Lake Worth Lagoon Watershed and Stormwater Loading Analysis

Submitted by

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for

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LIST OF ACRONYMS

BMP	Best management practice
BOD	Biological oxygen demand
C&CF	Central and southern Florida
COD	Chemical oxygen demand
DBHYDRO	Name of SFWMD Corporate Environmental Database
DO	Dissolved oxygen
EMC	Event mean concentration
ERM	Palm Beach County Department of Environmental Resources Management
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FLUCCS	Florida land use classification code system
GIS	Geographic information systems
HARN	High accuracy reference network
ICW	Intracoastal waterway
IWR	Impaired surface waters
JWCWMA	J. W. Corbett National Wildlife Refuge and Management Area
LWL	Lake Worth Lagoon
NO2	Nitrite
NO3	Nitrate
OPO4	Orthophosphate
PBC	Palm Beach County
pH	Alkalinity
SFWMD	South Florida Water Management District
STORET	STORage and RETrieval Florida Department of Environmental Protection Database
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TMDL	Total Maximum daily loads
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Service
WPB	West Palm Beach

STORET ACRONYMS (DATA SOURCES)

21FLBRA	Biological Research Associates Florida
21FLERDI	Environmental Research and Design, WC
21FLGFWF	Florida Fish and Wildlife Conservation Commission
21FLGW	Florida Department of Environmental Protection
21FLKWAT	Florida LAKEWATCH
21FLMRI	Florida Fish & Wildlife Research Institute
21FLPBCH	Palm Beach County Department of Environmental Resources Management
21FLSFWM	South Florida Water Management District
21FLWPB	Florida Department of Environmental Protection Southeast District
21FLWPBH	City of West Palm Beach
ELAB	PACE FL / ELAB
HBEL	Harbor Branch Environmental Lab
PPB	PPB Environmental Laboratories
USBS	US Biosystems

EXECUTIVE SUMMARY

Human activities over the past century have degraded natural habitats and water quality in the Lake Worth Lagoon (LWL). The discharge of untreated and treated wastewater, the discharge of stormwater from urban development and agriculture, and the increase in population in the watershed, all have contributed to the degradation of the lagoon's natural resources habitats (FDEP, 2006). These discharges include excess nutrients, suspended and dissolved organic matter, and other contaminants to the LWL which in turn affect the water quality, flora and fauna in the lagoon.

One of the goals of the SFWMD is to ensure that the LWL receives high quality water from its watershed. For this reason, the SFWMD commissioned Taylor Engineering to prepare an overview of the water quality in the LWL watershed, and, if feasible, to characterize the types and magnitude of selected pollutant concentrations in stormwater runoff — event mean concentrations (EMCs) —from contributing land uses that discharge to the LWL.

The best way to calculate stormwater loadings is to collect hydrologic and water quality data during storm events. A number of organizations have collected and analyzed many water quality samples from water bodies (ditches, canals, wetlands, and lakes) within the watershed, but not specifically to develop EMCs. Foreseeing the potential unsuitability of the existing water quality data to calculate EMCs, the SFWMD added to the project tasks the preparation of a three-year watershed EMC monitoring plan.

Review of the extensive water quality dataset for the LWL watershed indicated that the data included grab samples collected for general water quality characterization. Sampling locations were not linked to a specific land uses; the sampling locations integrated runoff from a variety of land uses. Samples were not collected to understand runoff from specific land uses or of specific storms, but to develop an understanding of general long-term water quality trends.

Data review and exploratory analysis of the water quality data indicated that DO, TKN, OPO_4, and TP are the parameters of concern in the LWL watershed. Water quality samples from basins on the west side of the LWL watershed (L-8, C-51 West, Acme B, or the C-16 North) where agriculture uses comprise a large fraction of the total land use showed elevated nutrient inputs (NO_2+NO_3, TKN, OPO_4 and TP). As the literature on stormwater quality support, these findings suggest that agriculture (pasture, row crops, and

citrus) are among the land uses that produce high concentration of TN and TP. Comparison of data collected in different seasons indicated that wet season parameter concentrations generally exceeded dry season values.

Basins on the east side of the LWL watershed where medium and high density residential land uses are most common (C-17, C-16, C- 51 East, and LWL) also showed elevated nutrient levels. In the C-17 basin, where commercial and industrial land uses are most common, values of TKN (a component of TN) were among the highest reported. These findings agree with the available literature, which suggests that medium and high density residential, and high density commercial land uses are among the land uses that produce high concentrations of TN and TP.

The development of a land use EMC dataset requires an understanding of the area land use and drainage patterns, which are the basis for locating sampling stations within the basin; each sampling station must collect data from a single predominant land use. Storms responsible for most pollutant runoff typically may not encompass the entire LWL basin, accordingly multiple sampling sites will increase the likelihood of capturing storm events. Accurate EMC sampling and EMC value calculation at each location is based on knowledge of the storm hydrology at the sampling point and the ability to collect samples throughout each storm event. Such a system carries a significant cost. The inclusion of existing active stations in an EMC monitoring effort may require the SFWMD to reevaluate the current monitoring frequency, consider adding new equipment, and assess the overall operational plan of the particular station. On the other hand, the location of new monitoring stations for EMC data collection will require a detailed study to define hydrologic conditions as well as sampling station construction.

The available data allowed calculation of preliminary annual stormwater loads (without respect to specific land uses) from the three main canals (C-17, C-51, C-16) that drain different parts of the basin and discharge to LWL. The annual loads from each canal varied significantly by year. Year to year differences in annual loads did not vary consistently among the canals. These two results suggest that rainfall patterns within the basin as well as land use differences affected annual pollutant loading from different locations within the basin.

SFWMD and their watershed communities will continue to focus on water quality improvement to restore Lake Worth Lagoon. Determination of land-use related EMCs will provide a basis to developing cost-effective best management practices (BMPs) for stormwater treatment in the LWL watershed. Accordingly, as EMC assessment goes forward, planning studies to evaluate the types, performance characteristics, location requirements, and costs of BMPs that could be employed in different land use settings should also begin.

1. INTRODUCTION

Human activities over the past century have degraded natural habitats and water quality in the Lake Worth Lagoon (LWL). The discharge of untreated and treated wastewater, the discharge of stormwater from urban development and agriculture, and the increase in population in the watershed, all have contributed to the degradation of the lagoon's natural resources habitats (FDEP, 2006). These discharges carry large influxes of nutrients, suspended and dissolved organic matter, and other contaminants to the LWL which in turn affect the water quality, flora and fauna in the lagoon.

One of the goals of the SFWMD is to ensure that the LWL receives high quality water from its watershed. For this reason, the SFWMD commissioned Taylor Engineering to prepare an overview of the water quality in the LWL watershed, and, if possible, to characterize the types and magnitude of selected pollutants in stormwater runoff — event mean concentrations (EMCs) —from contributing land uses that discharge to the LWL.

Stormwater runoff transports pollutant loads from the land surface into surface water conveyances (ditches, canals, lakes, etc.) and subsequently into the estuary. Pollutants and pollutant concentrations produced by different land uses vary, as do the amounts of rainfall absorbed (and discharged) by those land use categories. The best way to calculate stormwater loadings is to collect hydrologic and water quality data during storm events. A number of organizations have collected and analyzed many water quality samples from water bodies (ditches, canals, wetlands, and lakes) within the watershed, but not specifically to develop EMCs. Foreseeing the potential unsuitability of the existing water quality data to calculate EMCs, the SFWMD added to the project tasks the preparation of a three-year watershed EMC monitoring plan.

1.1 Lake Worth Lagoon

The first developments in the coastal areas of Palm Beach County, Florida occurred on well-drained natural coastal ridge that provided habitable land. The areas west of the coastal ridge, poorly-drained flat woods and lowlands, were subject to severe flooding and generally unsuited for development. As noted in the *Water Quality Status Report* (Florida Department of Environmental Protection [FDEP], 2006) for the Lake Worth Lagoon,

> Under the Central and Southern Florida (C&SF) Project of 1948, the U.S. Congress authorized the U.S. Army Corps of Engineers…to implement a major regional drainage and flood control program… The C&SF Project and accompanying smaller scale drainage projects significantly altered the hydrology and led to alteration of the area's landscape as wetlands were drained, natural drainage features were modified, and land was converted to the urban/residential and agricultural land uses of today. These drainage improvements connected isolated wetland areas and conveyed most of the water eastward to the estuary, resulting in an enlargement of the overall watershed area of the LWL and coastal estuary system.

The majority of the land west of the urban coastal area of Palm Beach County now correspond to one of three land use classifications: developed (e.g., residential, commercial, and recreational), agricultural (e.g., cropland, fruit grove, and nursery), or natural (wetland, forest). All land use types depend on a network of canals to drain the area. Most runoff from these urban and agricultural lands enters the canal systems where secondary canals, operated by water control districts, convey runoff to the Lake Worth Lagoon (LWL) (FDEP, 2006).

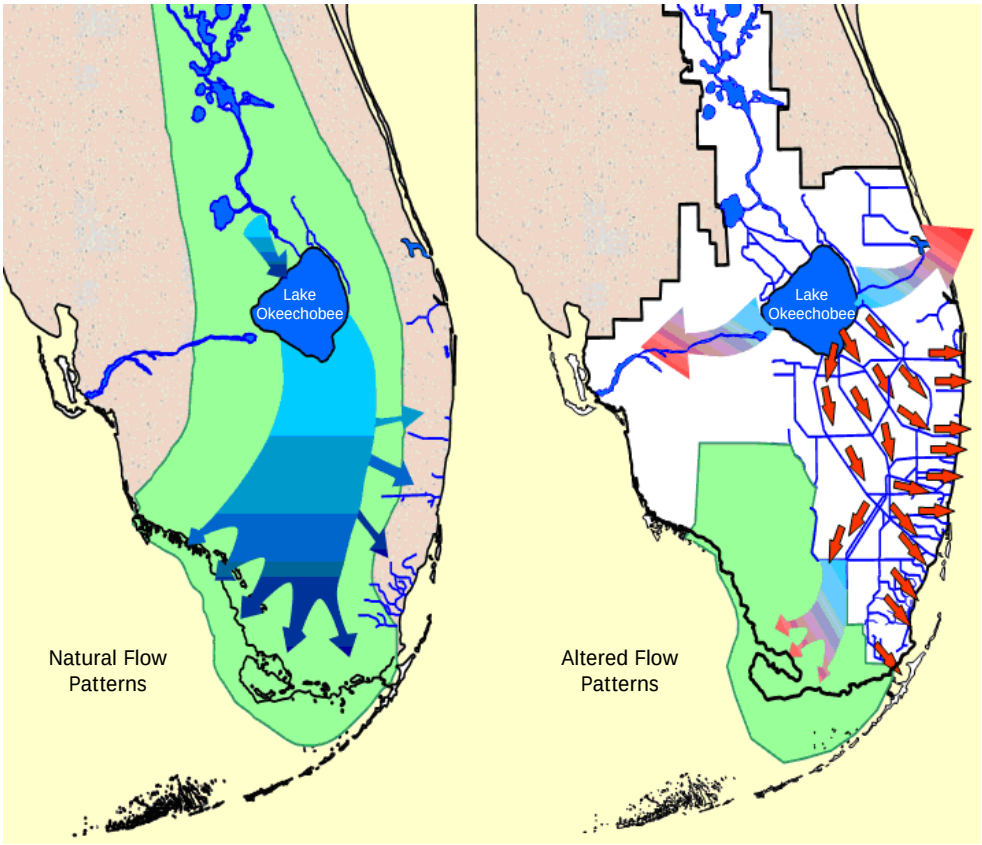

Figure 1.1 Natural and Altered Regional Drainage and Flood Pattern in the Southeast Coast of Florida (Source: SFWMD)

The South Florida Water Management District (SFWMD) maintains the major canals which receive discharges from secondary canals. Control structures and pumping stations regulate levels and

divert flow within the canals for flood control, irrigation, and groundwater recharge to prevent saltwater intrusion. The estuarine receiving water bodies in the county include the LWL and the Intracoastal Waterway (ICW) (FDEP, 2006).

The U.S. Army Corps of Engineers (USACE) finished construction of the first stable navigable inlet (Lake Worth Inlet) to the LWL in 1877. The construction of the ICW to Biscayne Bay was completed in 1910. “Early ecological problems due to poor circulation, noticeable by 1917, resulted in the construction of the South Lake Worth Inlet to improve flushing.” (FDEP, 2006).

As part of the C&SF Project, several primary water conveyance canals were constructed in the county: L-8, C-51 (West Palm Beach Canal), C-17 (Earman River), C-16 (Boynton Canal), C-15, and Hillsboro Canal (Figure 1.2). The West Palm Beach (WPB) Water Catchment, a remnant of the Loxahatchee Slough wetland incorporated into the City of West Palm Beach, provides the source of surface water for potable supply. The catchment, also a source of groundwater, recharges the municipal well fields in the City of West Palm Beach, Palm Beach County, Royal Palm, the city of Riviera Beach, and Seacoast Utilities. The M Canal conveys surface water to the WPB Water Catchment from the L-8 Canal and conveys water from the water catchment to Lake Mangonia. Lake Mangonia and Clear Lake interconnect with the WPB Water Catchment, and serve as potable water reservoirs for the City of West Palm Beach (FDEP, 2003).

The LWL watershed includes eight drainage basins: the L-8, the C-51 East and West, the C-17, the ACME basin, the C-16 and C-16 North, and the Lake Worth Lagoon basin (Figure 1.2). The estimated drainage area for the LWL watershed totals 450 square miles. Three major man-made canals discharge freshwater into the LWL watershed: the Earman River (C-17) Canal, which discharges to the north and upper segment of the lagoon; the West Palm Beach Canal (C-51), which discharges to the central segment; and the Boynton Beach Canal (C-16), which discharges to the southern segment. For this report, LWL watershed describes the entire watershed; LWL basin describes the upland basin draining to the lagoon itself or the LWL estuary.

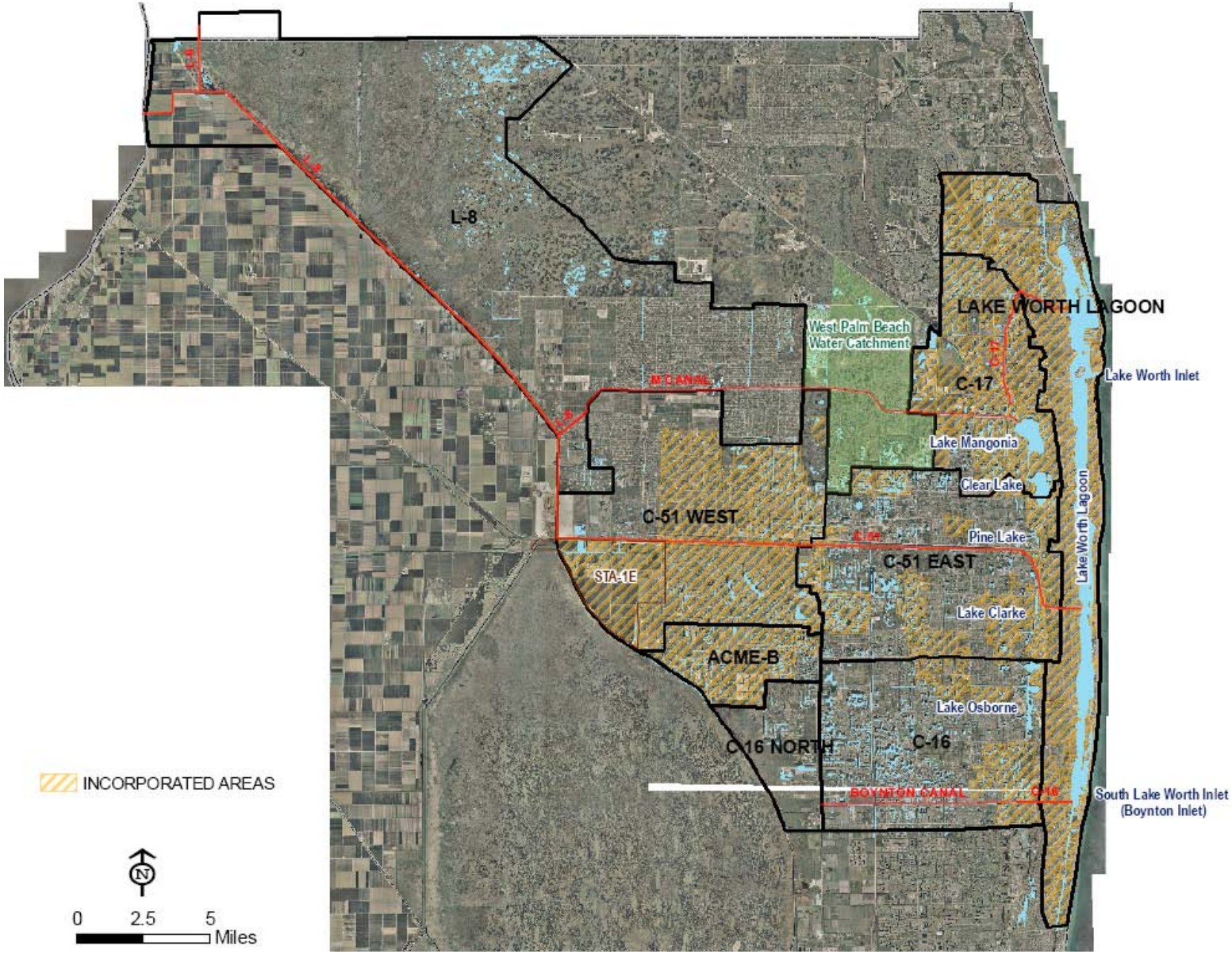

Figure 1.2 Lake Worth Lagoon Watershed Basins

The LWL, the largest estuarine system in Palm Beach County, runs approximately 20 miles parallel to the coast and averages half a mile in width (FDEP, 2008). Barrier islands separate the lagoon from the Atlantic Ocean; two permanent, man-made inlets — the Lake Worth Inlet and the South Lake Worth Inlet (Boynton Inlet) — interrupt the barrier islands. These inlets allow saltwater inflow into the lagoon. Due to the configuration of the lagoon, the points of entry of canal discharges, and the locations of the inlets that provide flushing, portions of the lagoon farthest from inlets (central section) have lower salinities for longer periods of time (Zarillo, 2003).

Human activities over the past century have degraded the LWL's natural habitat and water quality. Drainage from the upland basins within the watershed significantly influences water quality in the LWL. Although it receives inflow of locally generated storm water and fresh water from the other major canals, the West Palm Beach Canal (C-51) is the main source of freshwater discharged to the lagoon.

The LWL and much of the LWL watershed have undergone extensive development — dredging and filling of wetlands along the shoreline; the construction of the inlets, bridges, docks, marinas, and bulkheads along the shoreline; and operations associated with power plant, extensive residential and commercial development. The discharge over the last century of untreated wastewater, treated wastewater and storm water from all the various development activities and increased human population have contributed to the degradation of the lagoon's natural resources habitats (FDEP, 2006). "In 1975, 87% of the mangrove wetlands in the LWL were filled and 65% of the shoreline bulk headed" (FDEP, 2006). On a positive note, according to the Palm Beach County Department of Environmental Resources Management (ERM) and the FDEP the discharge of domestic wastewater diminished by the late 1990s (FDEP, 2006).

Located along the western slope of the coastal ridge in the eastern part of the C-16 and C-51 drainage basins, a chain of freshwater lakes — Pine Lake, Lake Clarke, Lake Osborne, and their connecting water body the E-4 Canal — provide recreation opportunities to the county. "The natural character of the lakes has over the years been changed by historical dredge and fills activities, encroachment of urban and residential growth into riparian areas and flood plains, invasion of nonnative plants, and increased discharge of pollutants and sediment in storm water from the canals" (FDEP, 2003).

1.2 Report Organization

Chapter 2 presents a review of documents associated with the Lake Worth Lagoon basin. These documents provide broad and a relatively comprehensive set of information and analyses relevant to this project. The information gathered from the literature provided the basis to develop some of the data analysis methodologies presented in Chapter 3. The literature review also provided the basic information to characterize the LWL watershed, basins and canal system that serves the watershed (Chapter 4).

The collection, review, and consolidation of meteorological, hydrological, and water quality data for the entire watershed (1990 – 2008) provides a comprehensive overview of the existing watershed information for these three types of data, (Chapter 4). A subset (1995 – 2008) of the meteorological, hydrological, and water quality data presented in the previous chapters provided the data for basin wide seasonal analysis presented in Chapters 5. The chapter compares the basin's wet and dry season water quality parameter concentrations.

The spatial analyses presented in Chapter 6 uses the smaller subset of data (2006 – 2008) to identify the areas of high concentrations for each water quality parameter, geographic trends, data gaps, and stations of concern. These stations monitor areas with elevated levels of a particular water quality parameter. In Chapter 7, Orthophosphate, nitrite + nitrate, total Kjeldahl nitrogen, total suspended solids, and flow data collected at the three stations that monitor the discharge points into the LWL from the three main canals provide the basis to calculate the annual loads from the C-17, C-51 East and West, and C-16 basins into the LWL.

