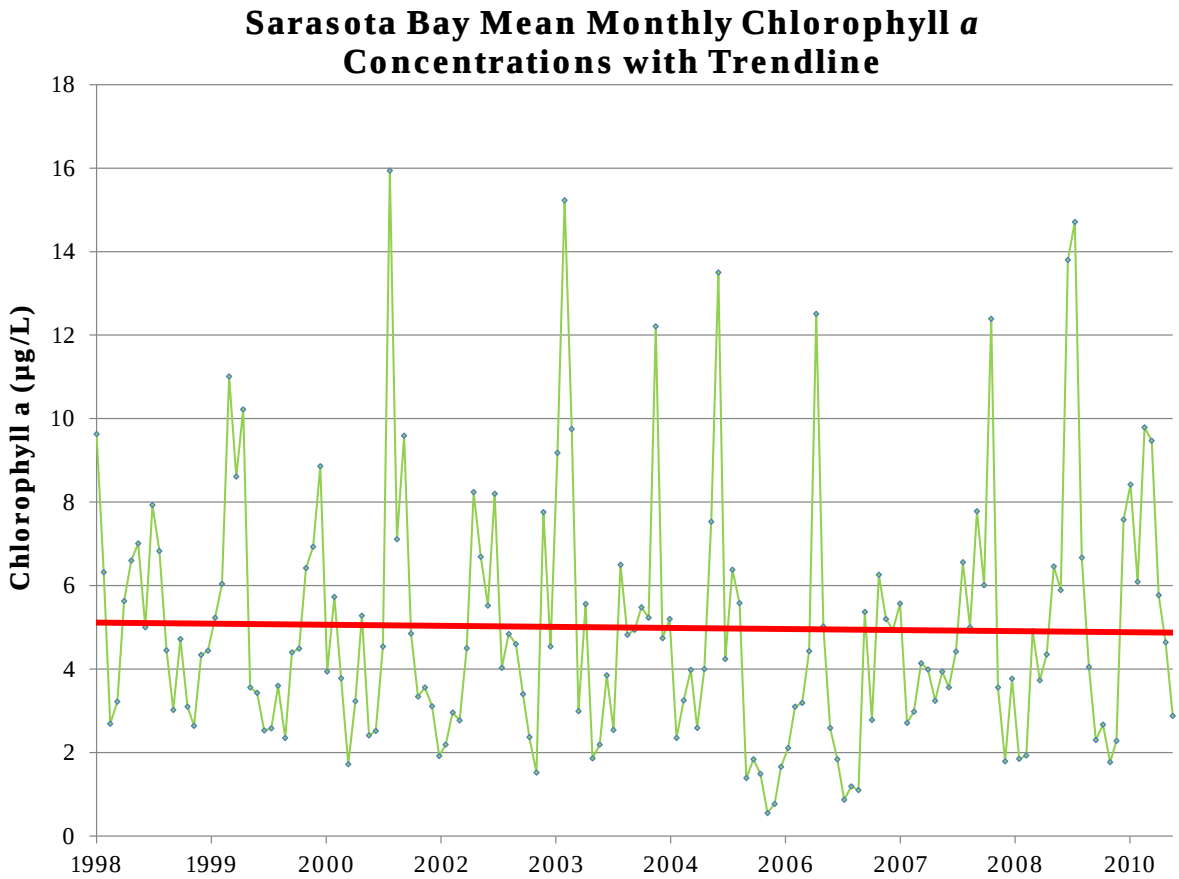


Figure 5-3 Sarasota Bay Mean Monthly Chlorophyll *a* Concentrations with Trend Line (non-parametric Kendall-Tau)

Because the recent extents of seagrass coverages are meeting and exceeding the established LOS targets, SBEP determined that recent chlorophyll *a* concentrations and associated water clarity protect the seagrasses in Sarasota Bay. Data from 2001–2005 were used to establish the LOS target. The resultant mean chlorophyll *a* concentration from this period was established as the LOS target. The LOS target was established with the recognition that there may be years in which the chlorophyll *a* targets are exceeded without resulting in a significant reduction in seagrass cover. This means that some variation in water quality will not result in a significant degradation to environmental quality with subsequent reduced seagrass coverage. The level of acceptable variation was established by SBEP as the standard deviation around the mean annual chlorophyll *a* concentrations in Sarasota Bay for the entire period of record.

A distinction was made between an LOS target (the desired chlorophyll *a* concentration) and a threshold (a chlorophyll *a* concentration above which undesirable conditions are likely to occur). The chlorophyll *a* threshold for the bay is the sum of the target and the standard deviation around the mean annual chlorophyll *a* concentrations in the bay.

Based on these premises, the chlorophyll *a* LOS target for Sarasota Bay was set at 5.2 µg/L and the threshold was set at 6.1 µg/L (equal to the target plus the standard deviation of 0.9 µg/L). The chlorophyll *a* LOS threshold was used to develop the numeric nitrogen LOS target for Sarasota Bay discussed below. As Figure 5-4 shows, annual arithmetic mean chlorophyll *a* concentrations in Sarasota Bay were below the threshold value in all years.

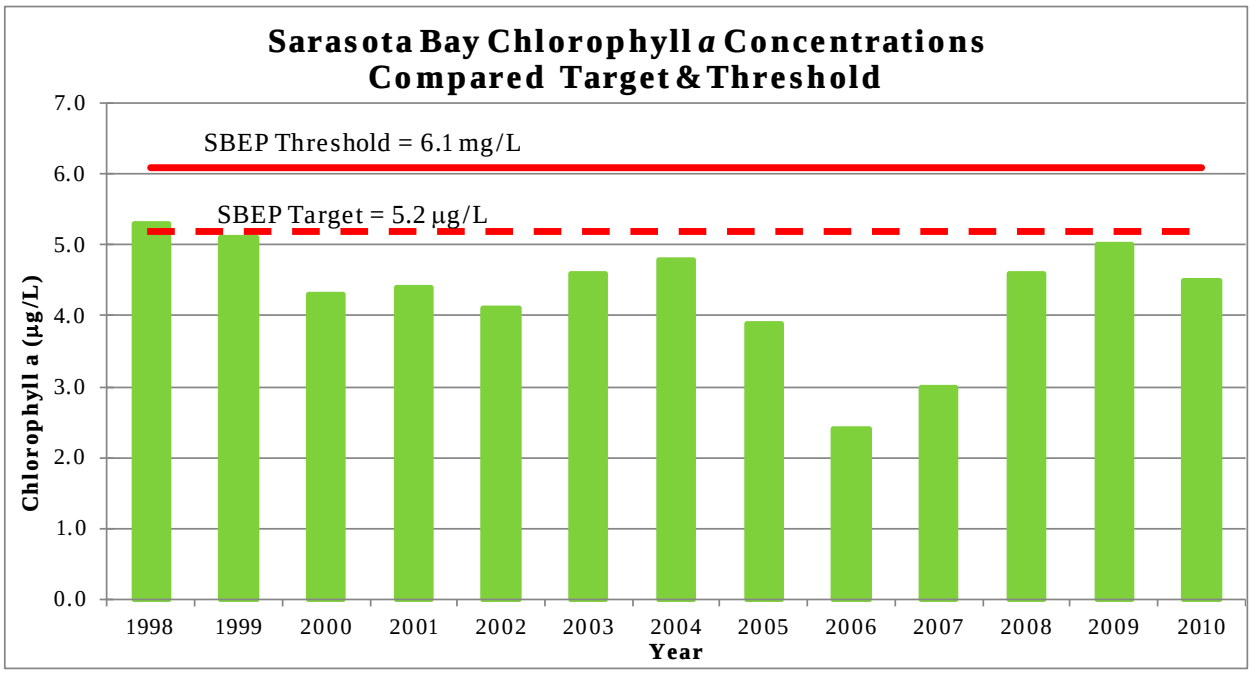


Figure 5-4 Sarasota Bay Chlorophyll *a* Concentrations (Annual Arithmetic Means) with Threshold Line (6.1 µg/L) and Target (5.2 mg/L)

5.4.3 Development of the Nitrogen and Phosphorus LOS

The relationship between nutrients (TN and TP) and eutrophication in the Sarasota Bay estuary system has been investigated by Janicki Environmental (2010a, b; 2011a). Janicki noted that nitrogen is well-documented as the most common growth-limiting nutrient in many estuarine waterbodies. That is, the concentration of nitrogen in the environment determines the growth and productivity of organisms in that environment. Aquatic systems with TN:TP ratios below 10, as is the case with Sarasota Bay, are commonly recognized as nitrogen-limited. Other empirically derived relationships also indicate that nitrogen has a dominant role in the eutrophication process in the Sarasota Bay system (Janicki Environmental, 2010a; 2011a). However, it has also been documented (Janicki Environmental., 2011a) that nitrogen limitation can shift to phosphorus limitation depending on the relative supply of nutrients, the season, or other factors. Thus, the nutrient LOS for Sarasota Bay presented below includes both TN and TP loads and concentrations.

5.4.3.1 Estuarine TN Concentration Target and Threshold

A stressor-response relationship was used to develop the TN concentration NNC as described in Janicki Environmental, Inc. (2010a) and similar to the approach published by EPA (2010). The identification of an empirical relationship (a regression model) between chlorophyll *a* and some measure of nutrient conditions was essential for this approach to be successful.

Figure 5-5 shows monthly average TN concentrations in Sarasota Bay. The decreasing trend line is shown but is not statistically significant. Mean monthly values for 1998 through 2010 ranged over an order of magnitude from under 0.1 mg/L (1998) to over 1.0 mg/L (2004); however, the vast majority of monthly values ranged from 0.2 to 0.5 mg/L. Figure 5-6 is a box-and-whisker plot of calendar month values for TN in Sarasota Bay. A distinct seasonal signal is evident, with higher TN values occurring during the summer months. Monthly means (represented by dots in Figure 5-6) ranged from a high of 0.49 mg/L (September) to a low of 0.29 mg/L (February).

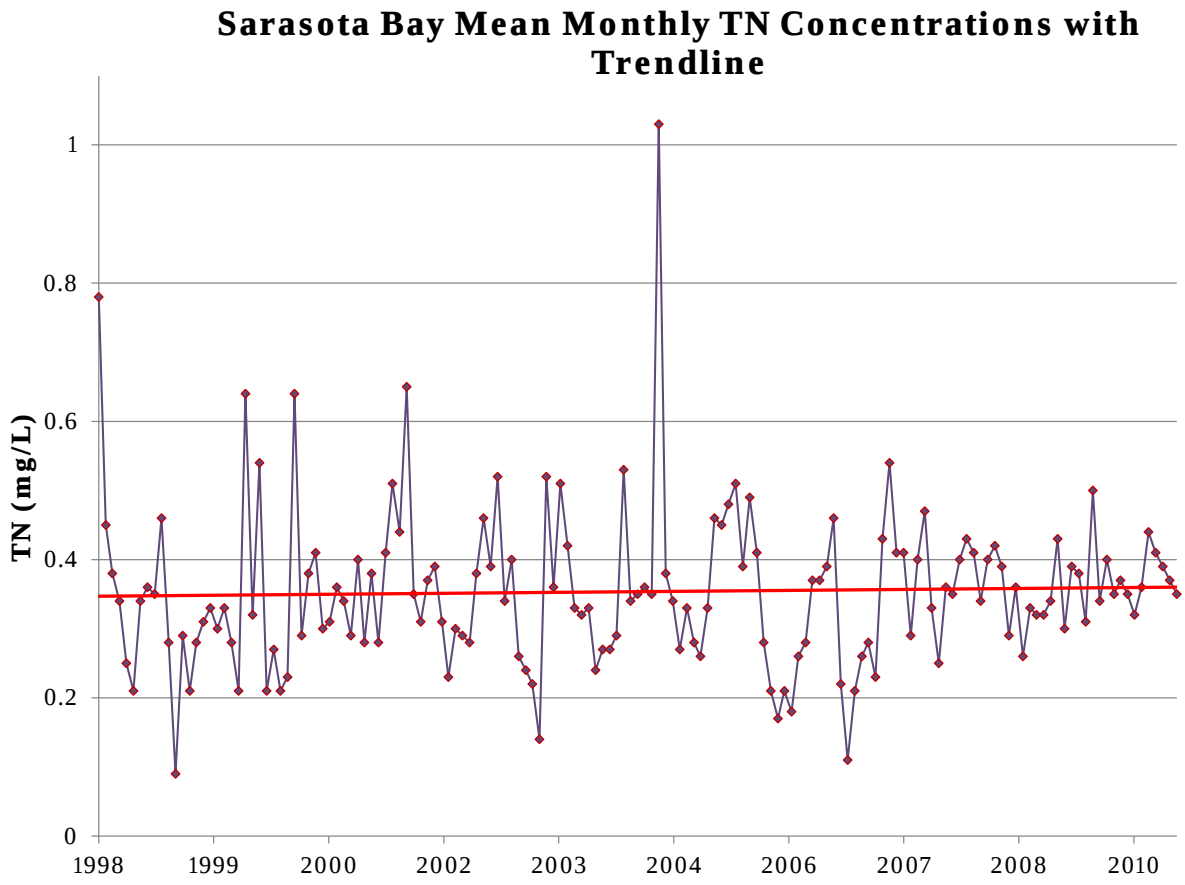


Figure 5-5 Mean Monthly TN Concentrations (mg/L) Observed in Sarasota Bay with Trend Line (non-parametric Kendall-Tau)

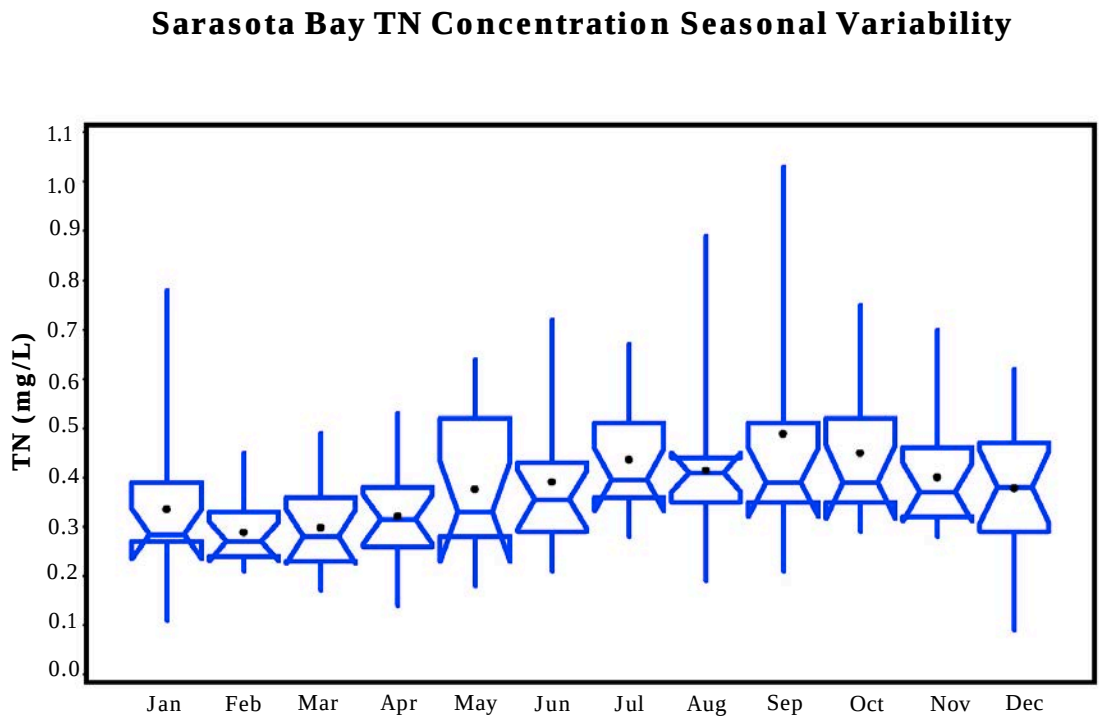


Figure 5-6 Box-and-Whisker Plots of the Monthly TN Concentrations (mg/L) Observed in Sarasota Bay

The independent variables used in the model-building included TN and TP loadings and concentrations, hydrologic loadings, and estimates of residence time of water in the bay. The loadings data investigated included monthly hydrologic, TN, and TP loads as well as cumulative total loads extending from 2 to 6 months (e.g., 2-month cumulative TN load = TN load current month + TN load 1-month prior). The water quality constituents included TN and TP concentrations as well as numerous other constituents. A complete presentation of the process followed to develop the criteria for SBEP can be found in Janicki Environmental (2010a). A general description of the methods and results of the analyses follows.

A regression equation was developed using a multi-step process to quantify the relationship between nutrients and chlorophyll *a* in the bay. The TN concentration was identified as the variable that made the greatest contribution to explaining the variability in chlorophyll *a* concentrations in Sarasota Bay. As expected, a pattern of increasing chlorophyll *a* concentrations with increasing TN concentrations was observed (Figure 5-7).

As in the regressions developed for other Sarasota Bay system segments (including Roberts Bay, Little Sarasota Bay, and Blackburn Bay), initial efforts to identify a quantifiable relationship revealed a seasonal difference in residuals. This indicated that given the same TN concentration, higher chlorophyll *a* concentrations are expected during the summer months. Therefore, a seasonal term was added to the regression equation. The seasonal term is a dummy variable that equals one during the wet season (June–October) and zero during other months.

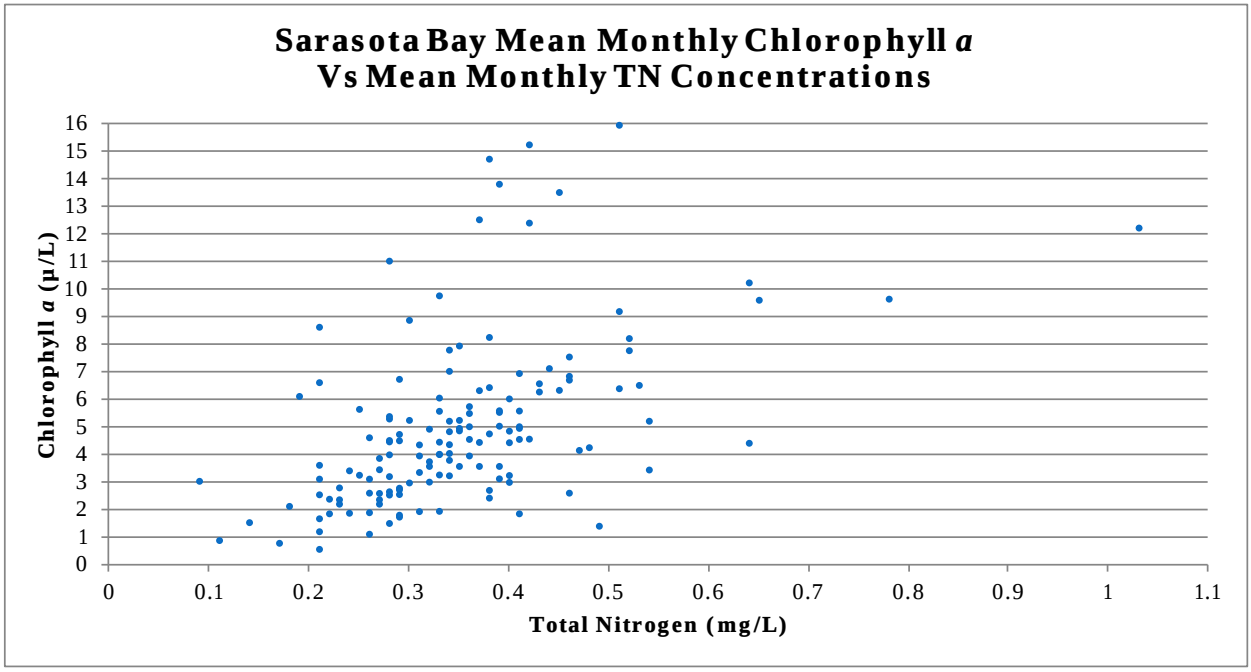


Figure 5-7 Relationship Between Monthly Average Chlorophyll *a* and TN Concentrations in Sarasota Bay

However, Sarasota Bay is a substantially larger estuary with greater spatial variability in TN concentrations than the other Sarasota Bay system segments. Specifically, TN concentrations in the north portion of the bay (the dividing line is shown in Figure 5-8) are greater than those in the south portion (Table 5-1). In contrast, less spatial variability (between sampling sites) occurs in the north chlorophyll *a* concentrations. Therefore, a regional term was added to the regression equation to account for the spatial differences in TN and chlorophyll *a* concentrations in Sarasota Bay.

Figure 5-8 North and South Portions of the Sarasota Bay Segment

Table 5-1 Comparison of Water Quality within North and South Sarasota Bay (Values Represent Medians for 1998–2009)

Variable	North Sarasota Bay	South Sarasota Bay
Chlorophyll *a* (µg/l)	5.2	3.4
TN (mg/L)	0.56	0.28
Color (PtCo units)	20	10

Further analysis of the residuals from the regression model revealed that color also contributed to the variation in chlorophyll *a*, and a color variable was subsequently added to the regression equation. The final regression equation (Equation 1) obtained was:

(Equation 1)
[Chlorophyll *a*] = -1.06 + (3.58 * [TN]) + (0.32 * [color]) + (2.03 * season) – (4.84 * region)

The analyses demonstrate that the relationships between chlorophyll and other parameters is different in the north part of the bay than in the south, so factors were included in the regression equation to improve predictive ability by accounting for what part of the bay is of interest and to recognize that color was shown to play a part in the relationships. The color variable was added

only to improve the fit of the regression model. This does not imply that color has a significant direct effect on chlorophyll *a*. Also, the magnitude of the different parameters does not equate to their influence in the relationships. Equation results are calculated by season and then aggregated annually.

The model was fit with 156 observations and resulted in an R2 value of 0.67. The regression was highly significant with a probability of a greater |F| value of <0.0001. The slope and parameter coefficients were also significant. Figure 5-9 is a plot of predicted versus observed chlorophyll *a* concentrations.

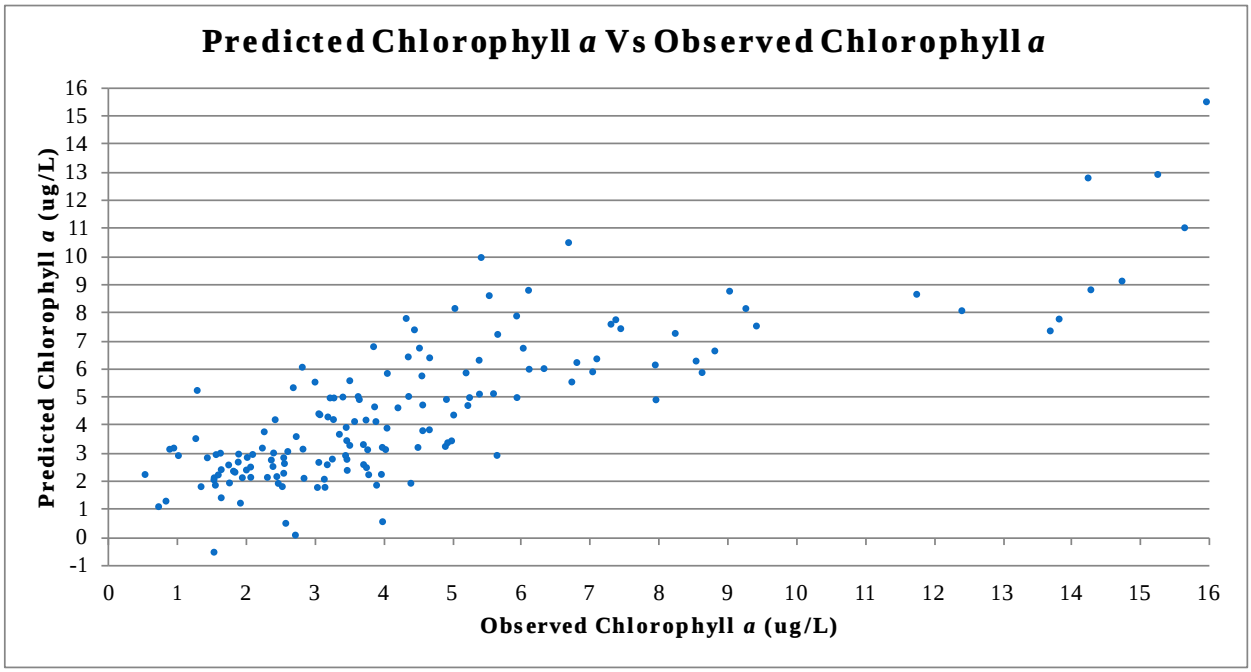


Figure 5-9 Predicted vs Observed Chlorophyll *a* Concentrations in Sarasota Bay ($R^2 = 0.67$)

Therefore, based on these data analysis results, the TN concentration NNC provides the LOS threshold for Sarasota Bay and is defined by Equation 1 and varies according to the observed color in any given year. Ambient TN concentrations in Sarasota Bay for 1998–2010 were compared to the TN NNC that were calculated for each year using Equation 1, as shown in Figure 5-10. Using annual geometric means of the concentrations, ambient TN concentrations were lower than the TN criterion for all years. The ambient concentrations are within a relatively tight range, between 0.2 and 0.4 mg/L. Much of the variability in the TN criterion was due to changes in color (see Equation 1).

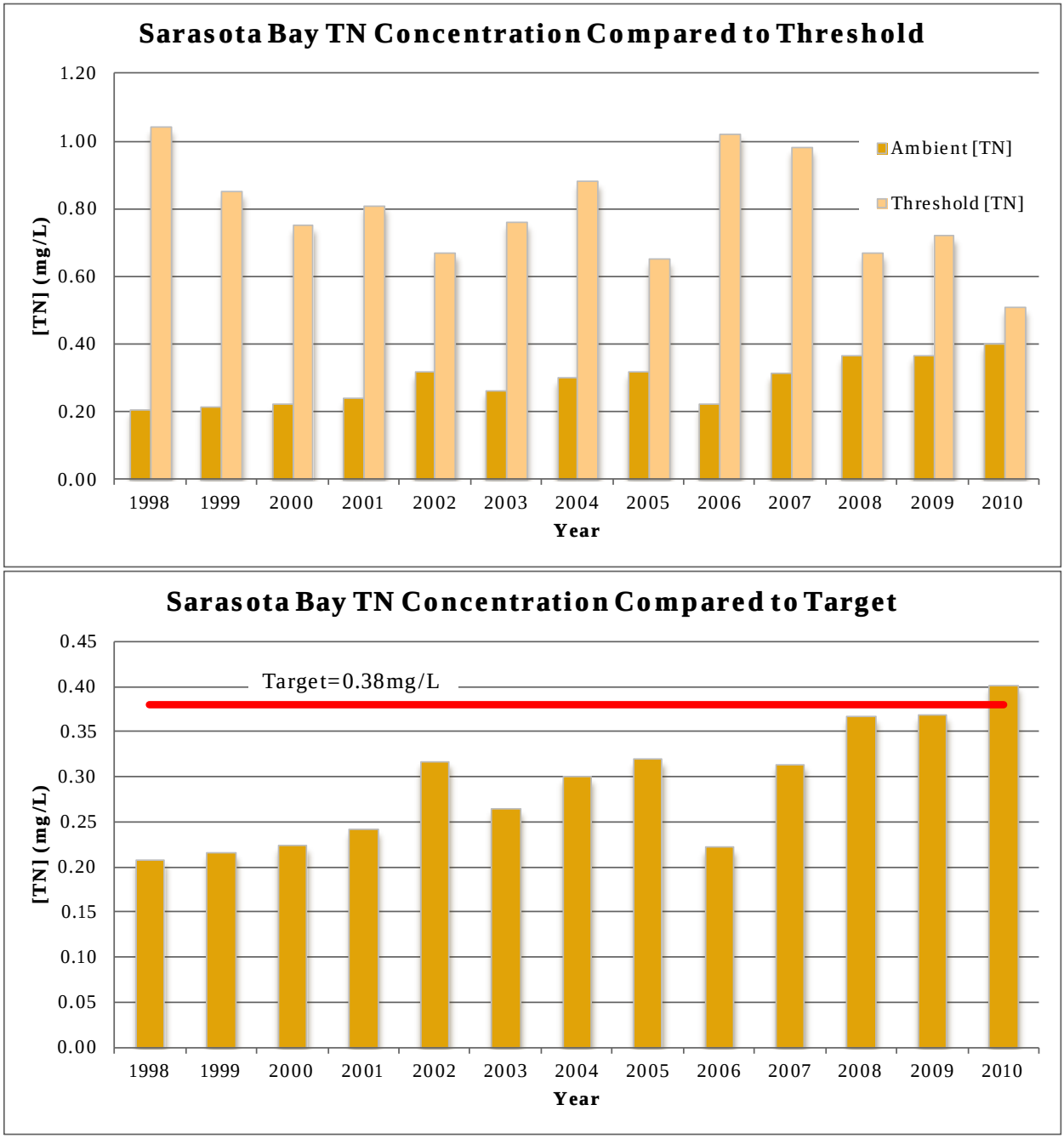


Figure 5-10 Comparison of Observed Annual Geometric Mean TN Concentrations in Sarasota Bay to Year-Specific TN Thresholds (shown in the upper panel) and TN Target (shown in the lower panel)

There remains the need for a TN concentration target for Sarasota Bay. To maintain consistency with the method used to set the chlorophyll *a* target, the TN concentration LOS target for Sarasota Bay is the annual mean for the 2001–2005 reference period. This target is 0.38 mg/L.

5.4.3.2 Estuarine TP Concentration Target and Threshold

The same approach that was used for TN loads above was used to develop LOS TP concentration target and threshold. Therefore, concentration-based NNC for TP were developed using the reference period approach (Janicki Environmental, 2011a). The TP concentration target for Sarasota Bay is the annual mean for the 2001–2005 reference period, which was deemed appropriate due to the seagrass coverage observed during this period (Janicki Environmental, 2010a). As described above, SBEP also considered the year-to-year variability in water quality conditions and arrived at a threshold (concentrations above this level indicate undesirable conditions) as the sum of the TP target and one standard deviation of the long-term TP concentrations.

Following this approach, the TP concentration target, standard deviation, and threshold for Sarasota Bay are 0.15, 0.04, and 0.19 mg/L, respectively. Figure 5-11 compares ambient TP concentrations for 1998–2008 to the target and threshold. TP concentrations were below the threshold in all years. Given that nitrogen is the limiting nutrient in Sarasota Bay, TP would not be expected to have a substantial influence on chlorophyll concentrations and seagrass growth.

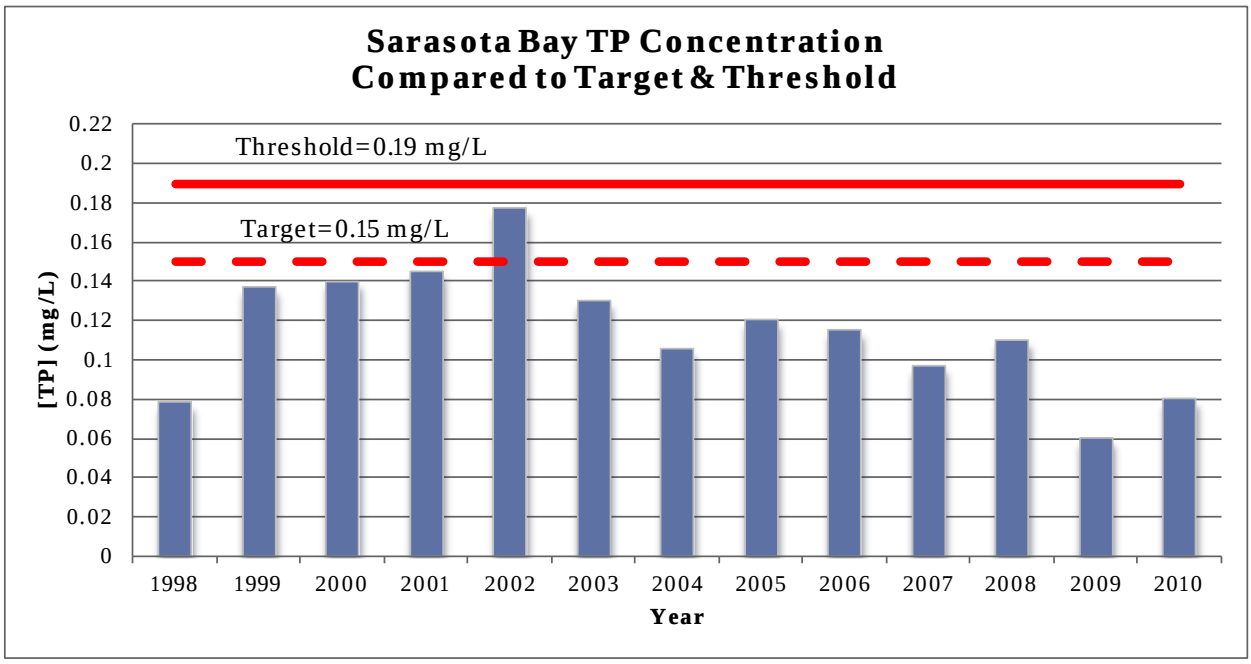


Figure 5-11 Comparison of TP Concentration Threshold (0.19 mg/L) and Target (0.15 mg/L) for Sarasota Bay to the Annual Geometric Mean TP Concentrations from 1998–2008

5.4.3.3 Estuarine TN Loading Target

Concentrations of chemicals including nutrients in a waterbody change in response to internal cycling in the water (e.g., uptake by vegetation), exchange with other waterbodies (e.g., between the bay and the Gulf of Mexico), and inputs (loadings) from the watershed. Of these factors, loadings can be most influenced by management actions. Loading rates normally vary depending

on rainfall and land use changes, among other watershed characteristics. However, adverse impacts to a receiving water such as the bay will only occur when the loading rate exceeds the bay's assimilative capacity—that is, the bay's ability to use or disperse the watershed-based inputs.

The relationship between loadings and indicators of ecological health (e.g., chlorophyll *a*, TN, and TP concentrations and the extent of seagrass) has been previously examined by Janicki Environmental 2010a, b; 2011a). Regression modeling was used to identify a technically defensible relationship between TN concentration and TN load and between TN concentration and chlorophyll *a* concentration (Janicki Environmental, 2011a). However, the best-fit regressions indicated that the TN load explained only 16% of the variability in TN concentration and 32% of the variability in chlorophyll *a* (r^2 = 0.16 and 0.32, respectively). Because of these weak relationships, the "reference period" approach was used to set TN loading targets and thresholds, with 2001–2005 used as the reference period. Chlorophyll *a* concentrations and seagrass targets were met during this period, so concurrent TN loads were assumed to protect the resources. The LOS target, standard deviation, and LOS threshold for TN loads were 215.3, 21.9, and 237.2 tons/year, respectively. Figure 5-12 compares the TN load target and threshold to the annual TN loads for Sarasota Bay. TN loads were below the LOS threshold for all years except 1992, 1995, and 2003. The process used to develop the TN load criterion is detailed in Janicki Environmental (2011a).

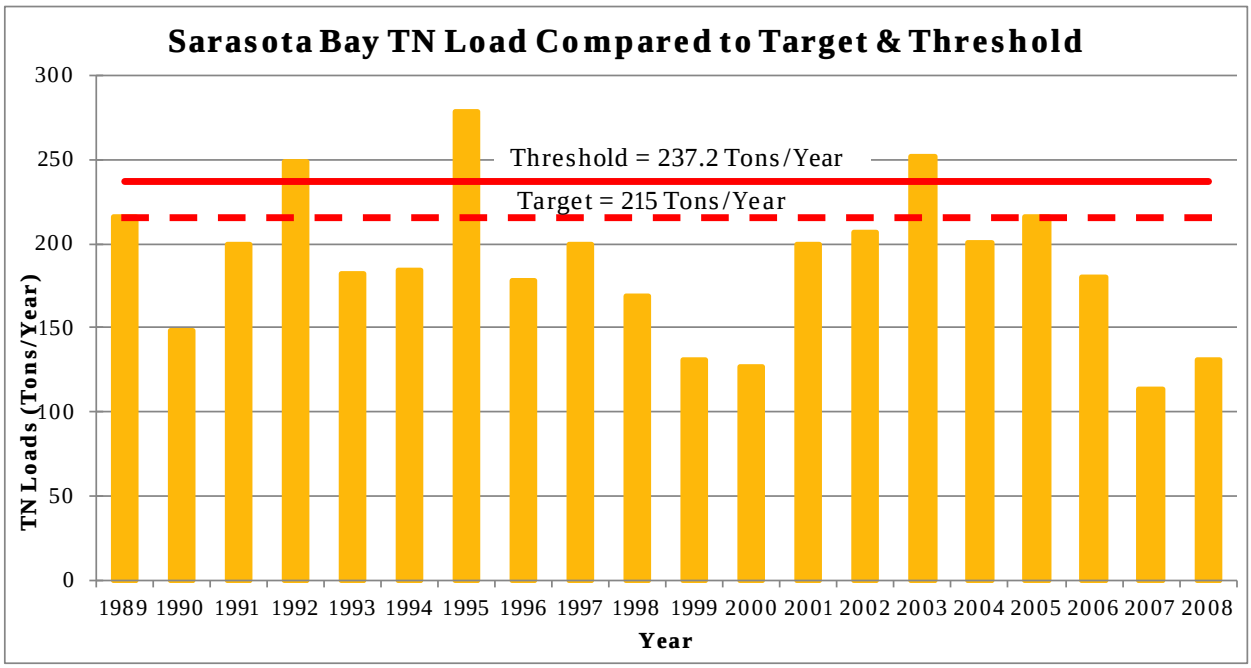


Figure 5-12 Comparison of TN Load Threshold (237.2 tons/year) and Target (215.0 tons/year) for Sarasota Bay to Annual Loads (1998–2008)

5.4.3.4 Estuarine TP Loading Target and Threshold

Regression modeling was used to identify a technically defensible relationship between TP concentration and TP load and between TP concentration and chlorophyll *a* concentration. However, the best-fit regressions indicated that TP load explained only 1% of the variability in TP concentration and 39% of the variability in chlorophyll *a* (r-squared = 0.01 and 0.39, respectively).

Because of the weak relationships, the reference period approach was used to set TP loading target and threshold. 2001–2005 were used as the reference period. The LOS target, standard deviation, and threshold for TP loads were 31.8, 3.4, and 35.2 tons/year. Figure 5-13 compares the TP load target and threshold and annual TP loads for Sarasota Bay. TP loads were below the threshold for all years except 1992, 1995, and 2003 when rainfall was elevated.