Chapter 8 briefly discusses the applicability of the available data for calculation of EMCs and presents the proposed three-year water quality monitoring plan to collect data suitable to calculate EMCs. Chapter 9 includes recommendations and final considerations.

2. LITERATURE REVIEW

Taylor Engineering reviewed a number of studies as part of this project. In addition to the documents referenced throughout this report, the texts summarized below provide broad and relatively comprehensive sets of information and analyses of interest to this project. This summary of the literature reviewed includes the study purpose, location, data sources and period, methodology, study findings, and a brief discussion of its applicability to this study. The References section of the full report provides full references for each of the citations below.

Reports: EMC sampling protocols and EMC values	
Chow and Yusop. 2008. *A Review of Event Mean Concentration (EMC) for Urban Stormwater Runoff* Harper. 1994. *Stormwater Loading Rate Parameters for Central and South Florida* Harper and Baker. 2003. *Evaluation of Alternative Stormwater Regulations for Southwest Florida Final Report (Revised Sept. 8, 2003)* US Environmental Protection Agency. 1992. *NPDES Storm Water Sampling Guidance* Whalen and Cullum. 1988. *An assessment of Urban Land Use/Stormwater Runoff Quality Relationships and Treatment Efficiencies of Selected Stormwater Management System.*	
Purpose	To develop EMC data for various locations in south and southwest Florida, including Palm Beach County
Monitoring data	**Number of monitoring sites:** Various **Monitoring frequency:** Various **Period:**1974 – 2008
Methodology	Grab and automated water quality sampling and storm flow monitoring
Results	Defines and establishes protocols for stormwater sampling, reports on water quality sampling results, calculation of event mean storm concentrations, provides literature review of event mean storm concentrations in South and Southwest Florida
Usefulness to this project	Provides relevant information on stormwater sampling procedures, storm EMC values for canals and land uses in south and southwest Florida reported over a 2-decade period. Useful comparison data for future EMC program in LWL.

Report: Wetland Loading and Runoff Assessment	
Zahina et al. 2001. *Functional Assessment of South Florida Freshwater Wetland and Models for Estimates of Runoff and Pollution Loading*	
Purpose	To discuss the theoretical background to estimate runoff and pollutant loading, and pollution mitigation capacity of wetlands

Monitoring data	**Data Source:** DBHYDRO database **Number of monitoring sites:** Unknown **Monitoring frequency:** Daily to monthly **Period:** Unknown
Methodology	Numerical modeling with SFWMM
Results	Estimated averages of runoff and pollutant loads
Usefulness to this project	Provides average runoff and pollutant loads for South Florida wetlands
Reports: Palm Beach County National Pollution Discharge Elimination System Permit Application and Annual Permit Compliance Reports Palm Beach County, 1993. *Characterization Data - 40 CFR 122-26(d)(2)(iii)* Mock Roos, 1998 – 2008. *Environmental Protection Agency National Pollutant Discharge Elimination System Joint Annual Reports*	
Purpose	To establish sampling sites, procedures, monitoring frequency for storm and water quality sampling for Palm Beach County Permit Application (Palm Beach County 1993). To provide annual report on results and progress in stormwater discharge monitoring and management (Annual Reports, NPDES Permit FLS000018 for Stormwater Discharges, 1998 – 2008).
Monitoring data	**Number of monitoring sites:** Various **Monitoring frequency:** Various – quarterly to storm event **Period:** 1993 – 2008
Methodology	Grab and automated water quality sampling and storm flow monitoring
Results	Established protocols for storm water sampling, reports on water quality sampling extending over more than a decade
Usefulness to this project	Provides relevant information on storm water sampling procedures, storm EMC values (for canals, not land uses), BMP implementation over the reporting period. Reports water quality trends for annual periods 1997 – 2008
Report: Lake Worth Lagoon Management Plans Palm Beach County. 2008. *Lake Worth Lagoon Management Plan Revision*	
Purpose	To describe the Palm Beach County Lake Worth Lagoon Management Plan including history, progress, status and future plans; summarize past findings of water quality in the study area based on monitoring data and to note changes in water quality
Monitoring data	**Number of monitoring sites:** 10 (1994 – 2006), 12 (after 2007) **Monitoring frequency:** Monthly **Period:** 1994 – 2006

Methodology	Correlation analysis between flow and water quality parameters by non-parametric Spearman rank method and confidence interval by bootstrap sampling
Results	(a) The water quality in the LWL is generally good based on this data set. (b) Significant increases have been occurring for a few parameters such as TN, chlorophyll-a, and turbidity. (c) Freshwater inflows affect turbidity, salinity, and nitrogen levels in the lagoon, and increasing proximity to the C-51 canal equates with worsening water quality conditions. (d) The effect of the C-51 Canal discharges from the S-155 structure is more apparent in the central portion of the lagoon then in the south or north. (e) High concentrations of TN are, in conjunction with other factors, often associated with algal blooms, as well as dense aquatic plant growth. (f) Statistical analysis (a best subset regression of transformed data) indicates that TN is likely the causative agent driving chlorophyll dynamics and the limiting nutrient for algal blooms. (g) The increasing nitrogen trend requires close monitoring to exclude potential biases from storm activities that increased discharges and runoff in the lagoon in 2004 and 2005.
Usefulness to this project	Provides background and relevant information on the area and on the general technical planning and implementation process ongoing in the LWL watershed.
Report: Lake Worth Lagoon Water Quality Assessment FDEP. 2003. *Water Quality Assessment Report – Lake Worth Lagoon – Palm Beach Coast*. FDEP. 2006. *Water Quality Assessment Report – Lake Worth Lagoon – Palm Beach Coast*.	
Purpose	Water Quality Assessment for Lake Worth Lagoon Basin as part of the Florida Department of Environmental Protection's (Department) watershed management approach for restoring and protecting water resources and addressing Total Maximum Daily Load (TMDL) Program requirements.
Monitoring data	**Source:** U.S. EPA STORET **Number of monitoring sites:** Numerous throughout LWL watershed **Monitoring frequency:** Monthly **Period:** 1992 – 2004
Methodology	Statistical summary of water quality parameters for each watershed, evaluation of water quality results against numeric and non-numeric water quality standards.
Results	(a) The L-8 Planning Unit is impacted by high loadings of nitrogen and low levels of DO. Additional sampling is needed in the basin to assess the iron concentrations that are possibly due to groundwater influences and for turbidity concentrations in the canal. (b) The C-51 Planning Unit is impacted by high nitrogen and phosphorus loads and low levels of DO. The C-51 basin shows low levels of DO linked to elevated nitrogen levels. (c) C-17 Planning Unit shows high concentrations of TN and total phosphorus (TP), and low levels of DO in the PB Stations/D Canal water body. Future data collection is required to evaluate the iron concentrations and abundance of coliforms in the planning unit.

	(d) The C-16 and C-16 North Planning Unit is influenced by the increased amount of freshwater inflows coming from the E-4 and L-14 Canals. Inflows reduce the amount of DO in the lake. (e) The water quality of the Hillsboro Canal Planning Unit is impacted by elevated nutrients or low concentrations of DO in the canals. The E-1, E-4, and Hillsboro Canals are the areas with the most elevated levels of nitrogen and phosphorus, resulting in depressed levels of DO. (f) The water quality of the Intracoastal Planning Unit has not been impacted by excessive nutrients that could result in depressed DO levels in the basin Priority list of impaired water bodies (303d list) provides schedule for TMDL development, application, implementation
Usefulness to this project	Will help prioritize locations and parameters for EMC sampling efforts
Reports: Lake Worth Lagoon Water Quality Reports Moiz and Metzler. 2002. *North Palm Beach County Data Summary*	
Purpose	To report water quality conditions and trends in Lake Worth Lagoon and North Palm Beach County
Monitoring data	**Source:** USGS Database, DBHYDRO **Number of monitoring sites:** Rainfall – 4 Flow, Stage – 17 Water Quality (numerous – all available data from DBHYDRO, Local, State, and Federal databases) **Monitoring frequency:** Daily – monthly, parameter dependent **Period:** Mid 1980s – 2000
Methodology	Not applicable
Results	Summary of data sources available by the year 2000
Usefulness to this project	Provides extensive listing of available data stations in the Lake Worth Lagoon and nearby basins
Report: Lake Worth Lagoon Water Quality Report Graves. 2007. *Preliminary Analysis of Lake Worth Lagoon Water Quality Data*.	
Purpose	To summarize water quality trends in the Lake Worth Lagoon

Monitoring data	**Data Source:** DBHYDRO **Monitoring frequency:** Monthly **Period:** 1990 – 2006
Methodology	Statistical analysis of available water quality data from Lake Worth Lagoon: box and whisker visible trend, correlation, regression analysis, non parametric statistics
Results	Increasing trend (Seasonal Kendall, $p<0.05$) for TN, Chl-a, and turbidity; No apparent trend for TP, TN, TP, Chl-a, turbidity correlates with discharges from C-51(Spearman rank, $p<0.05$)
Usefulness to this project	Provides clear overview of conditions in Lake Worth Lagoon, the receiving water body for the Lake Worth Lagoon watershed
Report: Chain of Lakes Water Quality Reports Palm Beach County. 1997. *State of the Lakes – A Report on the State of the Lakes of the Coastal Ridge in Palm Beach County and a Plan for Their Management*	
Purpose	To fully describe the physical, chemical, biological and land use conditions of the lakes of the coastal ridge in Palm Beach County and to develop a management plan
Monitoring data	**Data Source:** Various – see references cited **Number of monitoring sites:** Not applicable **Monitoring frequency:** Not applicable **Period:** Status of lakes as of 1996
Methodology	Analysis and interpretation of available data
Results	Complete descriptions of the Chain of Lakes and lake environmental conditions in the middle 1990s. Management Plans for restoration of the chain of lakes
Usefulness to this project	Useful baseline, background information to understand this portion of the LWL watershed.
Report: Chain of Lakes Water Quality Reports Harper et al 2002. *Palm Beach County Chain-of-Lakes Water Quality and Pollutant Loading Evaluation. Final Report*	
Purpose	Re-evaluate water quality conditions and ecosystem health in the Palm Beach County Chain of Lakes
Monitoring data	**Source:** Field sampling **Number of monitoring sites:** 8 surface water sites and 44 sediment sampling stations in 5 interconnected lakes **Monitoring frequency:** Monthly

	Period: September 2000 – August 2001
Methodology	Surface water quality sampling, surface and groundwater flow modeling, nutrient budget development, evaluation of lake restoration alternatives
Results	Significant improvement in water quality characteristics within the chain-of-lakes can be achieved by improving water quality within the E-4 and C-51 Canal systems which provide inflows to the lake system, and by sediment dredging for nutrient removal
Usefulness to this project	Provides further understanding of interconnected conditions within the LWL watershed
Report: Chain of Lakes Water Quality Reports Palm Beach County 2008. *Palm Beach County Chain-of-Lakes Water Quality Update Evaluation Period January 2006 to November 2006*	
Purpose	Update of Water Quality Assessment for Palm Beach County Chain of Lakes
Monitoring data	**Source:** Water quality sampling **Number of monitoring sites:** 15 surface water quality sampling sites **Monitoring frequency:** Monthly **Period:** 2006 – 2007
Methodology	Analyses of surface water quality data,
Results	Phosphorus, nitrogen, dissolved oxygen, chlorophyll a, and fecal coliforms remain parameters of concern in the lakes. The lakes vary in water quality, with summary quality stated as good to fair-poor. Some of the lakes show seasonal patterns of decreased water quality, and regular water quality sampling and analysis should continue
Usefulness to this project	Provides relatively status of water quality conditions in this portion of the watershed. Provides background information for consideration of EMC sampling locations
Report: Basin Modeling Mock, Roos & Associates, Inc. 2002. C-*17 Drainage Basin Study Tech Memo No 3*	
Purpose	To develop and calibrate hydrologic and hydraulic models capable of (1) assessing the capacity of the river network within the C-17 basin and (2) assessing hydraulic structures to handle a design storm (25- and 100-year), potential canal improvement, and (3) developing FEMA FIRMs
Monitoring data	**Source:** SFWMD **Number of monitoring sites:** Unknown **Monitoring frequency:** Daily **Period:** 1995 – 2001
Methodology	Numerical modeling: Hydrologic analysis with HEC-1 and hydraulic analysis with UNET

Results	Albeit low banks in some sections, the C-17 Canal could contain the flow from a 100-year storm event within the existing canal banks.
Usefulness to this project	Provides background and relevant information on hydrology and hydraulics for the C-17 basin
Report: Basin Modeling Mock, Roos 1992. *Lake Worth Drainage District (LWDD) Interbasin Study*	
Purpose	(1) To update hydrologic and hydraulic models for all four major basins — C-51, C-16, C-15, and Hillsboro — to reflect hydrologic and hydraulic changes since 1990, and (2) to evaluate hydrologic and hydraulic responses of the LWDD canal system during a district-wide storm event
Monitoring data	**Source:** Palm Beach County **Number of monitoring sites:** Unknown **Monitoring frequency:** Unknown **Period:** 1982 – 1996
Methodology	Numerical modeling: Hydrologic analysis with TR-20 and hydraulic analysis with WSP-2
Results	The LWDD system, with recommended improvements, has the equivalent capacity of a 10-year, 24-hour storm event, assuming a district-wide storm event with an exchange of flows between individual basins
Usefulness to this project	Provides hydrologic and hydraulic analyses of the project area

3. METHODOLOGY

This chapter discusses the selection criteria applied to assemble the meteorological, hydrological, and water quality datasets for the Lake Worth Lagoon watershed basins; describes the data review and quality control applied to the data; the data consolidation methodology; lists the land use criteria applied to create the land use classification GIS dataset; and describes the statistical methods used in the meteorological, hydrological, and water quality data analysis. This chapter also briefly discusses the geospatial analysis methodologies applied to the water quality datasets.

3.1 Data Review Methodologies

3.1.1 Selection of Monitoring Stations

Taylor Engineering selected the monitoring stations to characterize each basin in the LWL watershed based on the station location and the station meteorological, hydrological, and water quality data availability. Taylor Engineering included inactive monitoring stations (stations which no longer collect data) when historical data from those stations fell within the period of record (1990 – 2008) considered for this study.

3.1.2 Existing GIS Data Review

GIS data review consisted of compiling aerial photographs, county and watershed boundaries, land use, monitoring station locations, and other pertinent geographic data from the SFWMD, Palm Beach County (PBC), and FDEP GIS websites. All downloaded photographs were reviewed for visual quality and extent. Coverages were reviewed for completeness and mapping consistency.

3.1.3 Existing Meteorological, Hydrological, and Water Quality Data Review

Preliminary review of the SFWMD flow and rainfall data identified daily and instantaneous data for these two parameters between January 1, 1990 and December 31, 2008. Preliminary review of the SFWMD and PBC water quality datasets indicated that the majority of the historical water quality monitoring in the LWL watershed consisted of monthly ambient water quality data (surface samples) collected to determine the general water quality status and trends.

Meteorological data review consisted of uploading rainfall station datasets located within the LWL watershed from the SFWMD DBHYDRO database and identifying the period of each dataset. Figure 3.1 shows the location of the selected rainfall stations. Appendix A lists the selected station locations, data sources, and period of data available for each station.

3.1.3.1 Hydrological Data

Hydrological data review consisted of uploading flow station datasets located within the LWL watershed from the SFWMD DBHYDRO database, selecting data within the period of record, and removing stations where reverse flow occurred (where the flow in the canal changed direction). Figure 3.2 shows the location of the final set of flow stations selected for the analysis. Appendix B lists the selected station locations, data sources, and period of data available from each station.

3.1.3.2 Water Quality Data

Water quality data review consisted of uploading water quality data from stations located within the LWL watershed and selecting the data within the period of record with longer periods of record. The following water quality parameters were uploaded for this study: dissolved oxygen (DO), alkalinity (pH), ortho phosphate (OPO_4), total phosphorus (TP), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrite plus nitrate (NO_2+NO_3), total Kjeldahl nitrogen (TKN), total suspended solids (TSS), and total dissolved solids (TDS). Water quality data sources included

- SFWMD DBHYDRO database
- Palm Beach County Department of Environmental Resources Management (ERM)
- U.S. Geological Service (USGS) National Water Information System database
- Florida Department of Environmental Protection STORage and RETrieval (STORET)

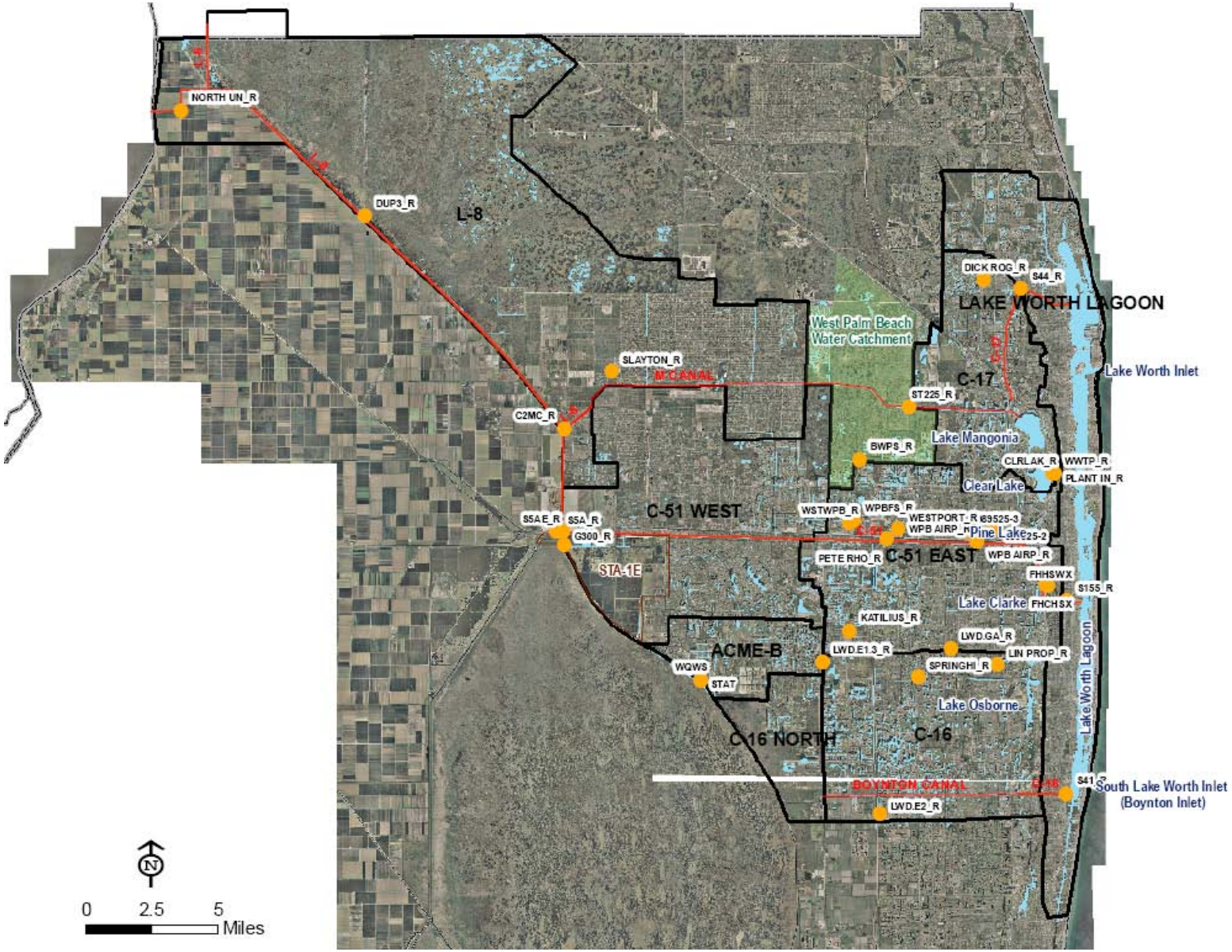

Figure 3.1 Selected Rainfall Stations in the Lake Water Lagoon Watershed

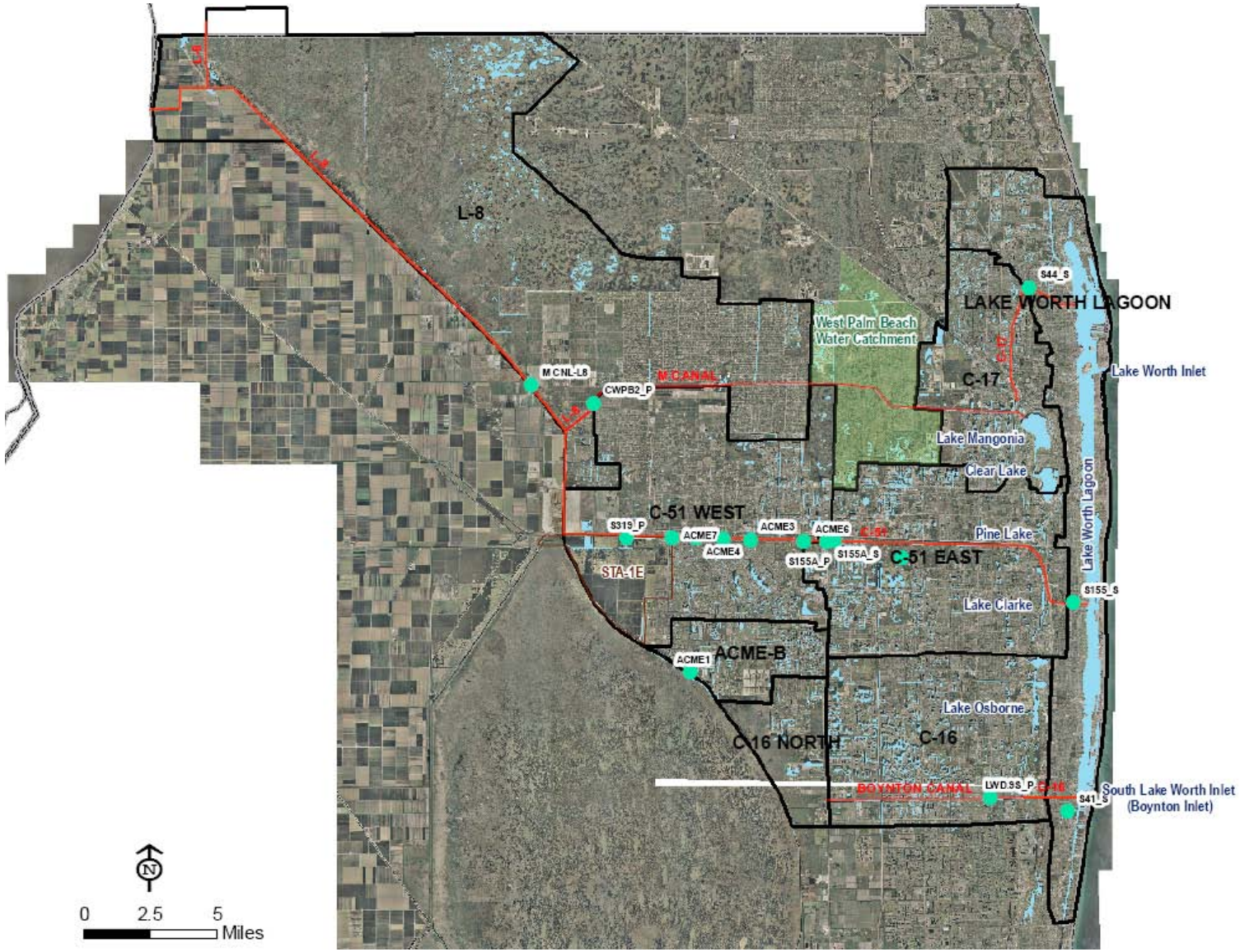

Figure 3.2 Selected Flow Stations in the Lake Water Lagoon Watershed

The Florida STORET database includes data from several governmental and private agencies including

- City of West Palm Beach
- Florida Fish & Wildlife Research Institute (FMRI)
- Florida Fish and Wildlife Conservation Commission (FWC)
- Florida LAKEWATCH
- US Biosystems
- Harbor Branch Environmental Lab
- PPB Environmental Laboratories
- PACE FL / ELAB
- Biological Research Associates
- Environmental Research and Design

Figure 3.3 shows the location of the water quality stations selected for the analysis. The figure distinguishes stations from different sources. The “Other” classification refers to data from organizations other than the major data sources (SFWMD, FDEP, and ERM). Appendix C lists the selected stations, data sources, and time series period for each station for each water quality parameter.

All water quality data in the DBHYDRO database were reviewed for consistency and quality. In this database, the field DBKey identifies each DBHYDRO time series. Review of the DBHYDRO datasets indicated that several stations had multiple or duplicate time series (represented by DBKeys) for the same period.

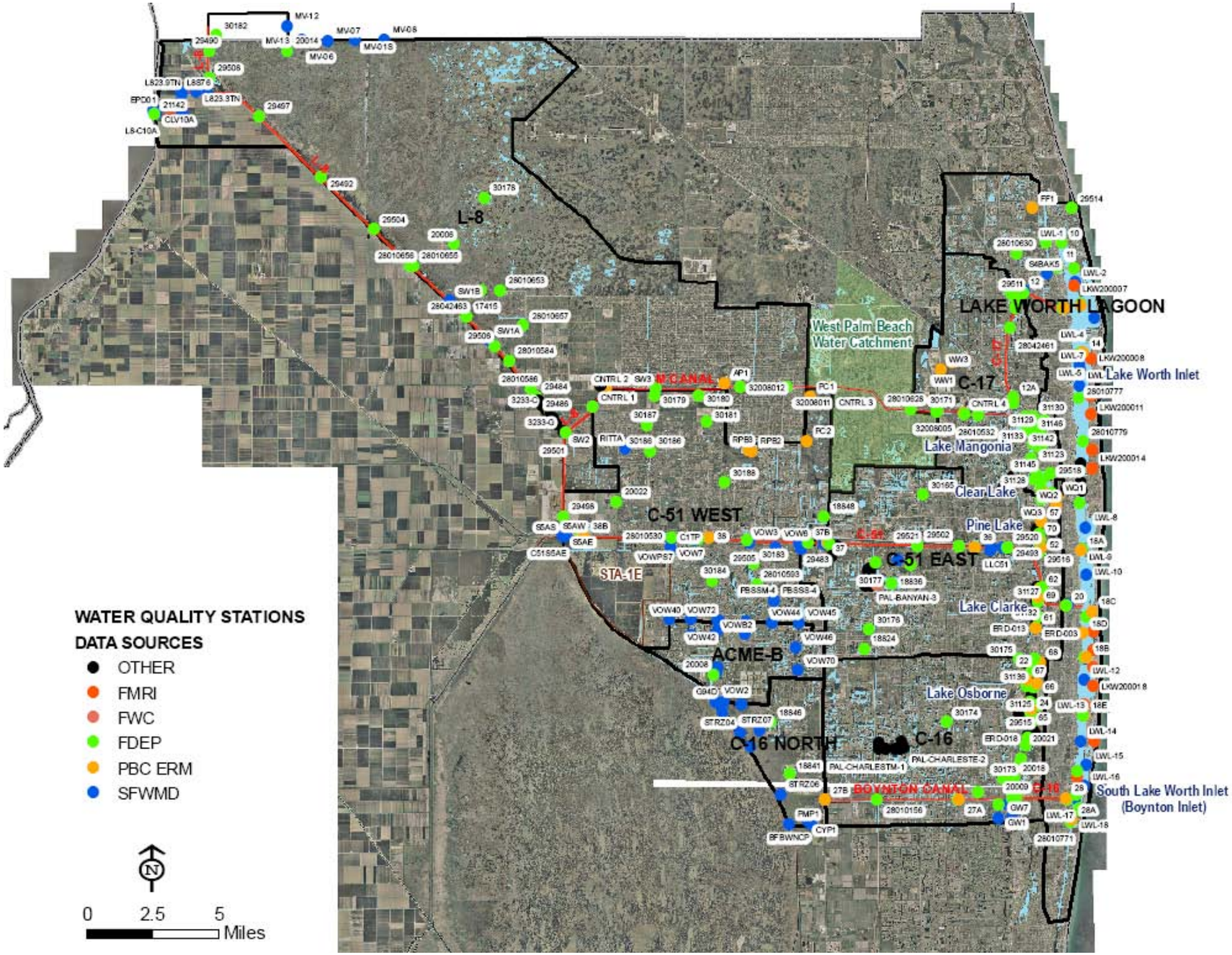

Figure 3.3 Selected Water Quality Stations in the Lake Water Lagoon Watershed

Given the duplication of some SFWMD DBHYDRO data the STORET database, Taylor Engineering (with SFWMD project manager approval) selected the SFWMD data available in the STORET database or chose the DBKeys, which matched the values reported in the STORET database. The following criteria governed the selection of the DBHYDRO datasets absent from the STORET database:

- Given multiple time series (different DBKeys) available for the same station, the time series with the longer time span took precedence.

- Water quality datasets consisted mostly of monthly averages; however, some stations reported multiple samples for a given month. Given more than one sample available for the same month, the mean value for all stations provided the final data point in the dataset.

The following criteria governed the removal of data points for all datasets:

- Duplicates, field blanks, times series data that did not satisfy the surface water criteria (sample collection depth more than 0.5 meters), or other data likely erroneously stored in the database (e.g., a value of 15000 among most other values of 0.005).

- The instrumentation and method of the laboratory water quality sample analysis determine the lowest detectable limit for a given water quality parameter (total phosphorus, for example). In this study, values below the laboratory method detection limits (MDL) were removed when the reported value fell below the detection limits for more than two consecutive months. When the laboratory MDL limit was known, values below that limit were substituted by one half of the MDL value.

3.1 Data Consolidation Methodologies

3.1.1 GIS Data Consolidation

GIS data consolidation consisted of uploading basemap and watershed-related geographic data into an ArcGIS geodatabase. Uploaded GIS layers include SFWMD and LWL watershed boundaries, water, canals, 2004 – 2005 land use land cover, flow, rainfall, and water quality monitoring station

locations. All GIS base map and all layers produced during the GIS analysis reference the Florida State Plane Coordinate System, East Zone, Feet, Horizontal Datum NAD83 (HARN) projection and the NGVD 29 vertical datum.

3.1.2 Meteorological and Hydrological Data Consolidation

Taylor Engineering stored all meteorological, hydrological, and water quality time series data in a Microsoft Access database. The tables in this database are also incorporated in the project's Arc GIS personal geodatabase, which includes the base map collected for the study as well as the data generated from the statistical and geospatial data analysis.

3.2 Data Analysis Methodologies

3.2.1 GIS Data Reclassification

GIS data reclassification consisted of grouping the Florida Land Use Classification Code System (FLUCCS) land use categories in the 2004 – 2005 SFWMD land use and land cover GIS layer into these major land use categories:

- Beach
- Agriculture, pasture and cropland
- Forest, rangeland, and barren land
- Water
- Wetlands
- Low density residential
- Medium density residential
- High density residential
- Low density commercial
- High density commercial
- Extractive
- Light industrial
- Heavy industrial
- Recreational
- Utilities
- Transportation, roads, and highways

Harper (1994) and Harper and Baker (2003), and Mock, Roos & Associates (2005) used these land use categories to reclassify the FLUCCS categories into broader land use categories. Figure 3.4 shows the proposed reclassification of the 2004 – 2005 SFWMD land use land cover layer into the selected categories for this study.

3.2.2 Statistical Data Analysis

Statistical data analysis of rainfall, flow, and water quality data began by calculating monthly statistics — minimum, maximum, 25%, 50% (median), and 75% percentiles, mean, and standard deviation — for all selected stations within the watershed. Taylor Engineering used the Microsoft Office Excel 2003 package for the statistical data analysis.

3.2.3 Water Quality Data Outlier Removal

Single values higher than three times the dataset standard deviation were removed from the datasets. Removing data based only on the three standard deviation criterion may. However, exclude legitimate data from the analysis. Multiple consecutive values higher than three standard deviations recorded for several consecutive samples were kept in the dataset because large changes in the concentrations of a measured parameter at a station may have occurred due, for example, to the installation of a stormwater treatment device at a site or a change in land use upstream of the sampling station.

3.2.4 Water Quality Data Seasonal Analysis

To evaluate differences between the dry and wet seasons, Taylor Engineering separated the water quality data for all stations, at each watershed basin, into two categories — dry season (data collected between November and April) and wet season (data collected between May and October). Taylor Engineering used all available data for all stations in each LWL basin to calculate seasonal statistics. The seasonal analysis considered data collected from stations at a variety of locations (lakes, canals, and the lagoon grouped by watershed basin); data collected with different frequencies (once a month for several months, every week for only a few months); data collected only during the wet or dry season; and data collected during both seasons.

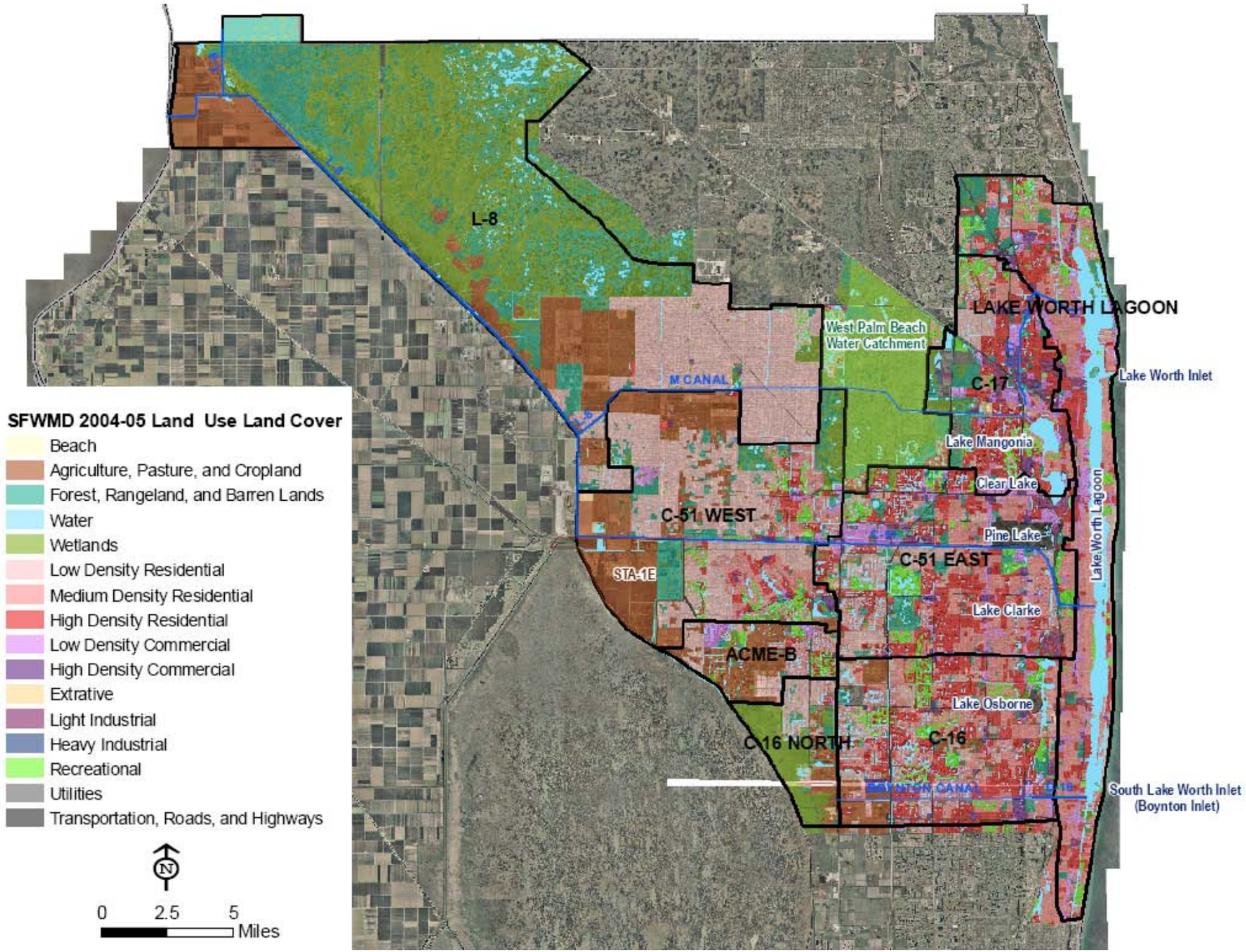

Figure 3.4 SFWMD 2004 – 2005 Land Use Land Cover Categories

3.2.5 Water Quality Data Annual Statistics

Given the assorted data collection periods and the variable number of samples in a year, annual water quality statistics may not represent true year minimums, maximums, 25%, 50% (medians), and 75% percentiles, means, or standard deviations. However, these statistics indicate whether the magnitude of the values measured for a specific parameter changed relative to the previous years. Further, they suggest water quality annual trends at stations reporting data for multiple years.

3.2.6 Water Quality Geospatial Analysis

Taylor Engineering created GIS layers with the annual medians for each water quality parameter for all basins. The geospatial water quality analysis consisted of overlaying the annual medians between 2006 and 2009 on the land use and canal network to identify areas with higher values for each parameter.

The data review and exploratory analysis determined that the available data (hydrologic and water quality data) provided insufficient information to characterize peak pollution loads from stormwater discharges that may occur during storm events, and revealed that the data did not have the characteristics necessary to calculate EMCs for the Lake Worth Lagoon watershed. Monthly grab samples, while sufficient for long-term characterization of general conditions in the watershed, were not timed to coincide with peak flows, although that may have occurred occasionally. No dataset identified in this study combined the intensive storm event-related sampling and location necessary to define a land use EMC.

4. WATERSHED AND BASIN CHARACTERIZATION

A main goal of this study is to evaluate the availability of land use, rainfall, flow, and water quality data to calculate EMCs. The EMCs "represent the concentration of a specific pollutant in the stormwater runoff from a particular land use type" for a basin or watershed (Chow and Yusop, 2008). To accomplish this goal, Taylor Engineering assembled and analyzed existing land uses, meteorological (rainfall), hydrological (flow), and water quality (pH, DO, BOD, COD, NO_2 + NO_3, TKN, OPO_4, TP, TSS, and TDS) data for the LWL watershed basins. This chapter briefly introduces each of the LWL basins, presents land use analysis results, and summarizes the rainfall, flow, and water quality data assembled for each basin.

Two reports — Integrated Water Quality Status (FDEP, 2003) and the Integrated Water Quality Assessment (FDEP, 2006) — for the Lake Worth Lagoon - Palm Beach Coast provided the basis for the LWL watershed basin introduction. These two reports include comprehensive descriptions of each of the LWL watershed basins as well as results from the first efforts to create a Total Maximum Daily Loads (TMDL) for the LWL watershed basins and for the lakes within each basin.

In addition to presenting the land use, rainfall, flow, and water quality data, this chapter briefly describes the basins' water quality data parameters as they changed over time and compares them the Florida Administrative Code (F.A.C.) 62-302 and F.A.C. 62-303(d) water quality standards.

The majority of water bodies reviewed in this study are classified according to the F.A.C. 62-302.400 surface water classification rule as Class III fresh (canals and lakes) and marine (LWL estuary) waters and Class I (M Canal, Lake Mangonia, and Clear Lake).The F.A.C. 62-400 Rule also sets the total dissolved solids (TDS) for Class I waters standards to no higher than 1000 mg/l.

The F.A.C. 62-302 rule sets surface water quality standards for dissolved oxygen of not less than 5 mg/l for fresh water and 4 mg/l for marine waters. The same rule sets standards for pH between 6.0 and 8.5 standard units (su) for Class I waters and Class III fresh waters, and between 6.5 and 8.5 su for Class III marine waters.

The F.A.C. Rule 62-303 "addresses chemical parameters, interpretation of narrative nutrient criteria, biological impairment, fish consumption advisories, and ecological impairment" (FDEP, 2003, 2006), and set the criteria for total phosphorus (TP) and total nitrogen (TN) for some of the water bodies

in the LWL basins. Water bodies placed in this 1998 F.A.C. 62-303(d) list meet "specific data sufficiency and data quality requirements in the state's identification of Impaired Surface Waters (IWR) Rule …" as the list "provides a science-based methodology for identifying impaired waters" (FDEP, 2003, 2006).

Data in the rainfall and flow data plots represent monthly averages for all stations shown in Figures 3.1 and 3.2 and listed in Appendices A and B. The data in the scatter plots for each water quality parameter represent monthly averages for all stations shown in Figure 3.3 and listed in Appendix C.

4.1 Land Use Data Analysis Results

Land use analysis included characterization of land uses within each the eight LWL watershed basins and quantification of acreage of each land use in each basin. The 2005 land use land cover dataset provided by the SFWMD Project Manager provided the basis for the analysis.

Taylor Engineering calculated the area occupied by each land use category for the entire LWL watershed and for each watershed basin (Appendix D). From the four general categories comprising the entire LWL watershed, undeveloped areas (including uplands, wetlands, and water bodies) covered 36.9% of the watershed, agriculture (general agriculture, pasture, cropland, and nurseries) occupied 12.5% of the total watershed area, residential uses (low, medium and high density) occupied 37.7% of the surface, and other development (commercial, industrial, recreational, transportation, etc) covered 12.7%. (Figure 4.1, Table 4.1).

Undeveloped land (uplands with and without forest, wetlands, and water bodies) dominate the L-8 basin (Figure 4.2). Agricultural land clusters on the western side of the LWL watershed (Figure 4.3). Urban land (residential and recreational lands) covers most of the eastern basins (Figure 4.4) together with commercial / industrial land uses (Figure 4.5).