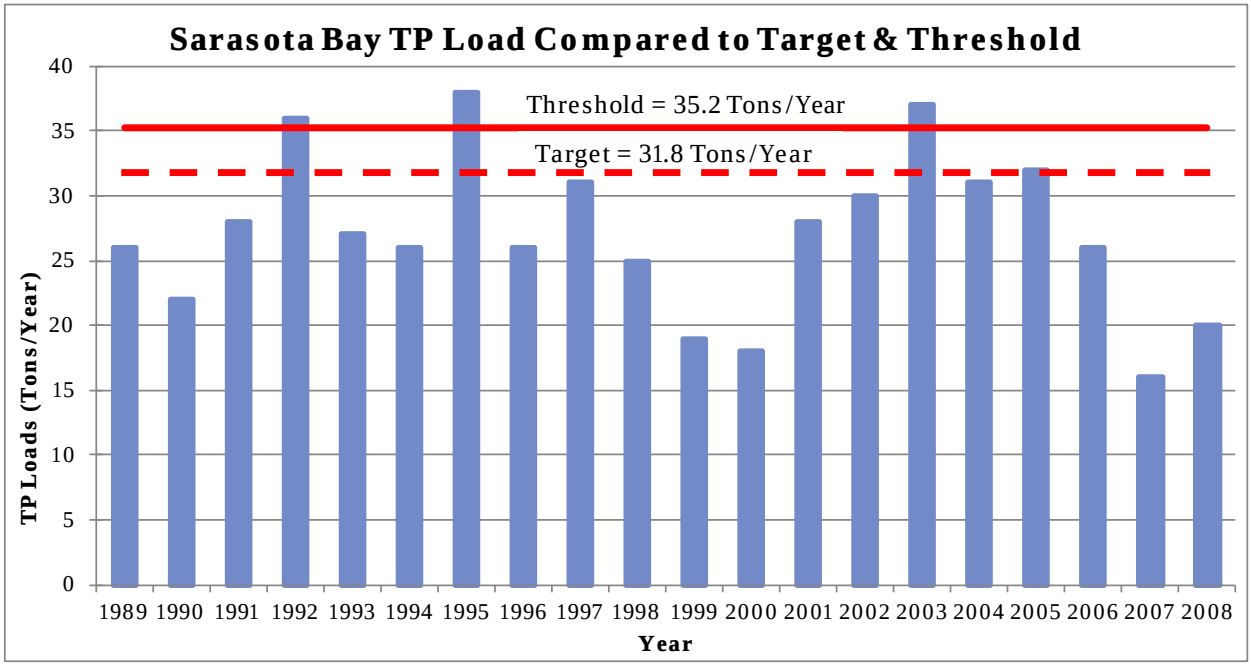
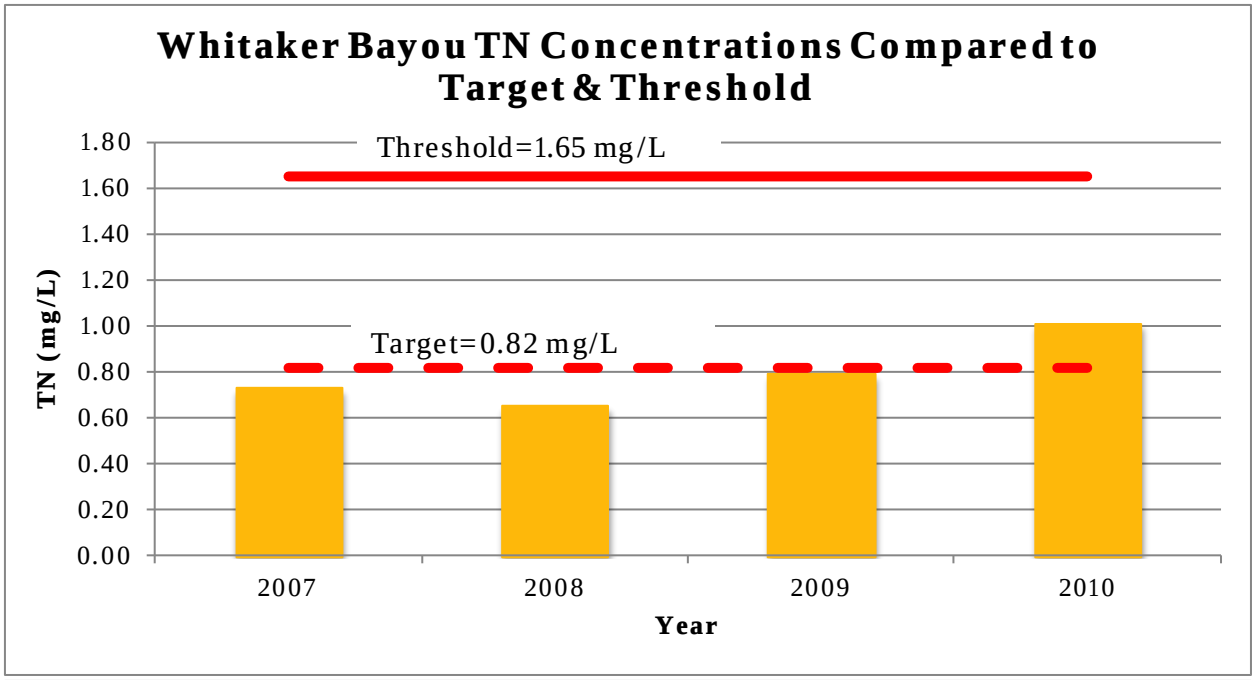


Figure 5-13 Comparison of TP Load Threshold (35.2 tons/year) and Target (32.0 tons/year) for Sarasota Bay to Annual Loads (1998–2008)

5.4.3.5 Development of Freshwater Tributary TN and TP Concentration LOS Thresholds and Targets

Data from the three freshwater sampling sites in Whitaker Bayou and two freshwater sites in Hudson Bayou were used to characterize ambient TN and TP concentrations for the respective tributaries. Data for 2007–2010 were compared to the FDEP NNC for the West Central Nutrient Watershed Region (FDEP, 2012a) as seen in Figure 5-14 and Figure 5-15. The only sampling site in Bowlees Creek is located in the marine reach.



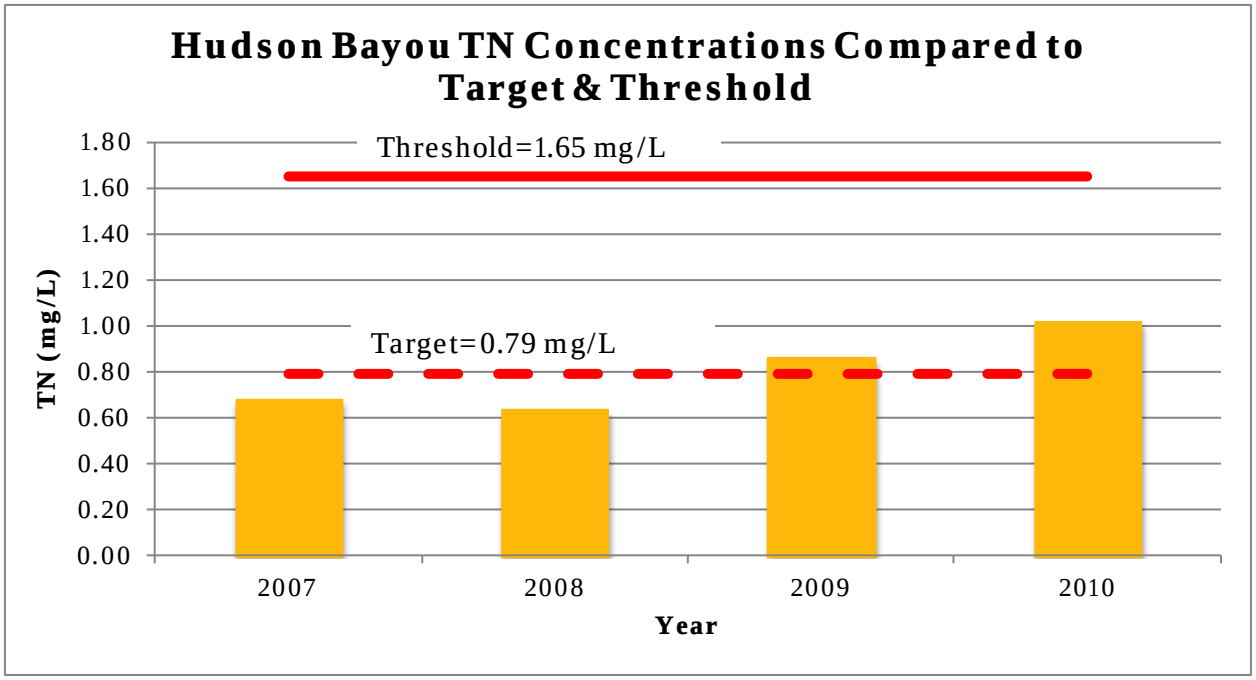
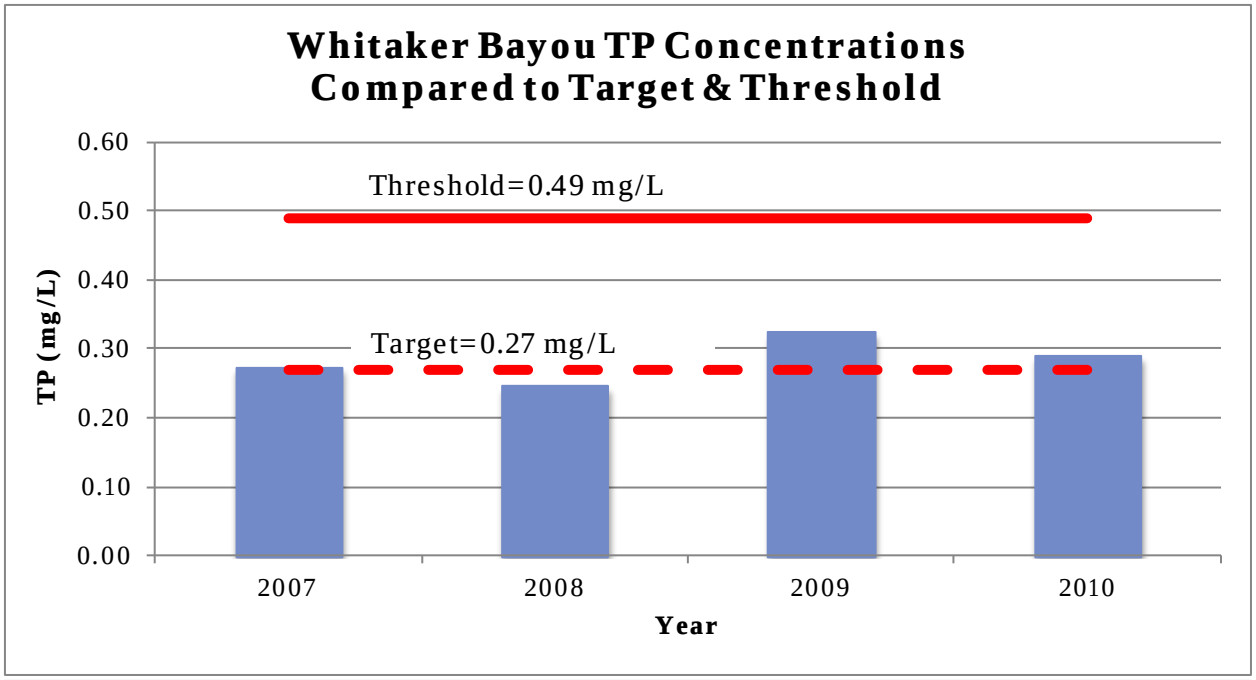


Figure 5-14 Comparison of the Freshwater TN Threshold (1.65 mg/L) and Targets to TN Concentrations in Whitaker Bayou (top) and Hudson Bayou (bottom)



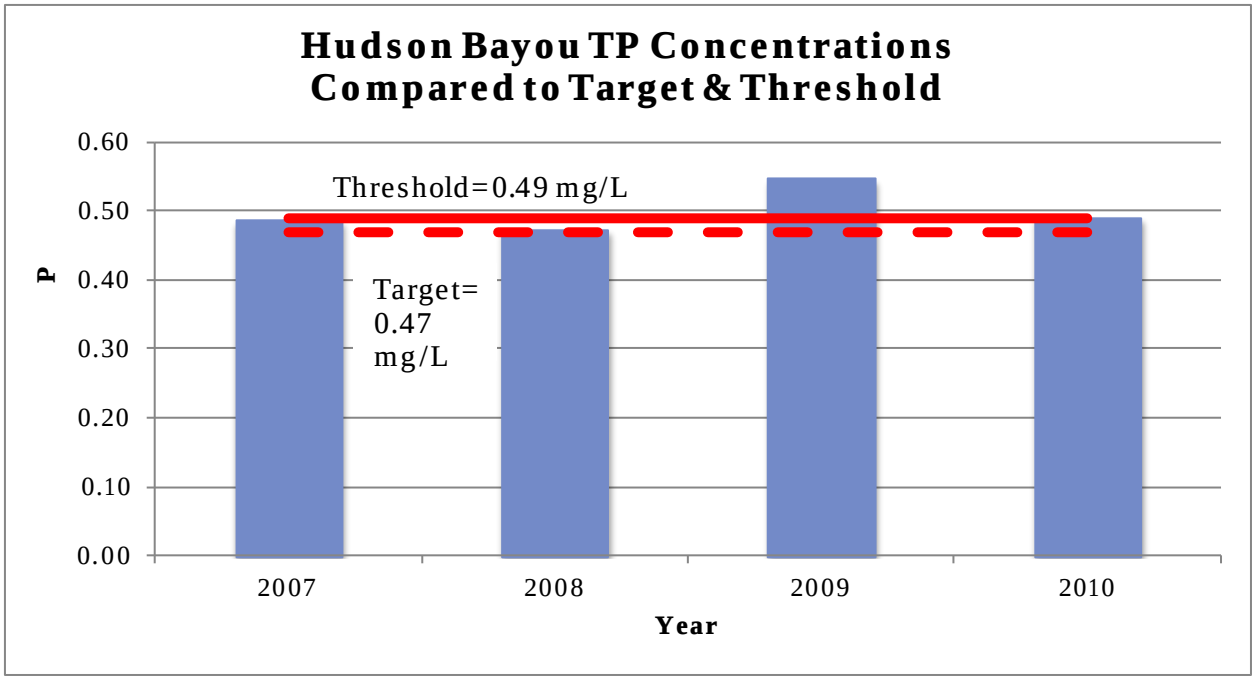


Figure 5-15 Comparison of the Freshwater TP Threshold (0.49 mg/L) and Targets to TP Concentrations in Whitaker Bayou (top) and Hudson Bayou (bottom)

The tributaries were also sampled in 2006 but only for October–December. Calculating an annual geometric mean for TN or TP using the FDEP (2012a) protocol requires at least four temporally independent samples per year with at least one sample taken between May 1 and September 30 and at least one sample taken during the other months of the calendar year. Thus, the geometric mean for the 3-month period in 2006 was not used to determine conformance with the criterion. Using annual geometric means of the concentrations, ambient TN concentrations

for freshwater sites in both Whitaker Bayou and Hudson Bayou were much lower than the TN criterion of 1.65 mg/L for all years. However, the ambient concentrations in both tributaries increased substantially (but not statistically significantly) between 2007 and 2010. The ambient TP concentrations for Whitaker Bayou are also well below the threshold of 0.49 mg/L. In contrast, Hudson Bayou TP concentrations were considerably higher than Whitaker Bayou. Hudson Bayou TP was higher than the threshold concentration in 2009 and equaled it in 2007 and 2010. To not meet the threshold, the threshold must be exceeded in any 2 years of a 3-consecutive-year period, thus the streams met the threshold criteria.

There remains the need for a TN and TP concentration target for the Sarasota Bay tributaries. To maintain consistency with the method used to set the estuarine TN concentration target, a reference period approach is recommended. The most recent data available for Sarasota Bay tributaries is 2006–2010. The mean of these recent data (0.39 mg/L) could be used as an initial target, as shown in Figure 5-14 and Figure 5-15 above. As more data become available, subsequent analyses can be applied to develop an appropriate target.

As Figure 5-14 and Figure 5-15 illustrate, both creeks met the TN target in 2007 and 2008, but neither met the target in 2010. Whitaker Bayou met the target in all 4 years, but Hudson Bayou did not meet the target in any year.

5.4.3.6 Development of Watershed Loading LOS

Basin-specific LOS criteria were developed using TN, TP, and TSS loadings from basins within the Sarasota Bay watershed. Evaluating watershed-based loadings can help prioritize watershed management efforts to protect critical estuarine and freshwater resources. The simplest method of setting LOS is to compare the TN, TP, and TSS loads originating from each basin.

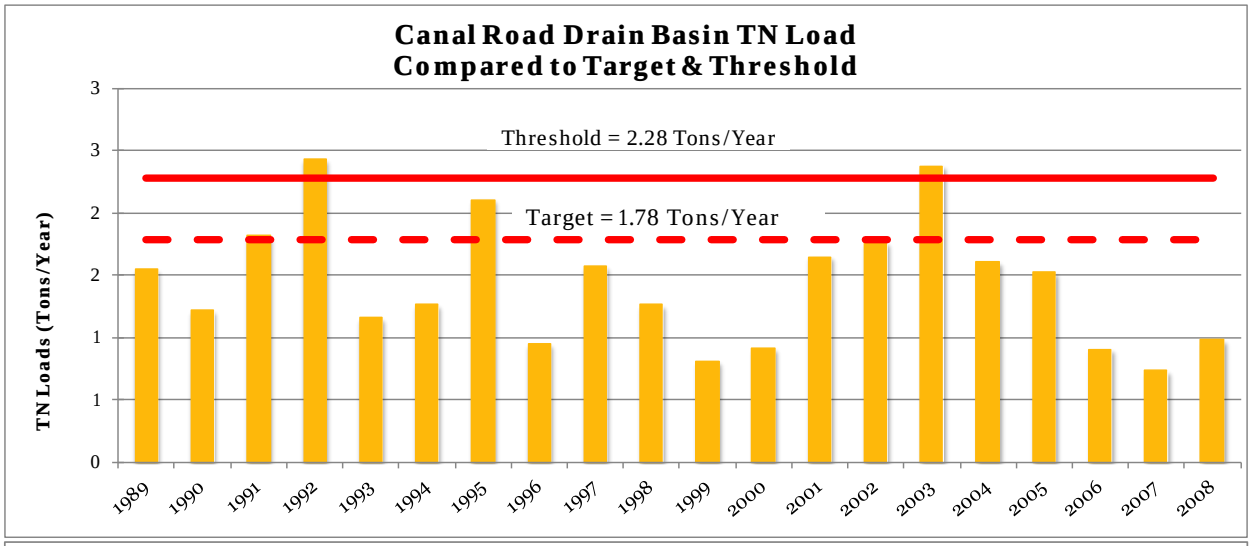
The basin LOS are intended to help the County and resource managers identify areas in which nutrient and TSS loads are elevated so that stormwater management activities can be prioritized. Thus, only stormwater-generated surface runoff and base flow were included in the LOS estimates. Irrigation, point sources, septic tanks, and atmospheric deposition to the estuary were not included in the estimated watershed loads. Point source and septic tank loadings are not controlled using the same mechanisms and are managed through independent programs. Irrigation is a beneficial use of highly treated reclaimed water and accounts for only 1% of the TN load to the bay.

Nutrient Loading LOS

Table 5-2 shows TN and TP loading targets for Sarasota Bay basins. To be consistent with the methods used to develop the chlorophyll target, annual loads for 2001 through 2005 were averaged to determine the target. The threshold is the target plus one standard deviation of all years' annual loads. As can be seen, the targets reflect the relative loading levels to each basin, with larger basins in general having higher targets. TN targets ranged from 0.31 (Siesta Key) to 34.0 tons/year (Bowlees Creek). TP targets ranged from 0.06 (Siesta Key) to 6.60 tons/year (Bowlees Creek). TN thresholds ranged from 0.43 (Siesta Key) to 41.24 tons/year (Bowlees Creek). TP thresholds ranged from 0.08 (Siesta Key) to 7.98 tons/year (Bowlees Creek). Basin loadings are compared to TN and TP targets and thresholds in Figure 5-16, Figure 5-17, Figure 5-18, Figure 5-19, Figure 5-20, Figure 5-21, Figure 5-22, Figure 5-23, Figure 5-24, and Figure 5-25.

Table 5-2 TN and TP Loading Targets and Thresholds for Sarasota Bay Basins

Basin	TN (tons/year)		TP (tons/year)	
	Target	Threshold	Target	Threshold
Canal Road Drain	1.76	2.26	0.31	0.40
Sarasota Bay Coastal North	18.5	23.3	3.14	3.89
Palma Sola Drain – Bayshore	7.03	8.68	1.28	1.57
Cedar Hammock Creek	16.6	20.3	3.25	3.97
Bowlees Creek	34.0	41.2	6.60	7.98
Longboat/Lido Keys	13.3	17.0	2.60	3.31
Sarasota Bay Coastal South	8.37	10.5	1.44	1.81
Whitaker Bayou	26.4	32.7	2.57	4.91
Hudson Bayou	13.9	17.6	2.46	3.10
Siesta Key	0.31	0.43	0.06	0.08



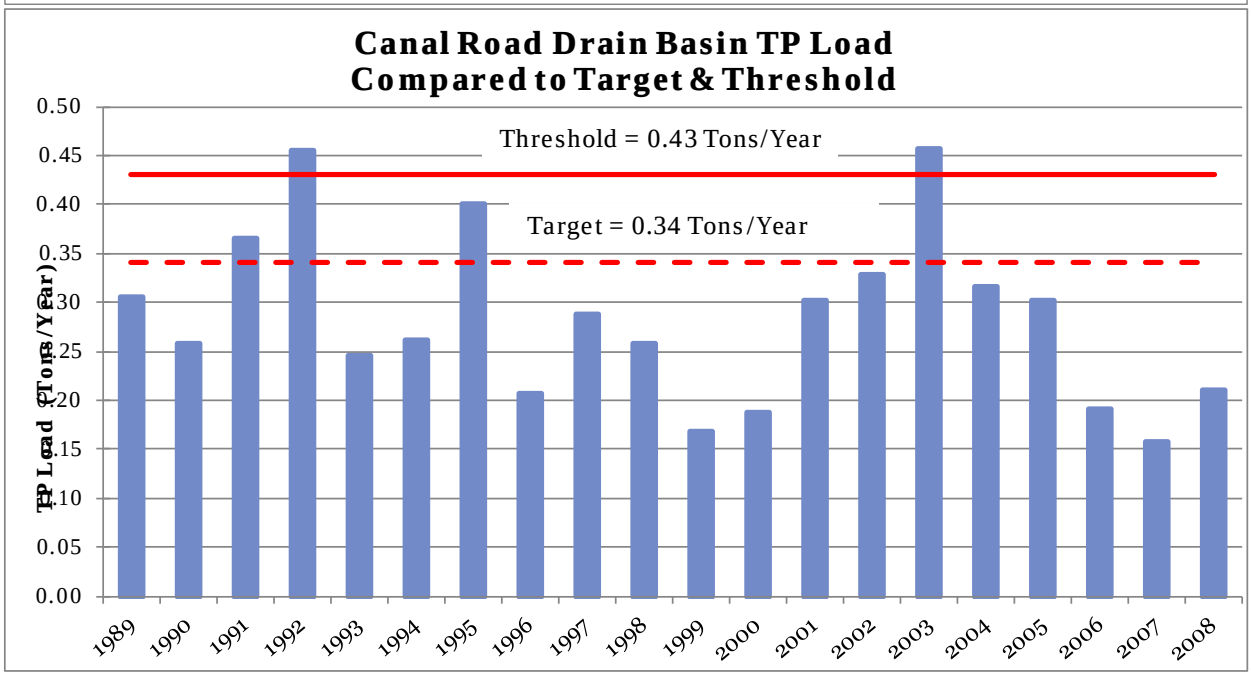
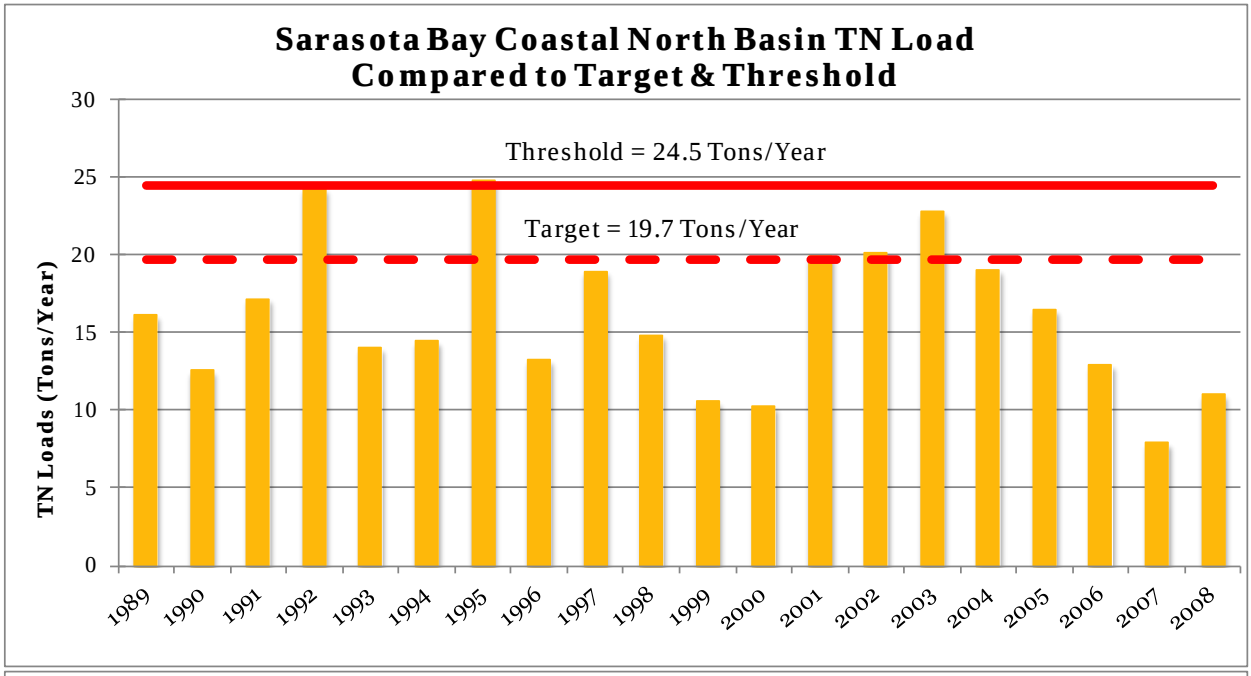


Figure 5-16 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Canal Road Drain



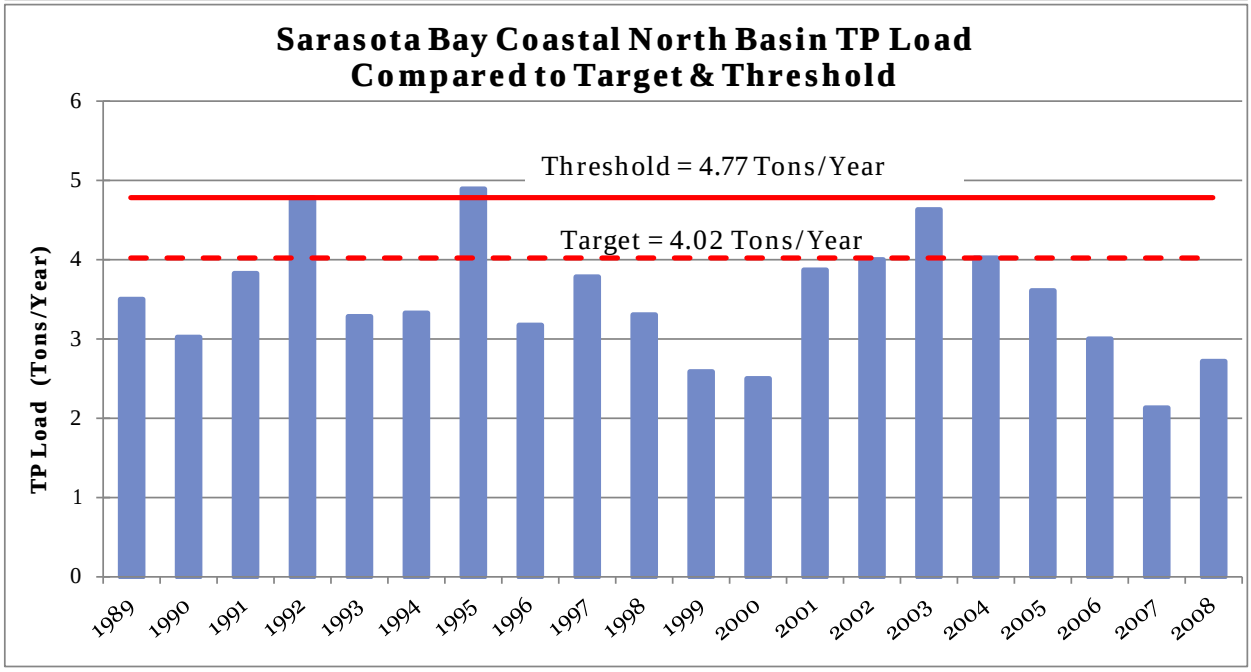
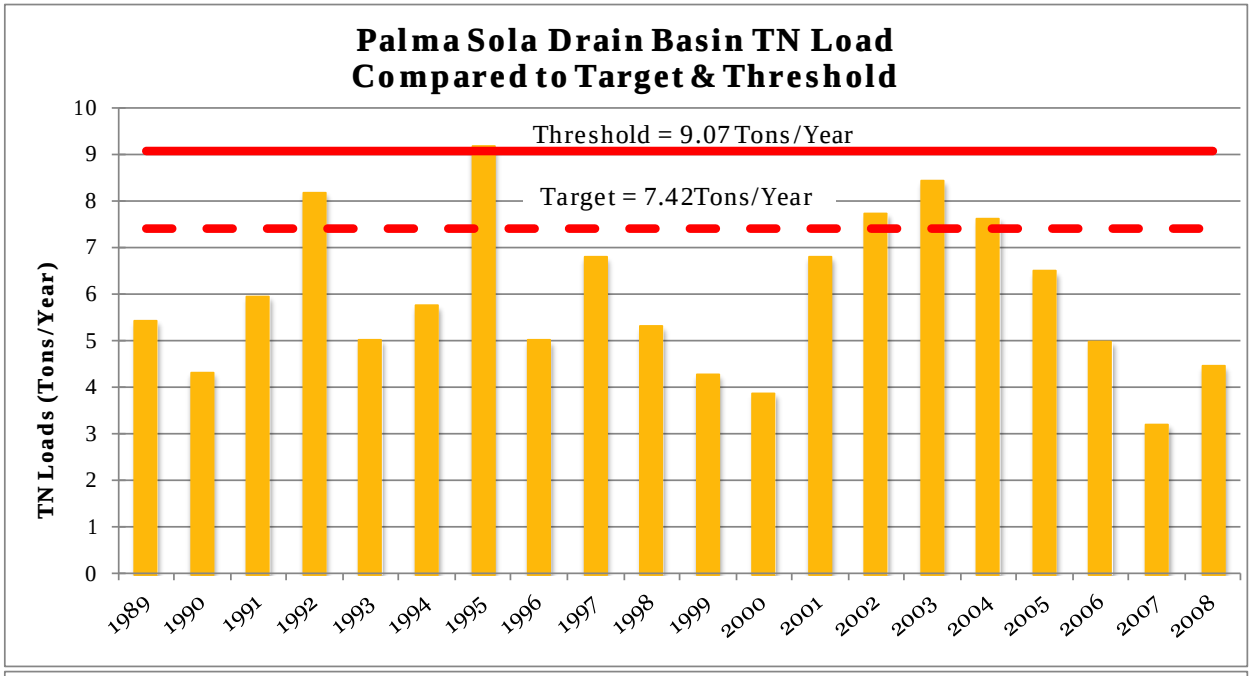


Figure 5-17 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Sarasota Bay Coastal North



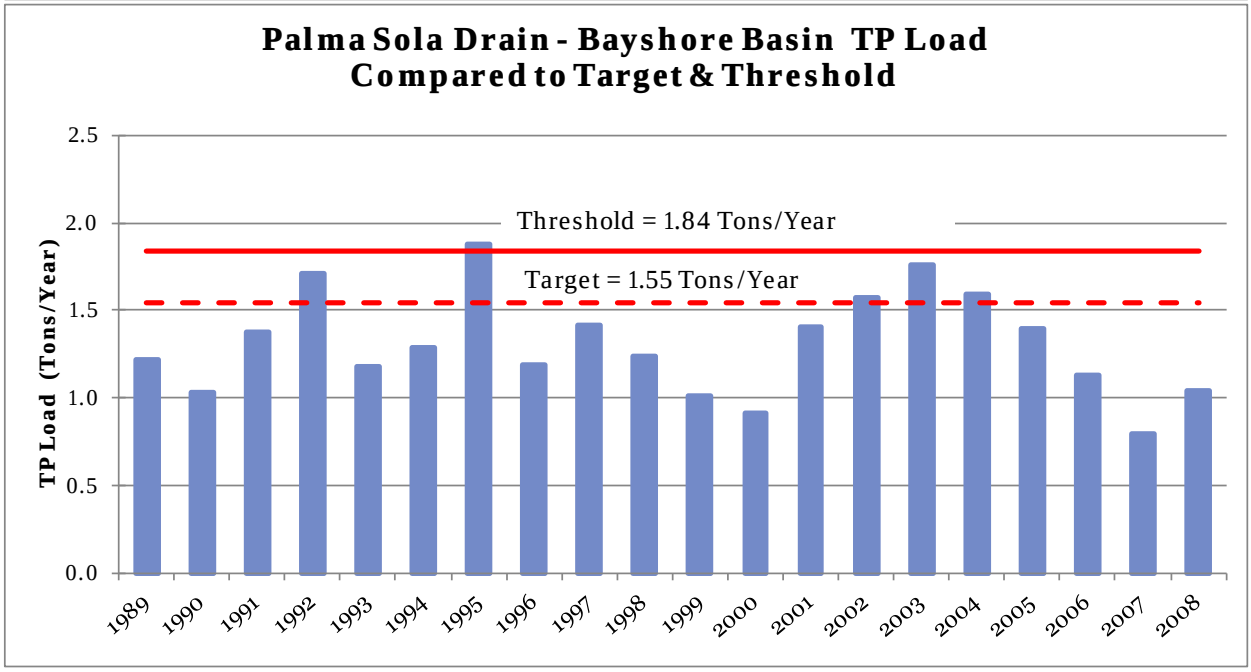
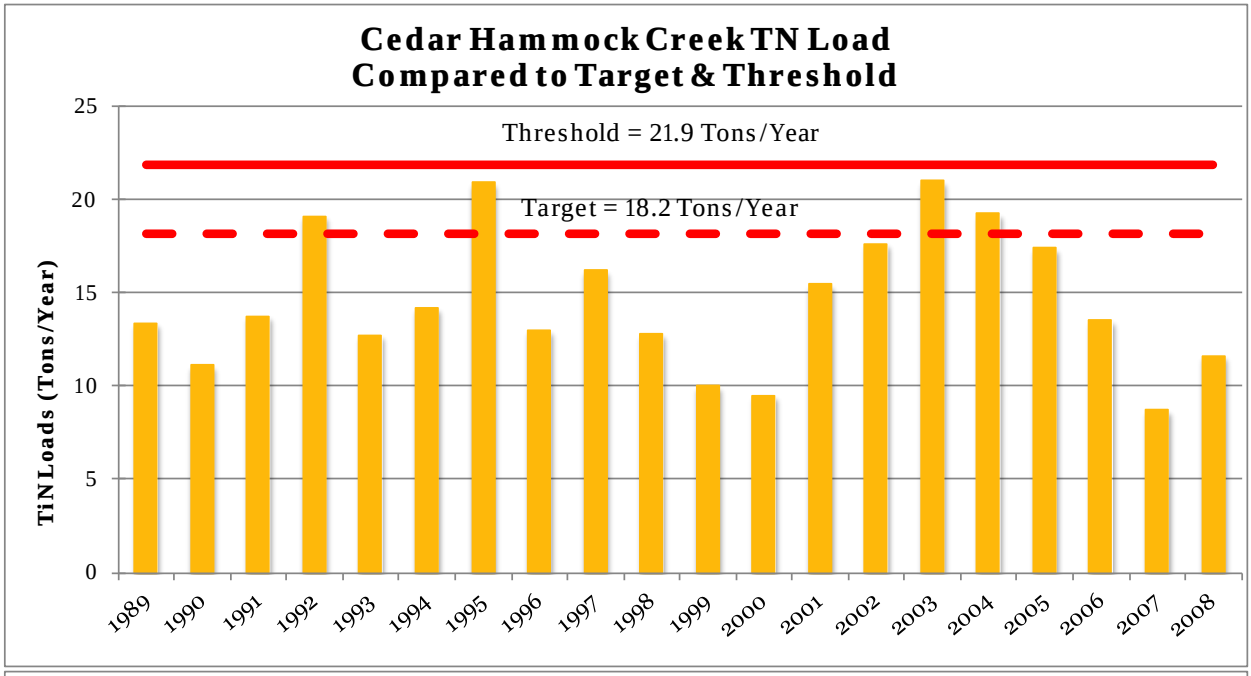


Figure 5-18 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Palma Sola Drain—Bayshore



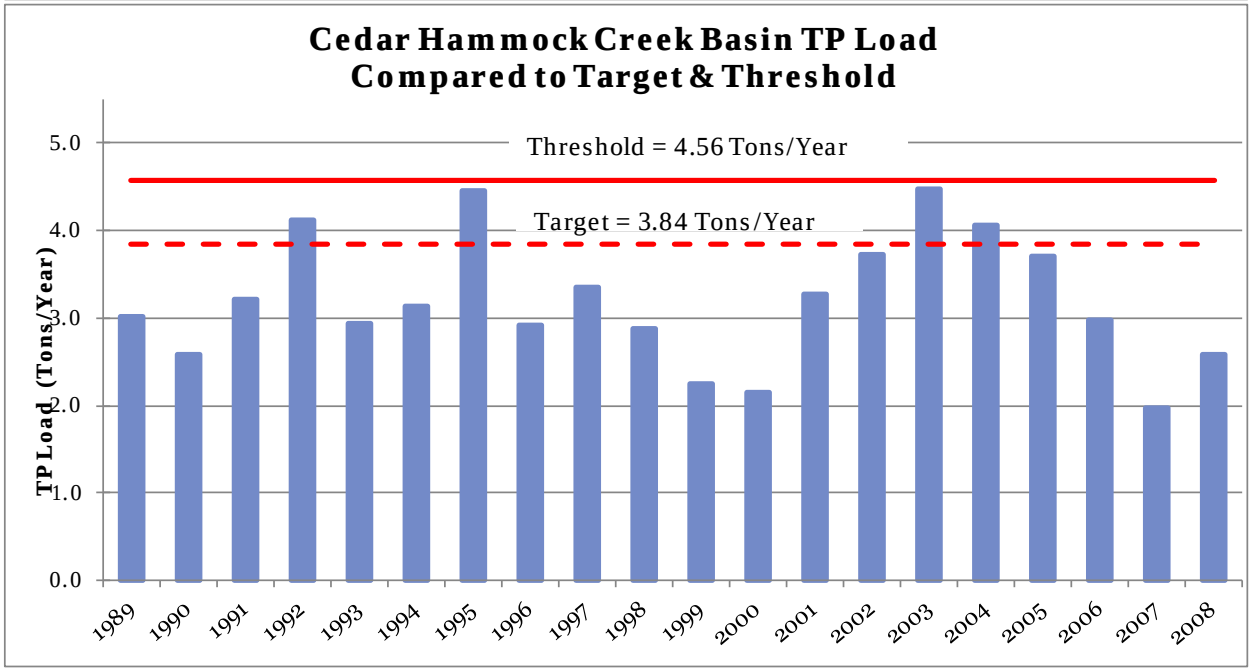
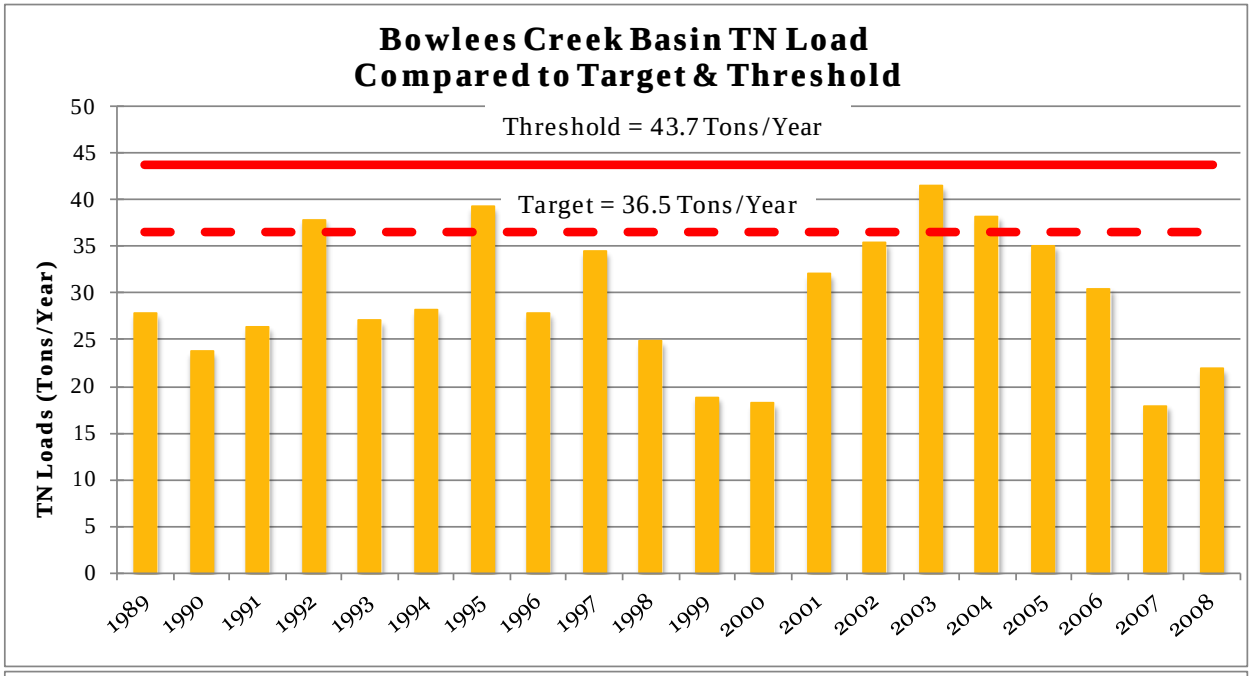