Figure 4.6 compares the allocation of land to each land use category for each basin in the LWL watershed. Urban development occupies more than 50% of the C-17, C-51 East, C-51 West, C-16 and the Lake Worth Lagoon basins. Agriculture, pasture, croplands lands occupy 43.2% of the Acme B basin,

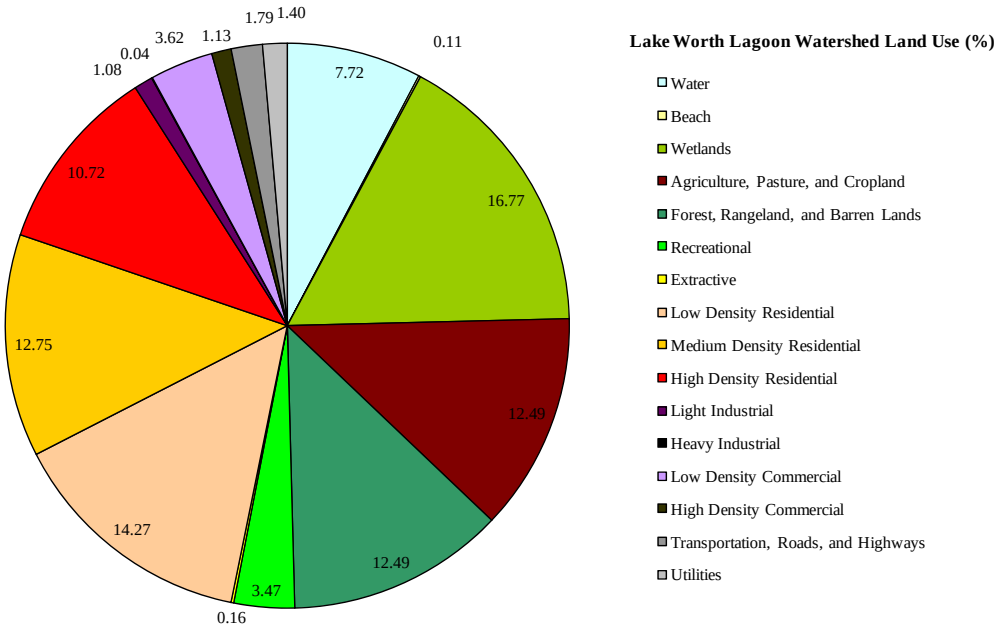

Figure 4.1 Percentage of Land Occupied in 2005 by Each Land Use Category in the Lake Worth Lagoon Watershed

Table 4.1 Natural and Developed Area Allocation in the LWL Watershed

Land Use Category	Percentage
Wetlands	16.7%
Forest, rangelands, and barren lands (beaches and other non-vegetated areas)	12.5%
Water (LWL, lakes, reservoirs, and canals)	7.7%
Total Undeveloped	**36.9%**
Agriculture, pasture, croplands (row crop production, citrus groves, nurseries, or pasture)	**12.5%**
Low density residential	14.3%
Medium density residential	12.8%
High density residential	10.7%
Total Residential Developed	**37.7%**
Commercial, industrial, extractive	6%
Recreational land uses (golf courses, parks, and athletic fields)	3.5%
Utilities, infrastructure, and transportation	3.2%
Total Other Developed	**12.7%**
Total Developed	**50.4%**

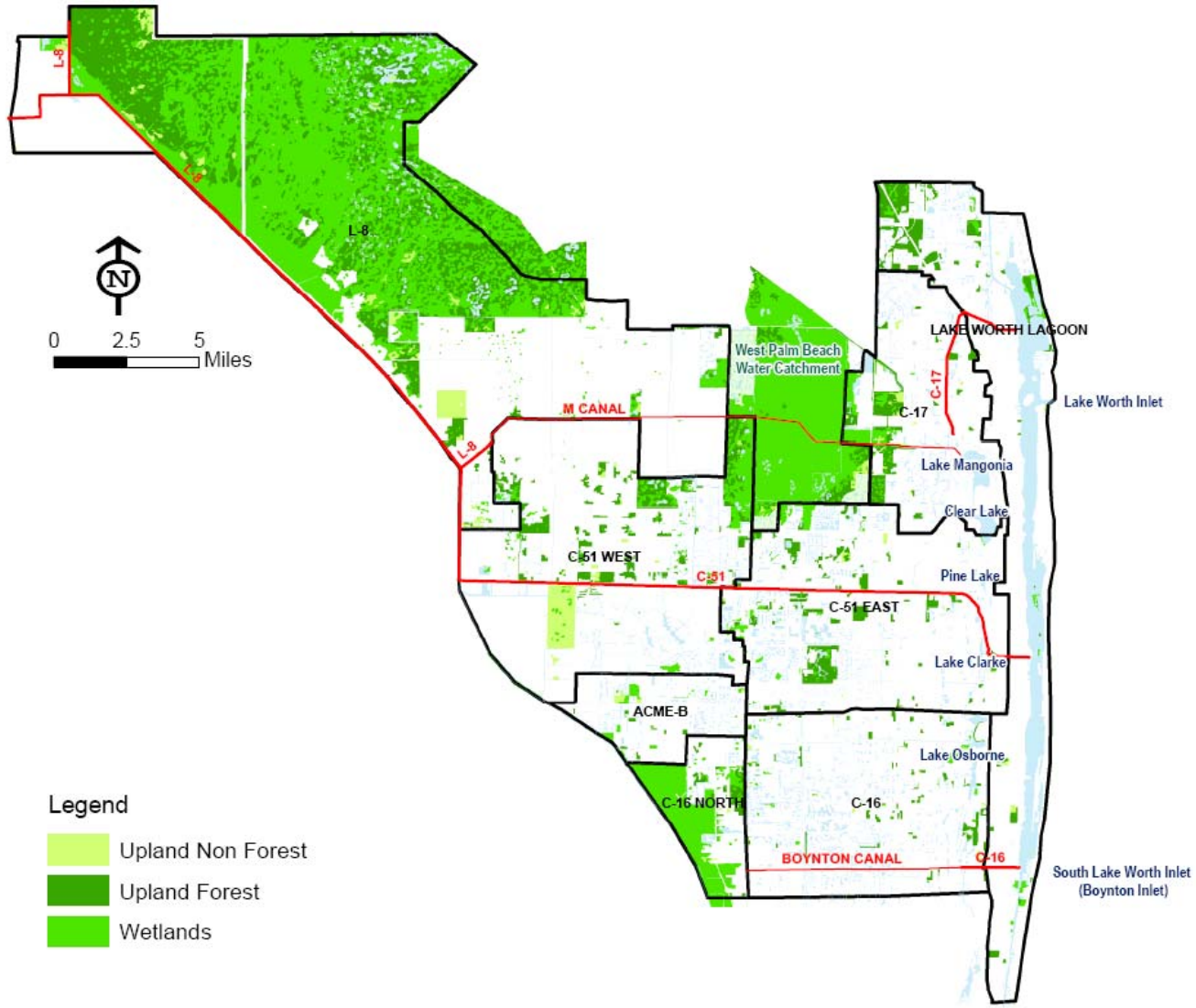

Figure 4.2 Undeveloped Lands in the LWL Watershed

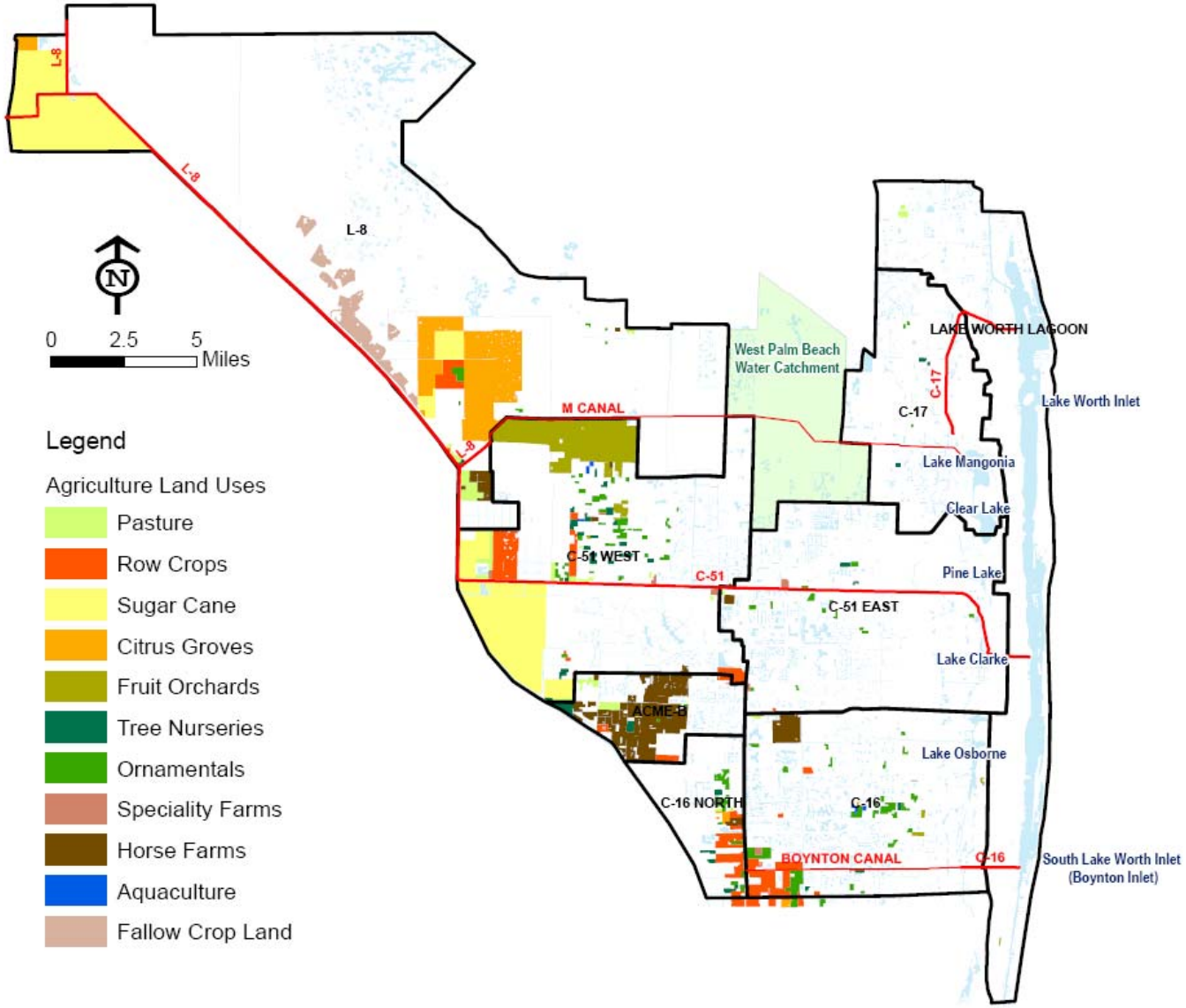

Figure 4.3 Agriculture Land Uses in the LWL Watershed

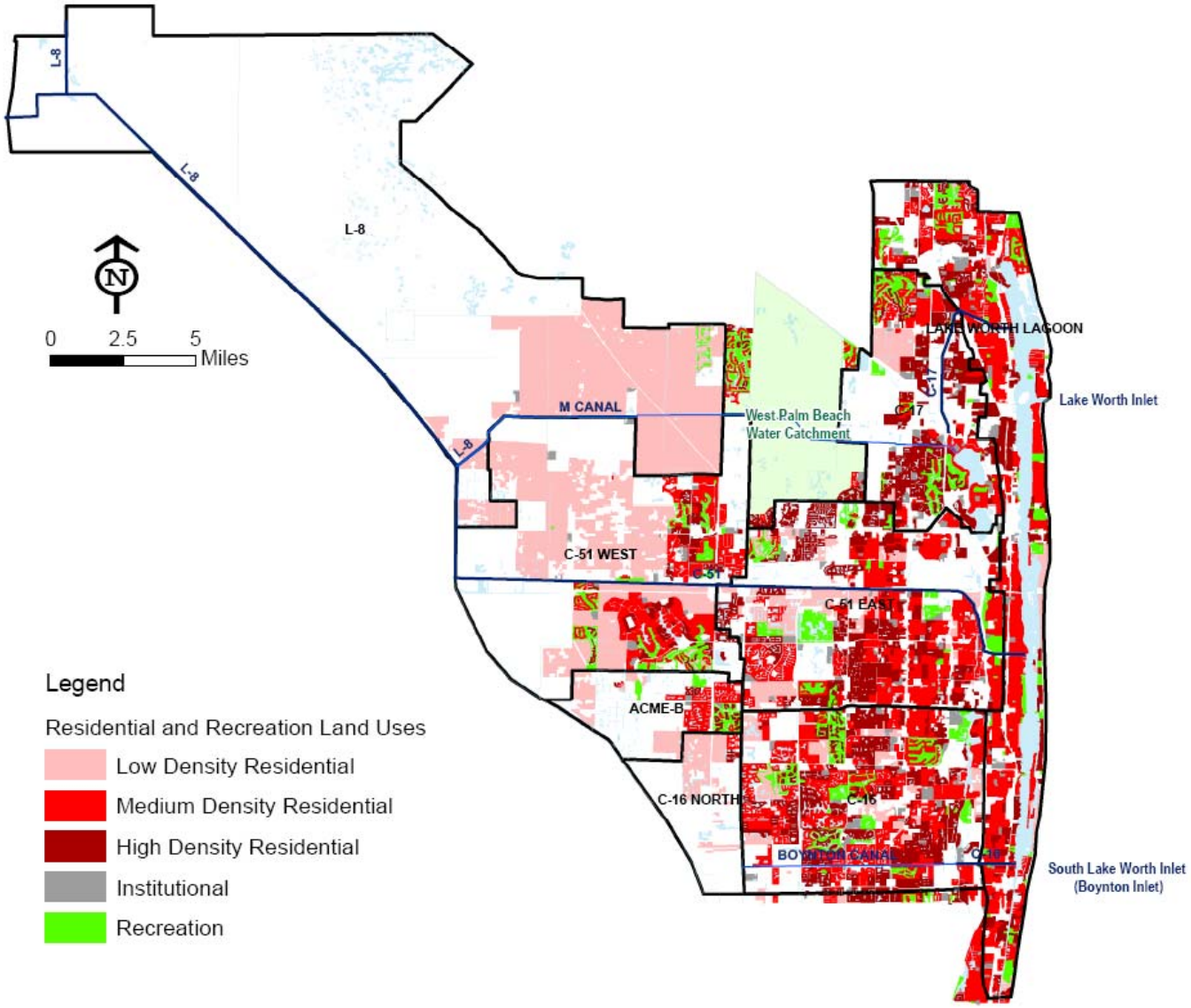

Figure 4.4 Developed Land Uses (Residential and Recreation) in the LWL Watershed

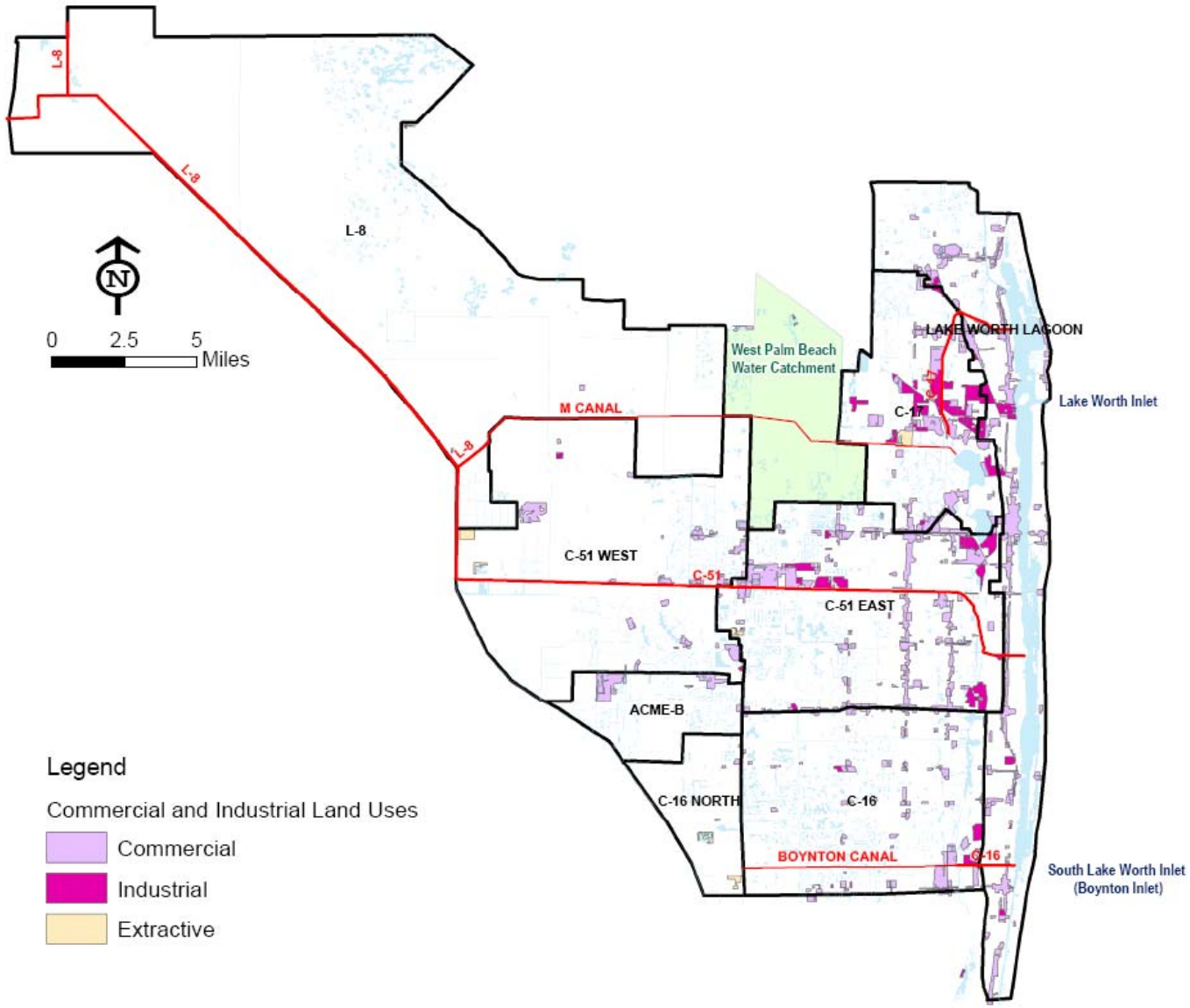

Figure 4.5 Developed Land Uses (Commercial and Industrial) in the LWL Watershed

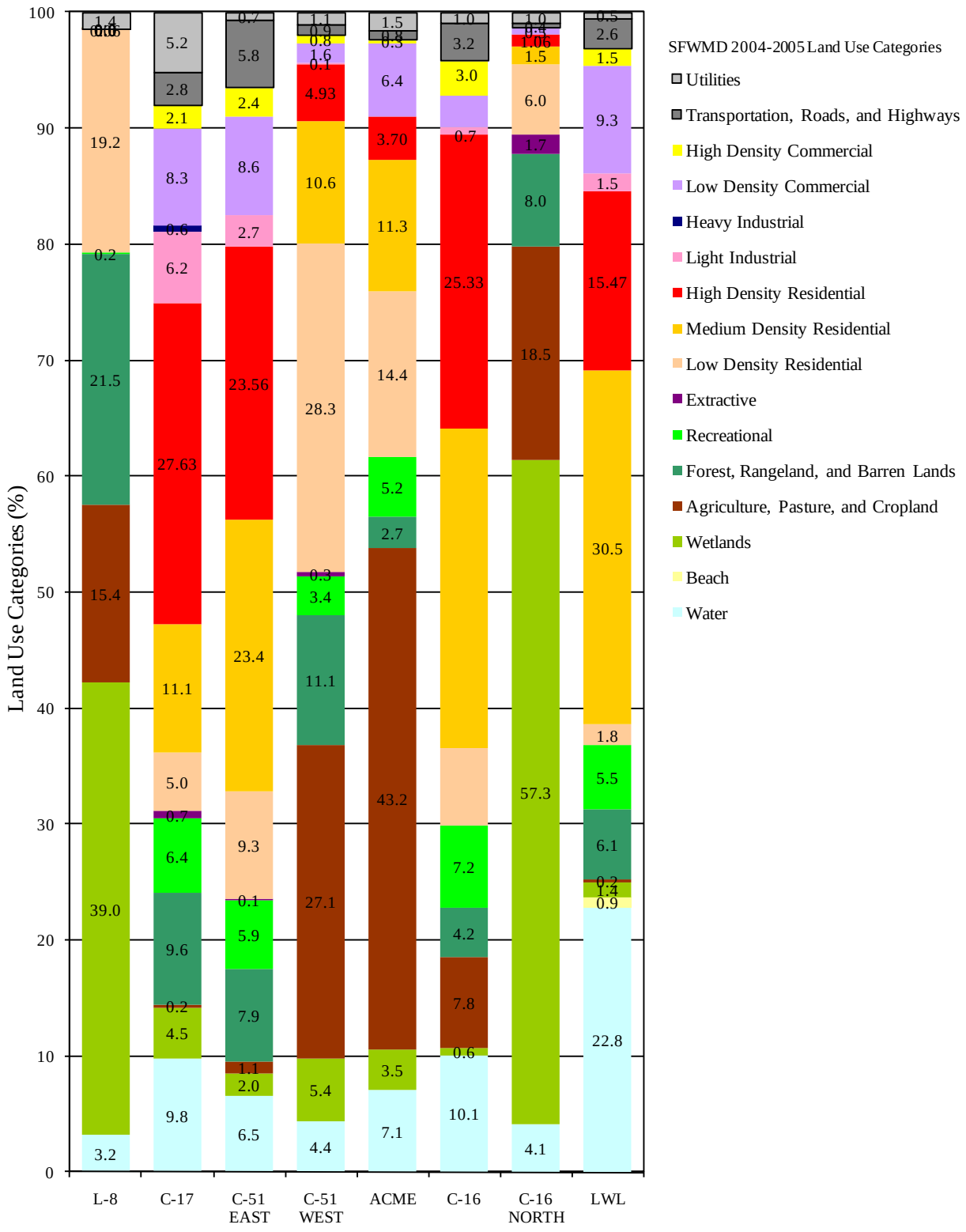

Figure 4.6 Percentage of Each Land Use Category for Basins in the LWL Watershed

27.1% of the C-51 West basin, 15.4% of the L-8 basin, and 18.5% of the C-16 North basin. Wetlands are the major land use in the L-8 basin (39%) and the C-16 North (57.3%) basins. Forest, rangelands, and barren lands category is larger in the L-8 (21.5%) and C-51 West (11.1%) basins. The basins with the least undeveloped lands (wetlands plus forest, rangelands, and barren lands) are the C-16 North (65.2%), the L-8 (60.5%), the C-51 West (16.4%), and the C-17 (14%).

4.2 Basin Summaries

The basin summaries provided below further detail the land use allocations for each basin. Presented in an order similar to the drainage pattern within the watershed, the basin summaries begin at the northwest corner of the LWL watershed with the L-8 basin, followed by the C-17 to the east. Summaries continue with the watershed middle basins, C-51 West and C-51 East, and the southern basins Acme B and C-16 North on the west side of the watershed and the C-16 on the east side of the watershed. This section ends with land use characteristics of the LWL basin, including the Lake Worth Lagoon.

4.2.1 L-8 Basin

The L-8 basin, located in the northwestern part of the watershed and one of the largest basins (142 square miles), lies mostly in northern Palm Beach County. A very small area of the basin (several acres) lies in southwestern Martin County. Several water control districts — the Northern Palm Beach Improvement District, Indian Trail Improvement District, and Seminole Water Control District — have water management responsibilities in parts of the L-8 basin.

Based on 2004 – 2005 land use classification (Figure 3.4), the majority of the basin surface area is undeveloped. Wetlands (dominated by cypress, ponds and sloughs, freshwater marsh, and wet prairie) cover approximately 39% of the basin area; upland forest, mainly pine flat woods, covers an additional 21.1% of the area. The J. W. Corbett National Wildlife Refuge and Management Area (JWCWMA) occupies most of the undeveloped area. The predominant land uses in the developed areas are agriculture, pasture, croplands (15.4% of the basin area). Agricultural land (primarily sugar cane fields, citrus groves, and row crops) occupy 15.4% of the basin, while urban/residential land use (mostly single family residential) occupies 19.3% of the area.

The L-8 Canal, which drains the L-8 basin, originates at the southeastern edge of Lake Okeechobee and extends southeastward and southward to its intersection with the C-51 Canal. The canal

receives stormwater from Lake Okeechobee (FDEP, 2003). The L-8 Canal passes through a large area of agricultural land consisting of citrus groves, sugarcane, and corn before it forms the boundary between the JWCWMA to the north and the Everglades Agricultural Area to the south. After passing the JWCWMA, the canal goes through a second area of agriculture lands until it reaches the C-51 Canal. The L-8 Canal receives relatively high quality runoff from the JWCWMA natural areas (FDEP, 2003). Agricultural runoff water quality to the canal varies with stormwater best management practices (BMPs) used before discharge of that runoff into the canal (FDEP, 2003). Just downstream of the JWCWMA, the L-8 Canal (a Class III water body), flows into the M Canal (a Class I water body) which provides raw potable water to the city of West Palm Beach. The lower water quality in the L-8 Canal may impact the city's potable water supply.

According to the FDEP reports (2003, 2006) and the 2005 F.A.C. 62-303(d) list of impaired water bodies (FDEP 2005a), the waters of the L-8 Canal are impaired due to high levels of nitrogen and low DO (DO lower than 5 mg/l). Inputs of nitrogen and/or phosphorus typically increase the biological activity and reduce the levels of DO in the water. In the L-8 Canal, the TN value of 1.951 mg/l for samples collected between January 1997 and June 2004 caused the canal's listing.

4.2.1.1 Meteorological Data Analysis

Reported daily rainfall amounts for each station within the L-8 basin vicinity were summed to obtain a monthly total for each station. Totals for each month for each station were then averaged to provide an average basin rainfall for each month. Figure 4.7 shows the rainfall monthly averages between 1990 and 2008 for the four rainfall stations (Figure 3.1, Appendix A) in the L-8 basin vicinity. The highest rainfall events occurred during 1993, 2001, and 2004.

4.2.1.2 Hydrological Data Analysis

Figure 4.8 shows the monthly flow averages between 1990 and 2008 measured at the two flow stations (Figure 3.2, Appendix B) in the L-8 basin. Station M CNL-L8, no longer active, was located on the southern section of the L-8 Canal. The CWPB2_P stations, located close to the intersection of the L-8 Canal with the M Canal, started collecting data in 2006. Highest flows in the L-8 Canal coincided with the largest rainfall events (1993, 2001, and 2004).

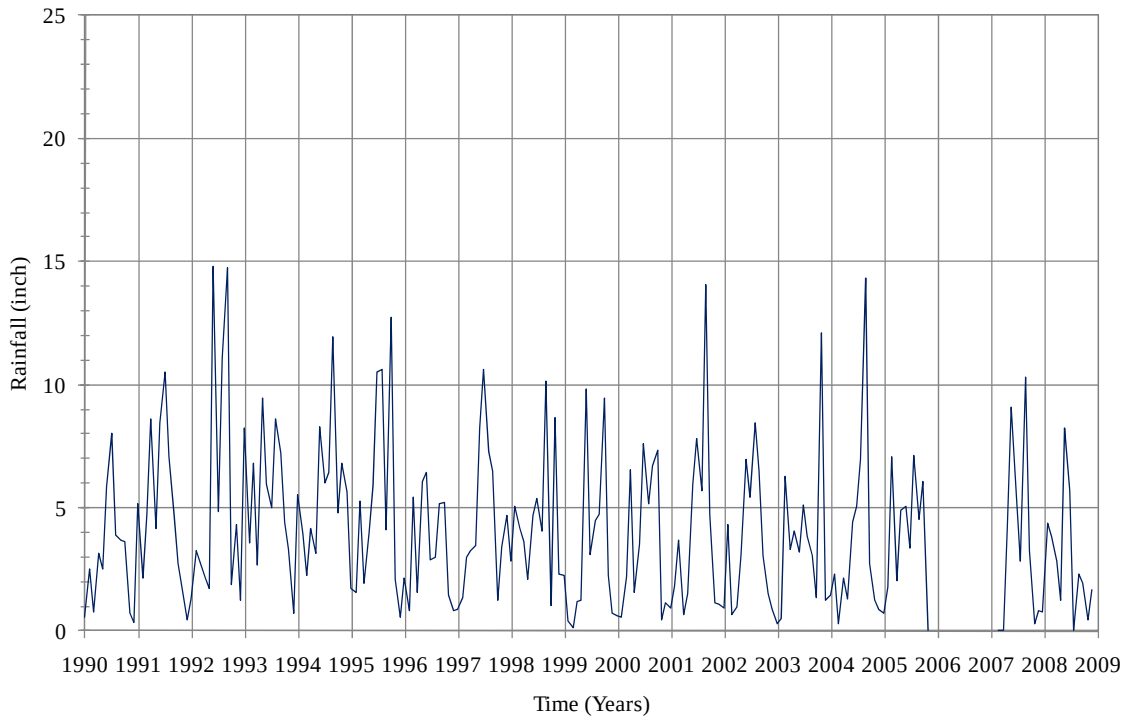

Figure 4.7 Monthly Average Rainfall for the L-8 Basin Stations

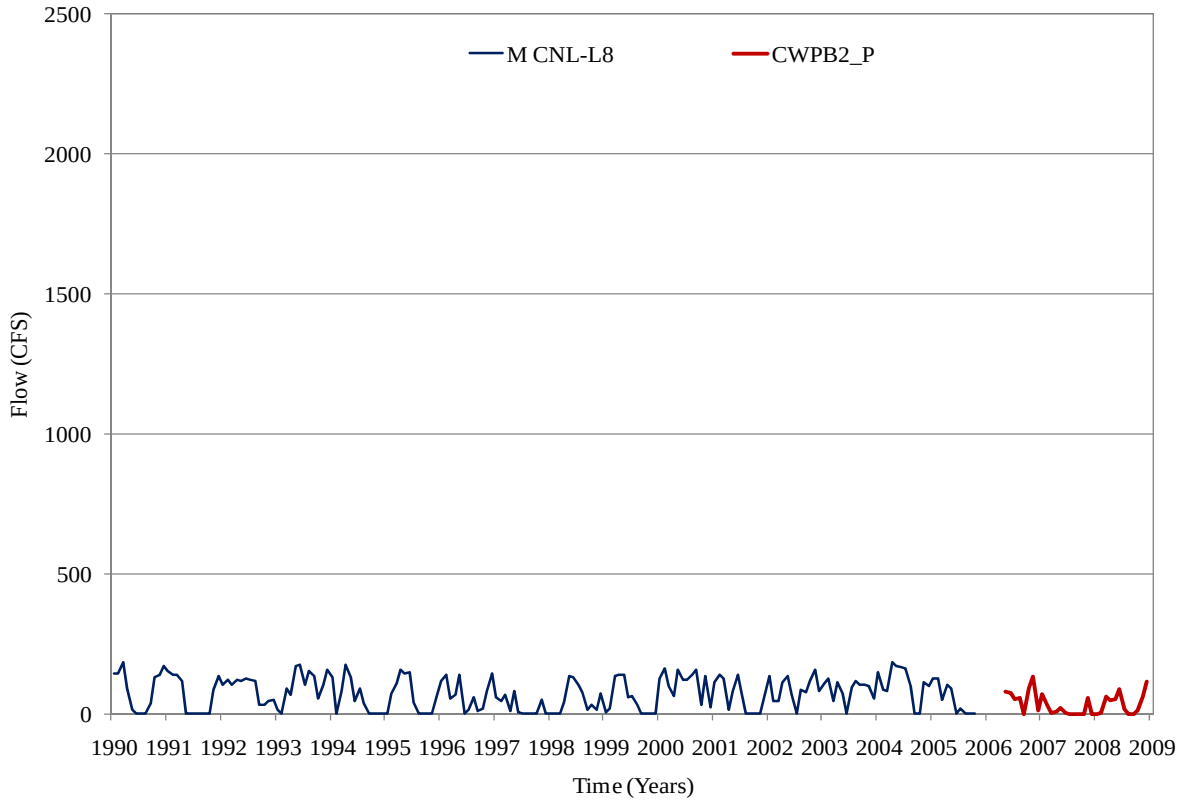

Figure 4.8 Stream Flow Annual Averages for the L-8 Basin

4.2.1.3 Water Quality Data Analysis

Figure 4.9 through 4.17 shows the water quality monthly averages between 1990 and 2008 measured at the 58 stations located in the L-8 basin (Figure 3.3, Appendix C). Figure 4.9 shows that very few pH samples collected between 1990 and 2008 in the L-8 basin exceeded rule F.A.C. 62-302 surface water quality standards for pH (6 – 8.5 su). Figure 4.10 shows that 187 out of a total of 539 samples collected in the basin fall below the F.A.C. 62-302 rule for the surface water quality standards for DO (minimum 5 mg/l.)

Taylor Engineering found very little BOD data (Figure 4.11) and no COD data for the L-8 Canal. BOD values varied between 0 and 6 mg/l. Total nitrogen includes a readily available nitrogen species measured by NO_3+NO_2 (Figure 4.12) and other forms of nitrogen measured as TKN (Figure 4.13). The analysis of Figures 4.12 and 4.13 suggest a strong contribution from TKN to the impairment of the canal waters (see Section 4.2.1), as the majority of the TKN values reported in the basin exceed 2 mg/l, a median higher than the total nitrogen median reported for the canal in the 1998 F.A.C. 62-303(d) list. The majority of the NO_3+NO_2 (Figure 4.12) values reported in the basin fall below 1 mg/l.

Figure 4.14 and 4.15 show OPO_4 and TP data for the L-8 basin. The majority of the values reported for OPO_4 are about one half of the values reported for TP during the same data period. Figure 4.16 shows the TSS for the L-8 basin. The majority of the data reported fall below 100 mg/l.

Figure 4.17 shows the TDS values reported for the L-8 basin. For the Class I waters (e.g., M Canal and Lake Mangonia) the total dissolved soils (TDS) F.A.C. 62-302 surface water quality criteria states a maximum of 1000 mg/l (FDEP, 2008). The L-8 Canal flows into the M Canal, and influences the water quality in the canal. All reported values for the basin were above the 1000 mg/l, which suggests that TDS are not an issue in the L-8 basin.