Figure 5-19 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Cedar Hammock Creek



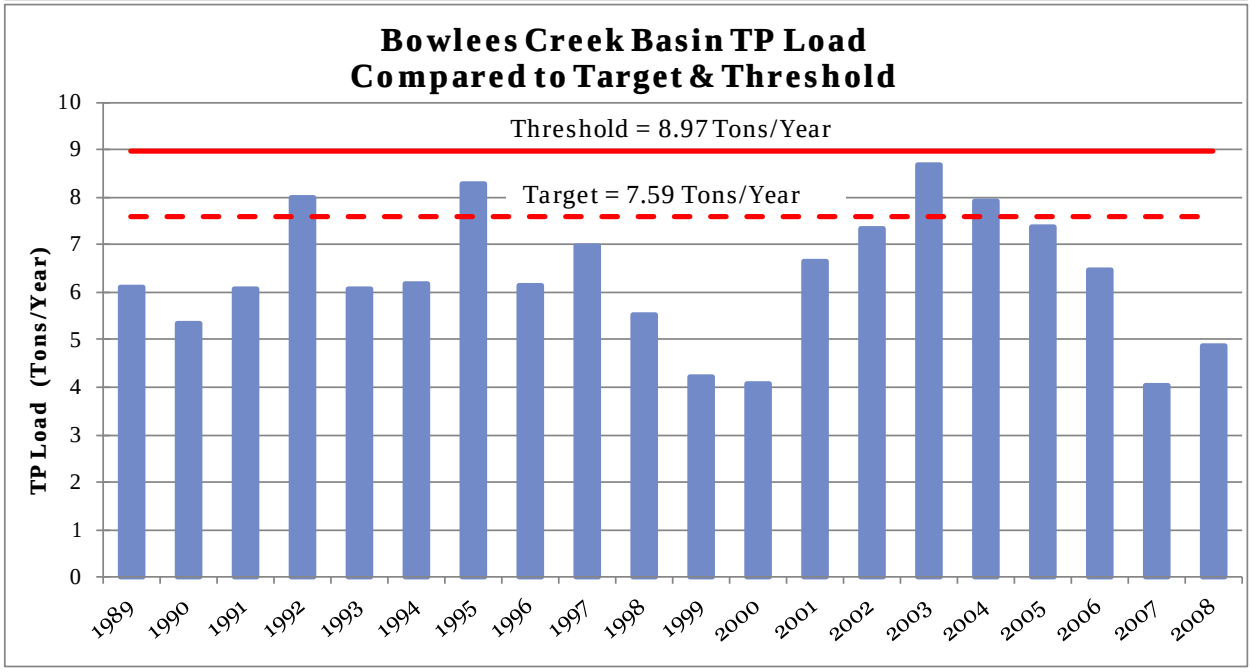
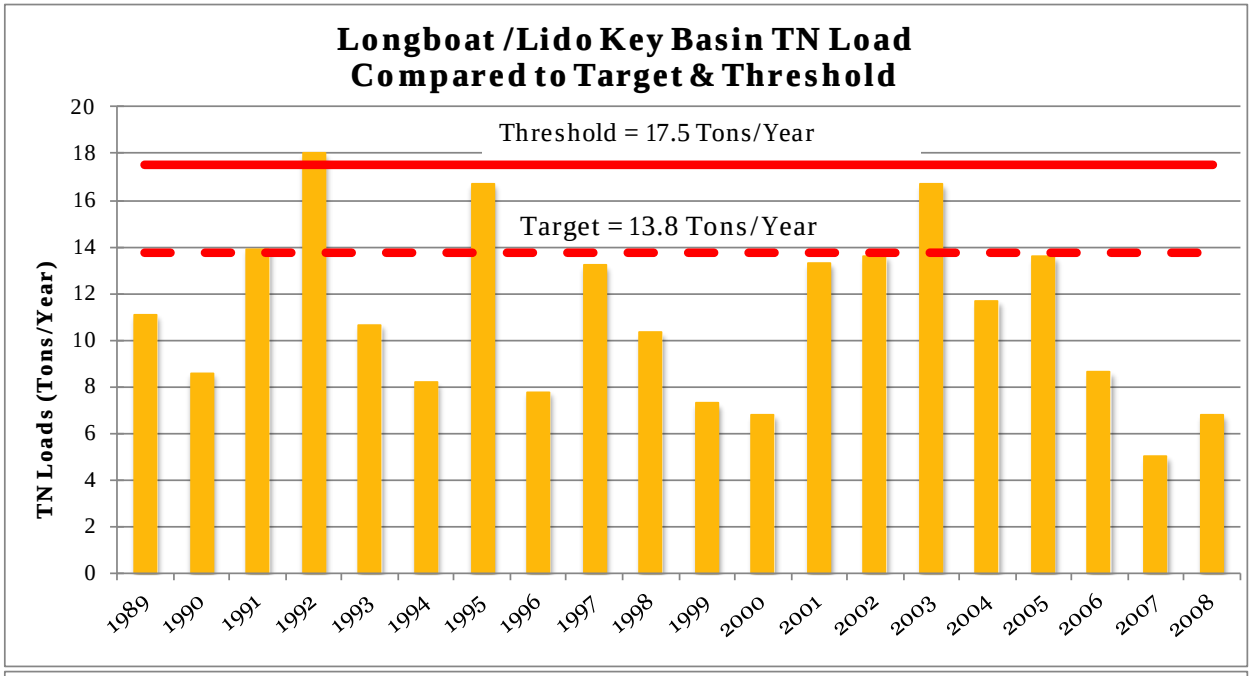


Figure 5-20 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Bowlees Creek



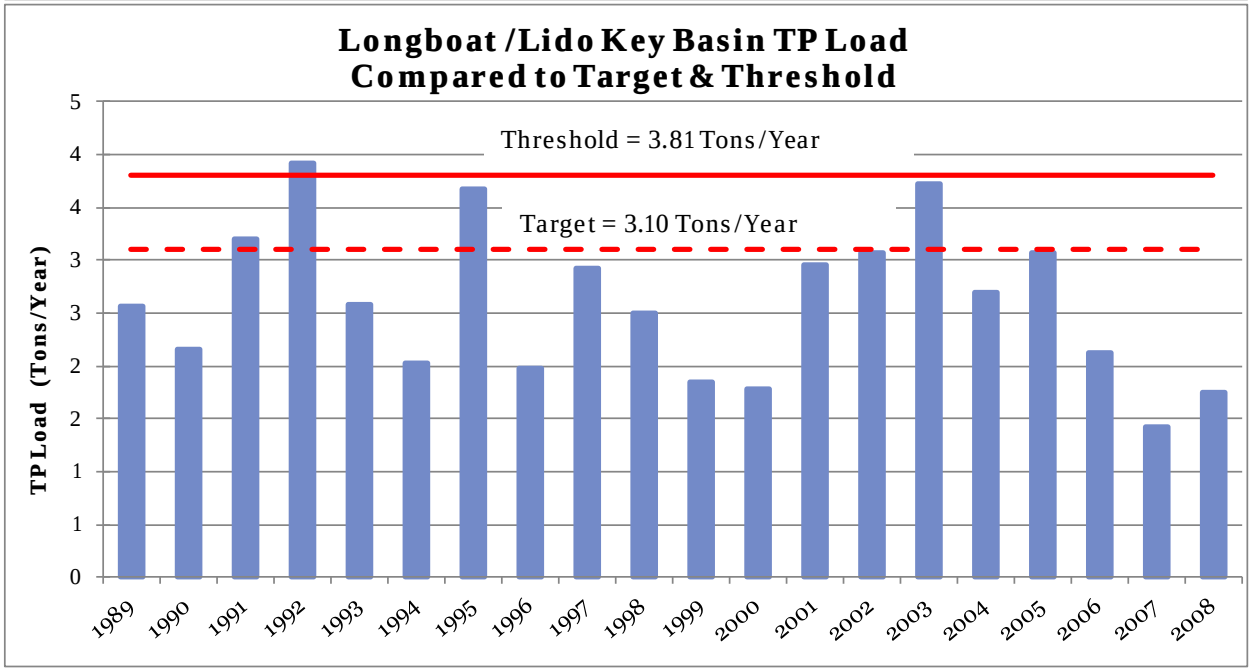
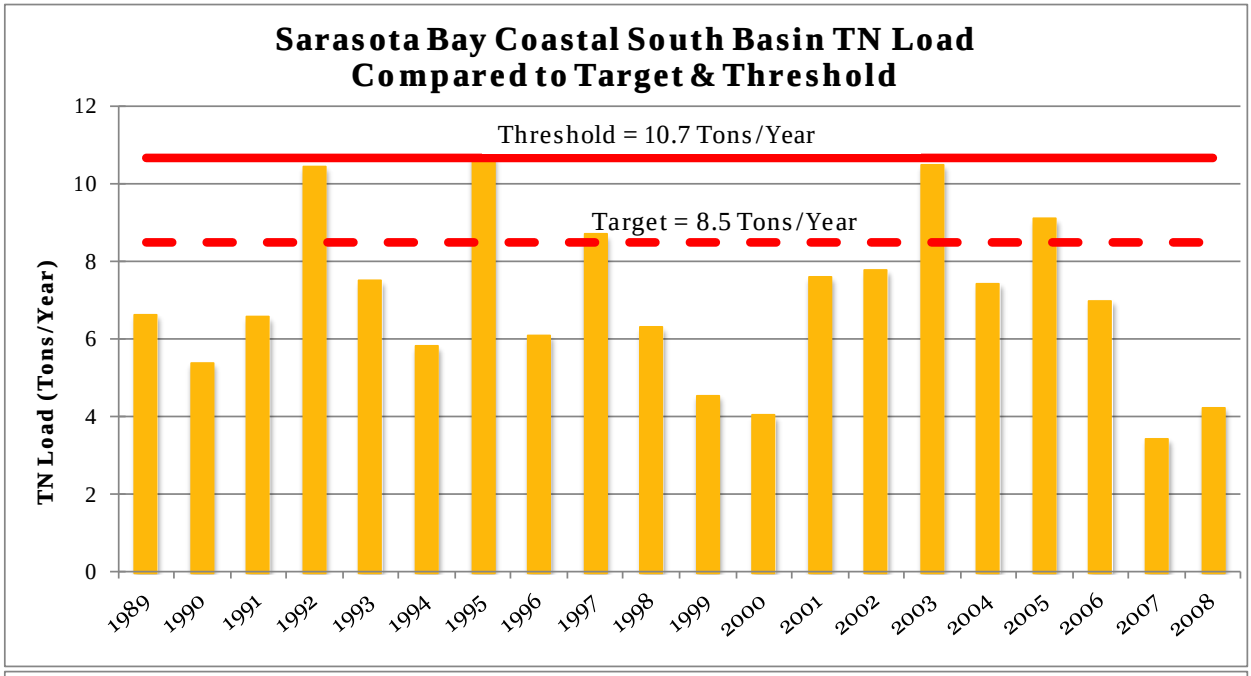


Figure 5-21 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Longboat/Lido Keys



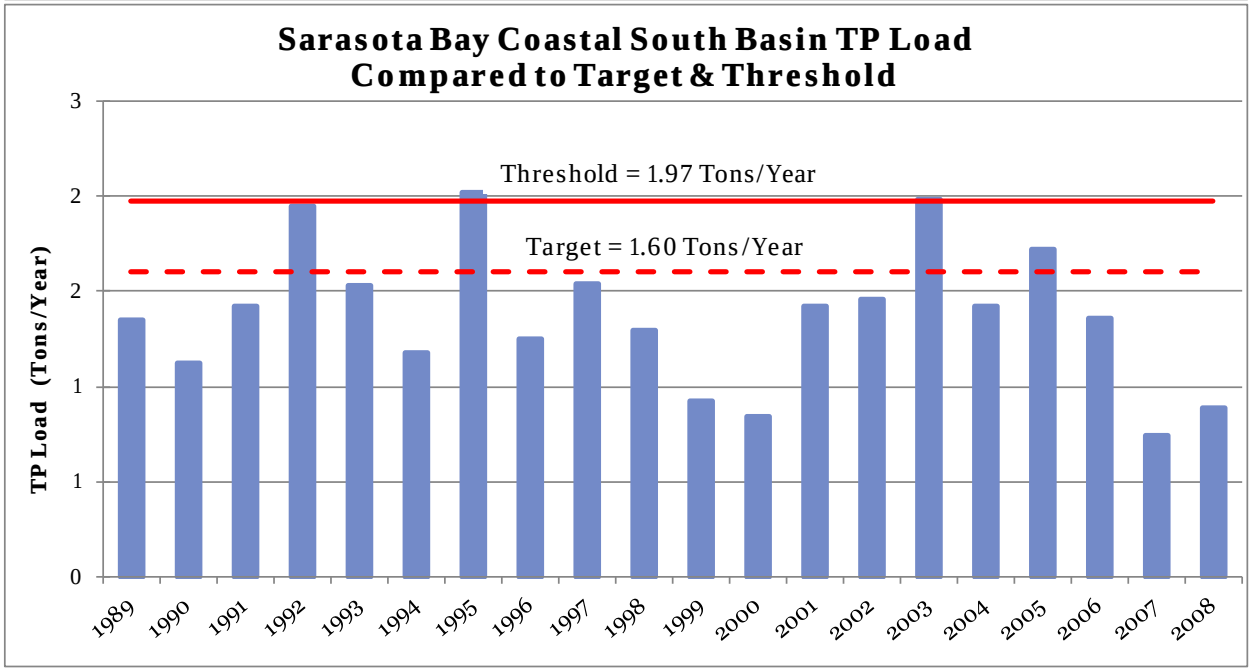
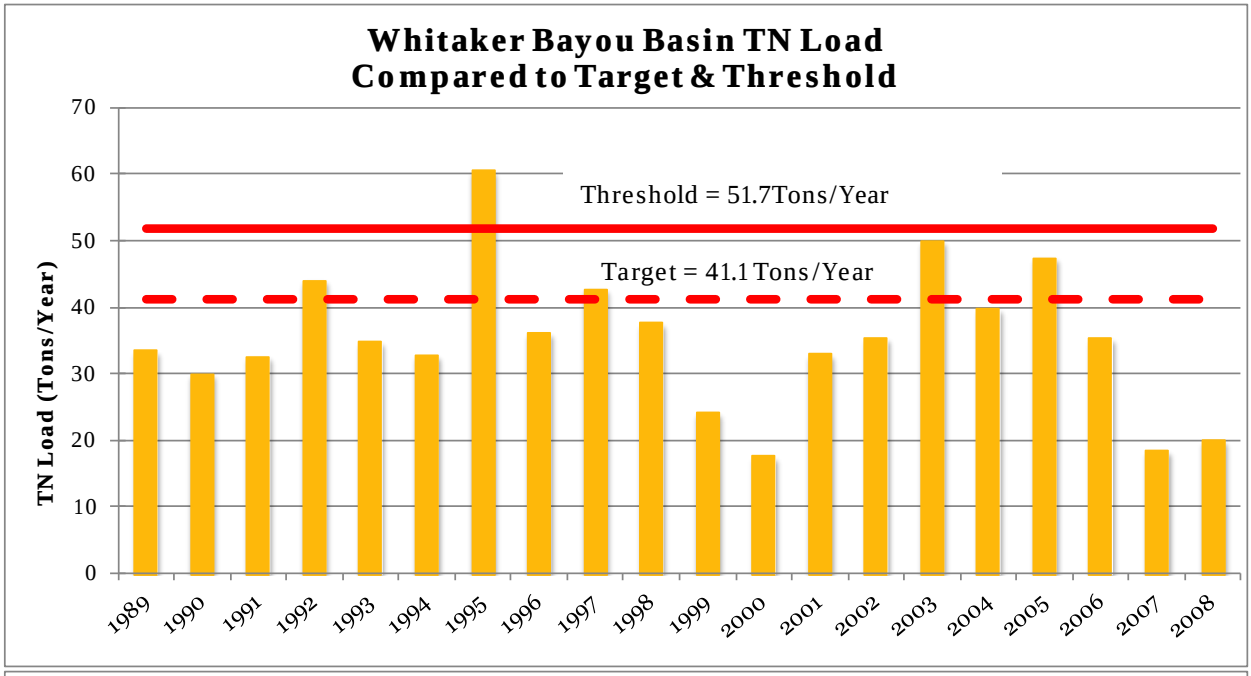


Figure 5-22 Comparison of Mean Annual TN (Top) and TP (bottom) Loads to Basin Targets and Thresholds—Sarasota Bay Coastal South



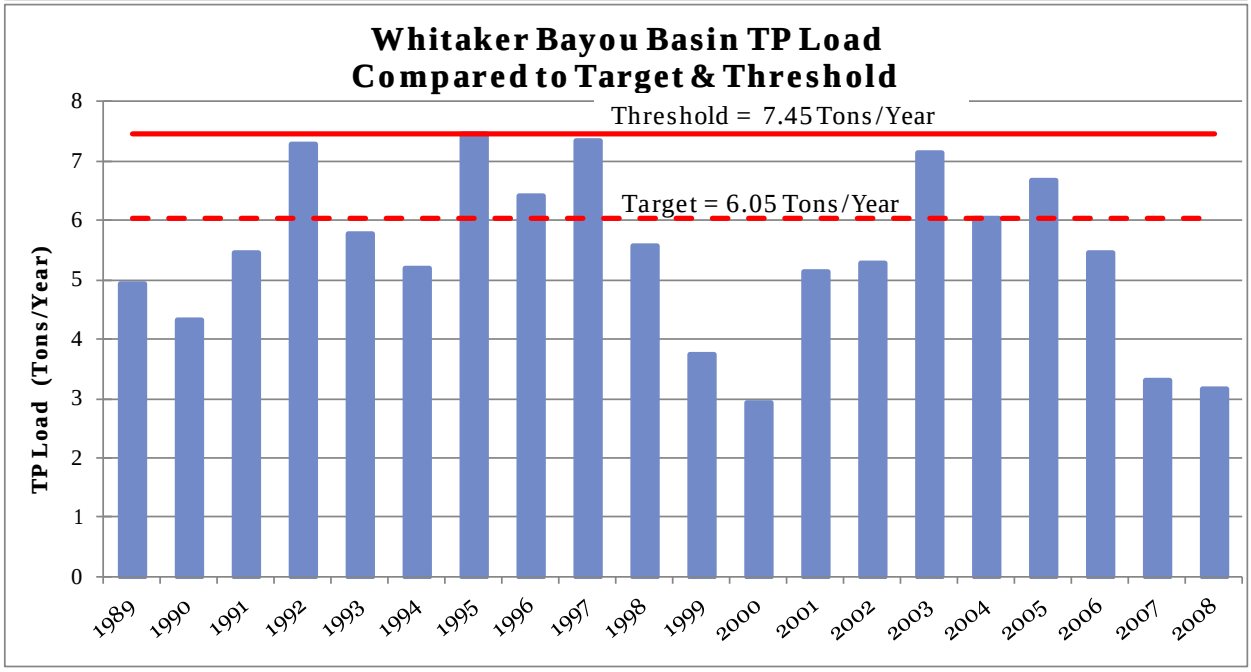
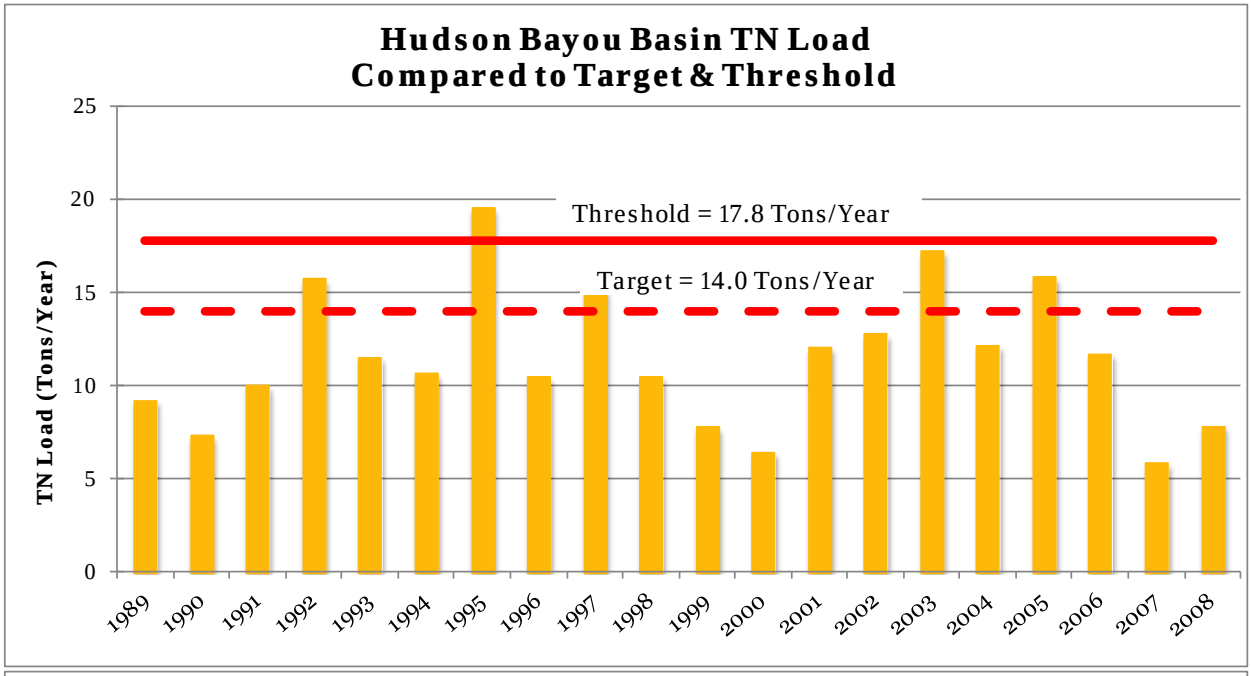


Figure 5-23 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Whitaker Bayou



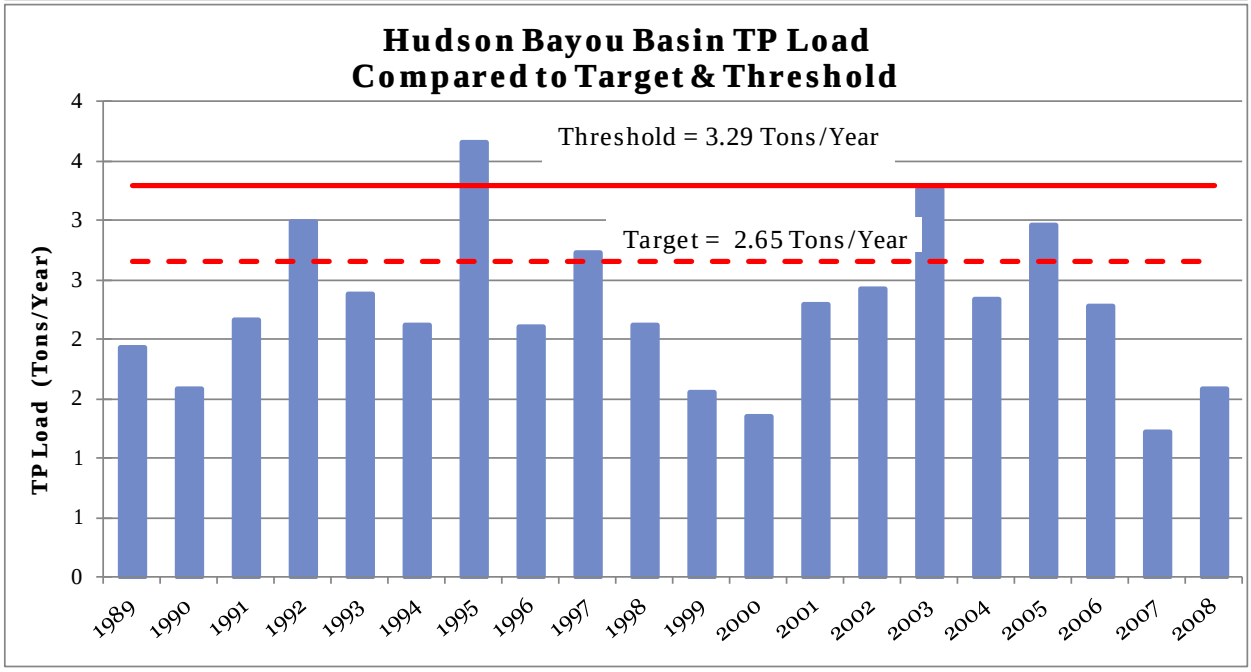


Figure 5-24 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Hudson Bayou

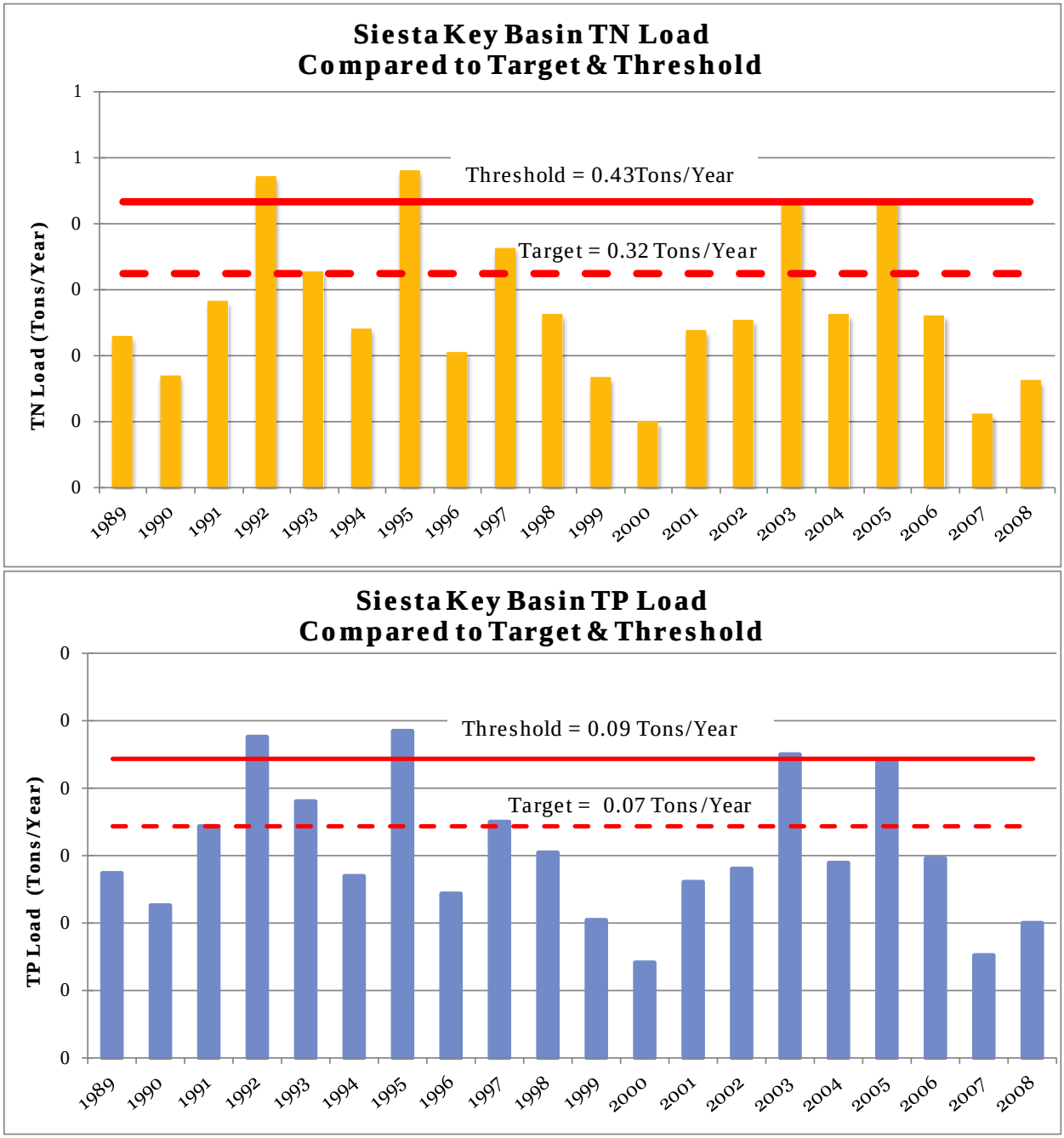


Figure 5-25 Comparison of Mean Annual TN (top) and TP (bottom) Loads to Basin Targets and Thresholds—Siesta Key

TSS Loading LOS

Table 5-3 shows TSS loading targets for Sarasota Bay basins. To be consistent with the methods used to develop the chlorophyll target, annual loads for 2001–2005 were averaged to determine the target. The threshold is the target plus one standard deviation of all years' annual loads. As can be seen, the targets reflect the relative loading levels to each basin, with larger basins in general having higher targets. TSS targets ranged from 0.31 (Siesta Key) to 34.0 tons/year

(Bowlees Creek). TSS thresholds ranged from 0.43 (Siesta Key) to 41.24 tons/year (Bowlees Creek). Basin loadings are compared to TSS targets and thresholds in Figure 5-26, Figure 5-27, Figure 5-28, Figure 5-29, Figure 5-30, Figure 5-31, Figure 5-32, Figure 5-33, Figure 5-34, and Figure 5-35.

Table 5-3 TN and TP Loading Targets and Thresholds for Sarasota Bay Basins

Basin	TSS (tons/year)	
	Target	Threshold
Canal Road Drain	1.76	2.26
Sarasota Bay Coastal North	18.5	23.3
Palma Sola Drain - Bayshore	7.03	8.68
Cedar Hammock Creek	16.6	20.3
Bowlees Creek	34.0	41.2
Longboat/Lido Keys	13.3	17.0
Sarasota Bay Coastal South	8.37	10.5
Whitaker Bayou	26.4	32.7
Hudson Bayou	13.9	17.6
Siesta Key	0.31	0.43

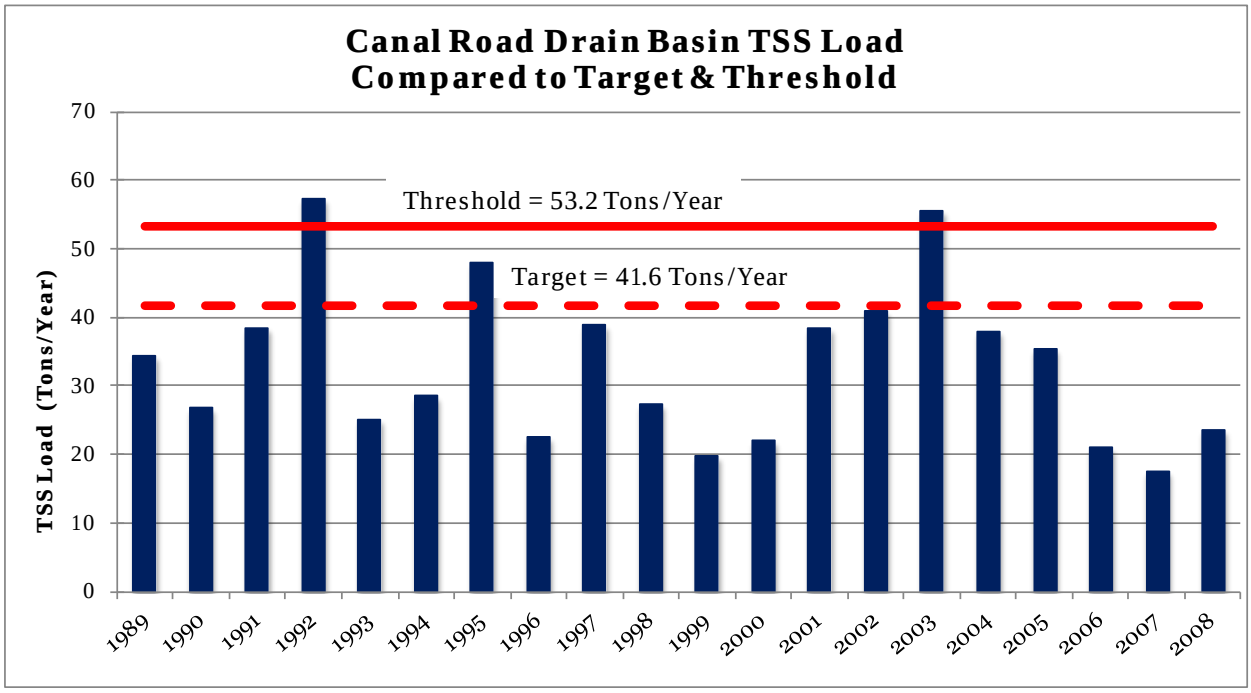


Figure 5-26 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Canal Road Drain

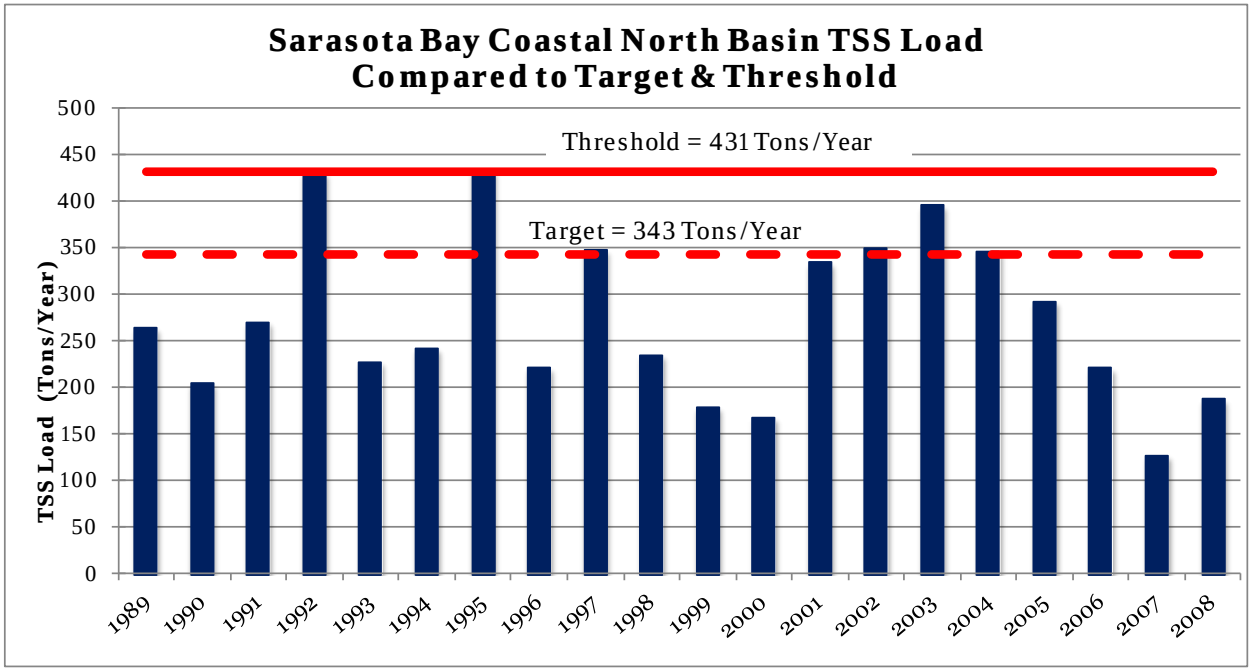


Figure 5-27 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Sarasota Bay Coastal North

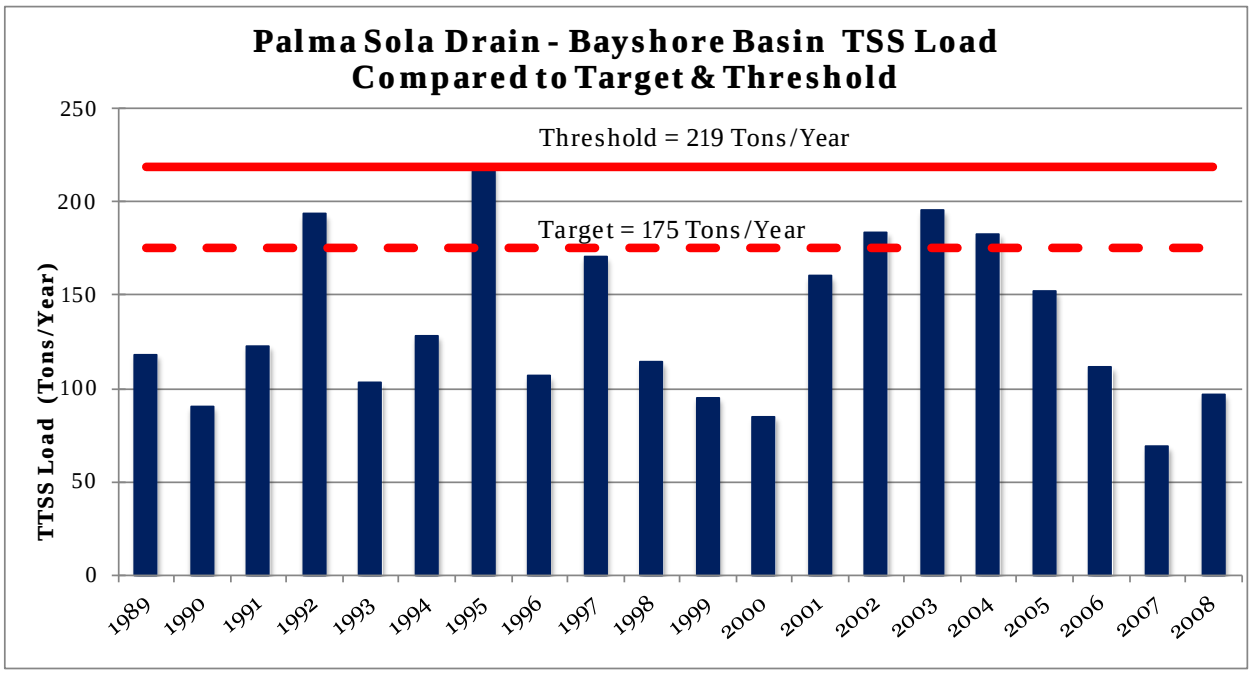


Figure 5-28 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Palma Sola Drain—Bayshore

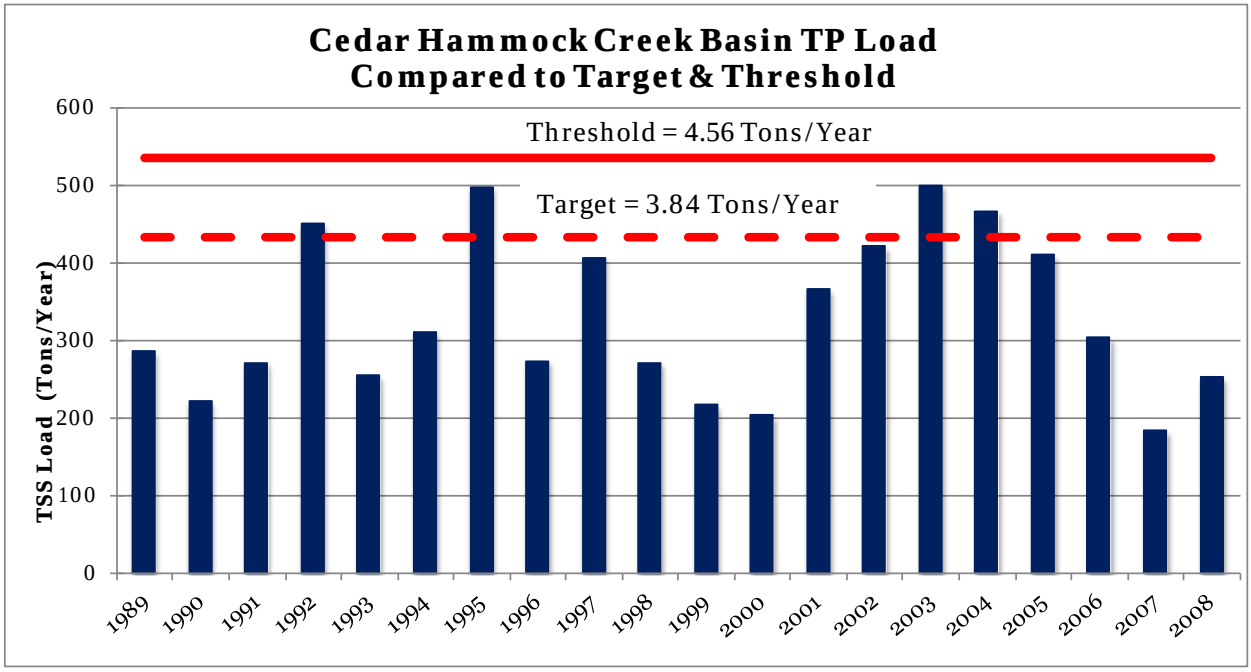


Figure 5-29 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Cedar Hammock Creek