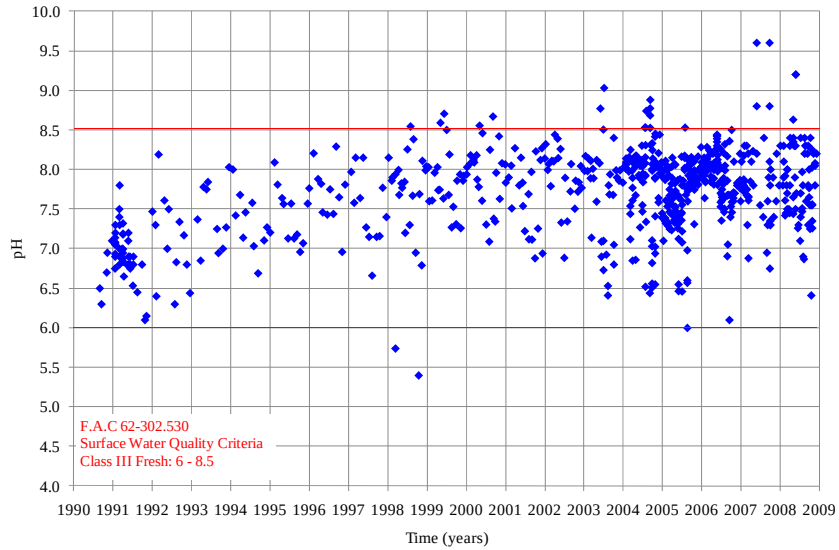

Figure 4.9 pH Monthly Averages for the L-8 Basin Stations

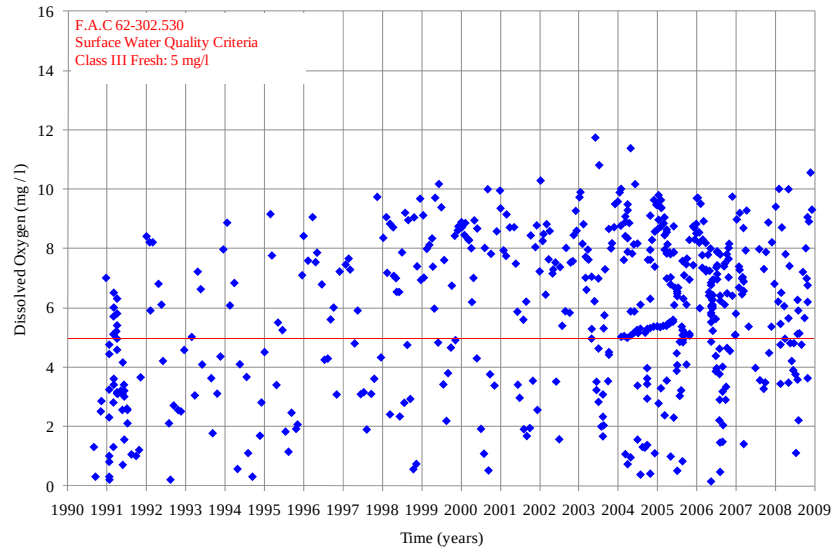

Figure 4.10 DO Monthly Averages for the L-8 Basin Stations

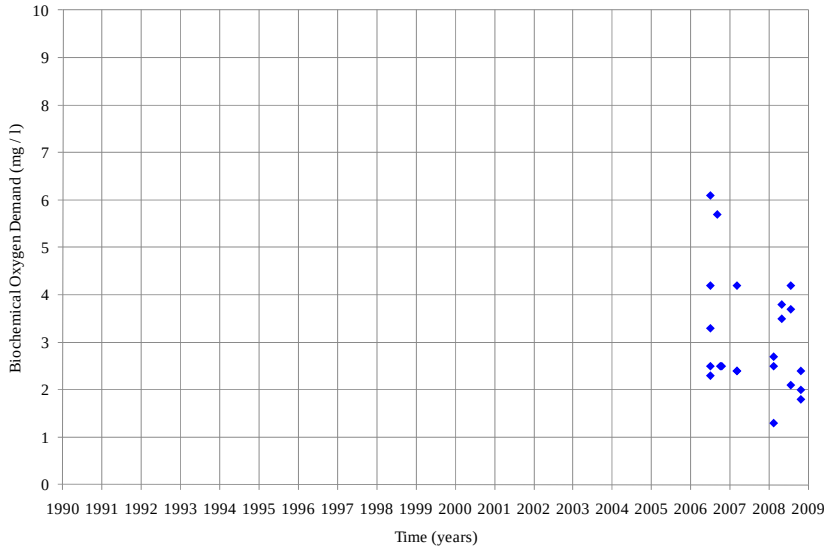

Figure 4.11 BOD Monthly Averages for the L-8 Basin Stations

No data found

COD Monthly Averages for the L-8 Basin Stations

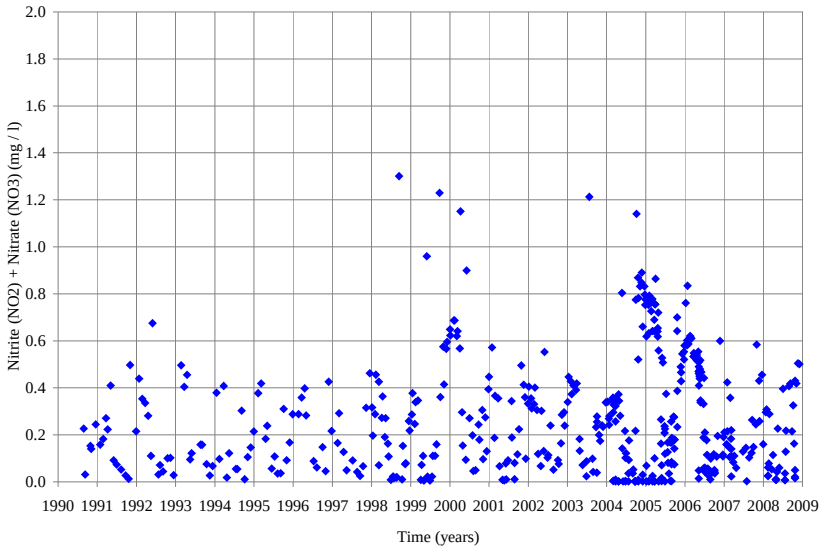

Figure 4.12 NO_2+NO_3 Monthly Averages for the L-8 Basin Stations

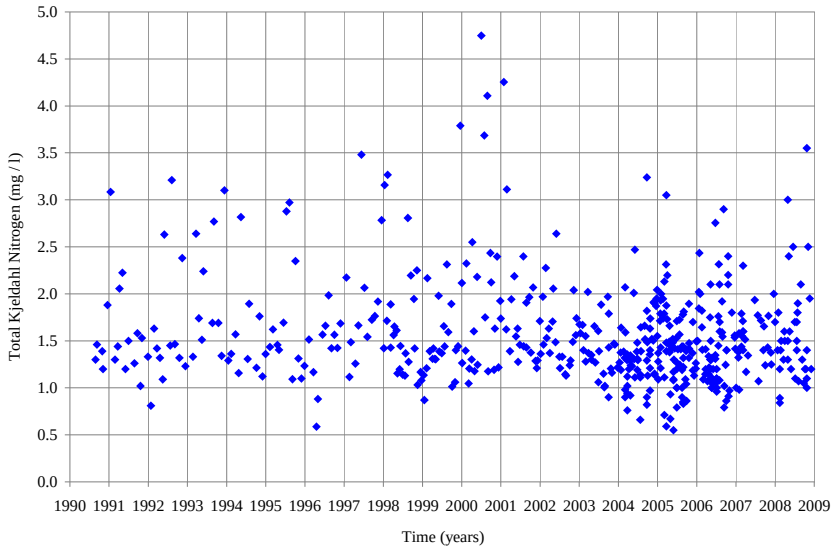

Figure 4.13 TKN Monthly Averages for the L-8 Basin Stations

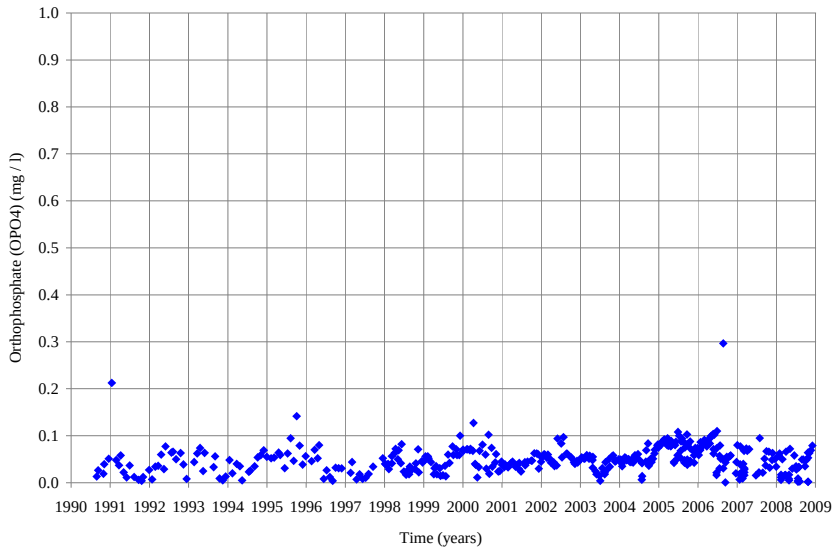

Figure 4.14 OPO_4 Monthly Averages for the L-8 Basin Stations

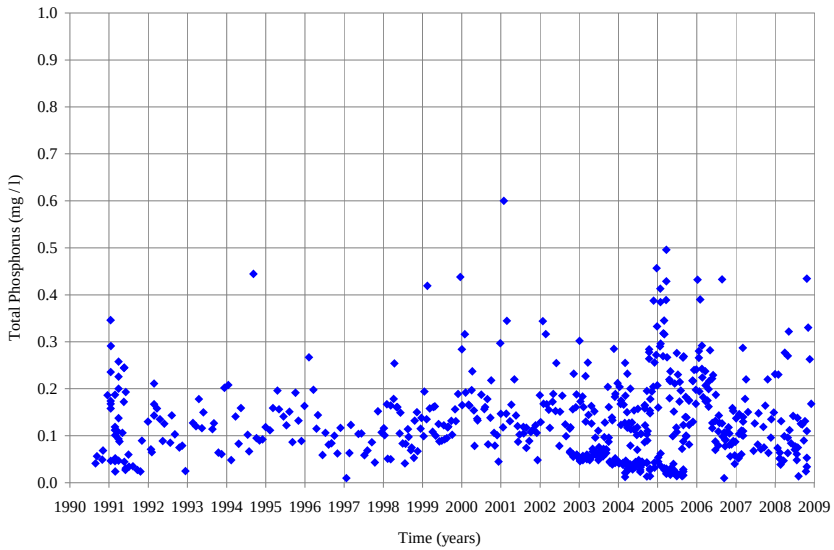

Figure 4.15 TP Monthly Averages for the L-8 Basin Stations

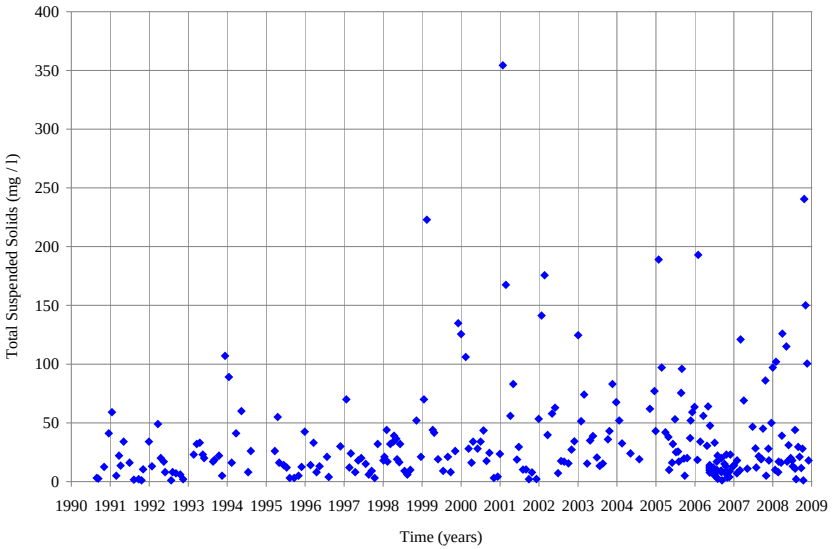

Figure 4.16 TSS Monthly Averages for the L-8 Basin Stations

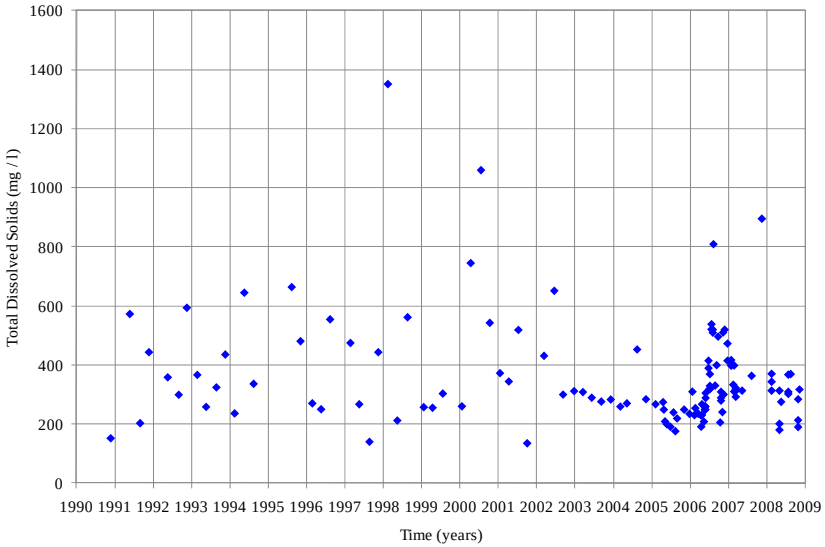

Figure 4.17 TDS Monthly Averages for the L-8 Basin Stations

4.2.2 C-17 Basin

The C-17 basin covers approximately 33 square miles. In addition to the two canals (C-17 and M Canal), the basin also includes the drainage basin of the Earman River (C-17 Canal) north of the C-51 basin and adjacent to the WPB Water Catchment. The C-17 basin is the third most developed basin in the watershed. Incorporated areas in the basin include West Palm Beach, Palm Beach Gardens, Riviera Beach, Lake Park, Cloud Lake, Glen Ridge, and Mangonia Park. The Northern Palm Beach County Improvement District and the Lake Worth Drainage District manage the basin's secondary drainage canals (FDEP, 2006).

Based on 2004 – 2005 land use classifications (Figure 3.4), urban/residential land uses account for approximately 67.3% of the land area in the basin: 43.8% of the total area is residential (5% low-density, 11.1% medium density, and 27.6% high density residential); 6.4% is recreational, 10.4% is commercial, and 6.8% is industrial. Transportation and utilities account for approximately 8% of the land use in the basin. Three major roads cross the basin: the Florida's Turnpike, Interstate 95, Beeline Expressway, and Military Trail. Undeveloped areas in the C-17 basin include upland forest (9.6%), wetlands (4.5%), and water (9.8%). The FDEP assessment study (2006) reports the presence of two wastewater treatment facilities that discharge to surface water within the C-17 basin.

Two main canals cross the C-17 basin: the C-17 Canal and the M Canal. The C-17 Canal provides drainage and stormwater protection for the C-17 basin. It also maintains groundwater levels and prevents saltwater intrusion into the basin. The SFWMD regulates the flow of the canal at the S-44 structure. The C-17 Canal flows north to south, west of the structure. The most northern section of the C-17 Canal flows east and discharges into the LWL. The M Canal flows east and transports potable water from the WPB Water Catchment to Lake Mangonia. No exchange of water occurs between the C-17 and M Canals at their intersection, as the C-17 Canal flows over the M Canal.

The 2005 update of the F.A.C. 62-303(d) list (FDEP 2005a) indicates that the C-17 Canal waters are impaired for DO and nutrients. The origin of the impairment is the inputs of nitrogen and phosphorus, which increase the biological activity and reduce the levels of DO. Samples collected between January 1997 and June 2004 show total nitrogen (TN) median values of 1.016 mg/l and of total phosphorus (TP) of 0.053 mg/l.

4.2.2.1 Meteorological Data Analysis

Reported daily rainfall amounts for each station in the C-17 basin vicinity were summed to obtain a monthly total for each station. Totals for each month for each station were then averaged to provide an average basin rainfall for each month. Figure 4.18 shows the 1990 through 2008 rainfall monthly averages for the six rainfall stations (Figure 3.1, Appendix A) in the C-17 basin vicinity. Rainfall events higher than 15 inches occurred during 1992, 1995, 1999, 2001, and 2004.

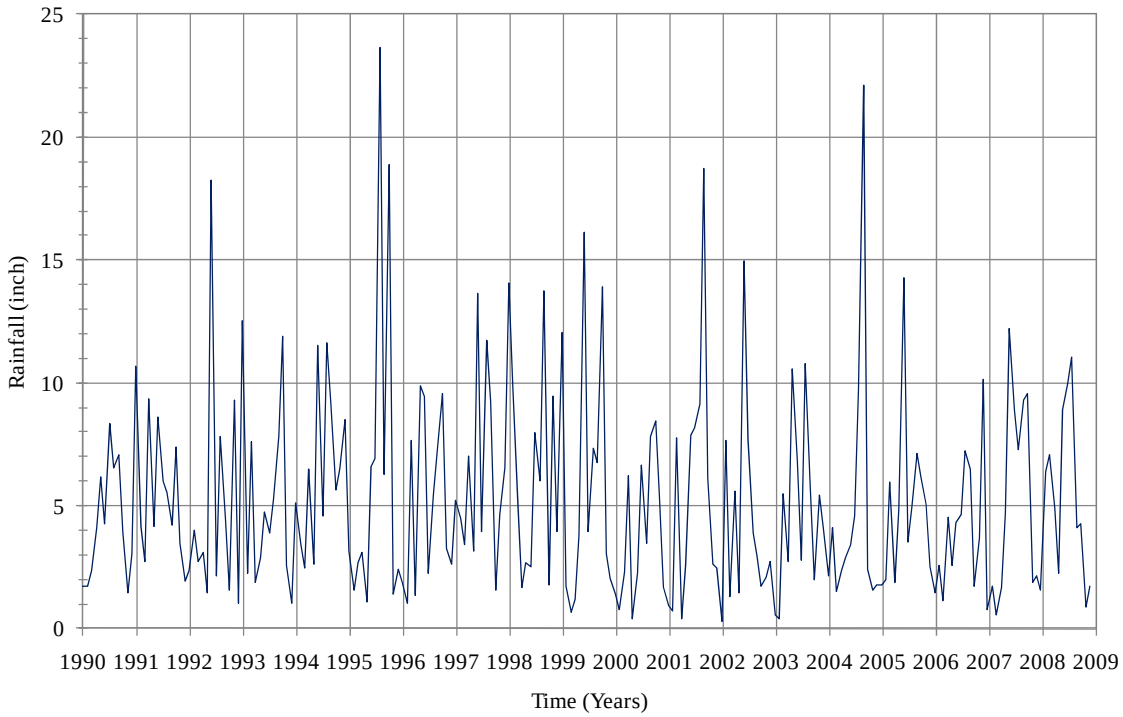

Figure 4.18 Monthly Average Rainfall for the C-17 Basin Stations

4.2.2.2 Hydrological Data Analysis

Figure 4.19 shows the flow monthly averages between 1990 and 2008 measured at S-44 structure in the C-17 basin. Station S44-S is the most eastern station on the C-17 Canal where it discharges to the LWL. Peak flows for the period of record occurred during 1992 and 1993, 1995 and 1996, 1999, 2001, and 2004.

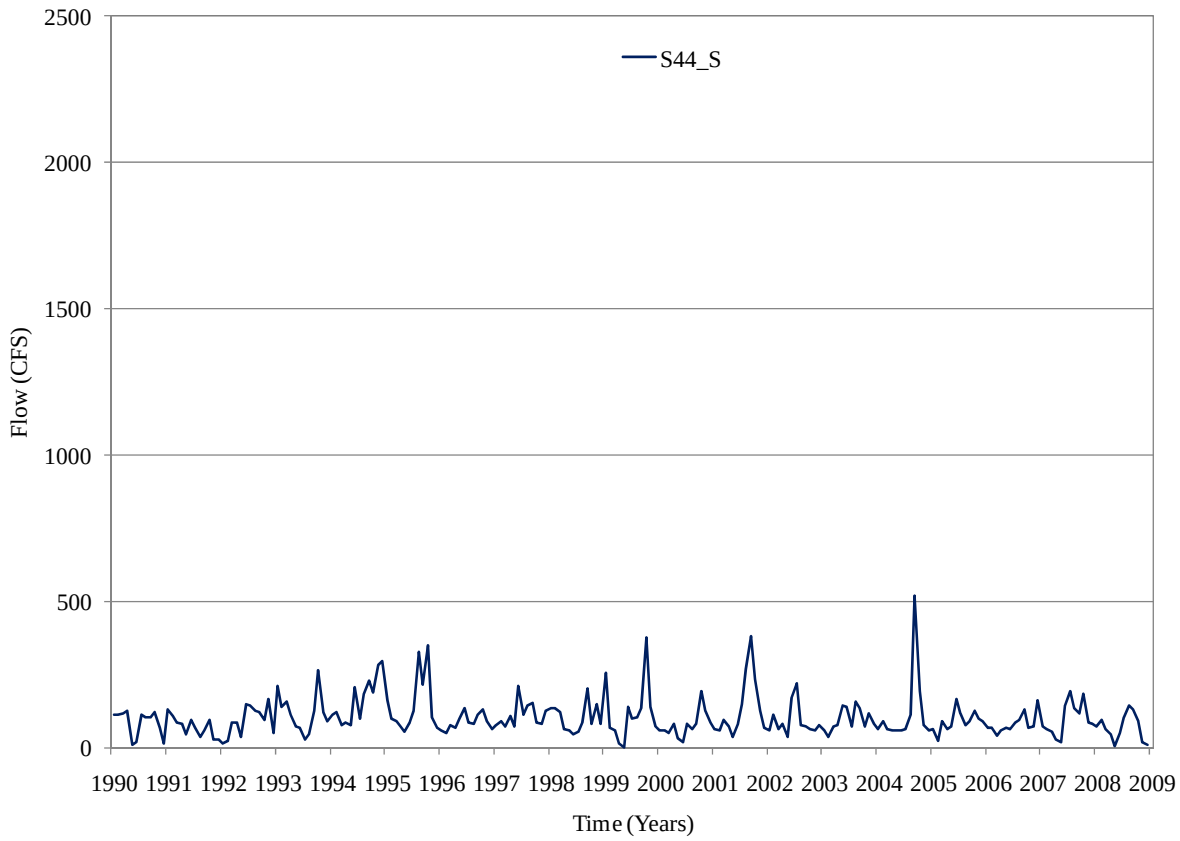

Figure 4.19 Flow Monthly Averages for the C-17 Basin Stations

4.2.2.3 Water Quality Data Analysis

Figures 4.20 through 4.28 show the 1990 through 2008 water quality monthly averages measured at the 40 stations located in the C-17 basin (Figure 3.3, Appendix C). Figure 4.20 shows that very few pH samples collected between 1990 and 2008 in the C-17 Canal exceeded the F.A.C. 62-302 rule surface water quality standards for pH (6– 8.5 su).

The majority of the samples collected in the basin (Figure 4.21) do not exceed the F.A.C. 62-302 rule surface water quality standards for DO (5 mg/l). However, a considerable number (106 out of 245) of samples fall below the standard, which suggests that DO remains an issue in the basin.

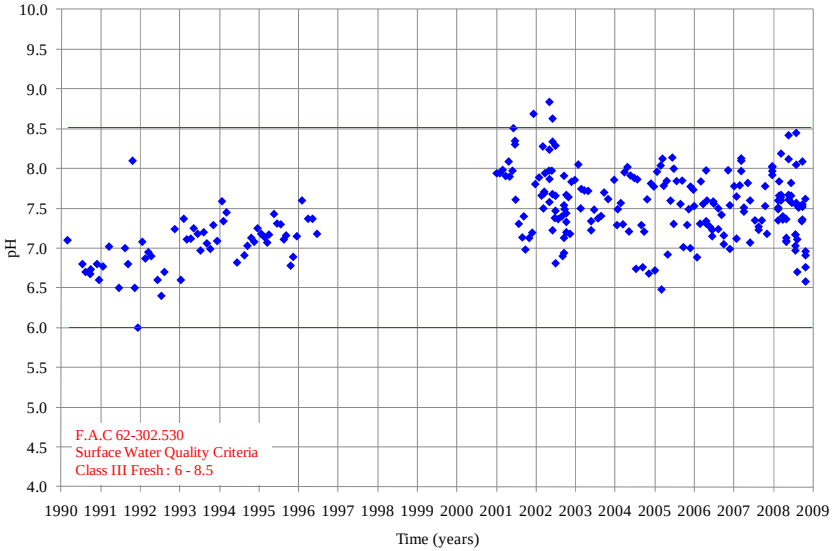

Figure 4.20 pH Monthly Averages for the C-17 Basin Stations

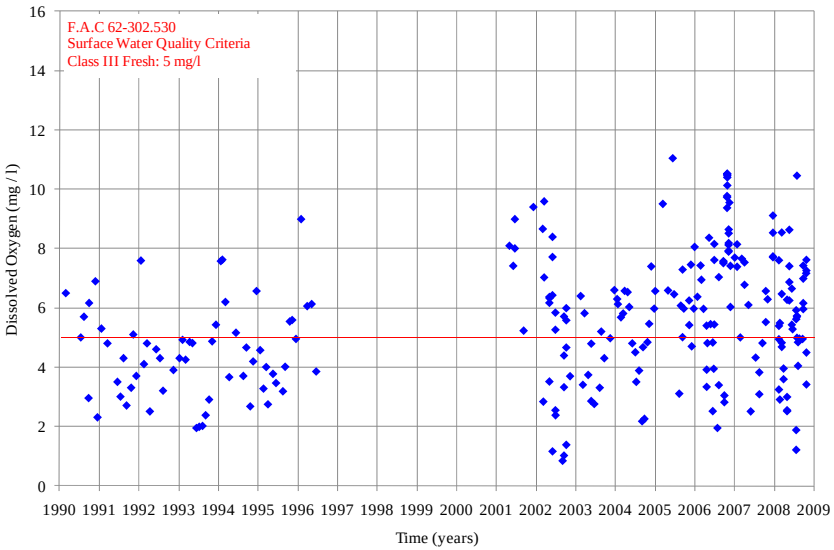

Figure 4.21 DO Monthly Averages for the C-17 Basin Stations

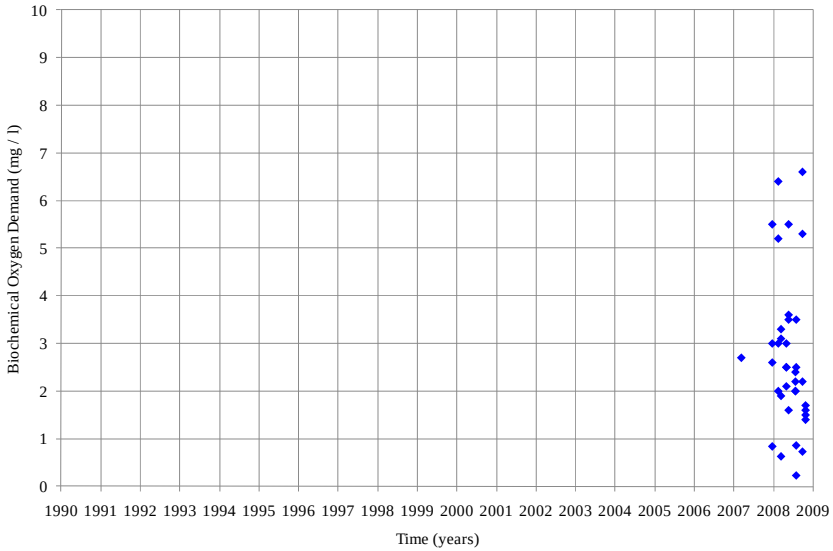

Figure 4.22 BOD Monthly Averages for the C-17 Basin Stations

No data found

COD Monthly Averages for the C-17 Basin Stations

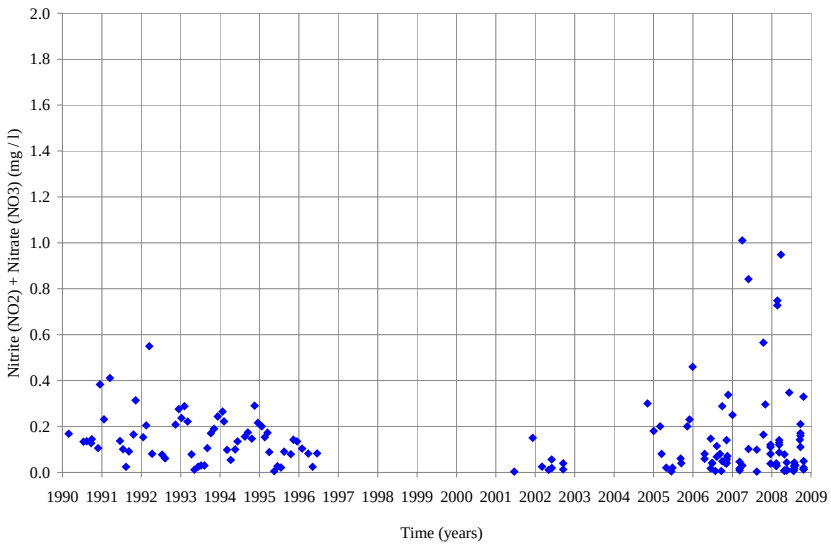

Figure 4.23 NO_2+NO_3 Monthly Averages for the C-17 Basin Stations

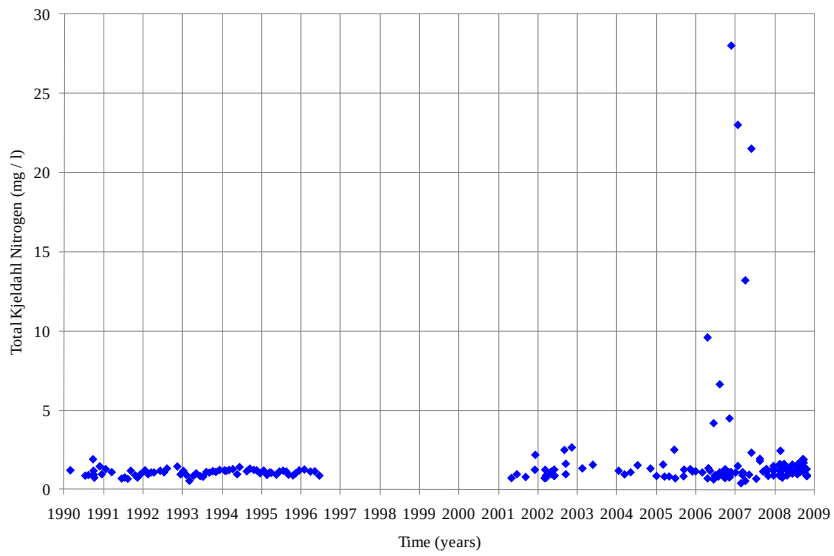

Figure 4.24 TKN Monthly Averages for the C-17 Basin Stations

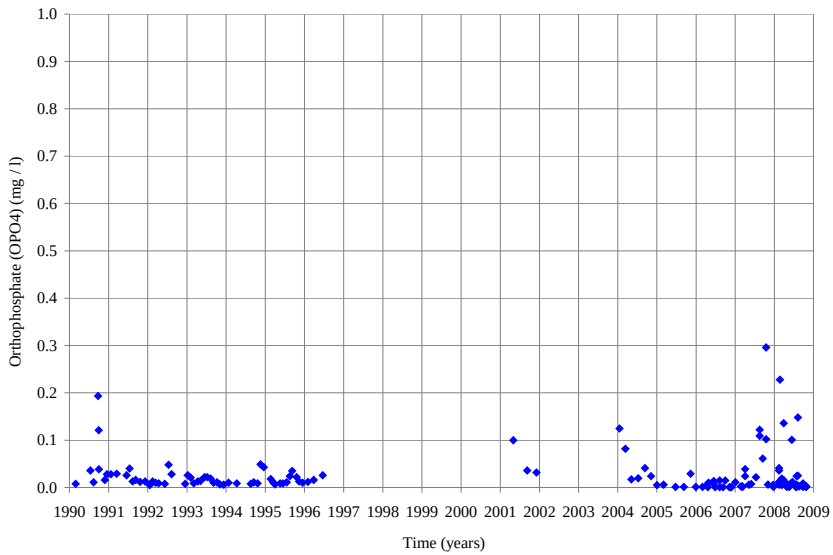

Figure 4.25 OPO_4 Monthly Averages for the C-17 Basin Stations

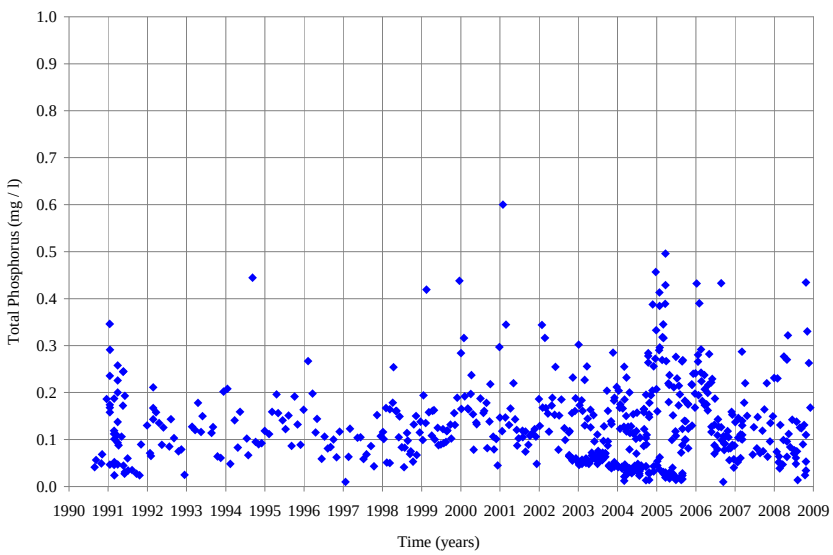

Figure 4.26 TP Monthly Averages for the C-17 Basin Stations

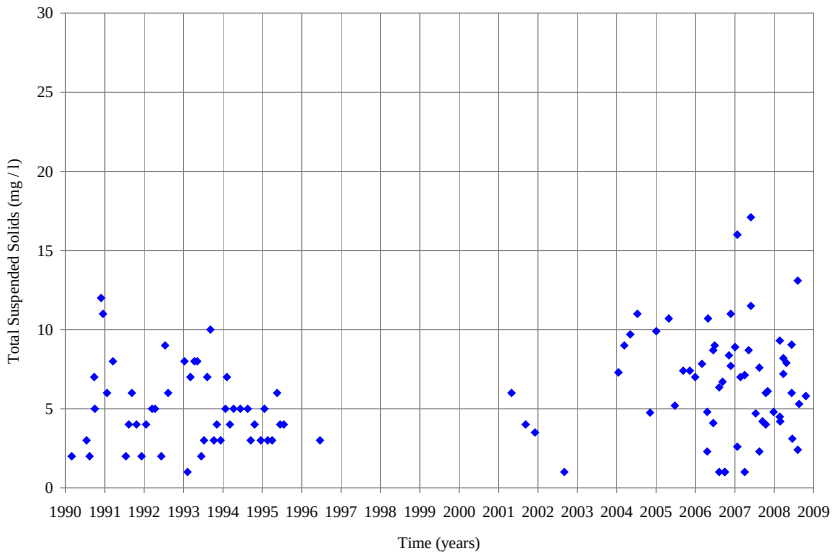

Figure 4.27 TSS Monthly Averages for the C-17 Basin Stations

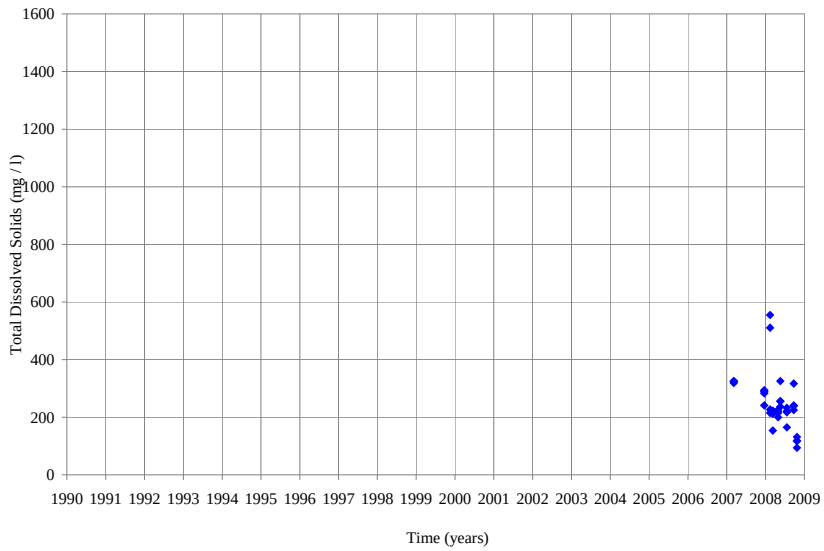

Figure 4.28 TDS Monthly Averages for the C-17 Basin Stations

Only 44 data samples were reported for BOD (Figure 4.22). BOD values varied between 0 and 7 mg/l. Taylor Engineering did not find any COD data for the C-17 basin.

The analysis of Figures 4.23 and 4.24 suggests a strong contribution of TKN to the impairment of the C-17 Canal (see Section 4.2.2), as the majority of the NO_3+NO_2 (Figure 4.23) values from basin fall below 0.2 mg/l and the majority of the TKN values exceed 2 mg/l (Figure 4.24). TKN values are generally higher than the total nitrogen median reported for the canal in the 2005 F.A.C. 62-303(d) impaired waters list (FDEP, 2005a).

Figure 4.25 and 4.26 show OPO_4 and TP data for the C-17 basin. The OPO_4 concentrations fall within the same range of those reported to TP for the same time period suggesting that the majority of the phosphorus in the basin takes the form of OPO_4 (inorganic phosphorus). The majority of the values for either OPO_4 or TP do not exceed the 0.053 mg/l median reported in the 2005 update of the 2005 F.A.C. 62-303(d) impaired waters list (FDEP, 2005a) suggesting improvement of the phosphorus inputs to the basin.

Figure 4.27 shows the monthly average TSS values for the C-17 basin. Most values reported fall below 20 mg/l. Figure 4.28 shows the TDS values reported for the C-17 basin. All but two monthly average values reported fall below 350mg/l.

4.2.3 C-51 West Basin

C-51 West, the second largest basin in the LWL watershed (approximately 74 square miles), includes one incorporated area: Royal Palm Beach. The Village of Wellington, also known as Acme basin A, located just north of the Acme B basin, is part of the C-51 West basin. Typically, Acme B basin discharges to basin A; however, under dry conditions, the reverse may occur (USACE and SFWMD, 2003). Five water control districts have jurisdiction over secondary canals in portions of the C-51 West basin: the Acme Improvement District, the Pine Tree Water Control District, the Indian Trail Improvement District, the Seminole Water Control District, and the Northern Palm Beach County Improvement District. The M Canal extends across the northern part of the C-51 West basin from its juncture with the L-8 Canal to the WPB Water Catchment but does not discharge or receive water from the C-51 Canal.

According to the 2004 – 2005 land use classification (Figure 3.4), urban/residential land uses predominate (over 43.8%) in the basin. Other urban land uses in the basin include commercial (2.4%), industrial (0.1%), recreational (3.4%), and transportation and utilities (2%). Agricultural land uses (mainly sugar cane, fruit orchards, and row crops, pasture and horse farms, and ornamentals) occupy approximately 27.1% of the basin. Other land use percentages include undeveloped land (11.1%) in the form of upland forest (pine flat woods and other coniferous forest), wetlands (5.4%), and water (4.4%).

The C-51 Canal, an extension of the West Palm Beach Canal, is the main surface water canal conveying water in the Palm Beach County area east of the Water Conservation Areas (WCAs). The West Palm Beach Canal (C-51 Canal) extends southeast from the southeastern part of Lake Okeechobee to where it connects to the L-8 Canal, and then east to the Intracoastal Waterway (ICW) at the LWL (at the S-155 structure). The canal provides flood protection and drainage to both the C-51 East and West basins, discharges flood flows from the L-8 watershed, transports excess flows not handled by the L-8 Canal from Lake Okeechobee, and transports storm water drained from the Everglades Agriculture Area (EAA). The canal also supplies water under low natural flows to its basins, maintains groundwater levels, and prevents saltwater intrusion.

Water sources for to C-51Canal include, within its basins, the Lake Worth Drainage District canals E-1, E-2, E-3, and E-4, which can generate very large inflows; the Acme Drainage District canals and the Indian Trail Improvement District canals; Lake Okeechobee; the L-8, L-40, and L-7 canals; and secondary agricultural canals west of the LWL watershed boundary (FDEP, 2006) outside the canal basin. Excess water in the western part of the C-51Canal may exit west to the WCA-1 or east to the LWL.

According to the FDEP reports (2003, 2006) and the 2005 F.A.C. 62-303(d) impaired waters list (FDEP, 2005a), the water quality of the C-51 Canal is impaired due to low DO related to high loadings of nitrogen. Samples collected between January 1997 and June 2004 (FDEP 2005) with a TN median value of 1.891 mg/l contributed to the listing of the C-51Canal for DO. As stated in the FDEP 2006 report, the C-51 Canal "is the largest inflow into the LWL and has a great impact on the health of the estuary, causing extreme fluctuations in salinity levels as well as transporting of pollutants…Runoff from urban and agricultural land uses may affect water quality in the C-51 Canal and the network of canals flowing into it."

4.2.3.1 Meteorological Data Analysis

Reported daily rainfall amounts for each station in the C-51 West basin vicinity were summed to obtain a monthly total for each station. Totals for each month for each station were then averaged to provide an average basin rainfall for each month. Figure 4.29 shows the 1990 and 2008 rainfall monthly averages for the three rainfall stations (Figure 3.1, Appendix A) in the C-51 West basin vicinity. The following years had rain events above 15 inches: 1994, 1999, 2005, and 2008.

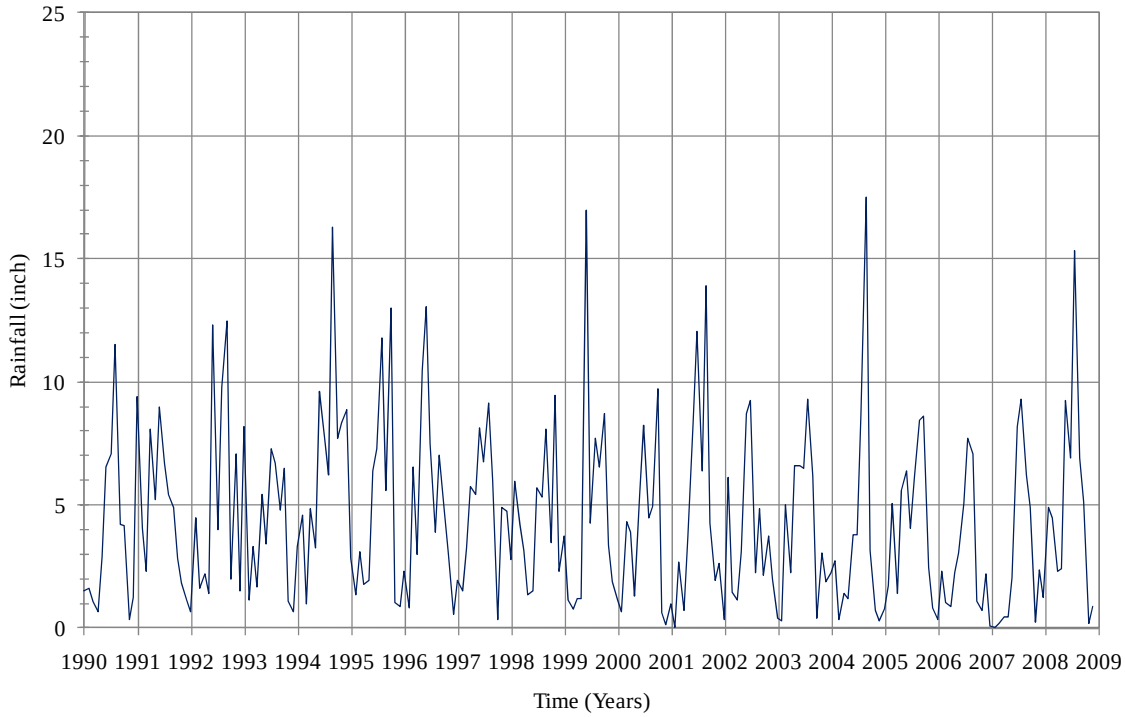

Figure 4.29 Monthly Average Rainfall for the C-51 West Basin Stations

4.2.3.2 Hydrological Data Analysis

Figure 4.30 shows the monthly flow averages between 1990 and 2008 measured at the four flow stations (Figure 3.2, Appendix B) in the C-51 West basin. Pump stations ACME3 and ACME4, located east along the C-51 Canal, registered peak flows during 1993, 1995, 1999, 2001, 2007, and 2008.

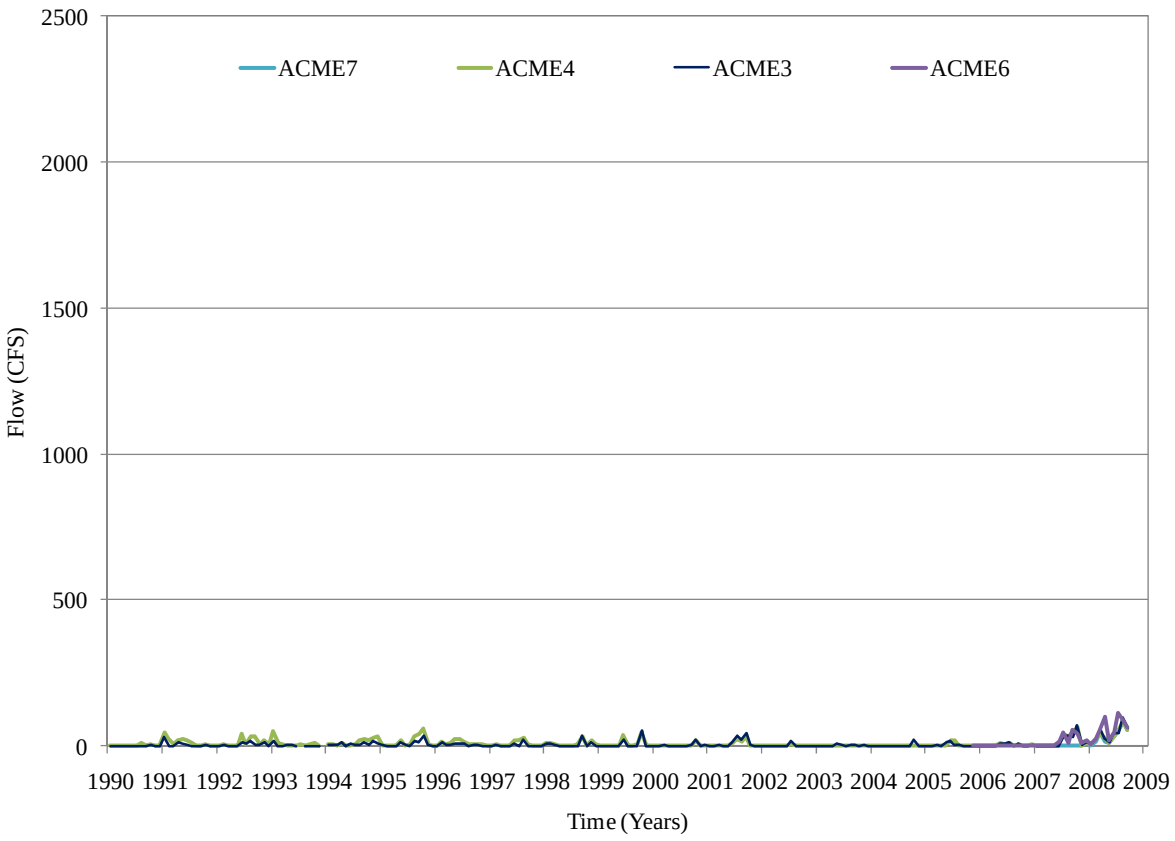

Figure 4.30 Flow Monthly Averages for the C-51 West Basin Stations

4.2.3.3 Water Quality Data Analysis

Figures 4.31 through 4.39 show the 1990 through 2008 water quality monthly averages measured at 47 stations (Figure 3.3, Appendix C) located in the C-51 West basin. Figure 4.31 shows 11 pH samples (4 above 8.5 su and 7 below 6 su) exceeded the F.A.C. 62-302 rule surface water quality standards (6 – 8.5 su) for pH in fresh waters.

Figure 4.32 shows that 359 out of 780 DO samples fall below the F.A.C. 62-302 rule standard (higher or equal to 5 mg/l). This suggests that low DO is an issue in the basin. Taylor Engineering found very little BOD (Figure 4.33) and no COD data for the C-51 West Canal. BOD values in the basin varied between 0 and 4 mg/l.