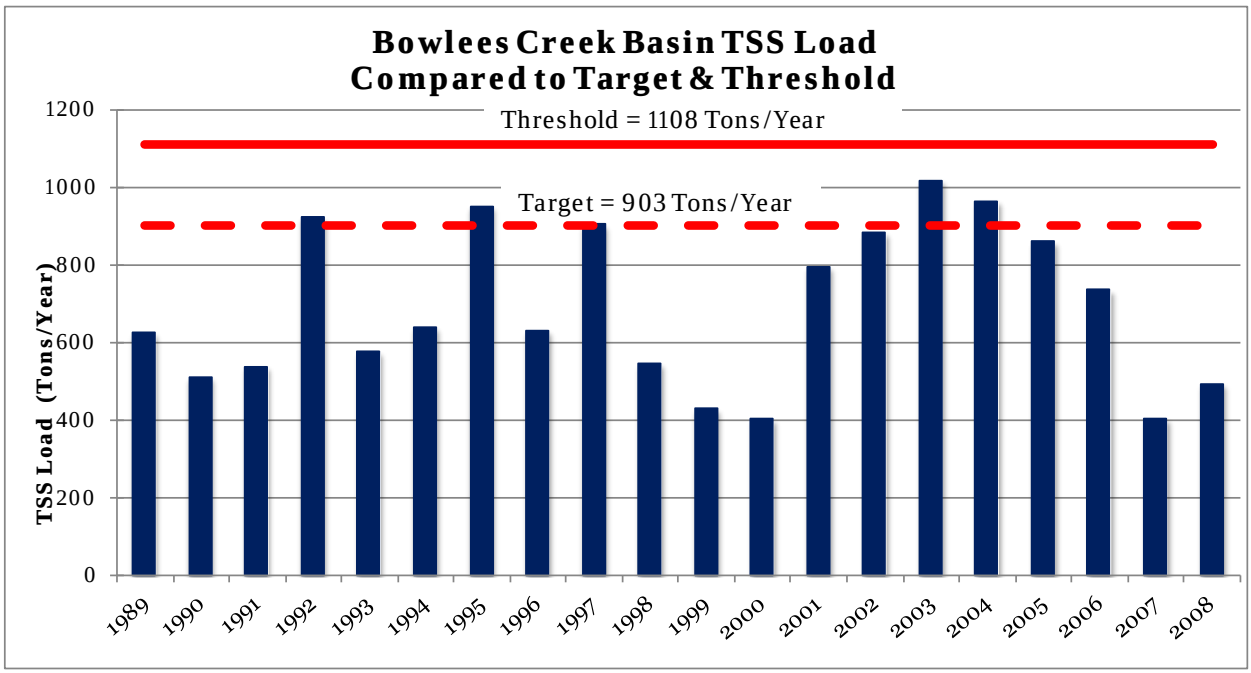


Figure 5-30 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Bowlees Creek

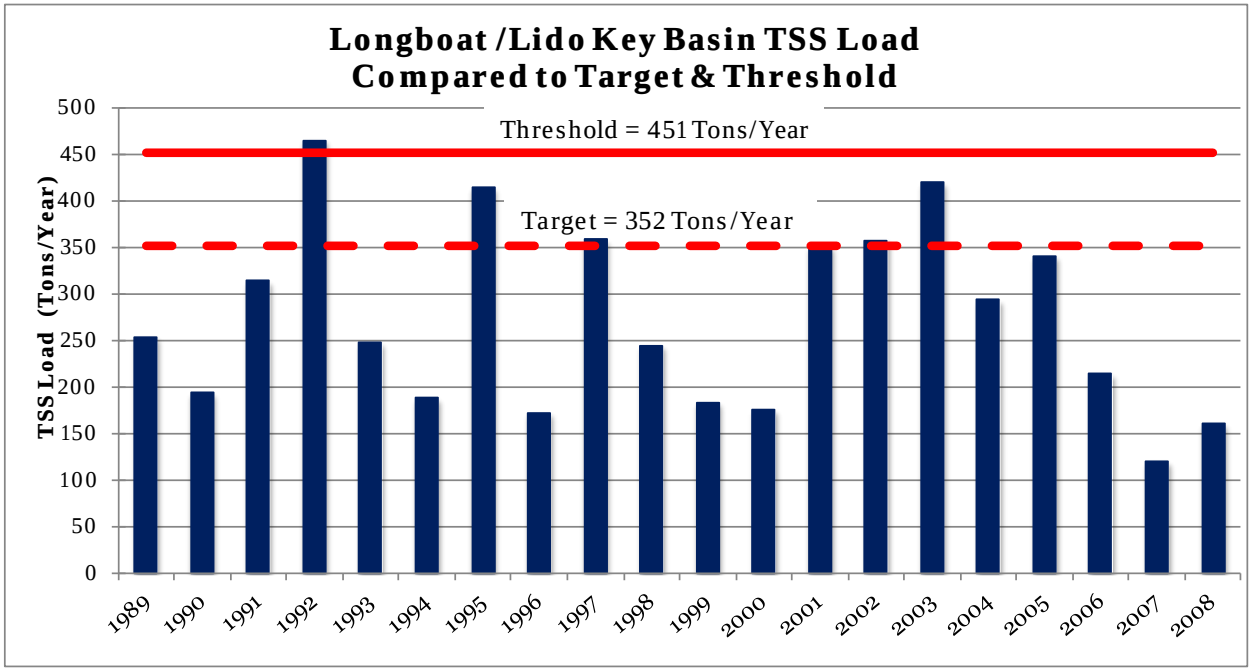


Figure 5-31 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Longboat/Lido Keys

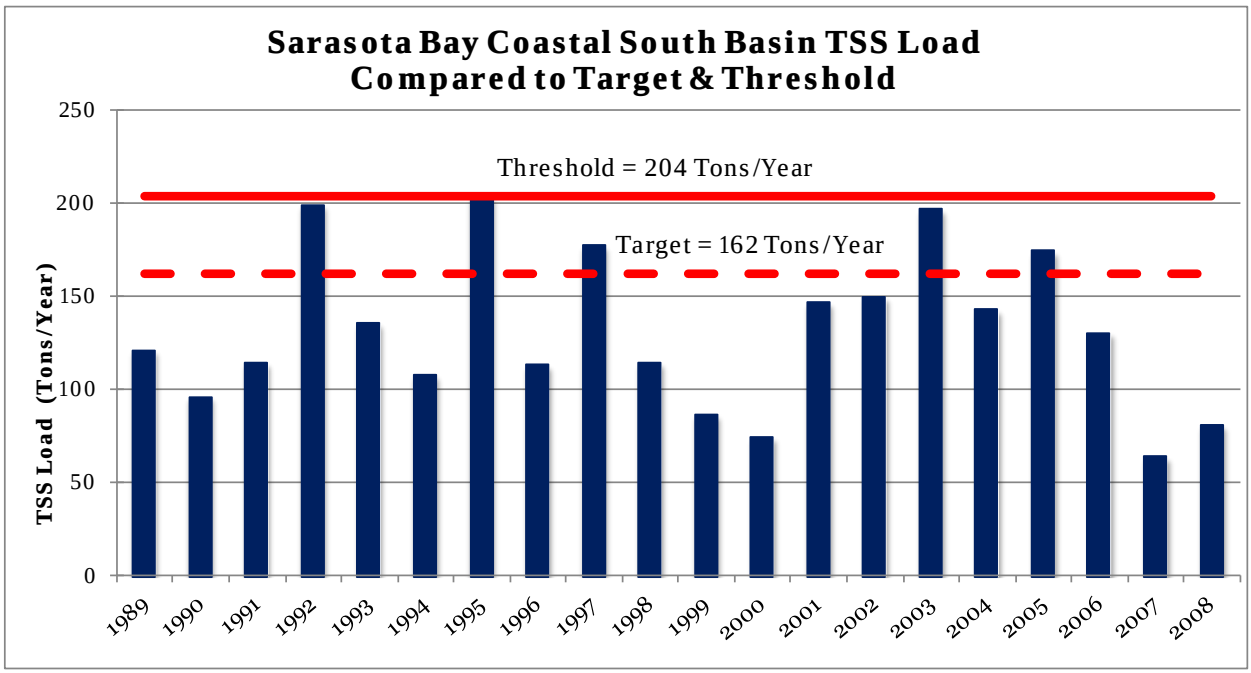


Figure 5-32 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Sarasota Bay Coastal South

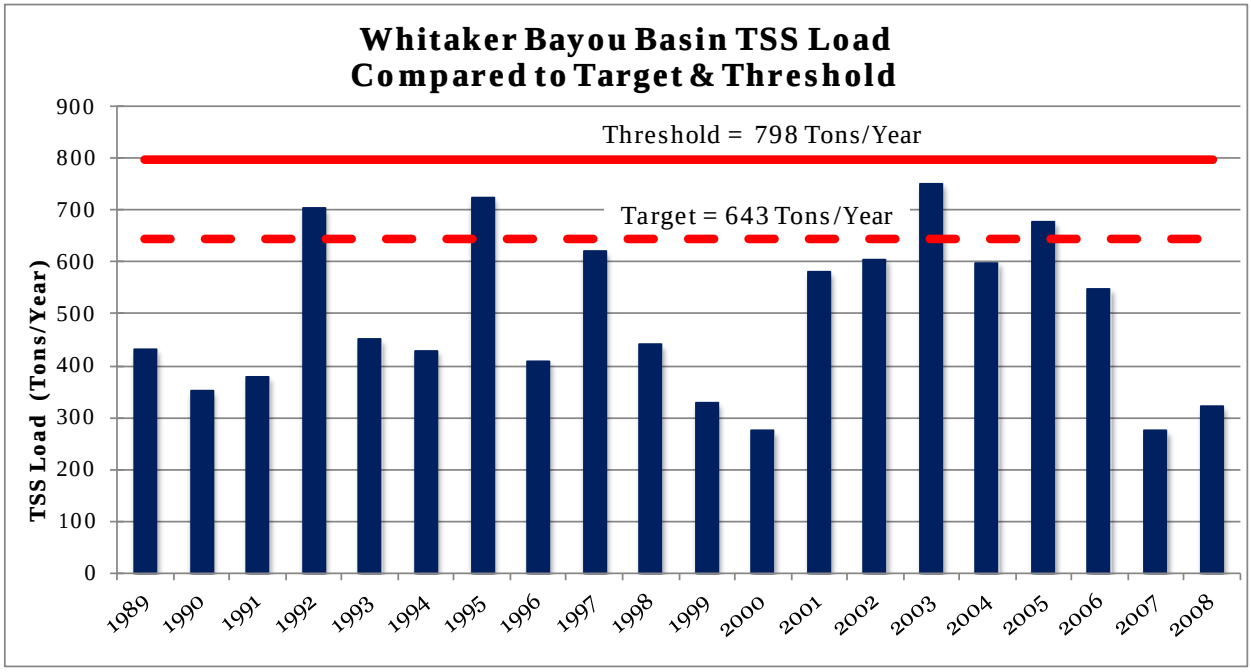


Figure 5-33 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Whitaker Bayou

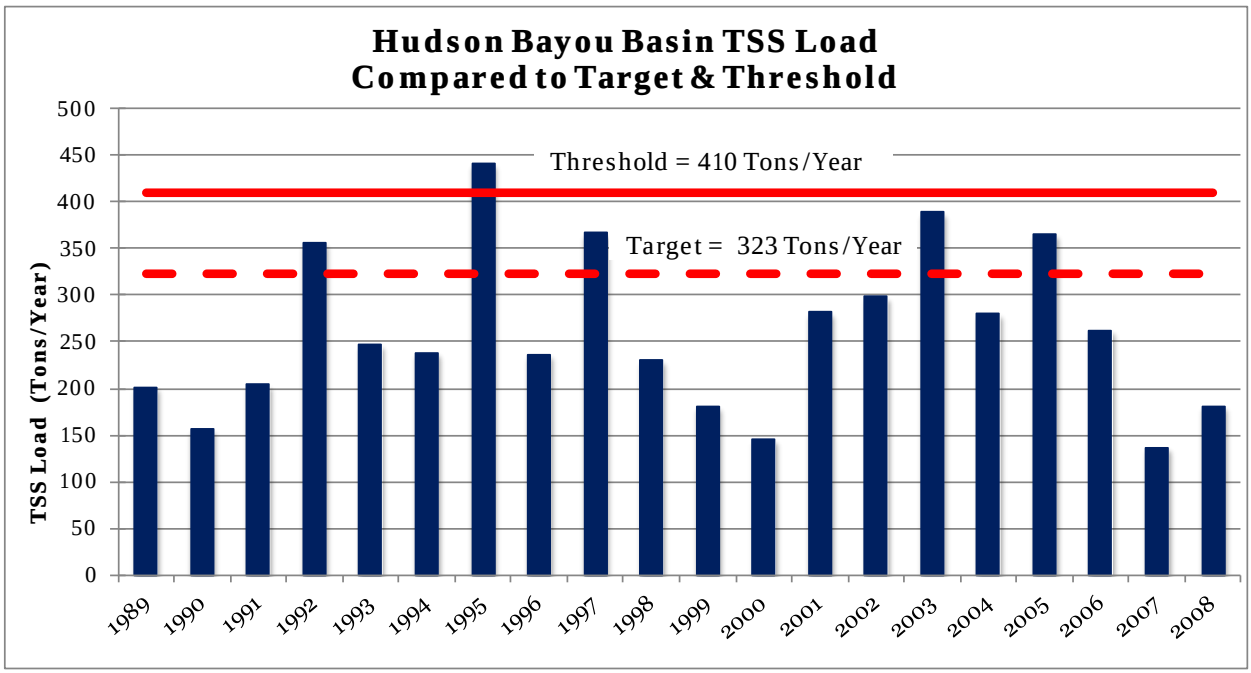


Figure 5-34 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Hudson Bayou

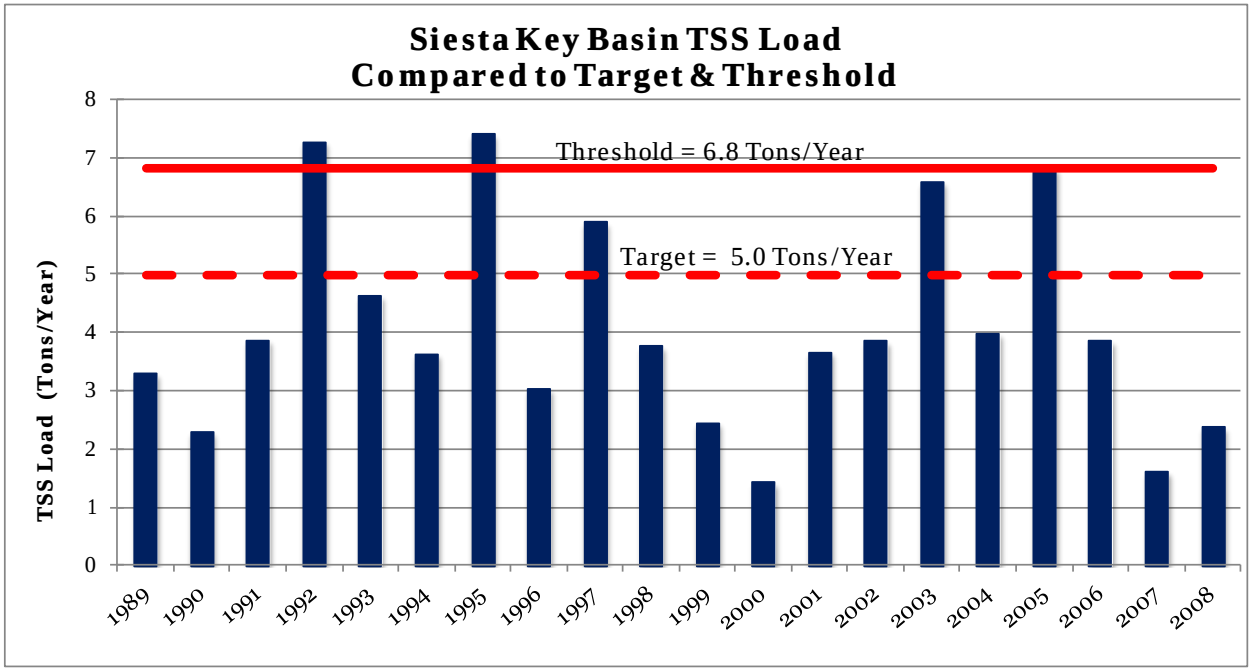


Figure 5-35 Comparison of Mean Annual TSS Concentrations to Target and Threshold—Siesta Key

5.4.3.7 Development of Freshwater Inflow LOS for Maintenance of Salinity Distributions

An additional water quality parameter that is important to the aquatic health of the estuary is salinity. Most estuarine flora and fauna have a preferred range of salinity for both juveniles and adults of the species. The study of the life histories of many estuarine species has revealed that most organisms that live in coastal waters tolerate a wide range of salinities, as shown in Table 5-4. This trait has been developed to allow biota to adapt to the natural variability in salt concentrations resulting from varying rates of freshwater inflows.

Table 5-4 Salinity Preferences for Selected Species (ppt)

Species	Lower Limit	Upper Limit
Oyster Adult	11	33
Oyster Larval	11	31
Bay Scallop Juvenile and Adult	14	36
Bay Scallop Larval stage	22	36
Blue Crab, Megalopae	16	38
Blue Crab, Spawning Female	21	38
Sea Trout	15	34
Turtle Grass	7	48
Bay Anchovy	10	20
Pinfish	20	25
Pink Shrimp	10	15
Black Mangrove	15	30
White Mangrove	17	25

The results of this work indicate that tidal exchange of bay water with the Gulf of Mexico is the predominant factor affecting salinity in the bay because of two factors. One factor is the relatively small watershed area in comparison to the bay surface area. The Sarasota Bay watershed is less than 20% larger than the bay itself. In contrast, the Tampa Bay and Charlotte Harbor watersheds are six and 16 times the size of their respective estuaries. The second factor is the conveyance capacity of the coastal inlets including Anna Maria Pass, New Pass, and Big Sarasota Pass. The mean ratio of freshwater inflow to tidal prism volume (the volume of water exchanged between the bay and gulf during a tide cycle) is approximately 0.15, which means that the tidal exchange volume is more than five times the freshwater inflow on average.

Figure 5-36 shows that current freshwater inputs are somewhat higher than historical at moderate and higher flow rates (above the 30th percentile). Figure 5-37 shows that the range of salinity was narrower under historical conditions, from approximately 33.0 to 37.3 ppt. Current salinities range from 30.2 up to 38.5 ppt, which is still well within the typical range of tolerance for most estuarine organisms. Although extreme salinities are outside the juvenile scallop preference zone, these organisms generally inhabit open waters of the estuary and are less vulnerable to high salinities. In contrast, oysters that colonize near the mouths of freshwater streams are much more tolerant of wide swings in salinity.

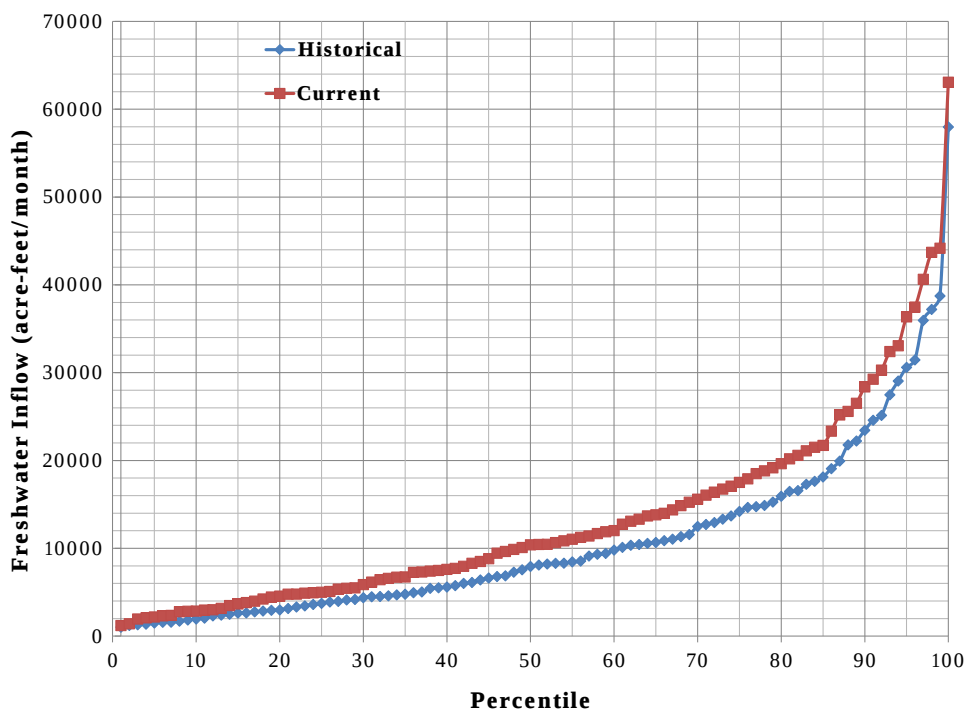


Figure 5-36 Comparison of Current and Historical Freshwater Inputs to Sarasota Bay

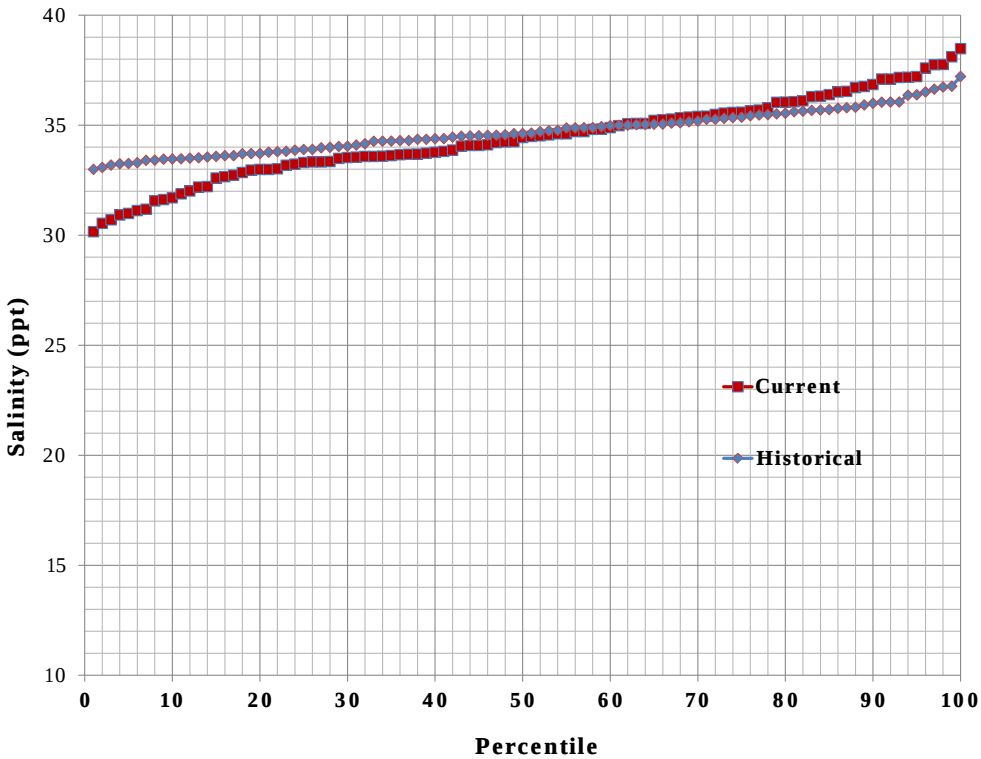


Figure 5-37 Comparison of Current and Historical Salinity Distributions in Sarasota Bay

Although the range of salinity has widened, the mean of the distribution has not shifted. The mean salinity of seawater is typically between 33 and 37 ppt, so freshwater inputs evidently have a limited effect on salinity in the bay. However, to ensure that the historical salinity regime is protected, the LOS target for freshwater inflows for salinity management should be the historical flow distribution. Although the historical inflows are lower than current inflows and would result in less freshwater entering the estuary and potentially increase residence time, the lower flows would also reduce pollutant loadings to the estuary.

5.4.3.8 LOS Conclusion

The previously-developed estuarine water quality LOS targets and thresholds for seagrasses, chlorophyll *a*, TN and TP concentrations and loads, and freshwater inputs are recommended to be included in the Sarasota Bay WQMP. The targets are focused on meeting water quality conditions that are conducive to maintaining seagrass coverage at or above the seagrass LOS target. Table 5-5 summarizes the water quality LOS targets for seagrasses, chlorophyll *a*, TN and TP concentrations and loads, and freshwater inputs.

Table 5-5 Summary of Water Quality LOS Targets and Thresholds for Sarasota Bay

Variable	Targets	Thresholds
Seagrass (acres)	7,269	NA
Chlorophyll *a* (µg/L)	5.2	6.1
TN Concentration (mg/L)	0.38	Varies per Equation.
TN Load (tons/year)	215	237
TP Concentration (mg/L)	0.15	0.19
TP Load (tons/year)	31.8	35.2
Freshwater Tributary TN Concentration (mg/L)	1.65	Varies by tributary
Freshwater Tributary TP Concentration (mg/L)	0.49	Varies by tributary
Basin-specific TN and TP loads	Varies by basin	Varies by basin
Freshwater Inflows	Historical inflow distribution	NA

6.0 DISSOLVED OXYGEN

6.1 INTRODUCTION

This section discusses the importance of DO in marine and freshwater systems, examines the relationship between DO and other water chemistry parameters, and compares ambient DO in the Sarasota Bay estuary and tributary system with proposed DO standards developed by FDEP. Additionally, the feasibility of identifying relationships between DO levels and aquatic biota is assessed. This section compiles information described in Tasks II-6.5 and II-6.6 of the Sarasota Bay WQMP Scope of Work.

6.2 THE RESOURCE AND ITS FUNCTIONS

DO is the amount of oxygen gas contained in water. All aquatic biota in the Sarasota Bay system and its tributaries depend on DO for respiration, and DO determines the types and abundance of organisms that can survive and thrive in the bay and its tributaries. Organisms have a variety of response mechanism to avoid harm when DO levels are reduced below physiological requirements in very low concentrations or moderately low concentrations for an extended period. Fish and other pelagic biota that have high mobility can swim to areas with more favorable conditions. Other species such as shrimp have limited ability to move to avoid low DO effects. Many benthic organisms such as oysters are sessile and cannot move to avoid low DO or are so small that they cannot move far or fast enough to reach higher DO concentrations. Therefore, if adverse conditions cannot be avoided, then the organisms must develop a tolerance to low DO to survive.

If DO levels outside an organism's range of tolerance cannot be avoided, then harm or death may occur. As a result, DO levels affect the temporal and spatial distribution of all organisms in estuaries and freshwater. Thus, establishing LOS criteria for DO in the estuary and tributaries is crucial to protecting aquatic life. In this document, the water quality criteria and standards are the LOS.

Florida's current DO standards were adopted about 40 years ago and were based on limited scientific data documenting the low DO conditions that are common in warmer waters and the response of southern warm water species to low DO conditions. Because of natural conditions, DO concentrations frequently fall below the existing DO criteria in many of Florida's minimally disturbed and healthy fresh and marine waterbodies; therefore, FDEP is revising the existing DO criteria to better reflect State-wide conditions. The current State DO standards (Chapter 62-302.530, FAC) are:

- For predominantly freshwaters (Class I and III):
  - Shall not be less than 5.0 mg/L. Normal daily and seasonal fluctuations above these levels shall be maintained.

- For predominantly marine waters (Class II and III):
  - 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.

These standards are based on DO concentration. A concentration-based standard does not account for natural variability in DO levels resulting from changes in environmental conditions. Another measure of DO in water is percent saturation, which is the expected amount of DO in aquatic environments given ambient conditions. Percent saturation depends on ambient water temperature and salinity. The DO concentration at 100% saturation decreases as water temperature and salinity increase. The empirical relationship between DO saturation and temperature for water is well documented (Benson and Krause, 1984). FDEP has proposed DO standards expressed as DO percent saturation that account for the seasonal variability that affects water temperature and salinity. The proposed standards also allow for regional conditions within the State. The proposed State DO standards are:

- For predominantly fresh waters (Class I and III):
  - The daily average percent DO saturation shall not be below 67% in the Panhandle West bioregion or 34% in the Big Bend, Northeast, and Peninsula SCI bioregions. (The entire Sarasota Bay system is within the Peninsula SCI bioregion.)

- For predominantly marine waters (Class II and III):
  - The daily average percent DO saturation shall not be below 41.7%.

    and
  - The 7- and 30-day average percent DO saturations shall not be below 51.0 and 56.5%, respectively.

The freshwater criteria were developed based on a State-wide examination of regional stream conditions. FDEP used its Stream Condition Index (SCI), which was developed based on the EPA's "rapid bioassessment" concept. The SCI uses a series of 10 metrics that indicates the levels of ecological integrity and anthropogenic disturbance to a site scored on a scale of 0 to 100. The metrics are measures of the composition and abundance of the in-stream macroinvertebrate community. Macroinvertebrates generally include all insects and other invertebrates (animals without backbones such as clams, snails, flatworms, and arthropods) that are large enough to be seen without the aid of a microscope. Because these organisms have limited or no mobility, they tend to reflect surrounding conditions and as such are good indicators of the environmental health of a site.

FDEP determined that a SCI score below 40 points indicated that the freshwater site was biologically impaired. A regionally based linear regression analysis was conducted to determine the percent DO saturation necessary to support a healthy macroinvertebrate community (SCI score of 40 or above). Multiple lines of evidence indicated that a DO percent saturation of 34

adequately ensures that a site in the SCI Peninsula bioregion, which includes the Sarasota Bay system, is not impaired. Because of regional conditions, the proposed standard is different for the West Panhandle bioregion.

In addition to DO, other factors have a significant influence on the SCI score in streams. Important environmental characteristics that affect SCI scores include stream morphometry, riparian buffer vegetation and width, water velocity, and substrate.

The proposed standards for tidal waters are based on the EPA Virginian Province protocol for setting DO standards, as applied to data available for Florida-specific species. The Virginian Province methodology incorporates assessments of organisms' biological responses to hypoxic stressors in aquatic ecosystems. The approach considers the response to continuous and cyclic exposures to low DO levels to derive criteria that are protective of aquatic life. Using this approach, a minimum daily average DO percent saturation of 41.7 and minimum 7- and 30-day average DO percent saturation of 51.0 and 56.5, respectively, were determined to be protective of marine life.

Both the existing and proposed DO standards are intended to characterize surface waters on a waterbody-wide and long-term basis. Aquatic species can be affected by localized, short-term DO excursions that are not addressed by the standards. If localized or short-term DO problems are identified, then a site-specific investigation should be completed.

Commonalities in the environmental processes affect DO in tidal and freshwater systems. However, unique features also influence DO levels in each waterbody. Characteristics of both systems are discussed below.

6.2.1 Estuary

Oxygen enters tidal waters through two natural processes: diffusion from the atmosphere and photosynthesis by aquatic plants. Mixing of surface water by wind, waves, tides, and currents increases the rate at which oxygen from the air can be dissolved into the water. The magnitude and timing of freshwater inputs to the estuary also affect DO levels. Oxygen solubility in water decreases as water temperature and salinity increase. Many processes influence the amount and distribution of oxygen in the marine environment. Plants and algae produce oxygen during the day as a byproduct of photosynthesis and take oxygen up at night during respiration. Microbes reduce DO levels in estuaries through uptake while decomposing organic matter. Fish and other fauna use oxygen during respiration.

Because of the shifting balance of physical, chemical, and biological processes, DO levels in estuaries vary seasonally, diurnally (daily), and spatially. DO may remain high enough for extended periods to support animals such as highly active fish and at other times decline below a critical threshold. Periods with elevated water temperature or high biological activity during summer can lead to naturally low DO levels in estuaries. Highly productive areas are more likely

to become oxygen-depleted at night during the summer when temperature and respiration rates are high. Long residence time in an estuary can also lead to DO depletion. Another cause of reduced DO in water is stratification, which can occur in deeper waters or where waters of different densities meet. Deeper parts of the bay may develop persistent hypoxia (low oxygen) or anoxia (no oxygen) during the late spring and summer, and DO levels may remain below critical thresholds for extended periods.

6.2.2 Tributaries

Tributaries possess a gradient of water quality characteristics that depends on the relative level of influence resulting from watershed-based freshwater inflows and from the open water estuary. Coastal tributaries are generally classified as freshwater (upstream of the influence of saline tidal water) or marine/tidal (mean specific conductance of at least 1,275 µmhos/cm, the State definition of "marine waters" in Chapter 62-302.530, FAC).

Oxygen exerts the same influence on the composition and abundance of aquatic organisms in tributaries as in estuaries. Aquatic organisms in tributaries must be able to avoid areas with low DO levels or adapt to changing DO conditions just as organisms in estuarine waters adapt to changing DO and salinity levels.

DO and biochemical oxygen demand in tributaries are tightly coupled to nutrient inputs via algal biomass, which responds quickly to increased nutrients, often consuming oxygen in the process (Mallin et al., 2004). Linkages among these factors are consistent across aquatic systems, though the nature of the relationships varies as a result of multiple factors. Typically, information on freshwater inflows, nutrient supplies, the associated phytoplankton response, and the biotic integrity of the system are more readily available than the supply rate of organic carbon, re-aeration rates, and sediment oxygen demand, all of which influence DO levels. Uncertainties related to the effects of these less-defined impacts adds to the complexity of developing relationships between nutrients, phytoplankton responses, and DO.

6.2.2.1 Freshwater Tributaries

Freshwater tributaries are upstream of the zone of saltwater mixing in the channel. However, stream hydraulic characteristics may be affected by backwater from tidal action during high tides. Freshwater coastal tributaries are more similar to inland streams in terms of vegetation cover and fish and benthic communities. Some biota have salinity tolerances that confine them to the freshwater portions of a tributary. Anadromous fish species, however, spend different life stages in either fresh or tidal waters, usually spending their adult lives in open tidal waters and returning to freshwater tributaries to spawn. Juveniles often spend their early life in the tidal areas of the tributary before traveling to the open waters. Examples of this behavior include the American shad and Gulf sturgeon. Other fish, such as the bull shark, exhibit a wide range of salinity tolerance and may be found in freshwater or tidal waters as adults.

As in estuaries, tributaries receive oxygen from the atmosphere and through photosynthesis by aquatic plants. Mixing from streamflow turbulence increases the rate at which oxygen from the air can be dissolved into the water. Unlike tidal tributaries, DO saturation levels in freshwater are not influenced by salinity but are still affected by temperature variations.

As a result of the freshwater tributaries' direct connection and proximity to watershed-based sources of nutrient inputs and their smaller volumes relative to the open estuary, these water bodies are likely to have relatively higher nutrient and chlorophyll concentrations and lower DO levels than downstream waters where nutrient loads are rapidly diluted by the greater water volumes (Holland et al., 2004; Sherwood, 2008).

Tributaries with low flushing rates or high nutrient inputs are especially vulnerable to becoming hypoxic as organic carbon is metabolized in the system and oxygen is consumed. Low flow rates or stagnant conditions in tributaries also allow water temperature to rise, further decreasing aeration capabilities. Lack of a tree canopy to provide shade to open water also results in increased water temperature and subsequently lower DO.

6.2.2.2 Tidal Tributaries

The downstream portions of coastal tributaries are subject to chemical and physical influences from the adjoining estuary and freshwater inflows. Salinity and temperature affect DO saturation levels, and tidal mixing provides more circulation than upstream freshwater areas. Although salinity levels in tidal waters may approach zero during periods of high freshwater discharge, salinity can be close to or equal that of the estuary during dry periods.

The vegetation, fish, and benthic communities of tidal tributaries more closely resemble the estuary than freshwater tributaries; however, stationary plant and animal species must be adaptable to large, rapid changes in salinity. Salt content in the tributary can fall from levels near those of the estuary to close to freshwater within hours if heavy rainfall occurs in the watershed. Low salinity can be sustained for prolonged periods, especially in larger watersheds where stormwater runoff takes longer to reach peak levels. DO levels often fall near the outfalls of tributaries, as the less dense freshwater forms a confining layer over the saltwater, effectively separating the bottom water layer from the atmosphere.

The interaction of tides and freshwater inflows results in a longer residence time in tidal tributaries than in upstream freshwater streams. This contributes to high productivity in tidal tributaries, which makes them suited to be nurseries and refuge for many fish and benthic species. The high productivity provides abundant food sources for juvenile fish, and the juveniles of many fish species have greater tolerance for low DO levels than adults.

6.3 OBJECTIVE

This section presents the approach, information and data used, and results associated with DO LOS criteria for the Sarasota Bay estuaries and associated freshwater tributaries. The information provided in this section will be used to identify potential management actions for the Sarasota Bay WQMP. The objectives of this section are to:

- Identify appropriate DO LOS for the estuary and tributaries that will be protective of tidal and other resources.
- Identify and discuss factors that affect DO in the estuary and tributaries.
- Compare reported DO levels in the Sarasota Bay estuarine system and tributaries with the proposed FDEP DO standards.
- Assess the potential for developing relationships between ambient DO levels and biota in tributaries.

6.4 MONITORING PROGRAMS AND OTHER DATA SOURCE(S)

- DO and conductivity data for 1996 through 2011 obtained from the State's STORET database and Sarasota County.
- Technical Support Document: Derivation of Dissolved Oxygen Criteria to Protect Aquatic Life in Florida's Fresh and Marine Waters (Draft) (FDEP, 2012a).
- Sarasota Bay Numeric Nutrient Criteria: Task 3 – Dissolved Oxygen (Janicki Environmental, Inc. 2011c).
- Sarasota County Tidal Creek Condition Index Data for 2008–2011 (Sarasota County, 2011).
- FDEP Stream Condition Index (SCI) Data for Sarasota Bay Waterbodies (2012b).

6.5 APPROACH

6.5.1 DO Relationships with Other Water Quality Parameters

To identify empirical relationships between DO and potential explanatory variables, linear regression techniques were employed. Linear regression is a parametric statistical technique used to explore the relationship between two or more variables. In ordinary linear regression, the relationship between the dependent variable (y-axis) and independent variable (x-axis) is developed. In linear regression, the data are assumed to be independent samples from the population being sampled. For example, if one is developing relationships between DO and explanatory variables in a stream, the data should come from samples that represent the spatial and temporal variability of the stream. Another important assumption of linear regression is that the error term of the model is normally distributed, with constant variance. Often, one or more of the variables exhibits a non-linear relationship with the other variables. While non-linear regression techniques can be employed, one should try transforming the data. Ordinary linear

regressions can be developed using transformed data, and these models will satisfy the assumptions of linear regression.

Diagnostic statistics and plots are commonly used to determine if the regression model meets the assumptions of linear regression. The most commonly used statistics are the statistical significance of the model coefficients and the coefficient of determination (r^2). The statistical significance of the model coefficients tests whether the slope and intercept of the model are significantly different from zero. The coefficient of determination is a measure of the variance in the dependent variable that is explained by the model. A plot of the residuals versus the independent variable(s) can be used to judge if the assumption of constant variance is met. Additional plots of residuals versus other variables can also be instructive. For example, a time-series plot of the residuals can be used to assess whether the residuals vary seasonally. Additional diagnostics can be run to identify outliers and test for leverage or influential points. Data points identified by these additional diagnostics should be further investigated to determine if they are the result of a data entry error or other problem that merits removing them from the analysis.

6.5.2 Comparison of Ambient DO Levels in Sarasota Bay and its Tributaries to Current and Proposed FDEP DO Standards

6.5.2.1 Estuary

DO levels in Sarasota Bay were compared with the current and proposed FDEP standards. In this document the LOS is the proposed FDEP standard. The analysis consisted of determining the frequency of occurrences of DO that failed to meet the current standard of 4.0 mg/L. The FDEP IWR requires that no less than 90% of samples meet water quality criteria (i.e., a maximum 10% exceedance) (Chapter 62-303, FAC). Therefore, years with more than 10% of the samples failing to meet the proposed standards were considered to fail. Figure 6-1 summarizes the results in a graphical format.

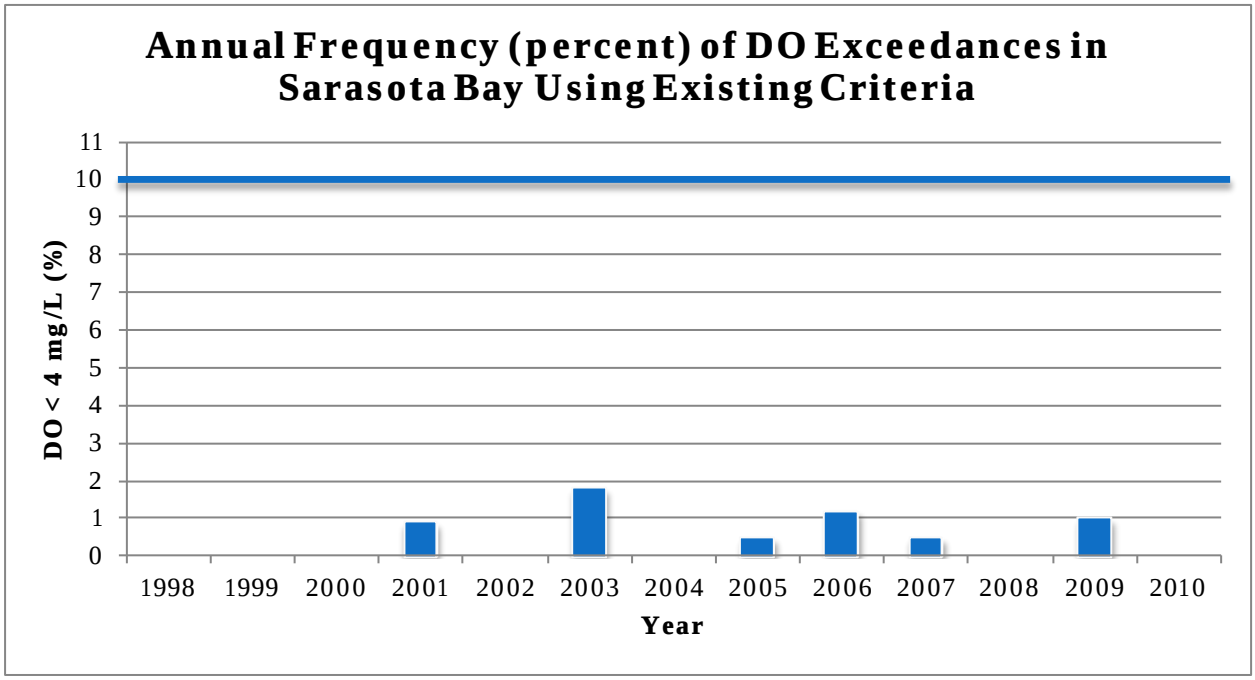


Figure 6-1 Annual Frequency (percent) of DO Exceedances in Sarasota Bay Using Existing Criteria
Horizontal line indicates 10% of samples.

The same DO sample data were also compared with the proposed DO standard for marine waters (41.7% saturation for daily values and 51 and 56% saturation for 7- and 30-day average, respectively) to determine if more or fewer exceedances would be likely using the new standards than the current criterion. Data used for the analysis included DO concentrations and percent saturation. Where concentration but not saturation was reported, percent saturation was calculated using the concentration, salinity, and temperature values.

6.5.2.2 Tributaries

DO levels in the County's tributaries were compared with the proposed FDEP standards. DO concentration and percent-saturation data for nine tributaries of the Sarasota Bay system were obtained from the State's STORET database and the County. The data were organized by water body, year, and whether the site was in fresh or tidal waters. If multiple values of a parameter at a site existed for a single day, the values were averaged to yield a daily value. Data sampling stations were identified as freshwater or marine water depending on salinity or conductivity values. The daily percent-saturation values were compared with the proposed DO standard (34% saturation for freshwater, 41.7% saturation for marine water for daily values, and 51.0 and 56% saturation for marine waters' 7- and 30-day average, respectively). Because of the different standard for freshwater and marine waters, tributaries are assessed based on their classification. Data used for the analysis included DO concentrations and percent saturation. Where concentration but not saturation was reported, percent saturation was calculated using the concentration, salinity, and temperature values.

The FDEP IWR requires that no less than 90% of samples meet water quality criteria (i.e., a maximum 10% exceedance) (Chapter 62-303, FAC). Therefore, years with more than 10% of the samples failing to meet the proposed standards were considered to fail. The results are summarized below.

6.6 RESULTS

6.6.1 DO Relationships with Other Estuarine Water Quality Parameters

A series of bivariate plots (DO vs potential explanatory variables) were completed and analyzed to better understand what factors influence DO concentrations in Sarasota Bay. In addition, multi-variate regression techniques were employed to identify variables that influence DO for each bay segment.

Attachment 1 presents plots of DO versus TN concentration, TP concentration, temperature, salinity, conductivity, chlorophyll *a*, TN loads, TP loads, and BOD loads. These analyses include all parameters listed in the original contract, with additional parameters. The plots show few discernible relationships between DO and other parameters. However, a higher probability of low DO concentrations occurs as temperature increases, as would be expected.

Likewise, the results of the stepwise linear regressions showed no strong statistical relationships between DO and any of the explanatory variables. The best multi-variate fit relationship for Sarasota Bay included explanatory variables salinity, temperature, BOD, and TN with a resulting r^2 of 0.43, meaning that changes in all variables combined could explain only 43% of variability in DO. Variation in DO can be largely attributed to variations in temperature, with lower DO concentrations during summer with warmer water temperatures and higher productivity and during the night when oxygen is consumed by respiration.

Although these relationships were statistically significant, they are all weak and several variables change in unison given the same influences, contributing to co-linearity between them. This further weakens the meaningfulness of the relationships.

6.6.2 DO Relationships with Other Tributary Water Quality Parameters

To better understand what factors are influencing DO concentrations in the tributaries, a series of bivariate plots (DO vs potential explanatory variables) were produced and analyzed. In addition, multi-variate regression techniques were employed to identify variables that influence DO for each tributary and class (freshwater or marine) in the Sarasota Bay system.

Attachment 1 presents plots of DO versus TN concentration, TP concentration, temperature, time of day, salinity, conductivity, chlorophyll *a*, TN loads, TP loads, and BOD loads for freshwater and tidal tributaries. These plots show no strong relationships between DO and any other

parameter. However, a higher probability of lower DO concentrations occurs as color, TN, and TP concentrations increase.

Table 6-1 presents the results of the stepwise linear regressions by tributary and class (3M is marine water, 3F is fresh). As expected from the bivariate plots, strong statistical relationships between DO and potential explanatory variables cannot be found. While statistically significant relationships between DO concentrations and potential explanatory variables were identified for most tributaries, these relationships left a majority of the variation unexplained, which is expected given the complex interactions that affect DO concentrations in tidally influenced systems.

Table 6-1 Summary of Relationships between DO and Explanatory Variables by Tributary and Class for Sarasota Bay Tributaries

Creek	Class	n	Equation	r^2
Bowlees Creek	3M	156	DO = 9.29 - 0.13 (temperature)	0.13
Whitaker Bayou	3F	135	DO = 10.09 – 6.50(TP)	0.07
Hudson Bayou	3F	99	DO = 10.83 - 0.26 (temperature)	0.11
	3M	48	DO = 4.03 – 0.11 (salinity)	0.37

The best r^2 values for the regressions developed ranged from 0.07 to 0.37, meaning that between 7 and 37% of the variation in DO could be attributed to changes in the selected explanatory variables. As with the estuarine analysis, the most common influential explanatory variable in the tributaries of Sarasota Bay was temperature. A combination of diurnal and seasonal variation in DO can be largely attributed to variations in temperature, with lower DO concentrations during summer with warmer water temperatures and higher productivity and during the night when oxygen is consumed by respiration.

6.6.3 Comparison of Sarasota Bay and its Tributaries to Existing and Proposed FDEP DO Standards

FDEP evaluates water quality criteria using the provisions of Florida's IWR (Chapter 62-303, FAC). Using the binomial hypothesis test, no more than 10% of the samples collected during an assessment period are allowed to exceed the standard. Results presented below use an annual assessment period.

6.6.3.1 Estuary

DO levels in the estuary were compared to existing and proposed FDEP DO standards. The frequencies of occurrences of ambient DO meeting and not meeting the current standard of 4.0 mg/L in Sarasota Bay are presented in Figure 6-1, which shows that the annual frequencies of

DO exceedances in the bay are well under 10% of samples for all years assessed (1998 through 2010) and that DO levels comply with the current standard on a bay-wide basis.

Figure 6-2 presents the frequencies of occurrences of in-bay DO meeting and not meeting the proposed standard of 41.7% saturation. As with the existing standard, the annual frequencies of exceedances of the proposed marine DO criterion in the bay are well under 10% of samples for all years assessed (1998 through 2010) and thus DO levels for Sarasota Bay also comply with the proposed standard.

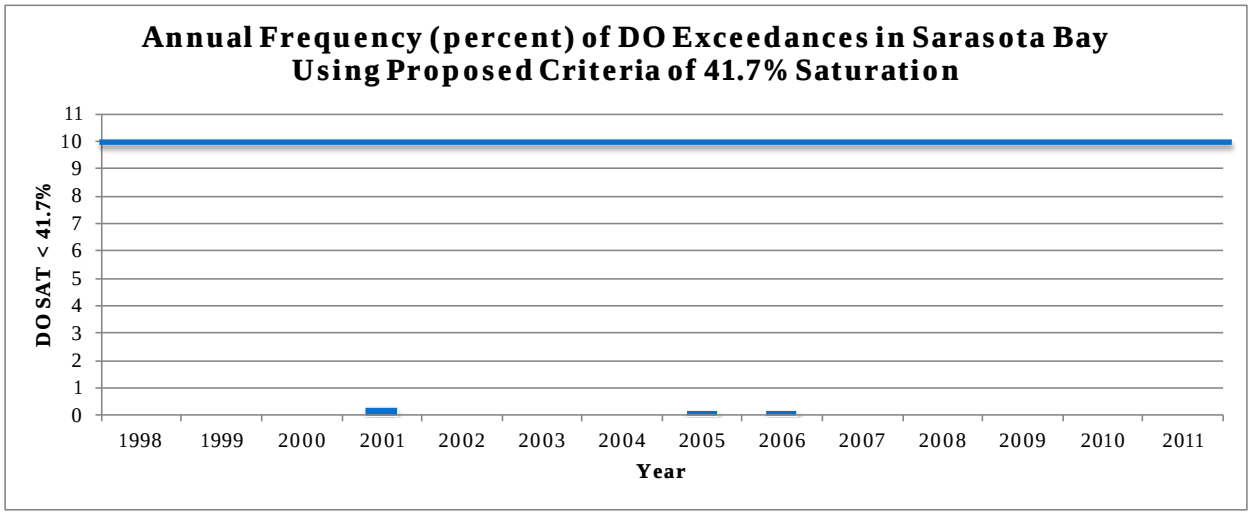


Figure 6-2 Annual Frequency (percent) of DO Exceedances in Sarasota Bay Using Proposed Criteria of 41.7% Saturation
Horizontal line indicates 10% of samples.

6.6.3.2 Tributaries

Ambient DO levels in Sarasota Bay tributaries and other tidal and freshwater tributaries in Sarasota County were compared to the proposed DO criteria. Table 6-2 presents the results including freshwater (Class 3F) and marine (Class 3M) areas of each creek and available data.

Table 6-2 Sarasota Bay and Other Tributaries Not Meeting Proposed FDEP DO Standards

Shading indicates years not meeting proposed standards. FW indicates freshwater, and TC indicates tidal creek.

Creek	Class	2003	2004	2005	2006	2007	2008	2009	2010	2011
Sarasota Bay Tributaries in Sarasota County										
Whitaker Bayou	3F (FW)									
	3M (TC)									
Hudson Bayou	3F (FW)									
	3M (TC)									

Table 6-2 Sarasota Bay and Other Tributaries Not Meeting Proposed FDEP DO Standards

Shading indicates years not meeting proposed standards. FW indicates freshwater, and TC indicates tidal creek.

Creek	Class	2003	2004	2005	2006	2007	2008	2009	2010	2011
Other Sarasota County Tributaries										
Philippi Creek	3F (FW)									
	3M (TC)									
Matheny Creek	3F (FW)									
	3M (TC)									
Elligraw Bayou	3F (FW)									
	3M (TC)									
Clower Creek	3F (FW)									
	3M (TC)									
Catfish Creek	3F (FW)									
	3M (TC)									
North Creek	3F (FW)									
	3M (TC)									
South Creek	3F (FW)									
	3M (TC)									

Compiled data for nine creeks for 2003 through 2011 were examined using the same methodology used for the estuary. Whitaker Bayou met the criteria in all years tested while Hudson Bayou did not meet the criteria from 2006 through 2011 (freshwater) and from 2007 through 2009 (marine).

For all tributaries combined, the proposed standards were not met for a cumulative total of 32 years (25 freshwater stream segments and seven tidal segments). This means that the proposed criteria were met 80% of the time. Clower Creek had the most years of failing to meet the proposed standard (7 years for the freshwater area and 4 years for the marine area). Phillippi Creek and Catfish Creek had no failing years. The years with the most waterbodies failing to meet the proposed standard were 2007 and 2009, both with six.

6.7 RELATIONSHIP OF DISSOLVED OXYGEN WITH BIOTA IN TRIBUTARIES

As discussed above, DO is a critical factor in determining the health of aquatic systems. Opportunities for quantifying the relationship between DO levels and benthic and fish communities in Sarasota Bay's tributaries were examined.

SCI data collected by FDEP for the Sarasota Bay system were obtained and examined. The SCI uses an array of indicators of biological integrity to demonstrate whether benthic species

composition, diversity, and functional organization are comparable to that of natural habitats in a region. DO has been shown to significantly influence SCI scores. However, environmental factors including but not limited to tributary morphometry, riparian vegetation, streamflow velocity, and substrate also influence the SCI score. Table 6-3 and Figure 6-3 present sample site locations and results of SCI testing in Sarasota Bay system tributaries. Ten SCI samples were collected from Sarasota Bay system tributaries between 1991 and 2006.

Table 6-3 FDEP Stream Conditions Index Sarasota Bay System Sites and Sample Results

Water Body	Station Name	Sample Date	SCI Class
Phillippi Creek	FLCITSOTST	8/20/1991	Poor
Phillippi Creek	FLCITSOREF	8/20/1991	Poor
Phillippi Creek	FLCTSOREF	8/1/1996	Excellent
Phillippi Creek	FLCTSOTST1	7/29/1996	Poor
Phillippi Creek	FLCTSOTST2	7/29/1996	Good
Catfish Creek	SSOTASW1	12/7/1998	Good
Whitaker Bayou	SSOTASW2	12/7/1998	Poor
Bowless Creek	SSOTASW3	12/7/1998	Poor
Phillippi Creek	SAR617US	6/28/2005	Poor
Phillippi Creek	SAR617US	1/9/2006	Very Poor

The scoring system has changed since the program started, so the earlier SCI numerical scores cannot be compared with more recent samples although the text categorizations have remained the same. Seven of the ten samples were taken in Phillippi Creek, and results range from “excellent” (1996) to “very poor” (2006) at different sites. Single samples were taken at Catfish Creek (1998, good), Whitaker Bayou (1998, poor), and Bowlees Creek (1998, poor).

Sarasota County’s Tidal Creek Condition Index (TCCI) program is the other source of biological sampling data for tributaries. The program and reported findings are further discussed in the *Critical Marine and Lotic Natural Resources* section of the WQMP.

Sixteen tidal creeks in Sarasota County were assessed annually for a variety of biological indicators including abundance and diversity of selected benthic invertebrates, density of burrows created by benthic invertebrates, oyster size and survival, and the extent of filamentous algae and periphyton covering the creek bottom. Two tidal creeks, Whitaker Bayou and Hudson Bayou, are in Sarasota Bay as shown in Figure 6-3. Results of the index scoring for all creeks sampled are shown in Figure 6-4.

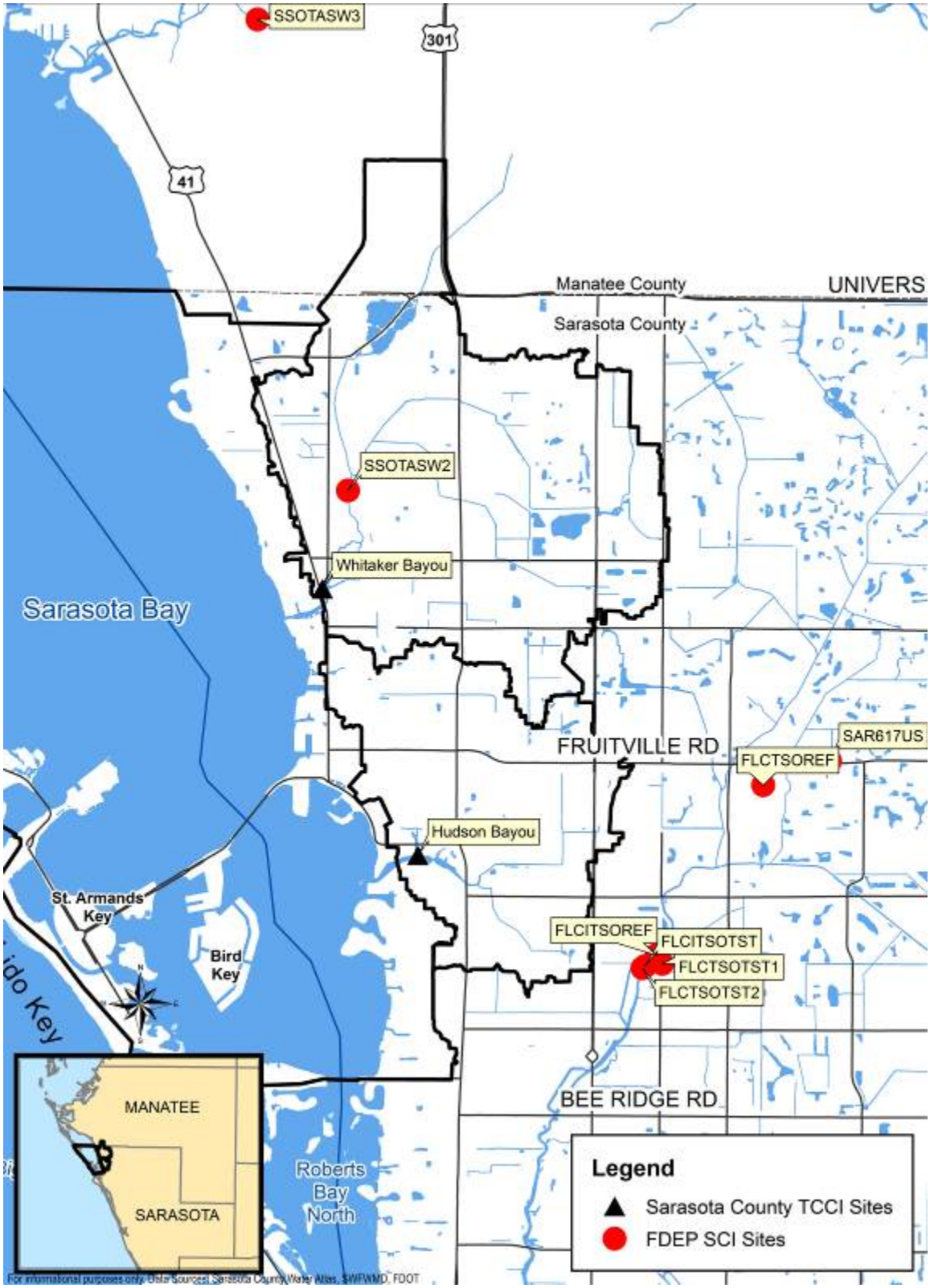


Figure 6-3 Biological Sampling Sites in Sarasota Bay Tributaries and Phillippi Creek

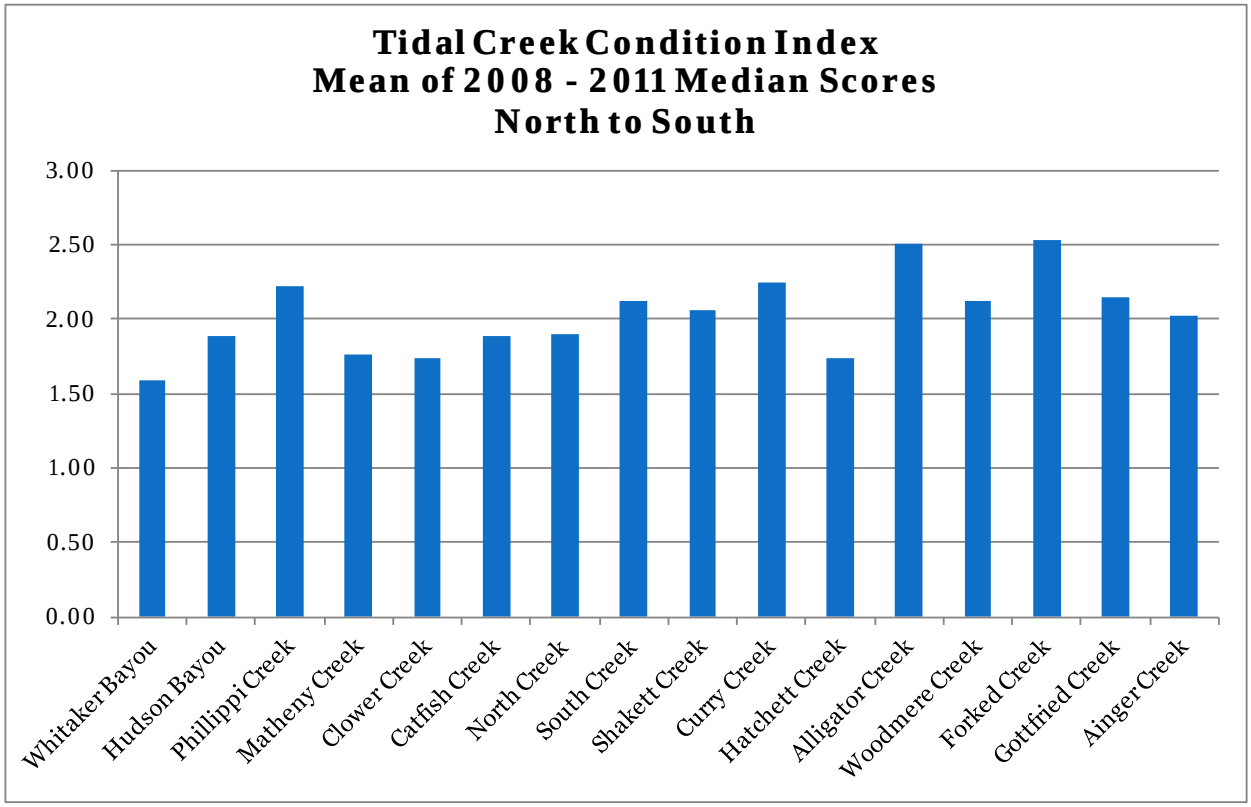


Figure 6-4 Sarasota County Tidal Creek Conditions Index Scores 2008 through 2011 Whitaker and Hudson bayous are tributaries of Sarasota Bay.

Samples were taken in these tributaries annually using the current methodology from 2008 to 2011 (the TCCI program has since been discontinued). Scoring, in which a low score indicates higher stress, indicates that Whitaker Bayou, in Sarasota Bay, was the most stressed of all creeks in the County, and Hudson Bayou was also among the most stressed.

The SCI and TCCI data are the only sources of biological data identified for the Sarasota Bay system's tidal streams. Other biological sampling (Serviss and Sauers, 2003; Culter and Leverone, 1993; MacDonald et al., 2010) was confined to the open water estuary. DO monitoring occurs in all these streams but only monthly.

The low density of data makes a quantitative assessment of the relationship between DO and tidal streams pelagic and benthic communities infeasible. Actions that can be taken to make this assessment possible include conducting a concentrated sampling effort involving synoptic biological and water quality sampling and developing a longer period of record and larger sample size.

6.8 CONCLUSIONS

DO has been shown to be a critical element of the tidal and freshwater environments. Reduced DO levels can lead to behavioral changes, harm, or death to aquatic organisms. A variety of

natural and anthropogenic biological, physical, and chemical processes affect the distribution and availability of oxygen in the environment.

FDEP has proposed new water quality standards for DO that are intended to be protective of aquatic natural resources and to account for natural variability in aquatic systems. The proposed standards were applied to the Sarasota Bay estuary system and tributaries. All bay segments met the proposed standard, and all tributaries combined met the proposed standard 80% of the time; therefore, DO levels in the bay are protective of estuarine resources and DO levels in the tributaries is protective in the majority of cases.

Based on the results of the DO analysis, the Hudson Bayou tributary in the Sarasota Bay system should be examined to identify potential causes for the repeated low DO saturation. The Hudson Bayou basin is highly urbanized with extensive directly connected impervious area, and the stream channel is highly altered. Stormwater runoff discharging to the channel from the paved watershed is likely at a high temperature, and the downstream zone of the tributary may receive high nutrient and organic material loads. All of these factors would affect in-stream DO. However, the pollutant-loading analysis shows Hudson Bay to have only moderate nutrient loading rates.

Results of the TCCI sampling indicate that Whitaker Bayou and Hudson Bayou are stressed, as they both have low scores compared with most of the County's other creeks. Although DO could be a factor in the low TCCI score for Hudson Bayou, other conditions are likely to be responsible for Whitaker Bayou's low score.

Analyses were completed to examine the relationship of DO to other parameters in the aquatic environment. No strong relationships were identified in the estuary or tributaries. Some relationships were observed, such as the tendency of lower DO levels to occur with warmer water temperatures.

Using the existing DO criteria, FDEP has determined that several WBIDs in Sarasota Bay and tributaries are impaired under the State's IWR (Chapter 62-303, FAC). WBIDs are impaired for DO as a result of either nutrients or BOD. The only Sarasota Bay WBID (with its waterbody type designated by FDEP) within the County that is impaired for DO because of nutrients is Whitaker Bayou (tidal). Hudson Bayou (tidal) is the only Sarasota Bay WBID in the County that is impaired for DO because of BOD.

The feasibility of identifying relationships between DO levels and the health of tidal and freshwater biota was explored; insufficient data exist to establish any quantifiable relationships.

7.0 SEDIMENT LEVELS OF SERVICE

Sediment is fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits and is transported by, suspended in, or deposited by water (EPA, 2003). Although sedimentation is a natural process, sediment becomes problematic when it is present in excessive quantities or is of poor quality.

Erosion and sedimentation plays an important role in influencing water quality, ecosystem health, and flood control. Population growth and development can increase stormwater runoff which delivers sediment and accelerate erosion and sediment deposition, overwhelming our natural systems. Excessive erosion and sedimentation are significant chemical and physical issues in watershed management. Excessive sediment alters the natural landscape, resulting in environmental and economic impairment. EPA recognizes sediment as a major contributor to impairment of the nation's waters and has cited sediment as the leading cause of impairment (EPA, 2003). Sediment-control strategies are therefore a key component of watershed management planning efforts.

Excessive erosion and sedimentation is an ongoing issue in Sarasota County. Excessive sedimentation generally occurs in two forms: mostly organic and mostly inorganic. The County recognizes that excessive sedimentation in its open-channel conveyances can significantly affect their natural character. This alteration can be due to the delivery of sediments through stormwater runoff or erosion to the conveyances or the accumulation of organic-rich sediments resulting from instream primary production.

The accumulation of organic sediments most often is the result of the responses in a stream to elevated nutrient loading. Elevated nutrient supply fuels primary production, primarily in the form of algal production within the water column and on the stream bottom. The decomposition of the organic-carbon compounds produced depends on the availability of DO. As the DO supply is depleted, incomplete decomposition or decomposition byproducts lead to accumulation of organic matter on the stream bottom. If the DO reduction is of such a degree that the DO standard is exceeded, the County will need to address this issue.

Inorganic sediment issues are most often related to excessive upstream channel erosion and the associated sediment transport, although shorter-term activities such as construction activities with inadequate erosion control can also contribute to the issues. For excessive channel erosion, visual identification and habitat response are better indicators of excessive inorganic sediment deposition which would lead the County to take preventative or remediation measures.

Irrespective of the source of the sediment, excessive sedimentation has deleterious impacts on the ecological health (e.g., low DO, impaired physical habitats) and the recreational and aesthetic nature of the stream. If sedimentation is to be effectively managed, the following must be addressed:

First, the current status of the sediment and physical characteristics in County streams needs to continue to be assessed. FDEP has developed a monitoring program that includes an assessment of the physical character of streams in Florida. This assessment includes several physical features: bank stability—the extent of erosion potential; habitat availability—the relative spatial abundance of productive habitats present; and habitat smothering—an assessment of sand and silt deposition onto what would otherwise be productive habitats. Field crews can be trained in the physical habitat assessment protocols, and the current status of the streams within the Sarasota Bay watershed can be determined. To achieve this objective, the County can segment the primary open-channel conveyances into reaches with similar geomorphic characteristics on which the County would collect the physical habitat parameters.

Second, in stream reaches where the organic accumulation of sediments is problematic, routine assessment of the longitudinal DO conditions would provide a means by which the current status can be determined.

Third, monitoring of trends in the conditions from Steps 1 and 2 can provide a temporal context to those conditions, i.e., temporal trends in sediment condition can be assessed. To this end, the frequency of sediment condition assessment can be defined. For those cases where inorganic sediments are the source of the sedimentation problem, stream sediment conditions should be assessed approximately once every 5 years. Where organic sediments are problematic, DO assessments should be conducted at a similar frequency employed for the ambient stream sampling.

7.1 INORGANIC SEDIMENT LOS

Physical habitat data collected in streams along the Florida gulf coast from Pasco County through Lee County have been obtained from FDEP. The statistical distribution of these data provides a framework for the sediment LOS recommendations. Excellent scores correspond to the range of conditions in the upper quartile of habitat scores. Good scores correspond to the interquartile range of conditions (i.e., between the 25th and 75th percentiles). Poor scores correspond to the range of conditions in the lower quartile of habitat scores. Using this framework, the recommended LOS for the physical habitat parameters are as follows:

- Bank Stability – scores range from 0 to 10.
- Excellent score when the bank stability exceeds 9.
- Good scores when the bank stability scores range from 5 through 8.
- Poor scores when the bank stability scores are less than 5.
- Habitat Availability – scores range from 0 to 20.
- Excellent score when the habitat availability exceeds 14.
- Good score when the habitat availability scores range from 7 through 13.
- Poor scores when the habitat availability scores are less than 13.
- Habitat Smothering – scores range from 0 to 20.
- Excellent score when the habitat smothering scores exceeds 16.

- Good scores when the habitat smothering scores range from 9 through 15.
- Poor scores when the habitat smothering scores are less than 9.

7.2 ORGANIC SEDIMENT LOS

With respect to the sediment LOS for those streams where the primary source of sediments is organic, the recommended surrogate for the sediment LOS is the level of DO in the stream. The recommended LOS is the same as that discussed in Section 6.6.3 for DO LOS.

8.0 WATER QUALITY IMPROVEMENTS

Jones Edmunds has identified 10 projects with the potential to reduce pollutant loading and improve water quality. Details concerning site and project selection are provided in Section 8.4.1and project and program recommendations are provided in Section 8.4.2.

8.1 BACKGROUND INFORMATION

The health of a watershed is reflected in the quality of the water. Numerous indicators, such as TN, TP, TSS, BOD, and fecal coliforms, can be assessed to determine water quality conditions and to provide clues as to why that condition exists. The objective of this section is to build on the results of previous sections to identify potential projects and programmatic recommendations that address pollutant loading within the Sarasota Bay watershed.

The major water quality problems in the Sarasota Bay watershed appear to stem from nonpoint source pollution. As water from rainfall and irrigation runs over the landscape of the watershed, it picks up pollutants and deposits them into tributaries, ponds, wetlands, and the bay. These pollutants include sediment, bacteria, chemicals, and nutrients. Nonpoint source pollution originates from an array of sources, such as agriculture, septic systems, boating, physical changes in stream channels, habitat degradation, and urban runoff. Reducing the quantity of pollutants entering the tributaries and bay is vital to the health of the watershed.

Watershed management includes identifying water quality problems, identifying the pollutant source(s), and recommending improvement projects. Using watershed health indicators, such as chlorophyll, DO, seagrass, and oysters, the County is working with local, state, and federal agencies to understand water quality conditions throughout the watershed, address impairments, and meet proposed water quality targets for the Sarasota Bay watershed. The ultimate goal is to improve water quality.

8.2 TMDL STATUS

FDEP has established criteria for evaluating water quality throughout Florida using a waterbody classification system and evaluative criteria for a variety of water quality constituents (Chapter 62-302.530, FAC). FDEP compiles surface water quality data collected throughout Florida primarily using its STORET database and its WBID system to assess water quality impairment of WBIDs under the IWR (Chapter 62-302.530, FAC). States are required to submit a list of surface waters that do not meet water quality standards (impaired waters) to EPA. This 303d list comprises waters that are impaired by pollution. Once verified, listed waterbodies require TMDLs to be developed. A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. Waterbodies can only be delisted when they have met the water quality standards or a TMDL has been developed and approved.

As of January 2010, the Sarasota Bay watershed had several waterbodies listed as impaired. Whitaker Bayou (WBID 1936), Hudson Bayou (WBID 1953), and Sarasota Bay Coastal (WBID 1916) were all listed as impaired for DO. The low DO in Whitaker Bayou is thought to be caused by elevated nitrogen, phosphorus, and BOD. A high oxygen demand (based on BOD measurements) was also identified as the cause of low DO in Hudson Bayou and Sarasota Bay Coastal. A detailed analysis of DO for these creeks was completed, see Section 6. Whitaker Bayou (WBID 1936), Hudson Bayou (WBID 1951 and 1953), and Sarasota Bay Coastal (WBID 1916, 1931, 1954, and 1961) are also listed as impaired for mercury based on high levels of mercury measured in fish tissue. In addition, Whitaker Bayou (WBID 1936) and Hudson Bayou (WBID 1953) are listed for fecal coliform based on the number of exceedances. Whitaker Bayou (WBID 1936) is impaired from excess nutrients based on elevated chlorophyll *a* as well. Additionally, a small portion of Sarasota Bay Coastal (WBID 1968BA) is listed for beach advisory based on excessive Department of Health (DOH) advisories. To date, no TMDLs have been developed for the Sarasota Bay watershed waterbodies.

8.3 WATER QUALITY IMPROVEMENT OPPORTUNITIES

Jones Edmunds identified potential water quality improvement opportunities in the Sarasota County portion of the Sarasota Bay Watershed. These projects and programmatic recommendations range from small, local improvement projects such as pervious pavers and curb cuts in the Bayfront Parking Lot (Section 8.4.1.2) to larger, regional programmatic recommendations such as Low-Impact Development (LID) (Section 8.4.2.6). Project selection methodology and results are provided in the following subsections.

8.3.1 Methodology

Jones Edmunds collected and assembled information, including previous studies, GIS data, and stakeholder input, to identify potential water quality improvement projects. Jones Edmunds began the investigation with a GIS desktop analysis to identify water quality 'hot spots' throughout the watershed. These hot spots were then refined to potential water quality project sites. Finally, Jones Edmunds conducted field investigation of these sites to evaluate potential water quality treatment options. This methodology is summarized in Figure 8-1 and detailed in the following sections. Results from the field analysis and potential project and program recommendations are provided in Section 8.3.2.3.

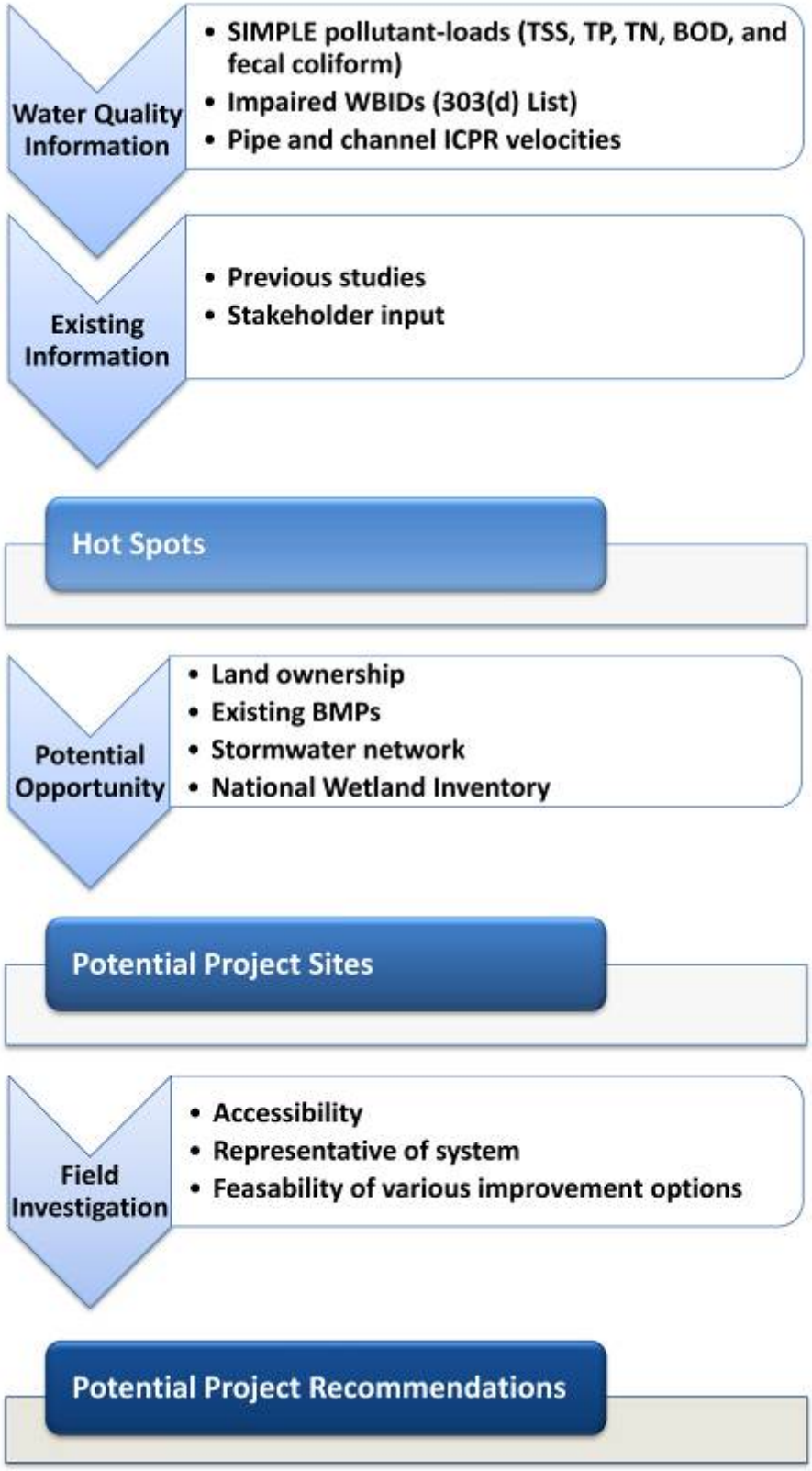


Figure 8-1 Water Quality Improvement Opportunity Identification Methodology

8.3.2 INVESTIGATION

Details concerning the elements of Jones Edmunds' investigations are provided in the following subsections.

8.3.2.1 Identification of Hot Spots

Jones Edmunds reviewed observations, input from stakeholders and County staff, and previous studies and data. A list of these water quality studies and data are in the Appendix. Jones Edmunds used GIS to compile and review data developed from the Pollutant Loading Model results together with aerials and other base data and information obtained from Sarasota County, SWFWMD, FDEP, and previous watershed studies and data. These datasets and information included the following:

- Pollutant-loads as estimated from the Spatially Integrated Model for Pollutant Loading Estimates (SIMPLE) (TSS, TP, TN, BOD, and Fecal coliform).
- 303(d) list.
- 2010 SWFWMD aerial imagery.
- Areas of concern identified in previous studies.
- Areas of concern noted by stakeholders and County staff.

A GIS desktop analysis of the parameters above yielded potential pollution hot spots in the watershed. Pollutant-load results and listed WBIDs are shown in Figure 8-2, Figure 8-3, Figure 8-4, Figure 8-5, Figure 8-6, and Figure 8-7 and are detailed in the pollutant-loading analysis sections.

8.3.2.2 Identification of Potential Project Sites

Jones Edmunds compiled the potential pollution hot spots with additional base data obtained from Sarasota County. Specifically, these datasets included the following:

- Sarasota County parcels.
- Best Management Practices (BMPs).
- Sarasota County stormwater inventory.
- 2010 SWFWMD aerial imagery.

Jones Edmunds identified 10 potential water quality improvement project sites in the watershed from a GIS desktop analysis of the parameters above (Figure 8-8 and Table 8-1).

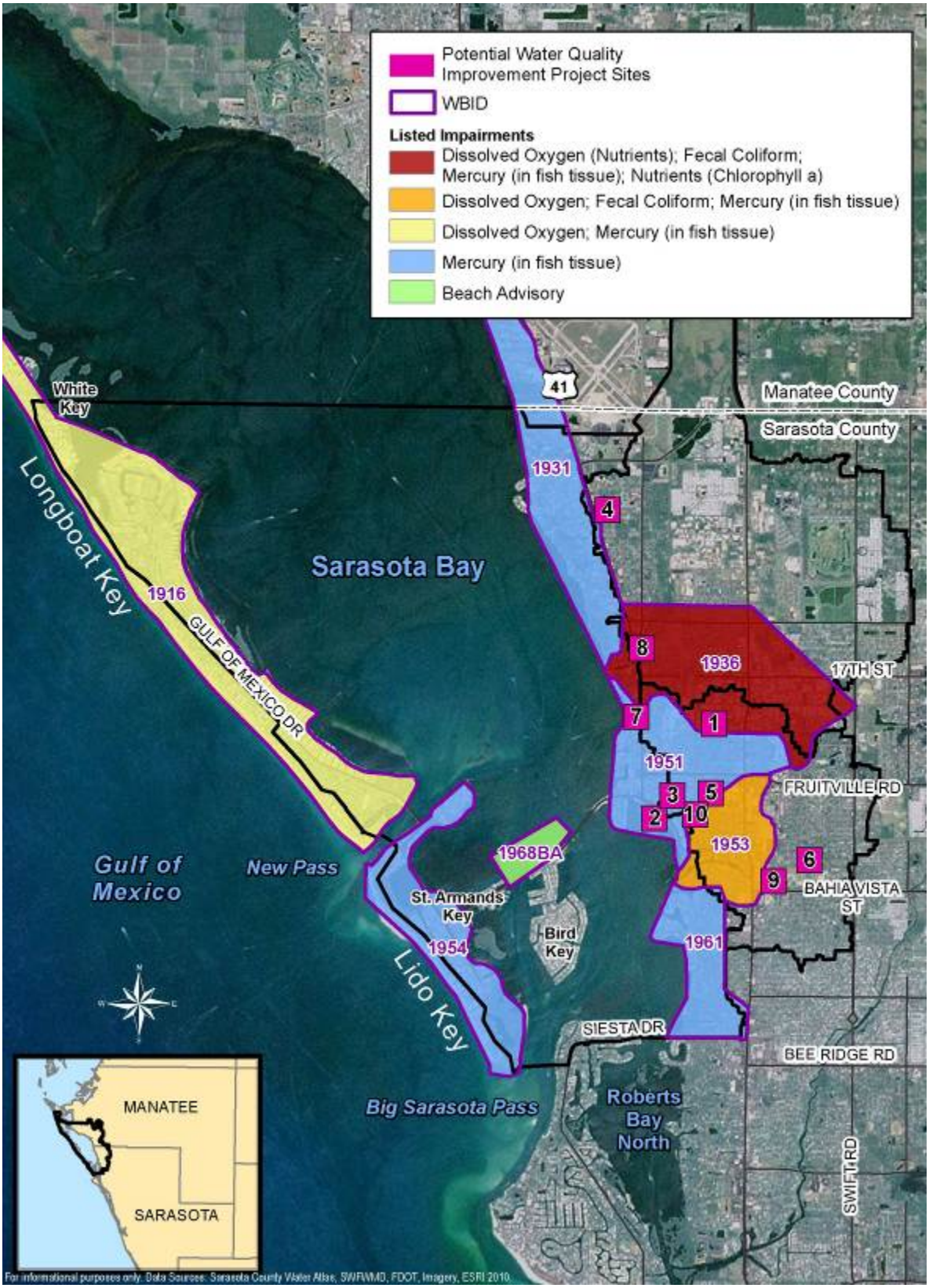


Figure 8-2 Sarasota County Sarasota Bay Watershed Impaired WBIDs

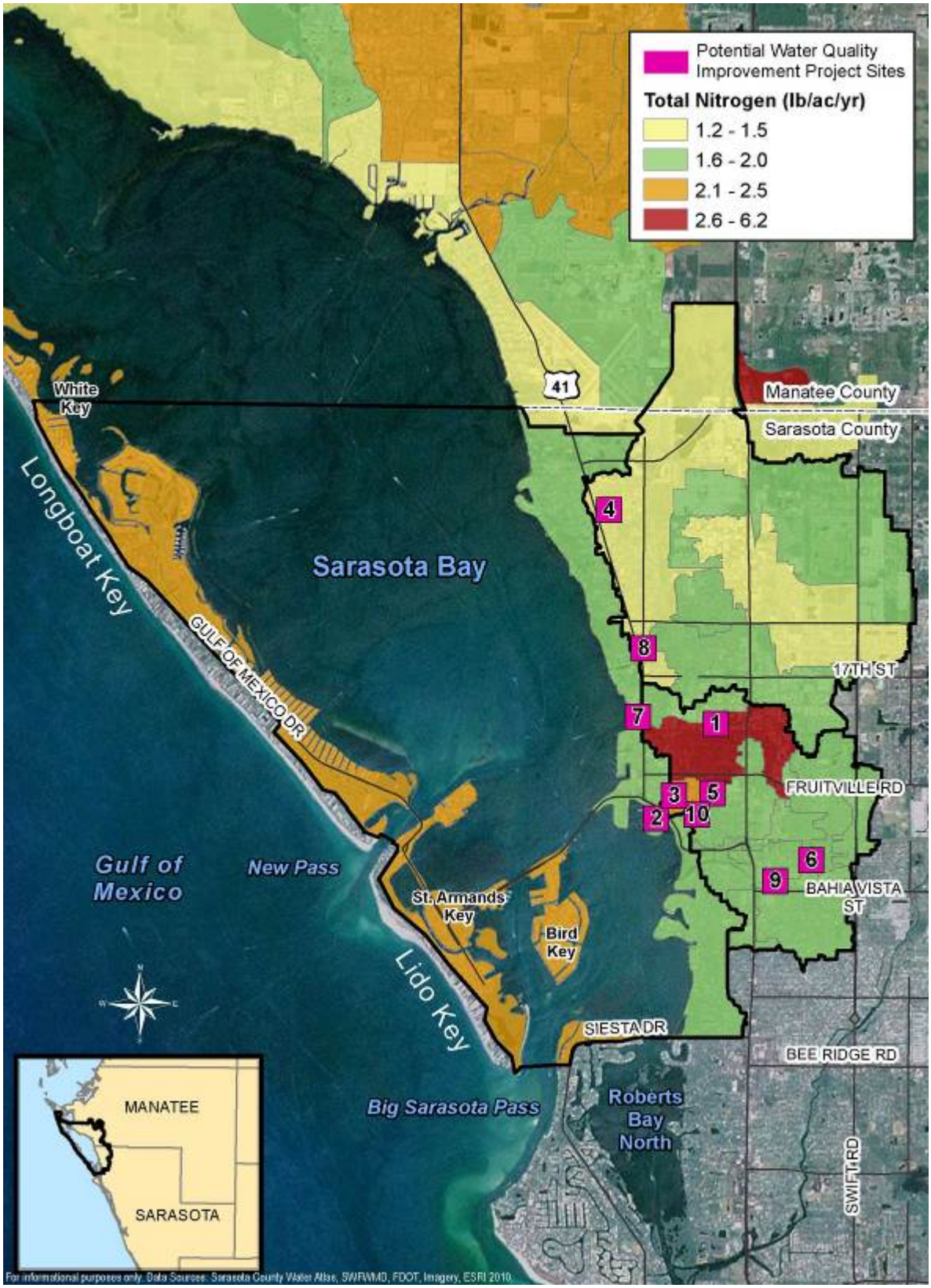


Figure 8-3 Sarasota Bay Watershed SIMPLE Total Nitrogen Loading

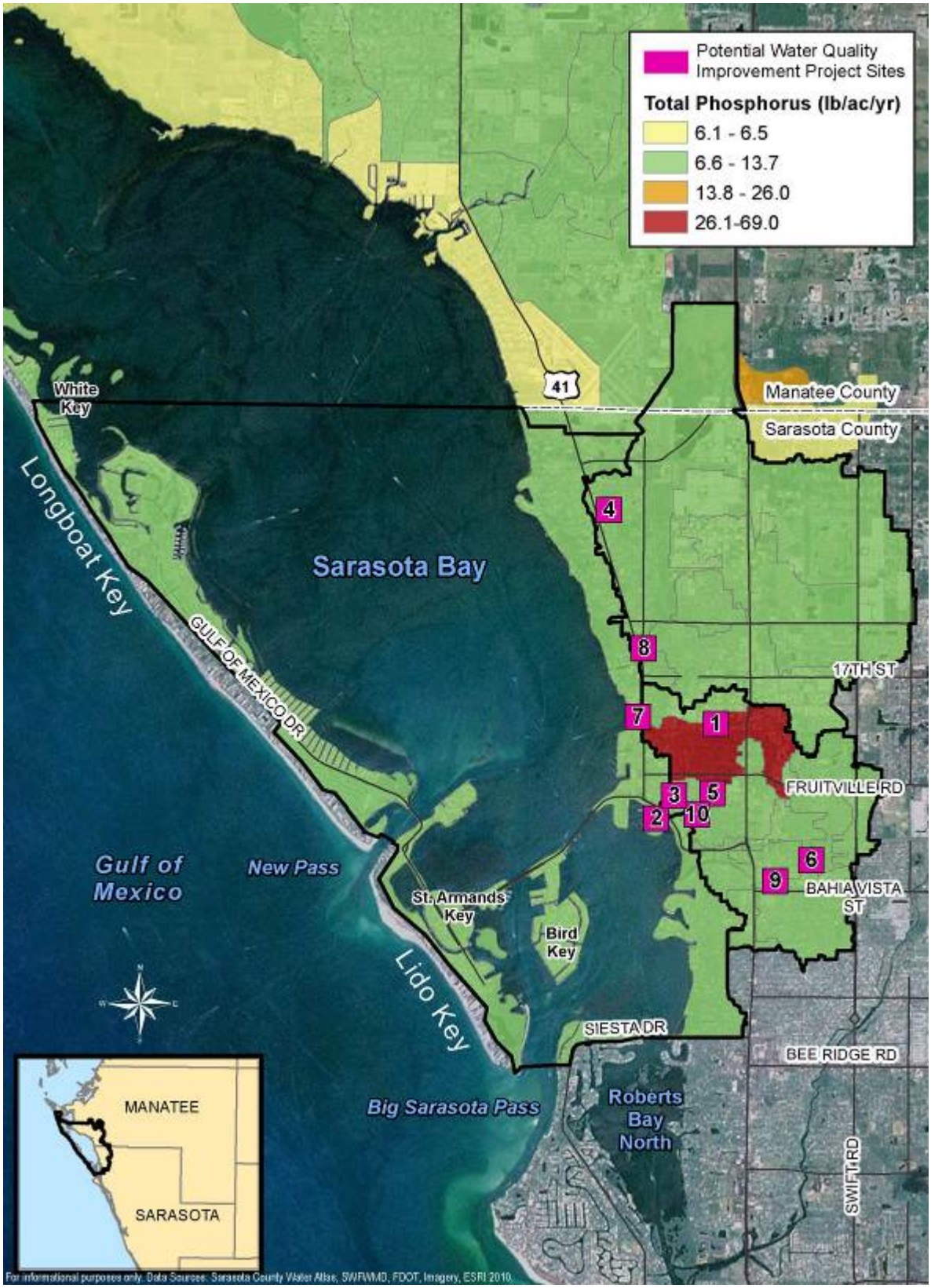


Figure 8-4 Sarasota Bay Watershed SIMPLE Total Phosphorus

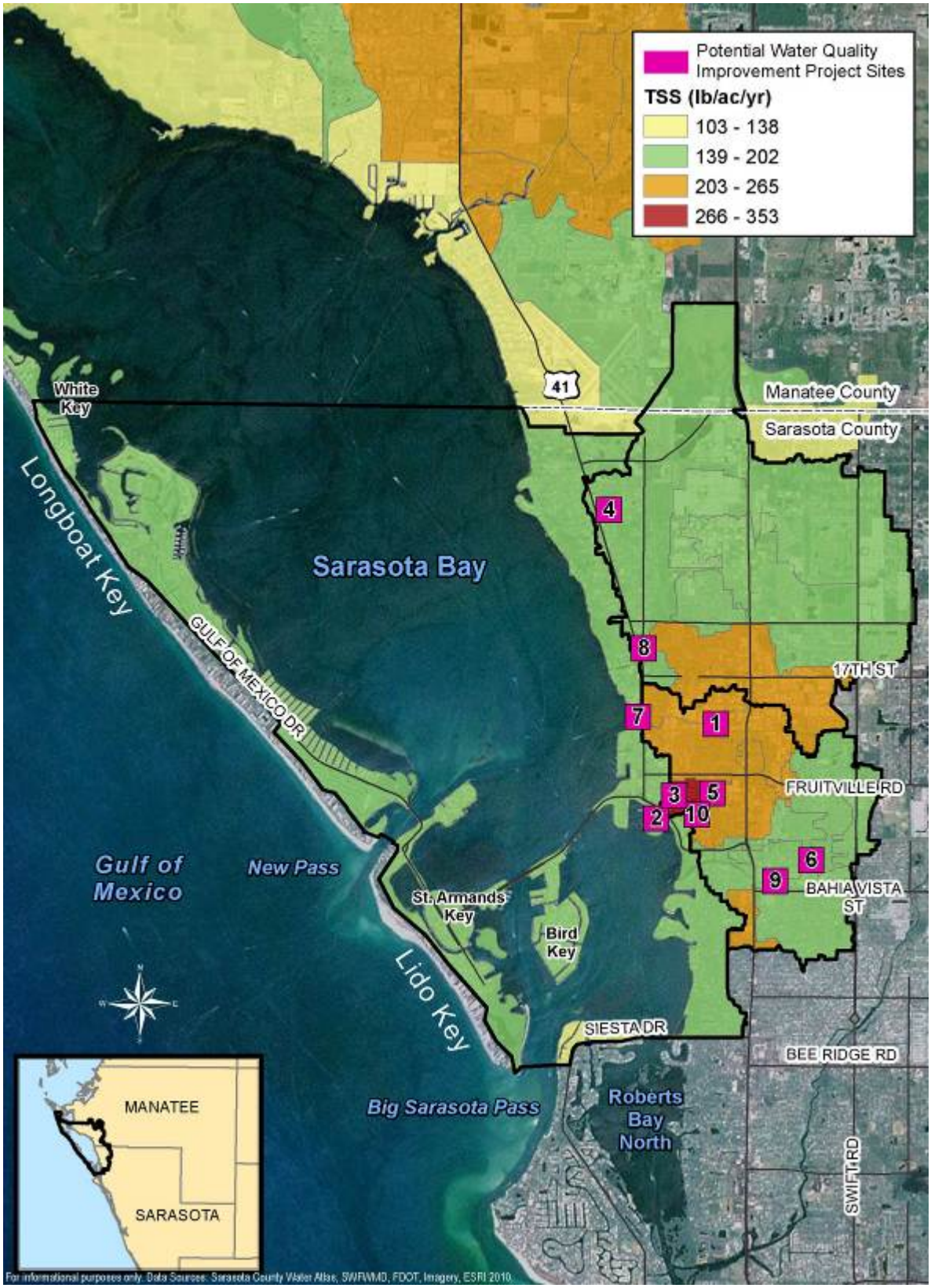


Figure 8-5 Sarasota Bay Watershed SIMPLE Total Suspended Solids (TSS)

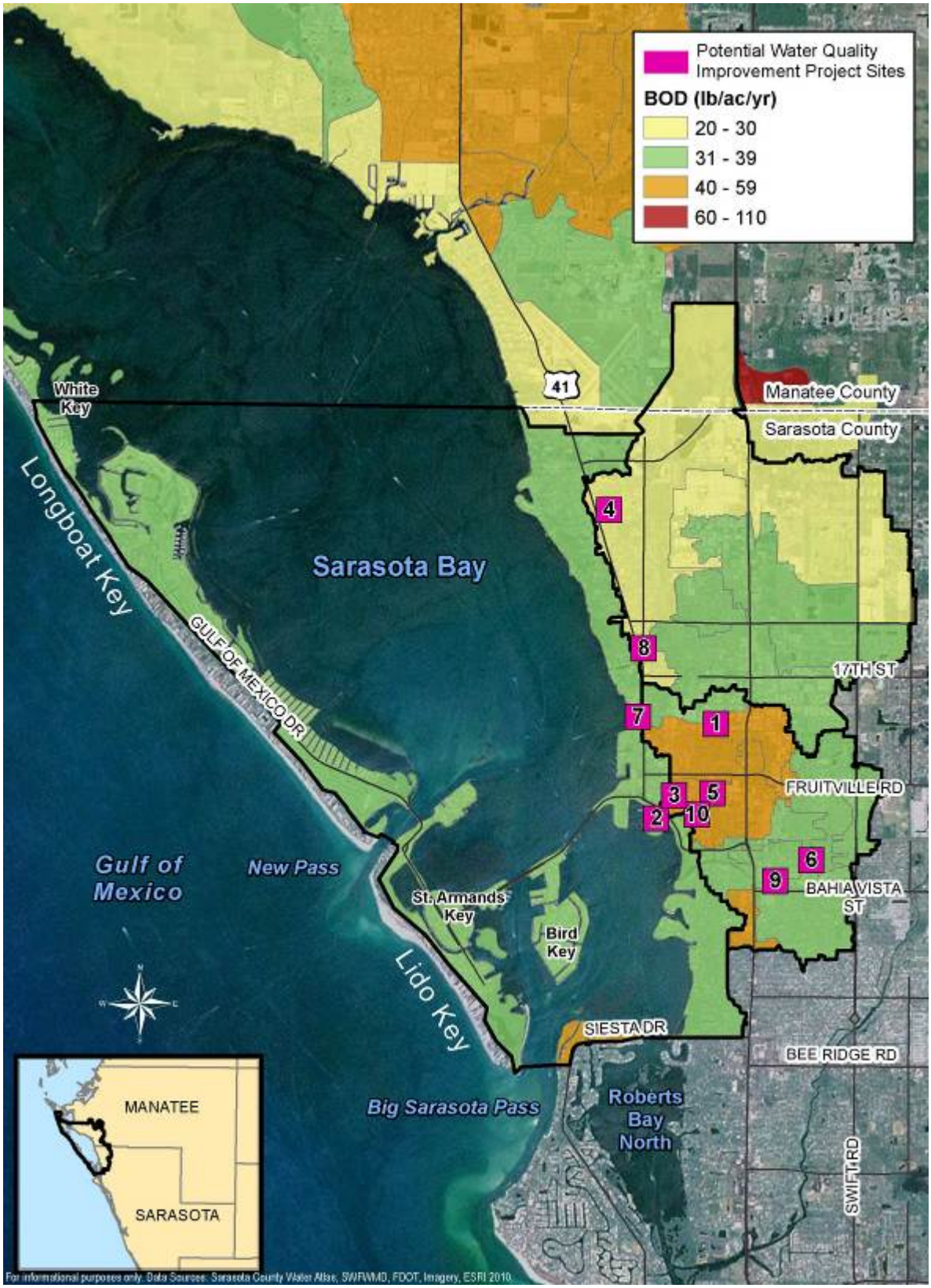


Figure 8-6 Sarasota Bay Watershed SIMPLE Biological Oxygen Demand (BOD)

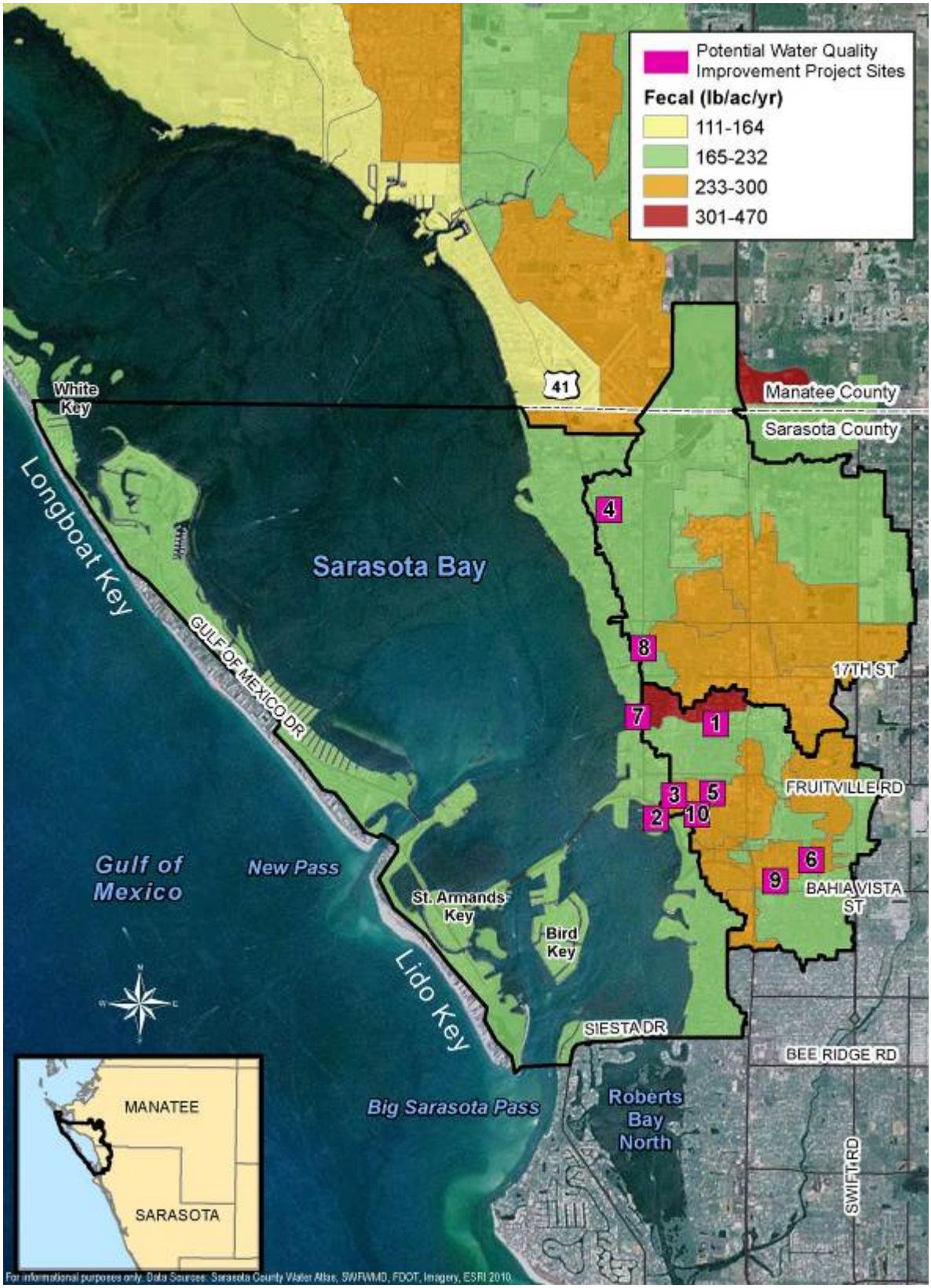


Figure 8-7 Sarasota Bay Watershed SIMPLE Fecal Coliform

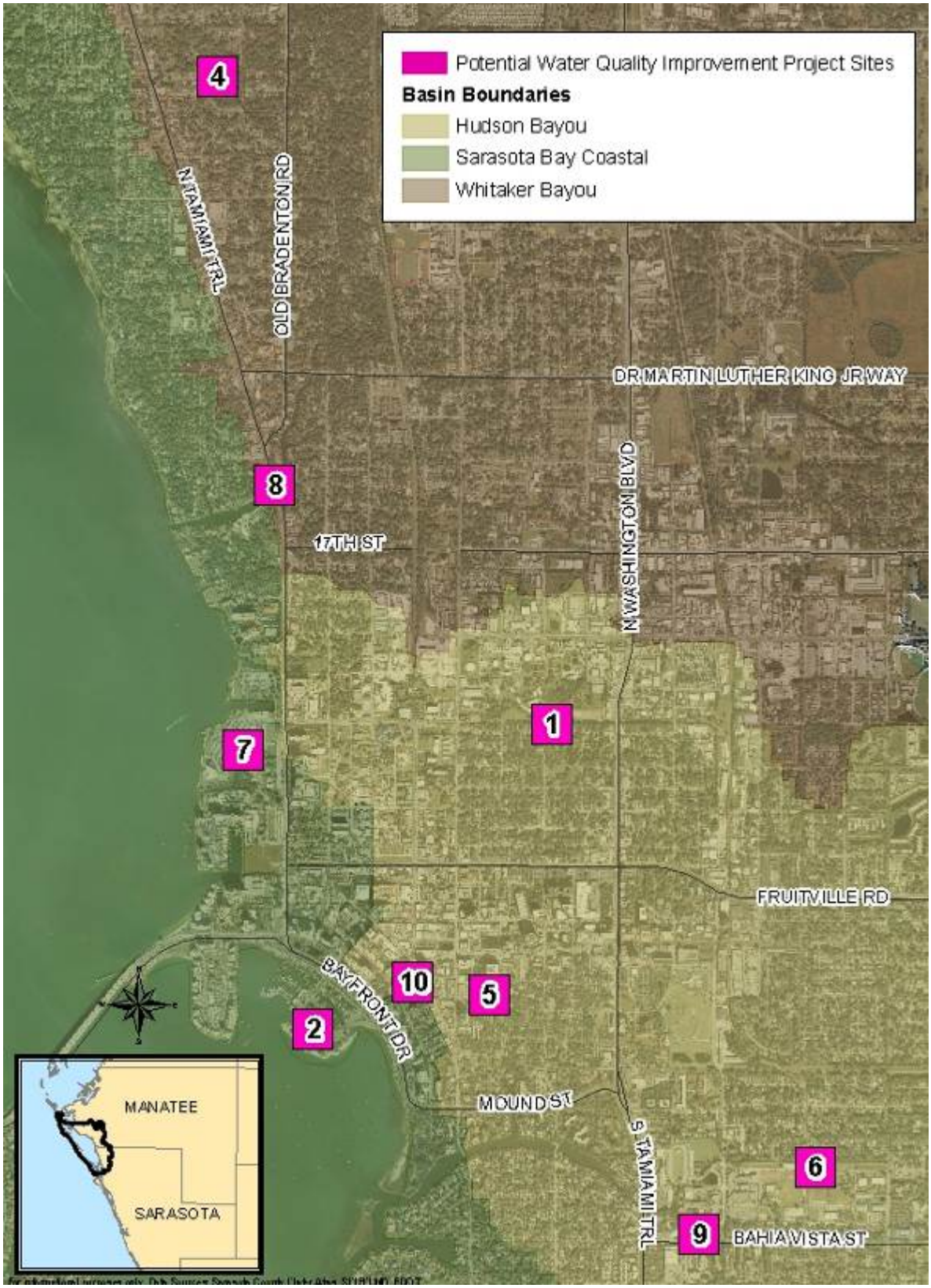


Figure 8-8 Potential Water Quality Improvement Project Site Locations

Table 8-1 List of Potential Water Quality Improvement Project Sites			
ID	Site Name	WBID	SIMPLE Basin ID
1	North Gillespie Park	1936	108
2	Bayfront Parking Lot	1951	101
3	Ringling Boulevard Diversion	1951	107
4	47th St Diversion	1936A, 1836	112
5	Hudson Bayou North Branch	1953	105
6	Hatton Street Ditch	1953A	102
7	10th Street Outfall	1951	101
8	Whitaker Bridge	1936	112
9	Hudson Bayou East Branch	1953A	103
10	Ringling Boulevard Sidewalks	1951	107

8.3.2.3 Field Investigation

Jones Edmunds conducted site visits to the proposed water quality improvement sites in April 2011 to characterize the potential project areas and to identify and determine potential water quality treatment options, including possible programmatic recommendations.

8.4 ANALYSIS\RECOMMENDATIONS

The following sections provide investigation summaries and recommendations for the selected project sites as well as program recommendations to help improve water quality in the watershed.

8.4.1 Projects

This section contains water quality improvement project descriptions.

8.4.1.1 Site 1 – North Gillespie Park

A. GIS Desktop Analysis

The North Gillespie Park site is northwest of Gillespie Park on the north side of 10th Street at Goodrich Avenue (Figure 8-9). Untreated stormwater runoff from a large contributing area flows via pipes into the channel that runs through this site. The channel flows to a large pipe that discharges the untreated runoff into the 10th Street boat basin in Sarasota Bay. The area has high TN, TP, TSS, and BOD load according to SIMPLE (Figure 8-10). In addition, the site is in WBID 1936, Whitaker Bayou Coastal, which is listed for DO, nutrients, and fecal coliform (Figure 8-10). The channel is entirely within the County-owned drainage easement but is bound by a power easement owned by the City of Sarasota on the north side. Parcel 2025-15-0019 is

owned by the City and covers about a quarter of an acre adjacent to the north side of the channel on the west side of Goodrich Avenue.

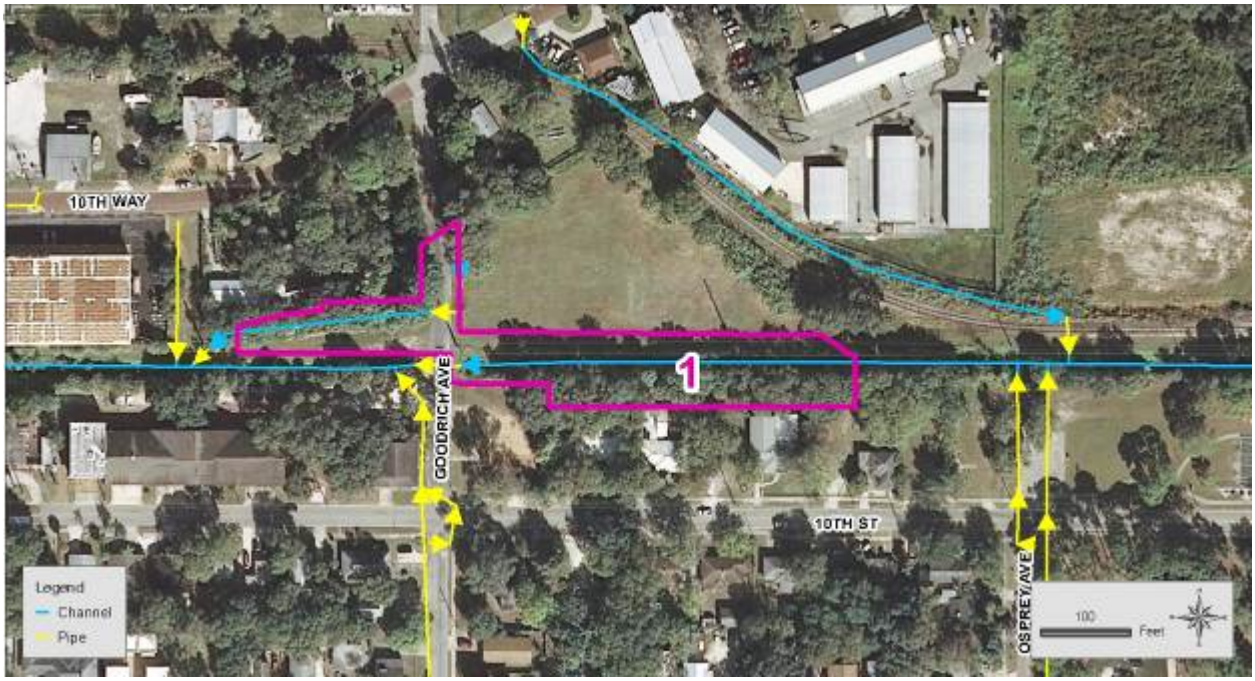


Figure 8-9 Aerial View of Site 1 (SWFWMD, 2010) with Sarasota County Stormwater Inventory

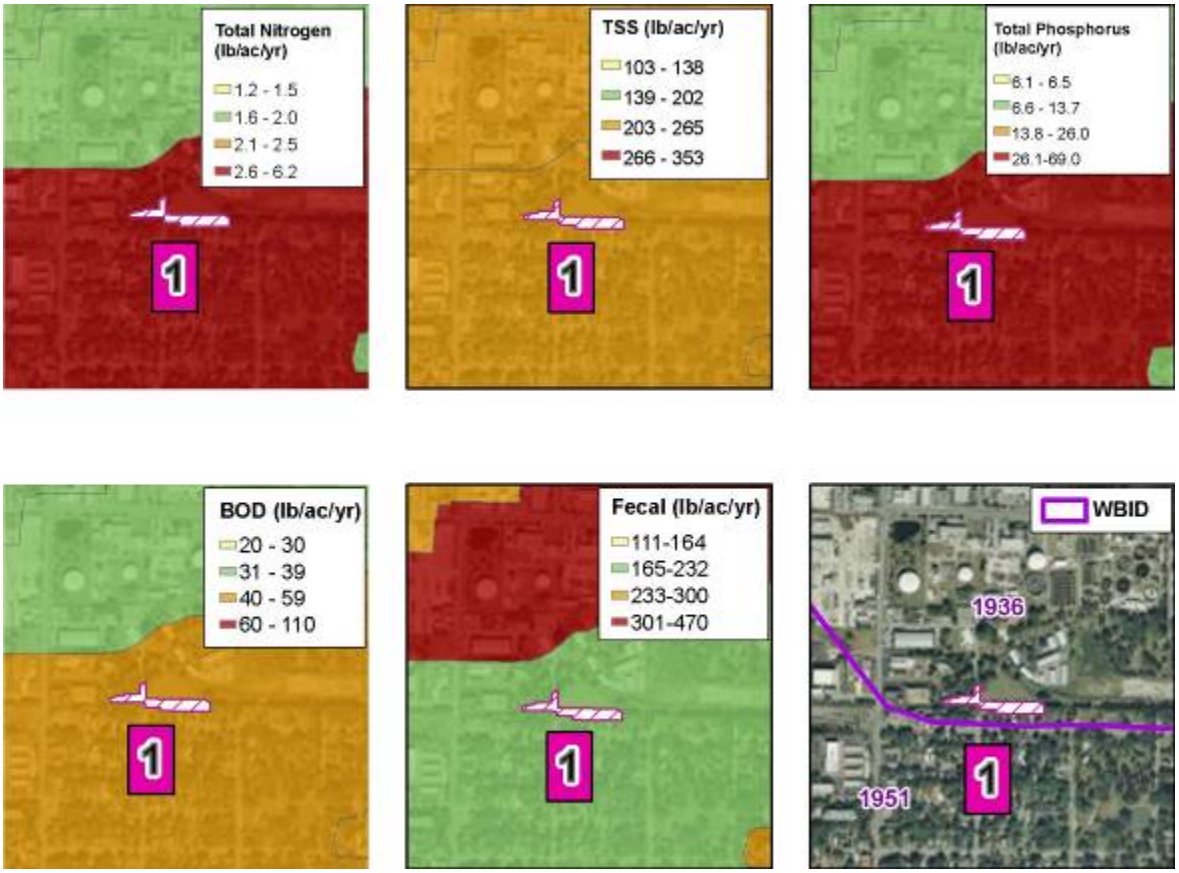


Figure 8-10 Site 1 Pollutant Loads and Listed WBIDs

B. Field Investigation

The channel runs east-west north of 10th Street as noted in the GIS desktop analysis. The banks on the north and south side have loose sands and are eroded (Figure 8-11). Multiple pipes (small PVC to 36-inch CMP) are discharging to the stream without signs of erosion control or water quality treatment. Several property owners have tried to stabilize the top of bank with bricks and sandbags. A small ditch carries flow parallel to the stream from Goodrich Avenue west approximately 200 feet.

A **B**

Figure 8-11 Site 1 Looking Downstream, West (A) and Upstream, East (B)

C. Recommendation

Jones Edmunds recommends bank restoration and education kiosks along this channel segment. We propose amending the soils and planting native vegetation on both banks. The soils should be evaluated to determine if organic or inorganic media would be best suited for the amendment to provide bank stabilization. The native plantings will help reduce bank erosion and will provide a buffer for stormwater runoff, which will help remove pollutants such as nutrients before they enter the waterway. Adding a sediment sump in the flowpath near Goodrich Avenue will provide the maintenance staff with an opportunity to remove sediments and particulates that enter the channel upstream.

We recommend working with the children's interactive garden on 10th Way to develop an education kiosk or signage that would explain the project elements and benefits.

Summary:

- Restore banks (soil amendment and vegetation).
- Add sediment sump.

- Add public education (partner with children's garden and kiosk).

8.4.1.2 Site 2 – Bayfront Parking Lot

A. GIS Desktop Analysis

The Bayfront Parking Lot site, owned by the City, is adjacent to Sarasota Bay along the west side of Bayfront Drive near Ringling Boulevard (Figure 8-12). Untreated stormwater from Bayfront Drive and the parking lot flows through curb inlet and grates that lead to several pipes that discharge into Sarasota Bay. Large pipes also discharge untreated runoff from Main Street, Ringling Boulevard, and an urbanized area on the east side of Palm Avenue to the bay at the parking lot. The drainage area just upstream of this project site contains high TN, TSS, BOD, and fecal coliform loads according to SIMPLE (Figure 8-13). Additionally, stakeholders and County employees have expressed concern about the amount of garbage and debris that comes out of these outfalls.

B. Field Investigation

Due to heavy traffic and a boat event, we were unable to access the Bayfront Parking Lot site.

C. Recommendation

Recommendations for the Bayfront Parking Lot site are based on the GIS desktop analysis and information provided by County staff. Jones Edmunds proposes adding a dedicated motorcycle and smart car parking area with pervious pavement and replacing foot traffic areas with pervious pavement to facilitate stormwater infiltration. Adding curb cuts and LID components to existing parking lot medians will provide water quality treatment before the flow enters the bay.

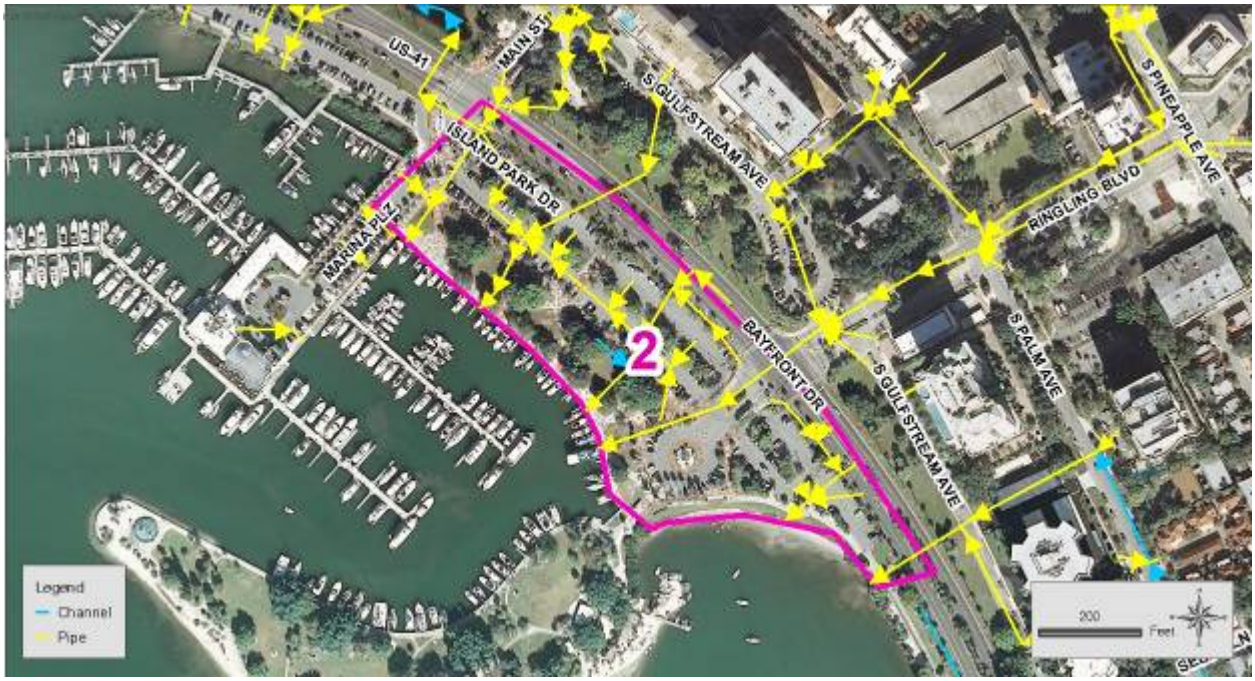


Figure 8-12 Aerial View of Site 2 (SWFWMD, 2010) with Sarasota County Stormwater Inventory

Figure 8-13 Site 2 Pollutant Loads and Listed WBIDs

Jones Edmunds also recommends incorporating baffle boxes in the easement between the parking lot and Bayfront Boulevard to intercept litter from the downtown area before it reaches the outfall. A Subsurface Utility Exploration (SUE) should be done to find the exact locations of underground infrastructure.

Summary:

- Install pervious pavement to parking lot.
- Install curb cuts and LID to medians.
- Install baffle boxes.

8.4.1.3 Site 3 – Ringling Boulevard Diversion

A. GIS Desktop Analysis

Site 3 is at the corner of Ringling Boulevard and South Palm Avenue (Figure 8-14). A large pipe along Ringling Boulevard carries untreated stormwater from a heavily developed drainage basin to Sarasota Bay. The area has high TN, TP, TSS, BOD, and fecal coliform loads according to SIMPLE and would benefit from diverting low flows through a treatment train before discharging to the bay (Figure 8-15). Ownership of this parcel could not be verified with available data.

Figure 8-14 Aerial View of Site 3 (SWFWMD, 2010) with Sarasota County Stormwater Inventory

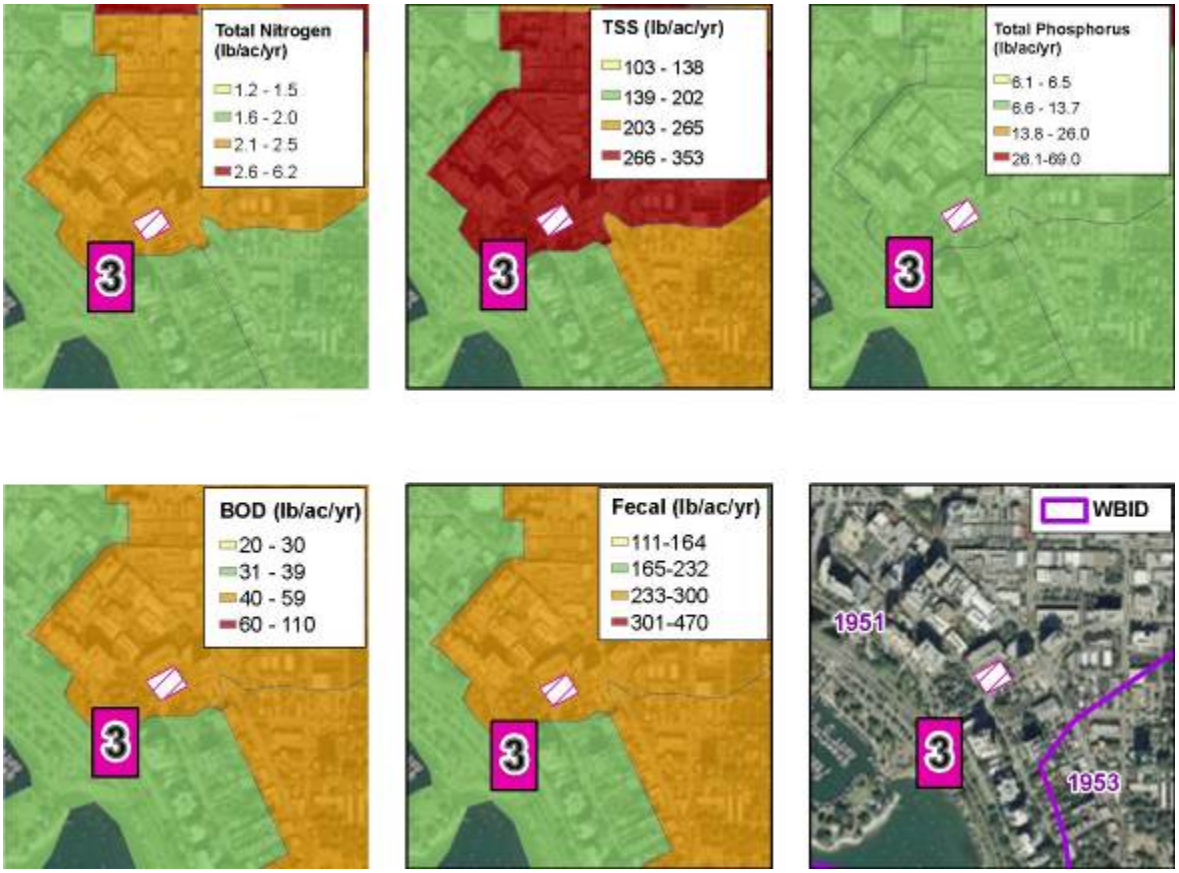


Figure 8-15 Site 3 Pollutant Loads and Listed WBIDs

B. Field Investigation

This parcel is at 1401 Ringling Boulevard, and a sign indicated that it is now owned by IStar Financial—a commercial real estate developer.

C. Recommendation

The stormwater system would benefit from a low-flow diversion through a treatment train; however, because this property is under private ownership and no other publicly owned parcels were identified adjacent to this system, no project is recommended. Jones Edmunds recommends that the County work with residents and stakeholders in the area using some of the programs listed in Section 8.4.2. For instance, rain barrels and cisterns would work well in this area to capture stormwater for beneficial use in landscaping irrigation, which would reduce direct runoff to the bay and provide much-needed treatment.

Summary:

- Work with private stakeholders to implement LID elements such as rain barrels and cisterns.

8.4.1.4 Site 4 – 47th Street Diversion

A. GIS Desktop Analysis

Site 4 is west of Water Tower Park (Figure 8-16). Untreated stormwater from a large contributing area currently drains from the Tamiami Trail (US 41) stormwater pipe network into a ditch adjacent to 42nd Street that leads to a channel that discharges to Whitaker Bayou. Stakeholders have expressed concern about the quality of stormwater that flows through the 42nd Street ditch and eventually into the bayou. Figure 8-17 shows the nutrient levels from the SIMPLE model.

Figure 8-16 Aerial View of Site 4 (SWFWMD, 2010) with Sarasota County Stormwater Inventory

Figure 8-17 Site 4 Pollutant Loads and Listed WBIDs

A wetland enhancement/treatment train in North Water Tower Park is part of the conceptual plan developed for the Natural Systems component of this Water Quality Management Plan (WQMP). The stormwater inventory shows a north-to-south 42-inch stormwater pipe that crosses Tamiami Trail south of 47th Street and north of 46th Street (Figure 8-18). The parcels between 46th Street and 47th Street and the east portion of 46th Street are privately owned. The County owns 47th Street and Royal Palm Avenue.

Figure 8-18 Site 4 Storm Sewer System

B. Field Investigation

A storm sewer system carries untreated runoff along US 41 at this location. A connection to the system is midway between 46th Street and 47th Street on the east side of US 41. The sidewalk along the east side of US 41 between these two streets is cracked and in disrepair. No public stormwater conveyance infrastructure is currently on or adjacent to 47th Street or 46th Street (Figure 8-19). The east portion of 46th Street is privately owned. There is also a lift station where 46th Street meets the west side of Water Tower Park (Figure 8-20).

A

B

Figure 8-19 47th Street (Source: Google Maps) (A) and 46th Street (B)

Figure 8-20 46th Street, Facing East Toward Proposed Wetland in Water Tower Park

A 47th Street homeowner indicated that in the 1960s there was a ditch behind her property. She pointed out that the ditch had been "over my child's head" but has filled in over the years. Neighbors have since dug the trench shown in Figure 8-21 to alleviate flooding. The homeowner also said that water backs up in this trench at the park entrance during heavy rain. There is no easement parallel to the backyards of the homes along the south side of 47th Street.

There is an open area at the Water Tower Park Royal Palm Avenue entrance. To the east is a parking lot with more open area on the south side of the lot. There is a golf disc course and pathways to the south under the tree cover.

Figure 8-21 Ditch Adjacent to Private Properties on the South Side of 47th Street

C. Recommendation

To provide treatment, Jones Edmunds recommends diverting flow from the US 41 storm sewer system to a treatment train project in the north grassed areas of the park. Replacing the sidewalks along 47th Street and between 46th and 47th Street with pervious concrete or pervious pavers is also recommended.

Summary:

- Replace sidewalks with pervious concrete.
- Construct treatment train in the park.
- Divert flow from the US 41 storm sewer to treatment train.
- This project has been incorporated into the Natural Systems section to expand the Natural Systems improvement project in the park to include this diversion and treatment project.

8.4.1.5 Site 5 – Hudson Bayou North Branch

A. GIS Desktop Analysis

Site 5 includes the County Administration Parking Lots, which are on the south side of Ringling Boulevard east of Rawls Avenue (Figure 8-22). Morrill Street is between the lots. A small City park is on the north side of the lots parallel to Ringling Boulevard. The site is in WBID 1953, Hudson Bayou Tidal, which is listed for DO and fecal coliform. The area has high TN, TSS, BOD, and fecal coliform SIMPLE pollutant-load results (Figure 8-23). Untreated runoff from Morrill Street and the north parking lot flows into the Ringling Boulevard drainage system via a 48-inch pipe under the City park. This runoff discharges directly into Sarasota Bay without treatment. Runoff from the south parking lot discharges untreated runoff into a 48-inch pipe that flows into the north branch of Hudson Bayou.

Figure 8-22 Aerial View of Site 5 (SWFWMD, 2010) with Sarasota County Stormwater Inventory

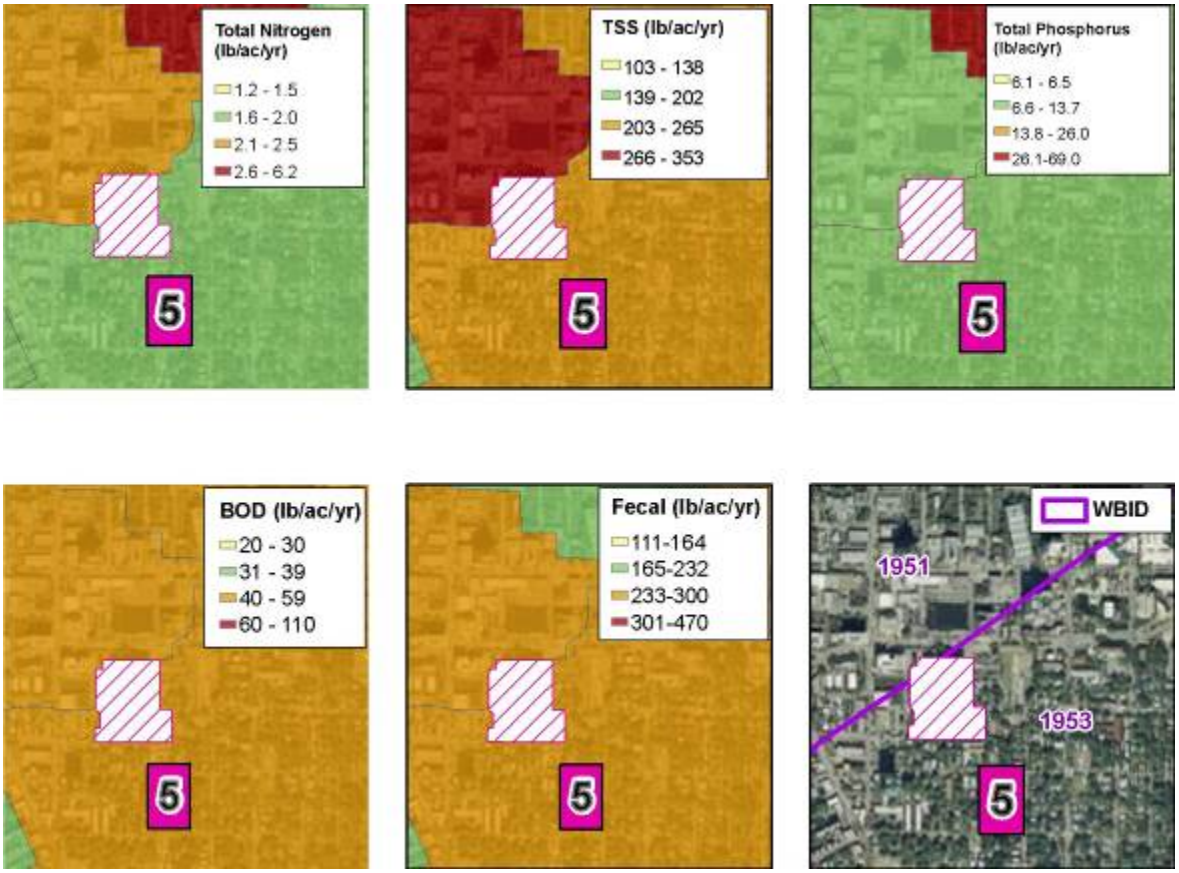


Figure 8-23 Site 5 Pollutant Loads and Listed WBIDs

B. Field Investigation

Runoff from the south lot flows through a rock-lined retention swale that runs the length of the lot on the south side of Morrill Street (Figure 8-24) and into a large outfall at the northwest corner (Figure 8-25). The outfall connects to the 48-inch pipe that discharges to Hudson Bayou. The retention area was full of leaves. There is a proposed 319 grant project to install a baffle box on the south side of the south parking lot.

Figure 8-24 Site 5 Retention Area at North Side of South Lot

Figure 8-25 Site 5 Outfall at North Side of South Lot

In addition to runoff from the parking lot, a steady flow of water from the cooling system in the County building was also being discharged to the Ringling Boulevard system.

C. Recommendation

This area is highly urbanized and consists primarily of directly connected impervious areas (DCIA). Jones Edmunds recommends adding LID components and curb cuts to the parking lot medians to treat the stormwater before it reaches the outfall structures. Retrofitting the retention areas in the south lot to be more LID-friendly will provide additional treatment without losing the flood-protection capacity. One option is to raise the bleed-down elevation in the control structure. Adding an architectural cistern or multiple rain barrels to the building in the north lot to capture roof runoff and air-conditioning condensation to be used for irrigation in the park is also recommended.

Summary:

- Install LID components and curb cuts to the parking lot medians.
- Install LID components to the retention areas in the south lot and raise the bleed-down elevation in the control structure.
- Install rain barrels or cistern on the building in the north lot.

8.4.1.6 Site 6 – Hatton Street Ditch

A. GIS Desktop Analysis

The Hatton Street Ditch site is adjacent to Hatton Street, north of Sarasota High School, and bisected by S. Shade Avenue (Figure 8-26). This site is on County property. SIMPLE pollutant-load results indicate high fecal coliform (Figure 8-27). Untreated runoff from much of the Hudson Bayou basin flows through this ditch, eventually discharging into Hudson Bayou.

Figure 8-26 Aerial View of Site 6 (SWFWMD, 2010) with Sarasota County Stormwater Inventory

Figure 8-27 Site 6 Pollutant Loads and Listed WBIDs

B. Field Investigation

The Hatton Street Ditch has very steep banks and erosion (Figure 8-28). There are multiple discharges without erosion control. On the south side of the Hatton Street Ditch are two stormwater ponds for the high school.

Figure 8-28 Hatton Street Ditch, Facing East

C. Recommendation

Due to the major erosion and sedimentation issues at this site, this project site is better suited for a sediment management project. Recommendations for this site will be provided in Appendix F – Sediment Management Plan.

8.4.1.7 Site 7 – 10th Street Outfall

A. GIS Desktop Analysis

Site 7 is adjacent to Sarasota Bay and Tamiami Trail at the west end of 10th Street (Figure 8-29). There are two areas of interest at this site—the Van Wezel Parking Lot and the 10th Street Outfall area. The area draining to this site has high TN, TP, TSS, BOD, and fecal coliform SIMPLE pollutant loads (Figure 8-30). Untreated stormwater from the parking lot flows through curb inlets and grates that lead to several pipes that discharge into Sarasota Bay. The 10th Street Outfall discharges untreated runoff from a large contributing area into the boat basin at the north

end of the parking lot. Stakeholders and County employees have expressed concern about the amount of garbage and debris that comes out of the large pipe from 10th Street.

Figure 8-29 Aerial View of Site 7 (SWFWMD, 2010)

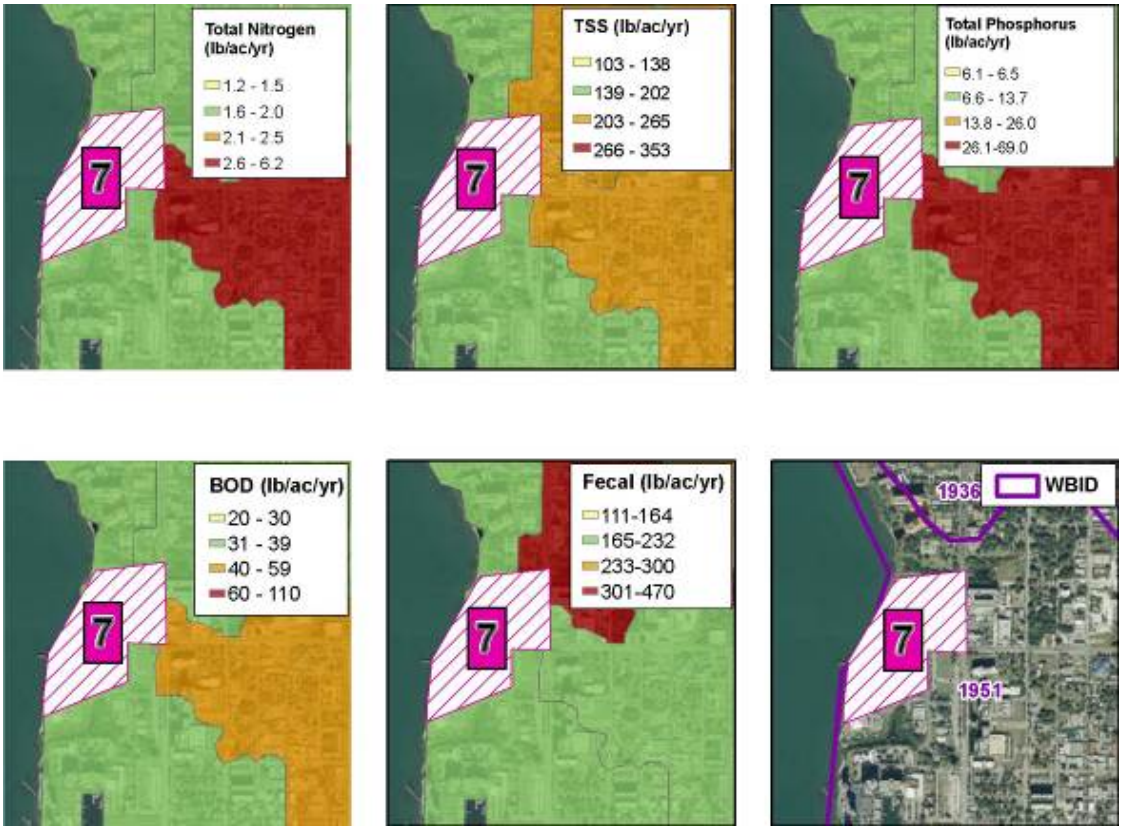


Figure 8-30 Site 7 Pollutant Loads and Listed WBIDs

B. Field Investigation

A U.S. Coast Guard station is at the northwest corner of the parking lot, and the Van Wezel Performing Arts Hall is at the southwest corner of the parking lot. There is a significant amount of median space in the Van Wezel Parking Lot as well as some small treatment areas close to the bay that could be improved for increased stormwater treatment (Figure 8-31).

Figure 8-31 Van Wezel Parking Lot

A large culvert in the southeast corner of the boat basin discharges untreated runoff from 10th Street and possibly Tamiami Trail (Figure 8-32). County staff noted that the boat basin typically acts as a settling basin for sediments and has many floatables after storm events. The northeast corner of the boat basin is sedimented and covered with terrestrial vegetation (Figure 8-33). A County employee suggested building a weir/baffle system across the boat basin to effectively catch the sediment and allow easy maintenance.

The sidewalks on either side of 10th Street east of Tamiami Trail are cracked and broken. There is no existing stormwater treatment.

Figure 8-32 10th Street Outfall

Figure 8-33 10th Street Boat Basin, Northeast Corner

C. Recommendation

This area is highly urbanized with little open space to allow for stormwater infiltration. Jones Edmunds recommends adding curb cuts and LID practices to all parking lot medians along the west boundary to allow runoff into the existing retention areas. Replacing select parking spots and approximately 5,000 linear feet of sidewalk along 10th Street with pervious pavement and adding rain barrels to all on-site buildings will reduce runoff. Regrading and adding vegetative buffers to existing retention areas between the parking lot and bay and constructing a sedimentation box (e.g., baffle box) upstream of the 10th Street Outfall will help improve water quality by removing pollutants such as sediment and nutrients before they enter the bay. Jones Edmunds advises installing backflow prevention at the outfall to prevent the sediment sump from filling with bay water. Stormwater harvesting from the vault for irrigation in the area is also recommended. In addition, because there is a gas station at the intersection of Tamiami Trail and 10th Street, the potential for groundwater contamination from underground storage tanks must also be considered at this site.

Summary:

- Install curb cuts and LID practices to all parking lot medians and along the west boundary.
- Install pervious pavement in the parking lot.
- Construct vegetative buffers in the retention areas.
- Install rain barrels at all onsite buildings.
- Construct a stormwater sedimentation box upstream of the 10th Street Outfall.
- Provide stormwater harvesting for irrigation
- Replace pervious sidewalk.

8.4.1.8 Site 8 – Whitaker Bridge

A. GIS Desktop Analysis

The Whitaker Bridge site is on the north bank of Whitaker Bayou adjacent to Tamiami Trail (Figure 8-34). County staff has indicated that making bridges less accessible to foot traffic would reduce the amount of pollutants, such as human waste, entering the bayou. This site is in WBID 1936, Whitaker Bayou Coastal, which is listed for DO, nutrients, and fecal coliform (Figure 8-35).

Figure 8-34 Aerial View of Site 8 (SWFWMD, 2010)

Figure 8-35 Site 8 Pollutant Loads and Listed WBIDs

B. Field Investigation

This site was not accessible.

C. Recommendation

There are no recommendations for this site due to inaccessibility.

8.4.1.9 Site 9 – Hudson Bayou East Branch

A. GIS Desktop Analysis

Site 9 is on the north side of Bahia Vista Street, west of School Street at Sarasota High School (Figure 8-36). Untreated runoff from a significant contributing area flows north through a ditch and into Hudson Bayou. The west portion of this site is in WBID 1953, Hudson Bayou Tidal, which is listed for DO and fecal coliform (Figure 8-37).

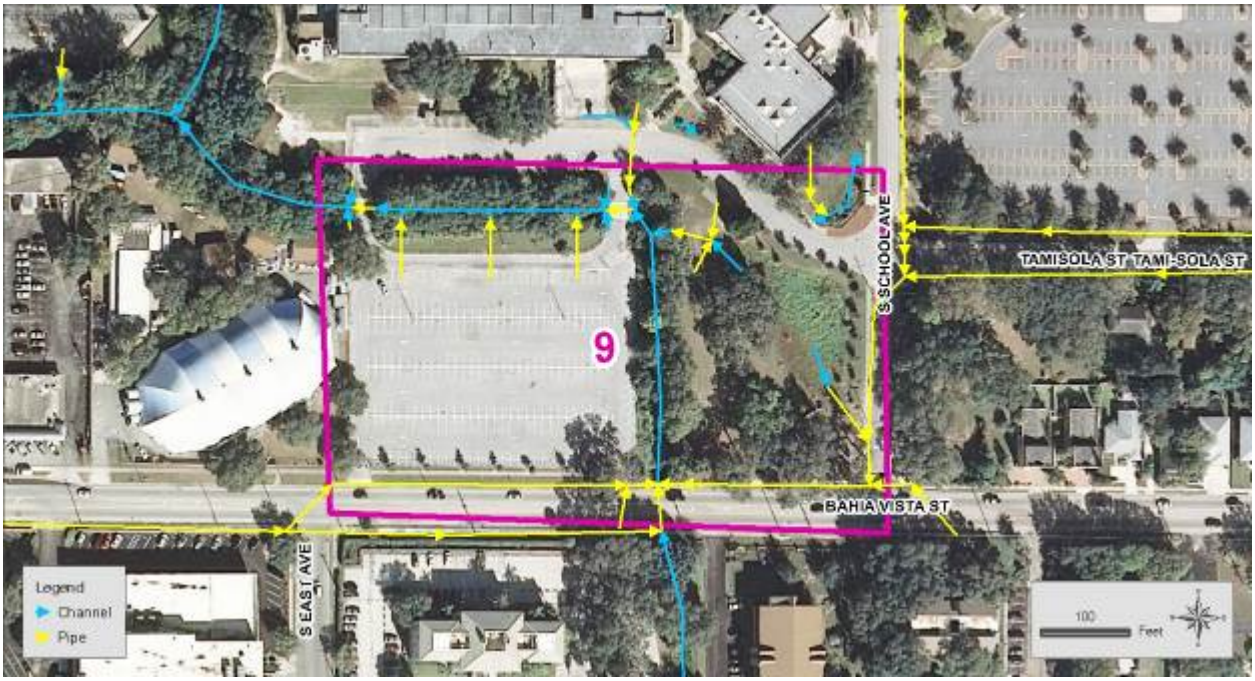


Figure 8-36 Aerial View of Site 9 (SWFWMD, 2010) with Sarasota County Stormwater Inventory

Figure 8-37 Site 9 Pollutant Loads and Listed WBIDs

B. Field Investigation

The south-to-north ditch from Bahia Vista Street is full of muck and trash (Figure 8-38). A 10-inch pipe discharges from a retention area to the north end of the ditch. The bank around the pipe is eroded, and the ditch is sedimented and heavily vegetated at this point. Approximately a meter north of this, the ditch bends 90 degrees to the west to a skimmer and 82-inch square culvert. The skimmer is full of debris, and both sides of the culvert contain muck and garbage (Figure 8-39).

Figure 8-38 Ditch to East Branch of Hudson Bayou, Facing South

Figure 8-39 Skimmer and Culvert to East Branch of Hudson Bayou, Facing Southwest

C. Recommendation

To minimize the floatables, sediment, and other pollutants flowing directly into the east branch of the Hudson Bayou, the following actions are recommended:

- Clean out the existing skimmer.
- Dredge ditch from the bend to the skimmer and the area on the opposite end of the square culvert (approximately 30 linear feet on either side of the culvert).
- Stabilize the ditch banks.
- Widen the ditch and add a baffle box for sediment and floatable collection on the north side of Bahia Vista Street.

8.4.1.10 Site 10 – Ringling Boulevard Sidewalks

A. GIS Desktop Analysis

Site 10 includes the length of Ringling Boulevard through downtown Sarasota (Figure 8-40). This area has high TN, TSS, BOD, and fecal coliform SIMPLE pollutant-load results (Figure 8-41). Untreated stormwater from Ringling Boulevard and surrounding developed areas enters the stormwater conveyance along Ringling Boulevard via curb inlets. A large pipe drains directly to Sarasota Bay.

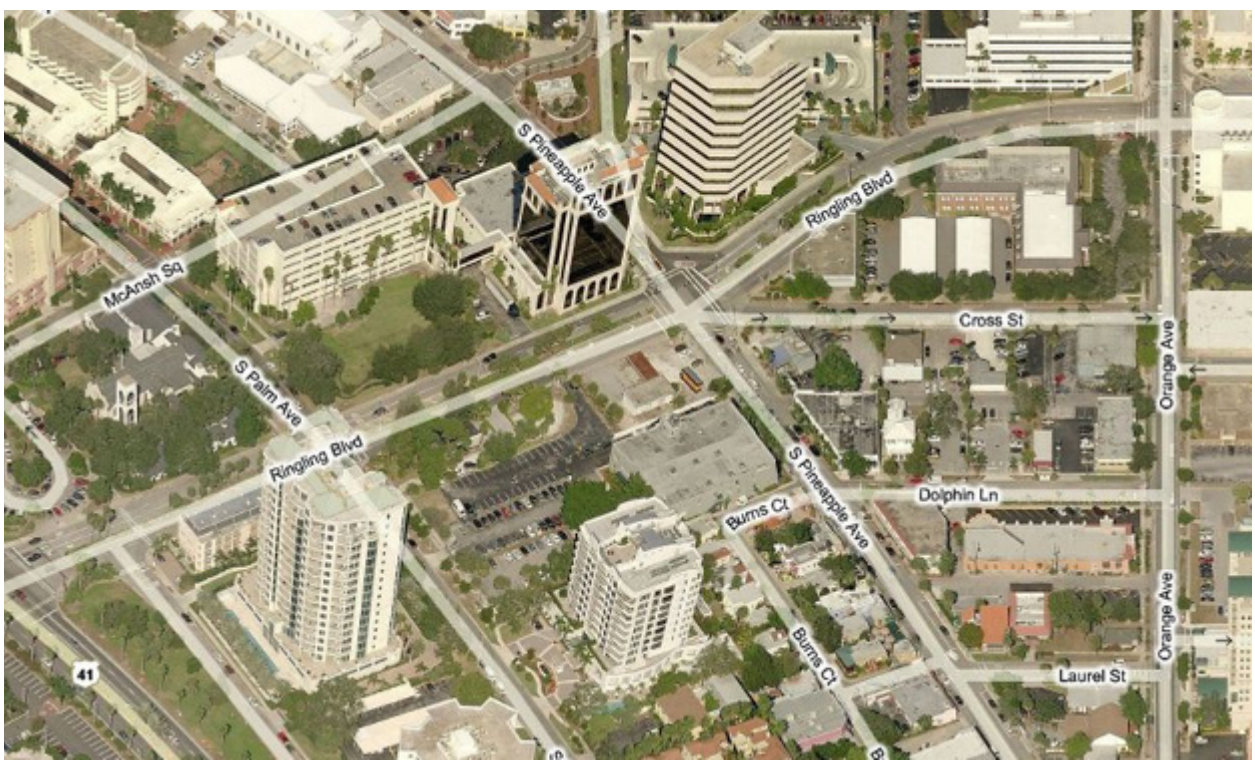


Figure 8-40 Bird's Eye View of Site 10 (Source: Bing Maps)

Figure 8-41 Site 10 Pollutant Loads and Listed WBIDs

B. Field Investigation

The area is highly urbanized and consists mostly of DCIA. There is very little space for infiltration to occur.

C. Recommendation

To increase infiltration of runoff in this highly urbanized area, Jones Edmunds recommends a phased replacement of traditional sidewalks with pervious concrete or pervious pavers along Ringling Boulevard from US 41 east to S. Orange Avenue.

Summary:

- ❖ Replace concrete sidewalks with pervious concrete or pavers.

8.4.2 <u>Programs</u>

This section describes programs and programmatic recommendations to promote environmental stewardship and improve water quality.

8.4.2.1 Sarasota County Fertilizer and Landscape Management Code

A. Description

The Sarasota County Commission approved an ordinance regulating the use of fertilizers containing nitrogen and/or phosphorus in Sarasota County in 2007. Ordinance No. 2007-062, the Sarasota County Fertilizer and Landscape Management Code, regulates the proper use of fertilizer and requires the use of BMPs to minimize negative secondary and cumulative environmental effects associated with the misuse of fertilizers. The ordinance establishes a restricted season, fertilizer content and application rates, fertilizer-free zones, low maintenance zones, exemptions, and training and licensing requirements for commercial and institutional fertilizer applicators.

Negative effects from fertilizer have been observed in and on Sarasota County's natural and artificial stormwater and drainage conveyances, lakes, canals, estuaries, interior freshwater wetlands, the Myakka River, and nearshore waters of the Gulf of Mexico. The health of these waterbodies is critical to the environmental, recreational, cultural, and economic wellbeing of stakeholders and the health of the public. Water quality problems, including harmful algal blooms, hypoxic zones, and declines in wildlife and habitat, can arise when excess nutrients get into waterbodies. Overgrowth of algae and vegetation can hinder the effectiveness of flood attenuation provided by natural and artificial stormwater and drainage conveyances. Regulation of nutrients, including phosphorus and nitrogen in fertilizer, therefore, is critical to improve and maintain water and habitat quality (Sarasota County Ordinance No. 2007-062).

B. Recommendation

Jones Edmunds recommends that Sarasota County continue to enforce Ordinance No. 2007-062, the Sarasota County Fertilizer and Landscape Management Code. In addition, the County should retain the support and funding required to continue the educational component of this ordinance.

8.4.2.2 Neighborhood Environmental Stewardship Team, NEST

A. Description

Sarasota County has developed a program for Neighborhood Environmental Stewardship Teams (NEST). NEST is a voluntary association of County residents (neighbors, civic groups, student organizations and others) who want to better understand and improve the environmental conditions in the watershed. The public purpose is two-fold: to provide constructive and meaningful activities to help residents improve the environmental quality of the watershed and their neighborhoods and to develop educational activities and materials regarding and advocacy for watershed improvement policies and management strategies. NEST's activities address issues such as water quality, natural system preservation, neighborhood drainage, landscaping, and

other water-related issues. NEST activities may include water quality or biological monitoring, volunteer restoration, research, and planning input. NEST provides individual and community awareness of appropriate fertilizer usage, buffer zones, LID practices, and conservation. Additionally, public outreach includes developing web/email campaigns and educational materials.

B. Recommendation

To maximize this program's potential, Jones Edmunds recommends that NEST:

- Solicit private landowners and condominium complexes in the downtown area to implement LID practices, such as rain barrels, cisterns, and pervious pavement, with the help and guidance of NEST.
- Solicit private landowners in residential areas, especially properties along tributaries, to implement LID practices, such as rain barrels, pervious pavement, and gutter bubblers (Figure 8-42 and Figure 8-43), with the help and guidance of NEST.
- Work with businesses along the US 41 corridor in Whitaker, especially to prevent litter and implement LID retrofits on their properties.

Figure 8-42 Rain Barrel System

Figure 8-43 Rain Gutter Bubbler System

8.4.2.3 National Pollutant Discharge Elimination System (NPDES)

A. Description

Sarasota County is a Municipal Separate Storm Sewer System (MS4) operator and holds a National Pollutant Discharge Elimination System (NPDES) permit (Number FLS000004) from FDEP. To maintain the permit, the County has developed a stormwater management program that includes BMPs with measurable goals to effectively implement eight minimum control measures outlined in the 2006 Comprehensive Plan.

B. Recommendation

Jones Edmunds recommends that Sarasota County continue to incorporate stormwater BMPs with other neighborhood redevelopment projects to meet the overall goals of the NPDES permit, which is to reduce or prevent pollutant loads from reaching waterbodies.

8.4.2.4 Septic to Cistern

A. Description

In June 2009 the County Health Department implemented a procedure for converting abandoned septic tanks into cisterns based on 64E-6.011, FAC. This conversion allows a single-family residence to convert an abandoned septic tank to a cistern by permit within 90 days of connecting the building plumbing to sanitary sewer.

B. Recommendation

Jones Edmunds recommends active public outreach and education to help homeowners permit and repurpose septic tanks to cisterns. Sarasota County should add a webpage about this program to the existing County website. The site should contain details about the program, the permitting and repurposing procedure, and all applicable documents. The County should send informative literature, including a reference to the webpage, to residences that have switched from septic tanks to the municipal system.

8.4.2.5 Strategic Maintenance Plan

A. Description

The *Strategic Maintenance Plan*, adopted in 1999, establishes level-of-service (LOS) goals for maintenance activities in the County. The plan identifies maintenance practices and classifies practices into *Routine*, *Extraordinary*, and *Support* activities in which the staff engages for maintenance repairs, improvement, management, and operation of the public stormwater system.

Stormwater maintenance has traditionally played an active role in maintaining the flood capacity of the stormwater system throughout the County. A more robust maintenance program incorporating the recommendations described below will play a larger role in improving the quality of the runoff reaching the estuaries and bays of Sarasota County.

B. Recommendation

Jones Edmunds recommends the following approach to expand and enhance the focus of the stormwater maintenance process to include water quality in addition to flood protection:

- Implement the 1999 Strategic Maintenance Plan.
- Achieve the inspection and maintenance frequency required in the MS4 Permit.
- Update the Strategic Maintenance Plan.
- Adopt practices listed below when fiscally feasible.

Updating the *Strategic Maintenance Plan* and adopting several non-structural BMPs and source control practices may provide the best opportunities to increase awareness and implement maintenance improvements aimed at improving water quality. The following modifications, additions, or removal of maintenance practices will help the County meet its water quality goals:

- Inspection and Permit Compliance:
  - NPDES Inspection.
  - Asset Management.
- FEMA Community Rating System.
- Facility Maintenance and BMPs:
  - Facilities: Scheduling.
  - Facilities: Denuding Conveyance Features.
  - Non-Structural BMPs: Buffer Zones.
  - Non-Structural and Structural BMPs: LID.
  - Source Control: Street Sweeping.
  - Source Control: Herbicides.
  - Source Control: Fertilizer Management.
  - Source Control: Harvesters.

Jones Edmunds analyzed current maintenance policies and procedures as part of the Roberts Bay North and Lemon Bay Watershed Management Plans (WMPs). The recommendations listed above are detailed in the Roberts Bay North and Lemon Bay WMPs.

8.4.2.6 Low-Impact Development (LID)

A. Description

LID is a stormwater management approach that uses a suite of hydrologic controls (structural and non-structural) distributed throughout the site and integrated as a treatment train (i.e., in series) to replicate the natural hydrologic functioning of the predevelopment landscape. Unlike conventional systems, which typically control and treat runoff using a single engineered stormwater pond located at the “bottom of the hill,” LID systems are designed to promote volume attenuation and treatment at or near the source of stormwater runoff via distributed retention, detention, infiltration, treatment, and reuse mechanisms. The fundamental goal of applying LID concepts, design, and practice is to improve the overall effectiveness and efficiency of stormwater management relative to conventional systems, reducing total and peak runoff volumes and improving the quality of waters discharged from the site.

A site-specific suite of LID integrated management practices can be applied to most if not all development scenarios in Sarasota County. Regardless of the project context, LID requires the following core site planning and design objectives to be considered:

1. Preserve or conserve existing site features and assets that facilitate predevelopment hydrologic function.
2. Minimize the generation of runoff from impervious surfaces (i.e., use peak and total volume controls) and contamination (i.e., use load controls) as close to the source as possible.
3. Promote distributed retention, detention, treatment, and infiltration of runoff.
4. Capture and reuse stormwater on site.
5. Minimize site disturbance and compaction of soils through low-impact clearing, grading, and construction measures.

The toolbox of LID-integrated management practices to facilitate these objectives is extensive, including structural and non-structural designs, and LID projects are most effective when applied in a treatment train or series of complementary stormwater management tools and techniques. In addition, a LID stormwater management approach is most effective when sites are evaluated for LID compatibility as early as possible in the planning process and site features are considered carefully in the design and construction of each LID practice. A County manual to help incorporate LID projects into new development and infrastructure retrofit projects was developed in 2010.

B. Recommendation

To achieve optimal performance of LID systems, project planners and engineers must adopt a comprehensive and iterative approach to site evaluation, planning and design, and monitoring and feedback. Fundamental LID principles such as those listed below should be considered in the development planning and design process:

1. Preserve or conserve site features and assets that facilitate natural hydrologic function.
2. Minimize generation of runoff from impervious surfaces (i.e., use peak and total volume controls).
3. Minimize runoff contamination (i.e., use load controls) as close to the source as possible.
4. Promote distributed retention, detention, treatment, and infiltration of runoff.
5. Capture and harvest stormwater on site.
6. Minimize site disturbance and compaction of soils through low-impact clearing, grading, and construction measures.

Consistently implementing LID concepts, design, and practice will improve the overall effectiveness and efficiency of stormwater management relative to conventional systems, reducing runoff and improving water quality. Jones Edmunds also recommends fully implementing the LID manual.

8.4.2.7 Keep Sarasota County Beautiful

A. Description

Keep Sarasota County Beautiful is a County-wide program with a mission to enhance and promote public interest and participation in the general improvement of the environment throughout Sarasota County. This is done through education, cleanup programs, recycling, and other methods of reducing solid waste. Keep Sarasota County Beautiful is an affiliate of Keep America Beautiful, Inc., a national, non-profit, public education organization dedicated to improving waste handling practices in American communities.

B. Recommendation

Litter is one of the most visible stormwater pollution issues in the watershed. Jones Edmunds recommends that the County increase the number of community cleanup projects in the watershed through the Keep Sarasota County Beautiful program. The County should work with homeowner associations and neighborhoods to recruit volunteers and organize educational and cleanup events. The County should also work with marinas to organize boating cleanups.

In addition, Jones Edmunds recommends that the County review dumpster and trashcan locations and handling and inspection procedures. The County should make sure that there are adequate trash receptacles in public areas, especially in marinas, along the waterfront and near major storm drains and that they are being properly emptied and maintained.

8.4.2.8 Wet Detention Pond Study

A. Description

Urban waterways receive pollutant loads from stormwater generated by impervious surfaces. Constructed wet detention ponds are effective for localized stormwater treatment; however, there is question about the accuracy of discharge volume and removal efficiencies generated by and/or used in model simulations.

Wet detention ponds are intended to maintain several feet of water in a permanent pool; however, this level can be affected by local conditions, such as drought. Wet detention ponds are designed to hold runoff for treatment for varying periods depending on the pond detention volume, the storm runoff rate and duration, and the antecedent water level.

In line with current literature, Sarasota County models wet detention ponds as impervious areas, regardless of antecedent conditions. This may be appropriate during wet season. During dry season, however, a wet detention pond may have enough storage to accommodate all of the runoff and therefore would not discharge during a storm event. Modeling such a pond as

impervious would result in an overestimate of volume and an underestimate of removal efficiency. Therefore, there is debate as to the accuracy of current modeling techniques.

B. Recommendation

Jones Edmunds recommends implementing a pilot study to monitor discharge from wet detention ponds. These data can be used to develop appropriate values to be used in Sarasota County model simulations.

9.0 CONCLUSION

Seven of the potential project sites were deemed viable locations for projects designed to improve water quality (Table 9-1). Implementation of these projects and programmatic recommendations will significantly reduce pollutant loading and improve water quality in the Sarasota Bay Watershed. Two of the project sites were better suited for a different area of responsibility and will be evaluated further under separate tasks.

Jones Edmunds will calculate pollutant-load reduction, develop conceptual plans and cost estimates, and provide project and program rankings for the selected project sites in Appendix G – Project and Program Recommendations.

Table 9-1 List of Recommended Water Quality Improvement Project Sites

ID	Site Name	WBID	SIMPLE Basin ID	Recommended
1	North Gillespie Park	1936	108	✓
2	Bayfront Parking Lot	1951	101	✓
3	Ringling Boulevard Diversion	1951	107	
4	47th St Diversion	1936A, 1836	112	✓
5	Hudson Bayou North Branch	1953	105	✓
6	Hatton Street ditch	1953A	102	
7	10th Street Outfall	1951	101	✓
8	Whitaker Bridge	1936	112	
9	Hudson Bayou East Branch	1953A	103	✓
10	Ringling Boulevard Sidewalks	1951	107	✓

10.0 APPENDIX—EXISTING DATA, STUDIES, AND INFORMATION

- Conceptual Design Report for Whitaker Bayou 32nd Street Greenway Park and Watershed Restoration (2010).
- Bradenton Road LID Project (2010).
- State of the Bay 2010 (2010).
- Numeric Nutrient Criteria for Sarasota Bay (2010).
- City of Sarasota Compliance Monitoring—2010 (2010).
- Five-year Habitat Restoration Plan 2010–2014 (2010).
- Sarasota City Plan 2030 (2008).
- Sarasota Bay Estuary Program Outfall Prioritization Project (2008).
- Final Report, Task 7: A Tidal Creek Condition Index & Task 8: Evaluation of the Tidal Creek Condition Index (2007).
- Tidal Creek Condition Index for Coastal Streams in Sarasota County, Florida (2007).
- Recommendations for the Development of a Water Quality Response Model and an Approach to Assessing Water Quality in the Estuarine Waters of Sarasota County (2007).
- Establishing Water Clarity Benchmarks for Sarasota County Estuarine Waters (2007).
- Sarasota Bay TMDL Support (2007).
- National Estuary Program Coastal Condition Report (2007).
- Effects of Karenia Brevis Blooms on Wild Coastal Bottlenose Dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida (2007).
- Sarasota County Comprehensive Plan (2006).
- Establishment of Estuarine Water Clarity Targets for Sarasota County Estuarine Waters (2006).
- Sarasota County Comprehensive Oyster Monitoring Program Annual Report 2006 (2006).
- Sarasota Bay Estuary Program Oyster Habitat Monitoring Results: Year 1 (2006).
- Modeling Channel Erosion at the Watershed Scale: Model Review and Case Study (2006).
- State of the Bay 2006 (2006).
- Reconnaissance of Listed Waterbodies on Roberts Bay, Little Sarasota Bay, Blackburn Bay, Donna Roberts Bay, and Lemon Bay and Recommendations for Future sampling (2006).
- Reconnaissance of listed water bodies on Roberts Bay, Little Sarasota Bay, Blackburn Bay, Donna Roberts Bay, and Lemon Bay and recommendations for future sampling (2006).
- Establishment of Estuarine Water Clarity Targets for Sarasota County (2006).
- Water Quality Assessment Report (2006).

- Sarasota Bay Reasonable Assurance Plan (2005).
- Whitaker Bayou Reconnaissance Report (2005).
- Water Quality Status Report (2003).
- Five-year Habitat Restoration Plan 2004–2009 (2003).
- Town of Longboat Key 2007 Comprehensive Plan (2003).
- County-wide Survey of Sediment Quality at Weir Structures (2003).
- Analysis of Changes in Seagrass Coverage, 1996–1999 and 1999–2001, for Anna Maria Sound, Sarasota, Roberts, Little Sarasota, Blackburn Bays. Final report (2003).
- Sarasota Bay SWIM Plan (2002).
- Hudson Bayou Stormwater Study (2001).
- Hudson Bayou Press Release (2001).
- Assessment and Impact of Microbial Fecal Pollution and Human Enteric Pathogens in a Coastal Community (2001).
- A Chronicle of Florida Gulf Coast (n.d.)
- A Historical Geography of Southwest Florida Waterways (n.d.)
- Stormwater Environmental Utility Strategic Plan (2000).
- Southern Coastal Watershed Comprehensive Watershed Management Plan (2000).
- The Occurrence, Distribution and Transport of Human Pathogens in Coastal Waters of Southwest Florida (2000).
- Surface Water, Sediment, and Biological Sampling for "Big Slough, Hudson Bayou, and Phillippi Creek Basins, Sarasota County, Florida (1999).
- Trend Analysis of Water Quality Data for the Sarasota Bay National Estuary Program (1999).
- Contaminant Survey of Sarasota Bay Priority Watershed—Cedar Hammock Creek, Bowlees Creek, Whitaker Bayou, Hudson Bayou, and Phillippi Creek (1999).
- Biological Effects of Atmospheric Deposition on Algal Assemblages. Draft Final Report (1999).
- Technical Synthesis of Sarasota Bay (1997).
- Sarasota County NPDES Sampling (1997).
- Hydrogeology of the Surficial and Intermediate Aquifer Systems in Sarasota and Adjacent Counties, Florida (1996).
- Potential for Water-Quality Degradation of Interconnected Aquifers in West-Central Florida (1996).
- The Effects of Anthropogenic Nutrient Enrichment on Turtle Grass (*Thalassia testudinum*) in Sarasota Bay, Florida (1996).
- Sarasota Bay: The Voyage to Paradise Reclaimed (1995).
- Integration of Flood Control, Wetland Habitat, Reuse, Recreational Features and Stormwater Treatment (1995).
- Light Attenuation with Respect to Seagrasses in Sarasota Bay, Florida (1995).

- Modeling the Impact of Nutrient Load Reduction on Water Quality and Seagrass in Roberts Bay and Little Sarasota Bay (1995).
- Baseline survey of pesticide and PAH Concentrations from Sarasota Bay, Florida, USA (1995).
- Characterization of Ecological Conditions and Impacts of Stormwater Runoff on Hudson Bayou and Phillippi Creek, with Recommendations for Analytical Methods and Management Objectives (1994).
- Hudson Bayou Basin Master Plan (1994).
- Phillippi Creek Basin Master Plan—Hudson Bayou Basin Master Plan (1994).
- Water and Sediment Quality: Trends and Status for Sarasota Bay (1993).
- Framework for Action Chapter 2: Physical and Chemical Properties—Bay Water and Sediment Quality (1993).
- Physical and Chemical Properties of Bay Water and Sediment Quality (1993).
- Bay Bottom Assessment; Final Report (1993).
- Point/Non-Point Source Pollution Loading Assessment (1992).
- Sediment Contaminants in Selected Sarasota Bay Tributaries (1992).
- Sarasota Bay National Estuary Program Pollutant Loading Assessment Phase I (1992).
- Sarasota Bay National Estuary Program Pollutant Loading Assessment Phase II (1992).
- Bivalved Shellfish of Sarasota Bay: A Framework for Action (1992).
- A Segmentation System for the Sarasota Bay Project National Estuary Program (1990).
- Potentially pathogenic marine Vibrio species in seawater and marine animals in the Sarasota, Florida, area (1990).
- A Bibliography on Sarasota Bay, Florida (1988).
- Sarasota Bay, Florida Identification of Resource Management Problems and Issues and National Estuary Program Analysis (1988).
- City Wide Master Drainage Plan City of Sarasota (1987).
- Tampa and Sarasota Bays: Issues, Resources, Status, and Management: Proceedings of a Seminar held Dec 10, 1987, Washington, D.C. (1987).
- Hydrogeology and the Surficial and Intermediate Aquifers of Central Sarasota County, Florida (1986).
- Proposed Designation of Sarasota Bay and Lemon Bay as Outstanding Florida Waters (1986).
- Coprostanol distribution from sewage discharge into Sarasota Bay, Florida (1984).
- Hydrogeology of the Sarasota-Port Charlotte Area, Florida (1983).
- Sarasota Bay Water Quality Study (1983).
- Water Resources and Data-Network Assessment of the Manasota Basin, Manatee and Sarasota Counties (1982).
- Environmental status of Sarasota Bay: Selected studies (1980).
- Hydrologic and Biological Monitoring of Lower Sarasota Bay 1975–1978 (1979).

- Checklist of Benthic Invertebrate Communities in Sarasota Bay with Special Reference to Water Quality Indicator Species (1974).
- The Florida Gulf Coast Red Tide (1955).
- A Field and Modeling Study of Circulation and Transport in Sarasota Bay.
- www.flrules.org
- www.sarasota.wateratlas.usf.edu
- www.ourgulfenvironment.net

11.0 REFERENCES

Benson, B.B., and D.D. Krause, Jr. 1984. *The concentration and isotopic fractionation of oxygen dissolved in freshwater and seawater in equilibrium with the atmosphere.* Limnol. Oceanogr. 29: 620–632.

Culter, J.K. and J.R. Leverone. 1993. *Bay bottom habitat assessment (Draft Final Report).* Prepared for Sarasota Bay Estuary Program. Mote Marine Laboratory Technical Report No. 303. Sarasota, FL.

Estevez, E.D. and C. Palmer. 1990. A segmentation system for Sarasota Bay National Estuary Program. Mote Marine Laboratory Technical Report No. 161. Prepared for Sarasota Bay National Estuary Program. Sarasota, FL.

Florida Department of Environmental Protection. 2011a. Chapter 62-302. F.A.C., Draft. Surface Water Quality Standards. Tallahassee, FL.

Florida Department of Environmental Protection. 2011b. Numeric Nutrient Criteria Briefing for the Environmental Regulatory Commission. November 3, 2011. Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2011c. Verified List of Impaired Water Bodies "sbpm-verified-c2". Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2012a. *Technical support document: derivation of dissolved oxygen criteria to protect aquatic life in Florida's fresh and marine waters (Draft). May 2012*. Prepared by Bureau of Environmental Assessment and Restoration Support. Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2012b. Stream Condition Index for Sarasota Bay Waterbodies. Prepared by Bureau of Environmental Assessment and Restoration Support. Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2012c. Florida's Adopted Numeric Nutrient Criteria and Proposed Revisions to the Dissolved Oxygen Criteria. Prepared by Bureau of Environmental Assessment and Restoration Support. Tallahassee, FL.

Holland, A.F., D.M. Sanger, C.P. Gawle, S.B. Lerberg, M.S. Santiago, G.H.M. Riekerk, L.E. Zimmerman, and G.I. Scott. 2004. *Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds.* Journal of Experimental Marine Biology and Ecology. 298:151–178.

Janicki Environmental, Inc. 2010a. *Numeric Nutrient Criteria for Sarasota Bay.* Prepared for Sarasota Bay Estuary Program. Sarasota, FL.

Janicki Environmental, Inc. 2010b. Empirical Approaches to Establishing Numeric Nutrient Criteria for Southwest Florida Estuaries. Prepared for Tampa Bay Estuary Program, Sarasota Bay Estuary Program, and Charlotte Harbor National Estuary Program. St. Petersburg, FL.

Janicki Environmental, Inc. 2011a. *Sarasota Bay Numeric Nutrient Criteria: Task 1 – TN and TP Concentration and Loading Based Criteria*, Prepared for Sarasota Bay Estuary Program. Sarasota, FL.

Janicki Environmental, Inc. 2011b. *Sarasota Bay Numeric Nutrient Criteria: Tidal Creeks - Letter Memorandum.* Prepared for Sarasota Bay Estuary Program. Sarasota, FL.

Janicki Environmental, Inc. 2011c. *Sarasota Bay Numeric Nutrient Criteria: task 3 – dissolved oxygen.* Prepared for Sarasota Bay Estuary Program. Sarasota, FL.

MacDonald, T.C., E. Weather, P.W. Stevens, and R.H. McMichael, Jr. 2010. *Nekton of Sarasota Bay and a comparison of Nekton community structure in adjacent Southwest Florida estuaries.* Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute. St. Petersburg, Florida.

Mallin, M.A., D.C. Parsons, V.L. Johnson, M.R. McIver, and H.A. CoVan. 2004. *Nutrient limitation and algal blooms in urbanizing tidal creeks.* Journal of Experimental Marine Biology and Ecology. 298:211–231.

Manatee County. 2012. Ambient surface water data. Department of Air/Watershed Management. Bradenton, FL.

Serviss, G.M. and S. Sauers. 2003. *Sarasota Bay juvenile fisheries habitat assessment*. Prepared for Sarasota Bay National Estuary Program. Sarasota, Florida.

Ray, D. 1999. Ecological and morphological significance of old growth deadhead logs in The Blackwater River. Florida Department of Environmental Protection, NWD Unpublished Report.

Sarasota County. 2011. Tidal Creek Index Data for 2008–2010. Department of Natural Resources. Sarasota, FL.

Sarasota County. 2012. Ambient surface water quality data. Department of Natural Resources. Sarasota, FL.

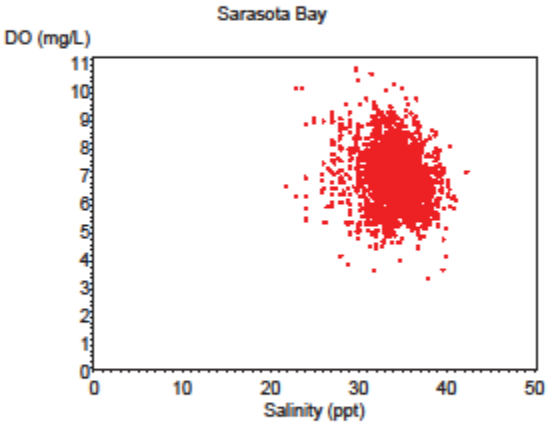
Sherwood, E.T. ed. 2008. *Tampa Bay Tidal Tributary Habitat Initiative Project: final report and management recommendations.* Tampa Bay Estuary Program Technical Report 02-08. Report to the Pinellas County Environmental Fund. Tampa Bay Estuary Program, St. Petersburg, FL. 83 pp.

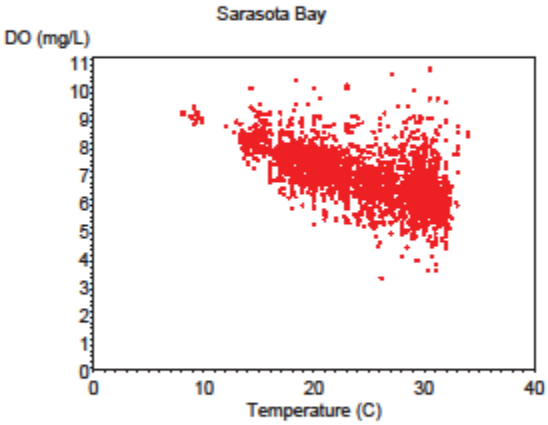
Southwest Florida Water Management District (SWFWMD). 2011. Seagrass coverage for 1950, 1988, 1994, 2001, 2004, 2006, 2008, and 2010. Geographic Information System library. Brooksville, FL.

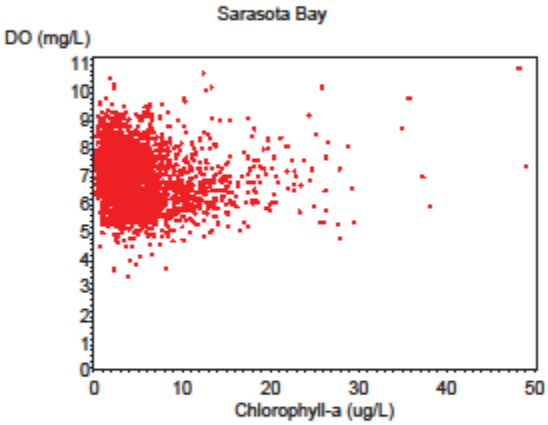
U.S. Environmental Protection Agency (EPA). 2010. Methods and Approaches for Deriving Numeric Criteria for Nitrogen/Phosphorus Pollution in Florida's Estuaries, Coastal Waters, and Southern Inland Flowing Waters. Washington, D.C.

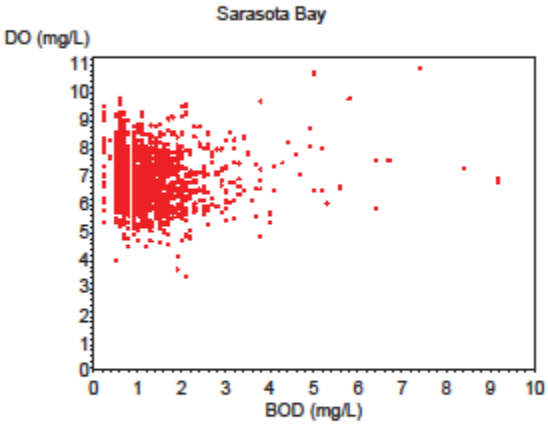
ATTACHMENT 1

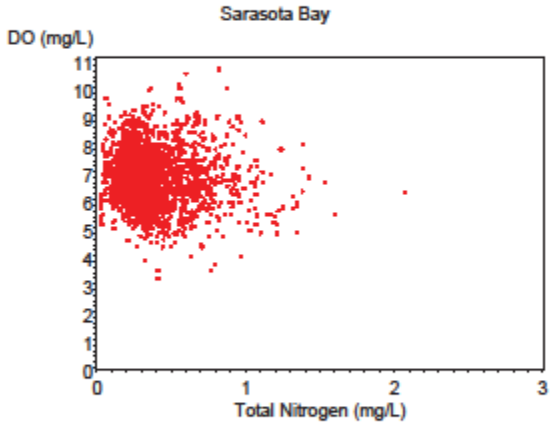
BIVARIATE PLOTS OF DO VERSUS TN, TP, TEMPERATURE, TIME OF DAY, SALINITY, CONDUCTIVITY, CHLOROPHYLL *A*, TN LOADS, TP LOADS, AND BOD LOADS FOR SARASOTA BAY AND SARASOTA COUNTY TRIBUTARIES

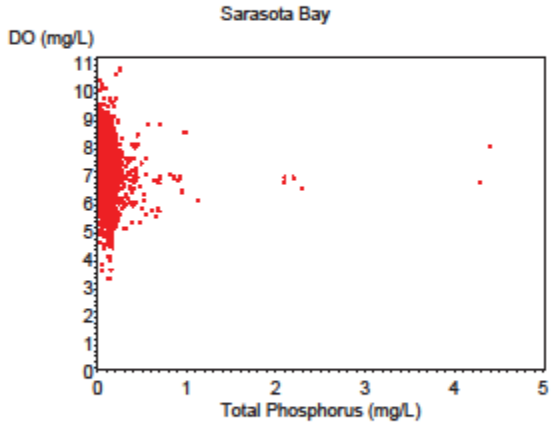

Sarasota Bay
DO (mg/L)
Salinity (ppt)

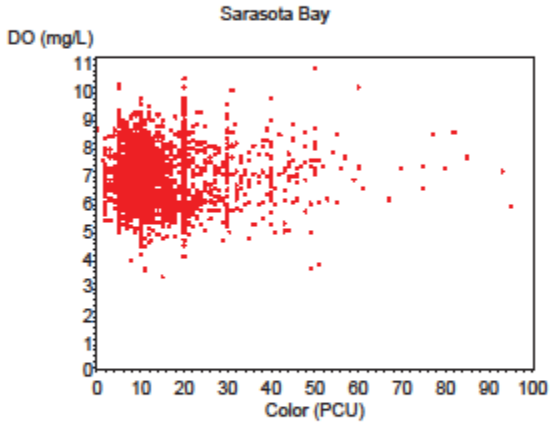

Sarasota Bay
DO (mg/L)
Temperature (C)

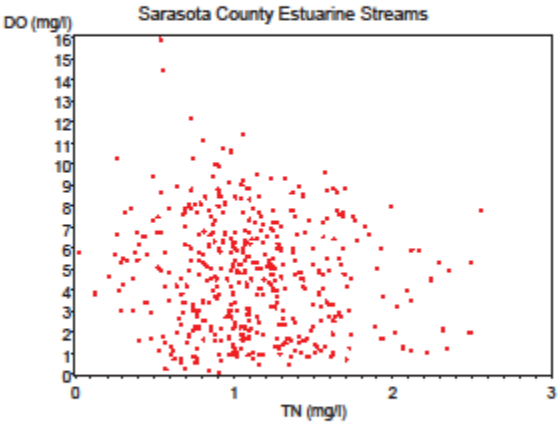

Sarasota Bay
DO (mg/L)
Chlorophyll-a (ug/L)

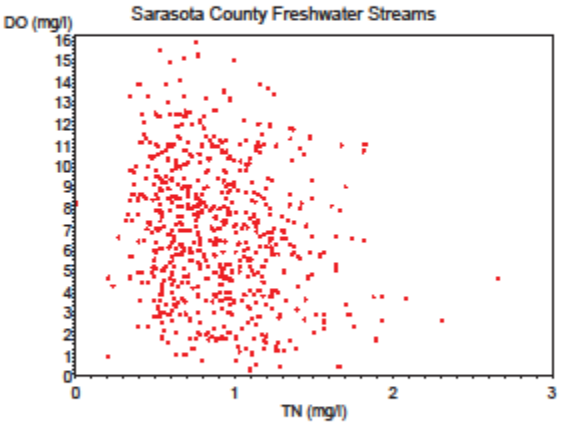

Sarasota Bay
DO (mg/L)
BOD (mg/L)

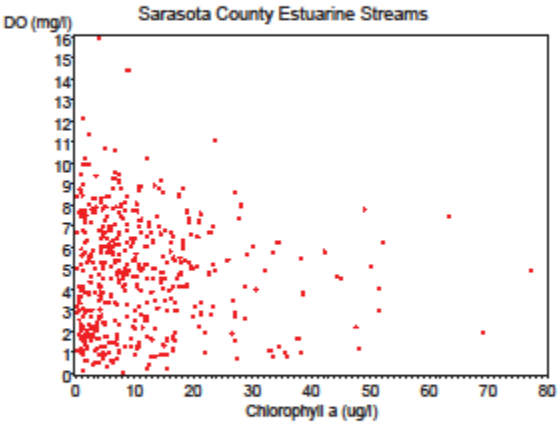

Sarasota Bay
DO (mg/L)
Total Nitrogen (mg/L)

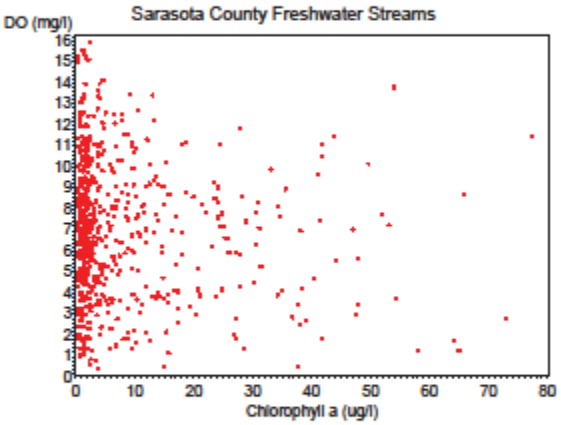

Sarasota Bay
DO (mg/L)
Total Phosphorus (mg/L)

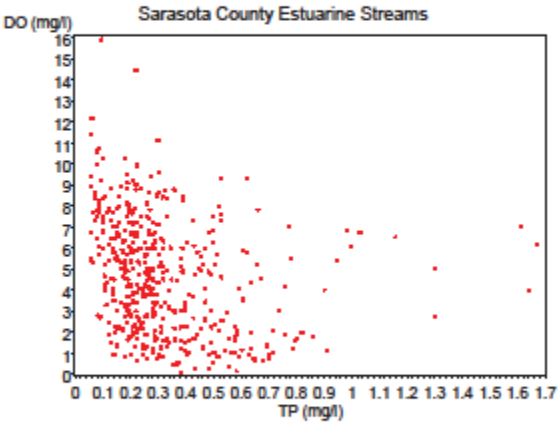

Sarasota Bay
DO (mg/L)
Color (PCU)

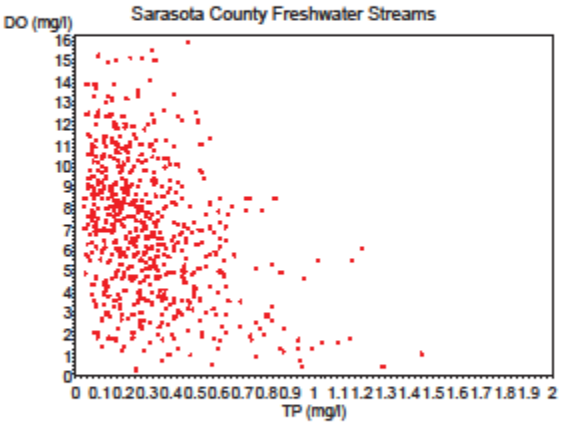

Sarasota County Estuarine Streams
DO (mg/l)
TN (mg/l)

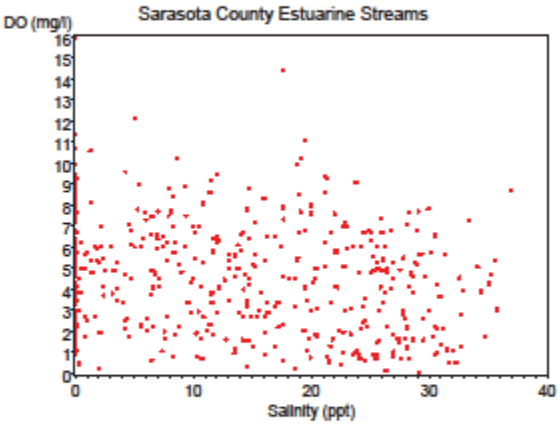

Sarasota County Freshwater Streams
DO (mg/l)
TN (mg/l)

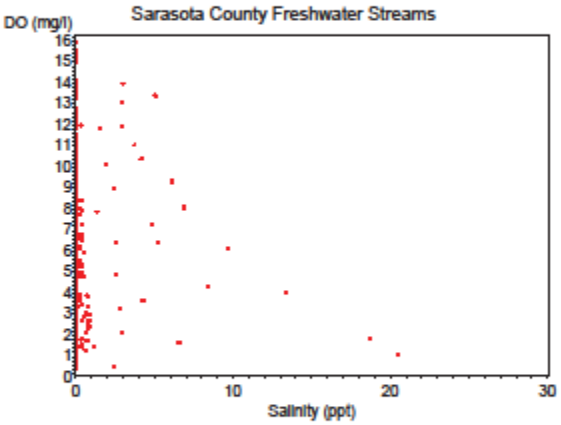

Sarasota County Estuarine Streams
DO (mg/l)
Chlorophyll a (ug/l)

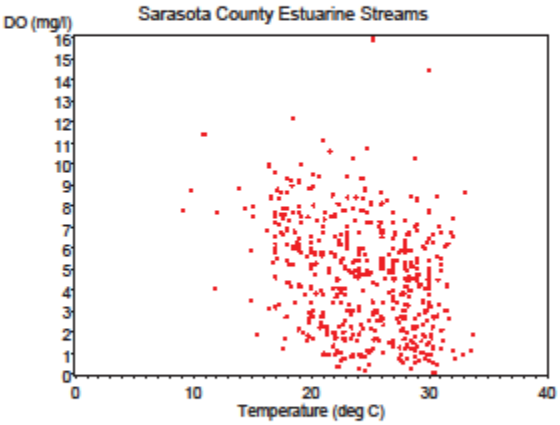

Sarasota County Freshwater Streams
DO (mg/l)
Chlorophyll a (ug/l)

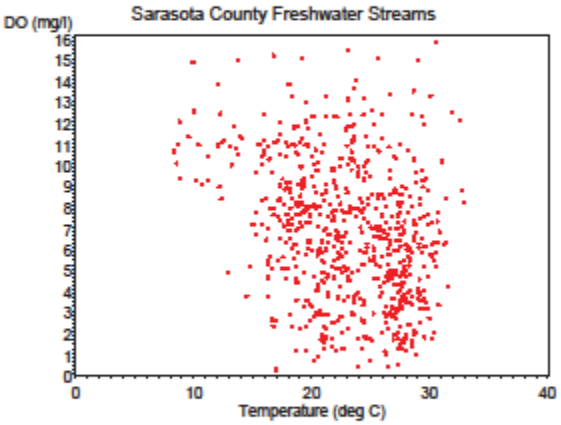

Sarasota County Estuarine Streams
DO (mg/l)
TP (mg/l)

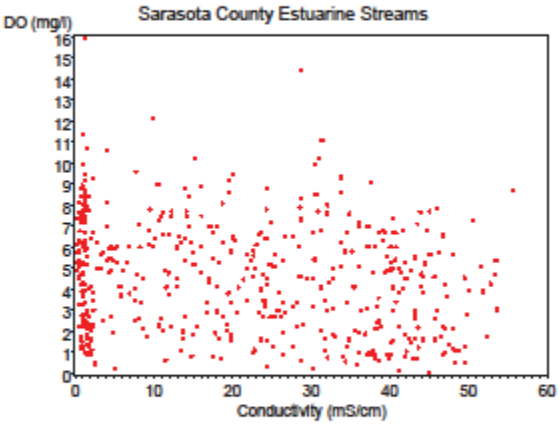

Sarasota County Freshwater Streams
DO (mg/l)
TP (mg/l)

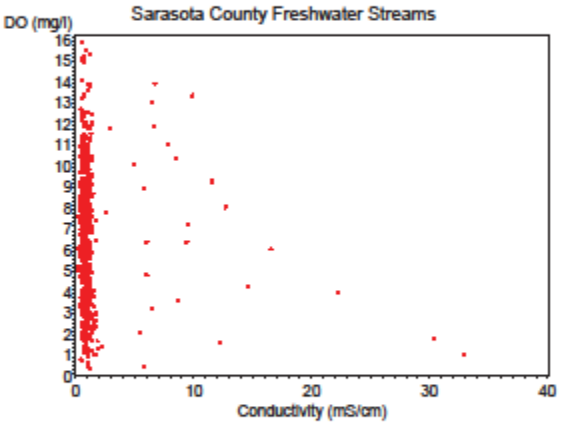

Sarasota County Estuarine Streams
DO (mg/l)
Salinity (ppt)

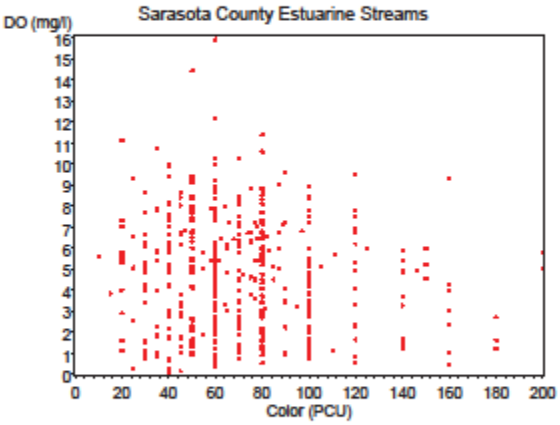

Sarasota County Freshwater Streams
DO (mg/l)
Salinity (ppt)

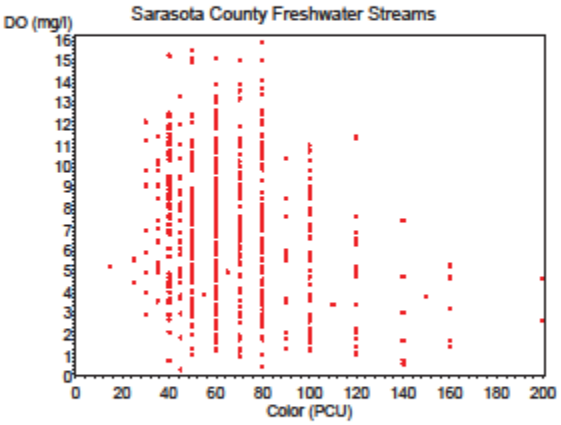

Sarasota County Estuarine Streams
DO (mg/l)
Temperature (deg C)

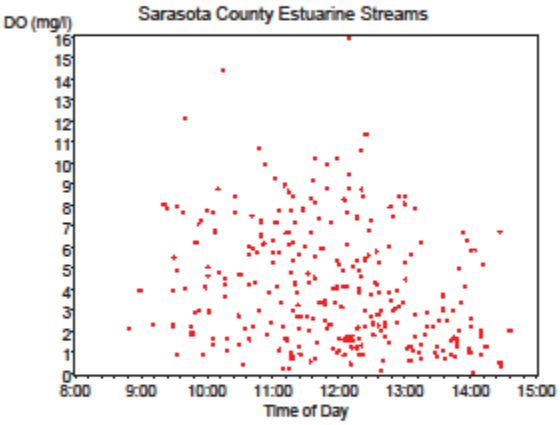

Sarasota County Freshwater Streams
DO (mg/l)
Temperature (deg C)

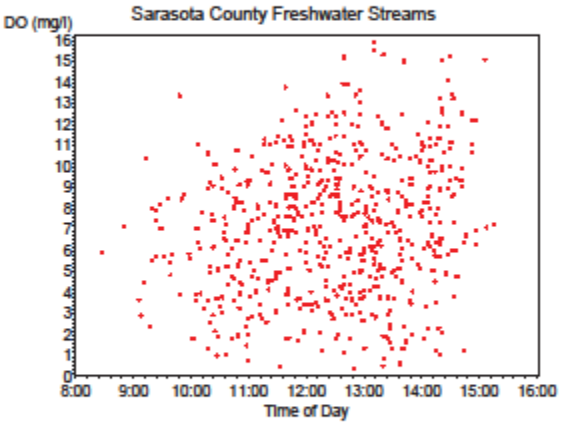

Sarasota County Estuarine Streams
DO (mg/l)
Conductivity (mS/cm)

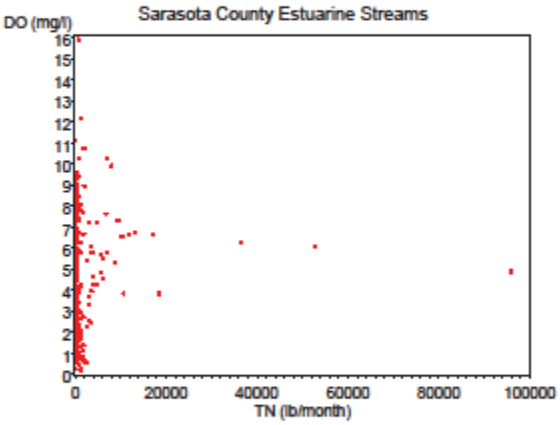

Sarasota County Freshwater Streams
DO (mg/l)
Conductivity (mS/cm)

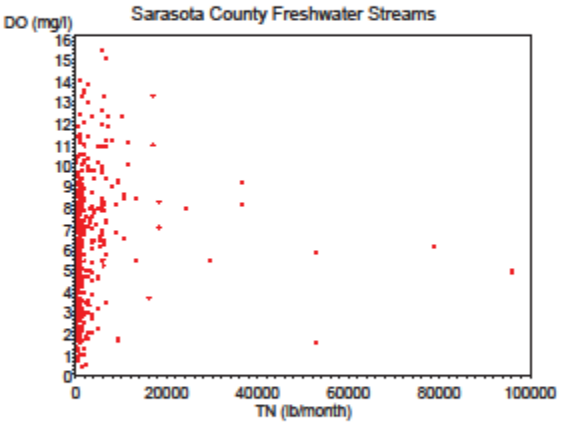

Sarasota County Estuarine Streams
DO (mg/l)
Color (PCU)

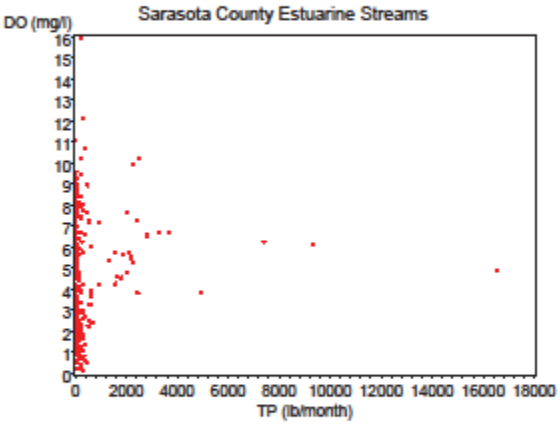

Sarasota County Freshwater Streams
DO (mg/l)
Color (PCU)

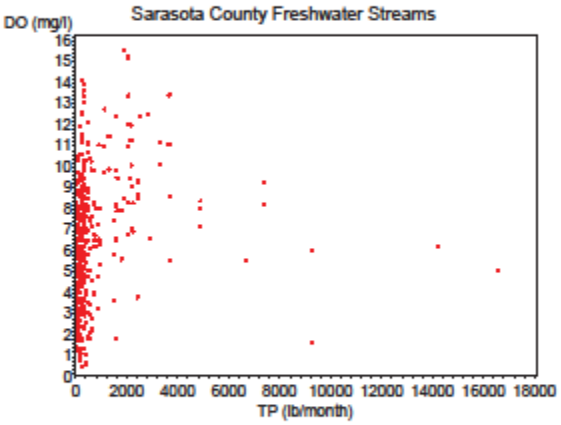

Sarasota County Estuarine Streams
DO (mg/l)
Time of Day

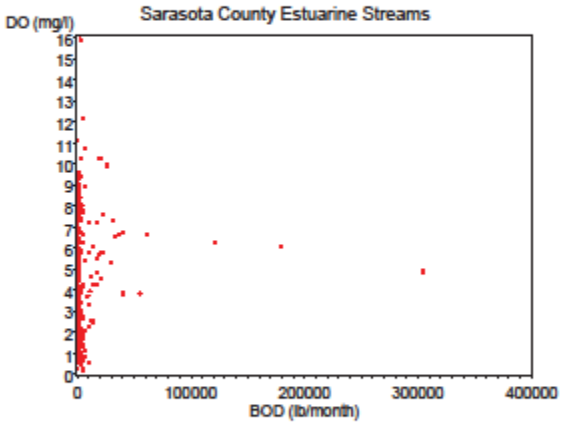

Sarasota County Freshwater Streams
DO (mg/l)
Time of Day


Sarasota County Estuarine Streams
DO (mg/l)
TN (lb/month)


Sarasota County Freshwater Streams
DO (mg/l)
TN (lb/month)


Sarasota County Estuarine Streams
DO (mg/l)
TP (lb/month)


Sarasota County Freshwater Streams
DO (mg/l)
TP (lb/month)


Sarasota County Estuarine Streams
DO (mg/l)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
100000
200000
300000
400000
BOD (lb/month)