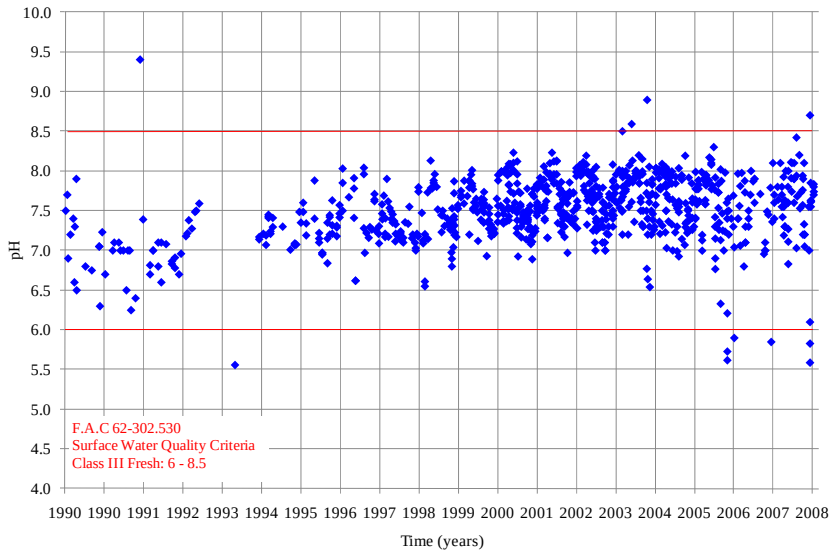

Figure 4.31 pH Monthly Averages for the C-51 West Basin Stations

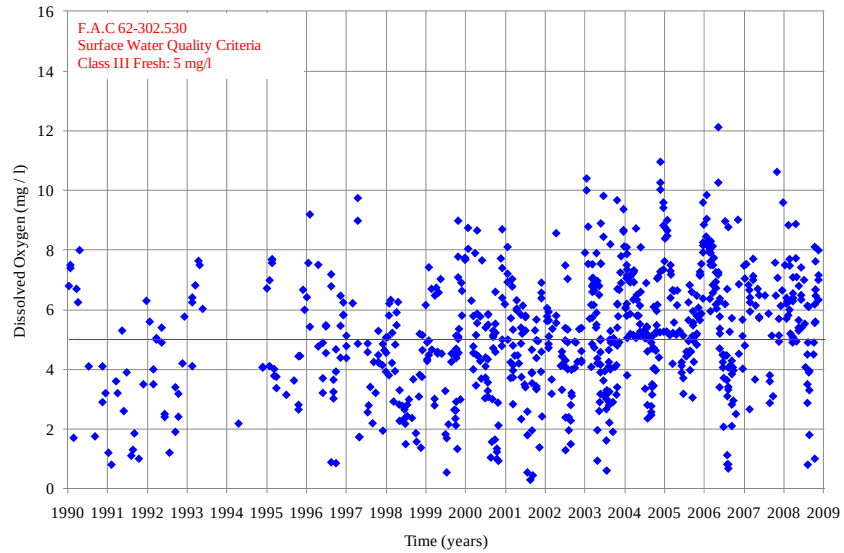

Figure 4.32 DO Monthly Averages for the C-51 West Basin Stations

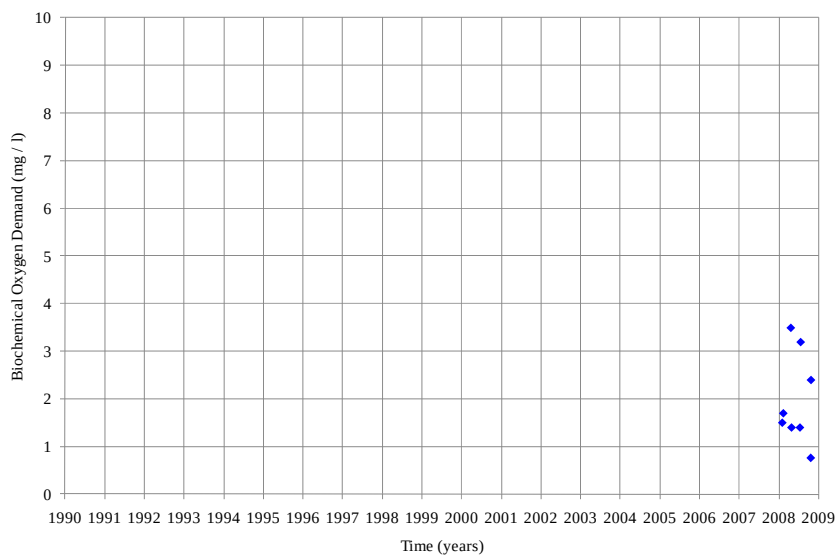

Figure 4.33 BOD Monthly Averages for the C-51 West Basin Stations

No Data Found

COD Monthly Averages for the C-51 West Basin Stations

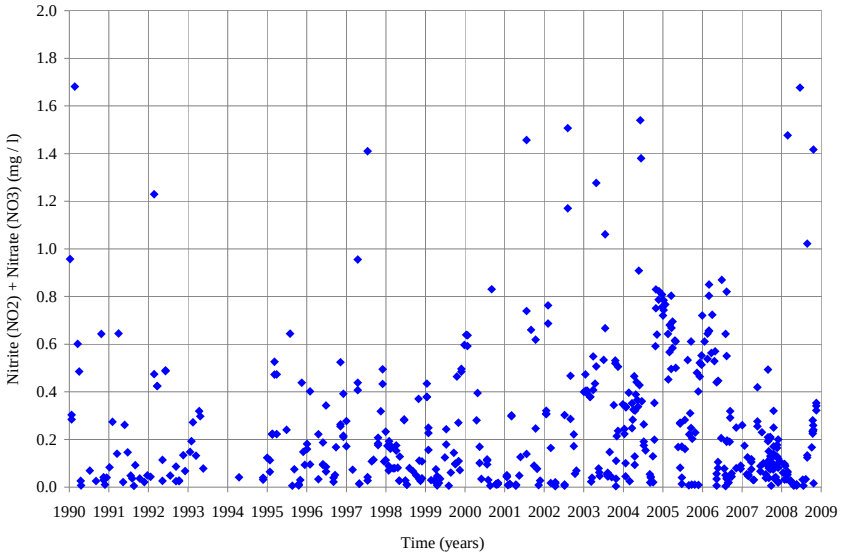

Figure 4.34 NO_2+NO_3 Monthly Averages for the C-51 West Basin Stations

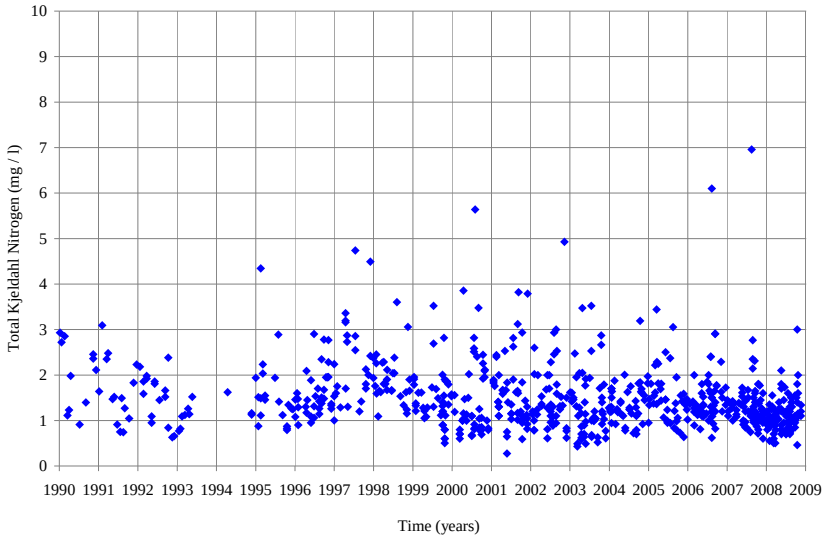

Figure 4.35 TKN Monthly Averages for the C-51 West Basin Stations

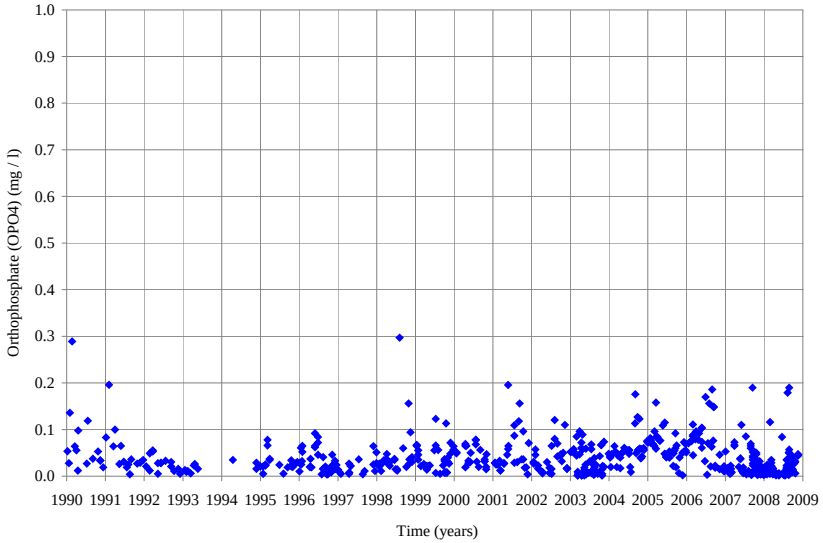

Figure 4.36 OPO_4 Monthly Averages for the C-51 West Basin Stations

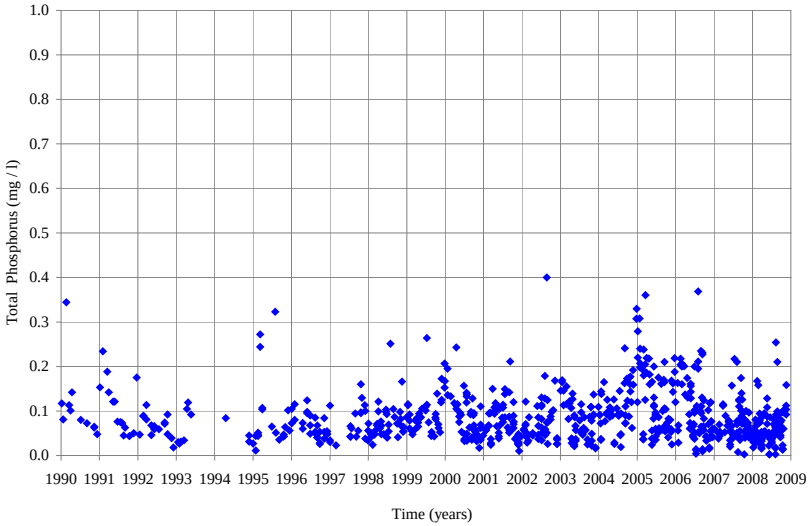

Figure 4.37 TP Monthly Averages for the C-51 West Basin Stations

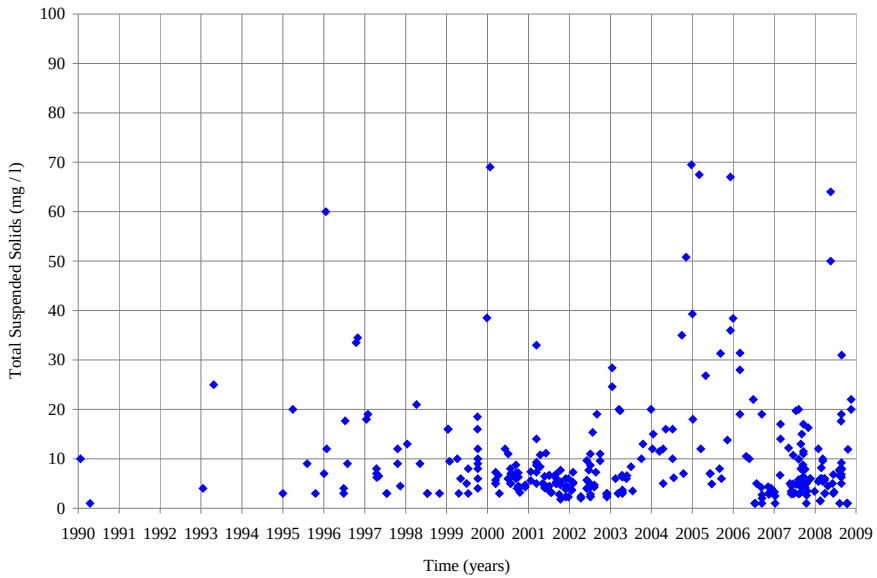

Figure 4.38 TSS Monthly Averages for the C-51 West Basin Stations

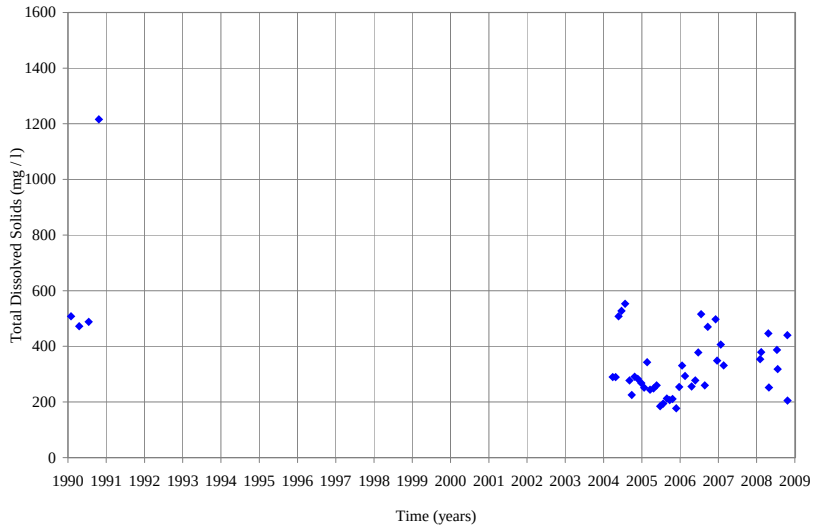

Figure 4.39 TDS Monthly Averages for the C-51 West Basin Stations

Figure 4.34 shows the majority of the NO_3+NO_2 samples above 1.89 mg/l. Figure 4.35 also shows TKN samples above that value. A high value (1.89 mg/l) for TN, a composite of NO_3+NO_2 and TKN, contributed to the listing of the C-51 East Canal (see Section 4.2.3) on the F.A.C. 62-303(d) rule list of impaired waters (FDEP 2005a). Given the relationship between TN and NO_3+NO_2 and TKN, values of either parameter above 1.89 mg/l indicate excess of in the basins' waters.

Figures 4.36 and 4.37 show available data for OPO_4 and TP for stations within the C-51 West basin. Most values fall below 0.5 mg/l. Data from McPherson and Halley (1996) suggest that phosphorus concentrations above 0.05 indicate water quality degradation.

Figure 4.39 shows TSS for the C-51 West basin. The majority of the values reported fall below 70 mg/l. Figure 4.40 shows the TDS values reported for the C-51 West basin fall below 600 mg/l. These values are lower than the more stringent F.A.C. 62-302 Class I waters requirements of 1000 mg/l criteria for TDS (FDEP, 2008). The C-51 West Canal, a Class III fresh water body, must meet less stringent values than a Class I of water body. Accordingly, TDS is not likely an issue in this basin.

4.2.4 C-51 East Basin

C-51 East, the most developed basin within the LWL watershed, covers approximately 58 square miles. The basin includes several incorporated areas: West Palm Beach, Lake Worth, Greenacres City, Palm Springs, Lake Clarke Shores, and Haverhill. Two water control districts have jurisdiction over the C-51 East basin: the Northern Palm Beach County Improvement District and the Lake Worth Drainage District.

The C-51 East basin includes the two most northern lakes of the freshwater Chain of Lakes on the coastal ridge: Pine Lake and Lake Clarke. The two remaining lakes in the chain are located in the C-16 and C-15 basins to the south. The E-4 Canal, which intersects with the C-51 Canal east of Lake Clarke, connects the lake chain. According to the 2005 F.A.C. 62-303(d) impaired waters list, the water quality in Lake Clarke is impaired due to low DO related to high loadings of nitrogen and phosphorous. The TN median value, 1.3785 mg/l, contributed to the lake's listing. Based on samples collected between January 1997 and June 2004 (FDEP 2005a), TP showed a median value of 0.081 mg/l.

Based on 2004 – 2005 land use classification (Figure 3.4), urban/residential land use (over 56.2%) dominates the basin. Other urban land uses include commercial (11.2%), industrial (2.7%),

recreational (7.9%), and transportation and utility (6.5%). Compared with the C-51 West basin (27.1%), agriculture, pasture, and croplands occupy very little (1.1%) of the C-51 East basin. Other land uses include undeveloped land (approximately 7.9%) in the form of upland forest (pine flat woods and other coniferous forest) wetlands (2%), and water (6.5%).

Originating in the C-51 West basin, the C-51 Canal continues into the C-51 East basin. Section 4.2.3 provides a characterization of the C-51 Canal.

4.2.4.1 Meteorological Data Analysis

Reported daily rainfall amounts for each station were added together to obtain a monthly total for each station. Totals for each month for each station were then averaged to provide an average basin rainfall for each month. Figure 4.40 shows the rainfall monthly averages between 1990 and 2008 for the 13 rainfall stations (Figure 3.1, Appendix A) in the C-51 East basin vicinity. The following years had rainfall events above 15 inches: 1995, 1999, 2001, and 2005.

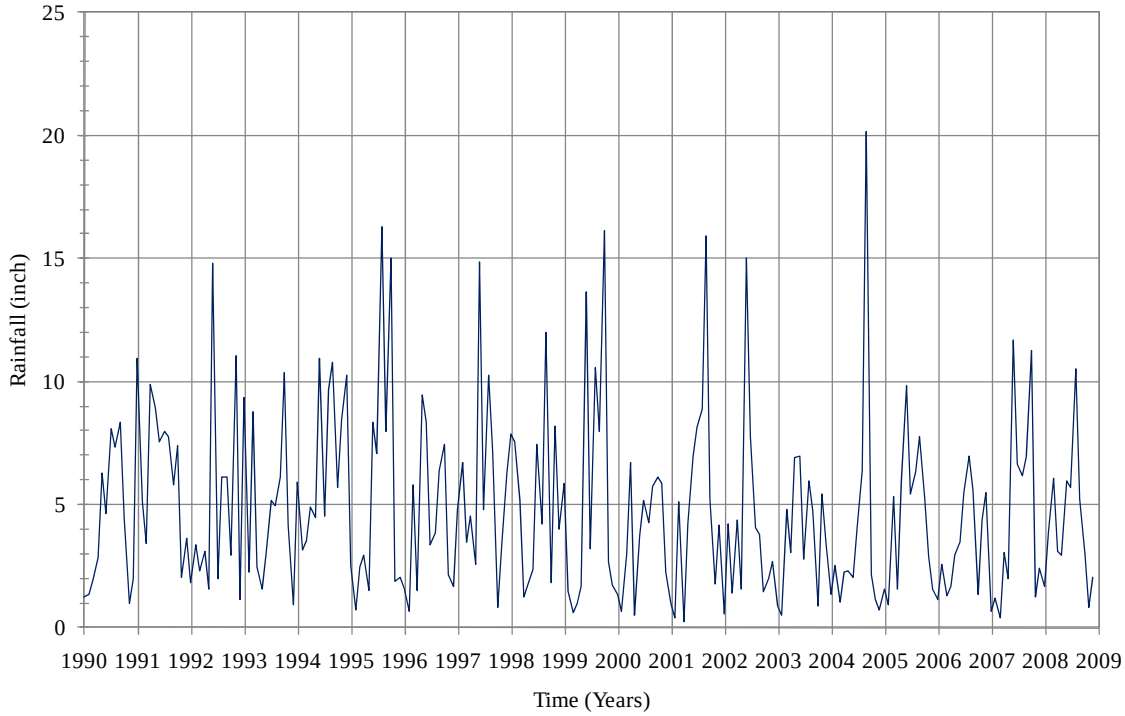

Figure 4.40 Monthly Average Rainfall for the C-51 East Basin Stations

4.2.4.2 Hydrological Data Analysis

The C-51 Canal drains both the C-51 West basin and C-51 East basin. As a result, flows exceed flows from the other canals in the watershed. Figure 4.41 shows that the C-51 Canal flows exceeded 1500 cfs during 1994, 1995, 1999, and 2004.

Figure 4.41 shows the flow monthly averages between 1991 and 2008 measured at the three stations (Figure 3.2, Appendix B) in the C-51 East basin. All three stations are located along the C-51 Canal, within the C-51 basin. Station S155A-S, the most western station, and Station S155-S, the most eastern station, are located where the C-51 Canal discharges to the LWL. The S-155A structure, built in 2003, controls the water flow between the western and eastern sections of the C-51 Canal (TBE Group, BPC Group, and SFWMD, 2004). Water flows in the C-51 West basin to the C-51 East basin depend on the operation of the structure. For this reason, flow data for the S155A-S monitoring station only begins in March of 2004.

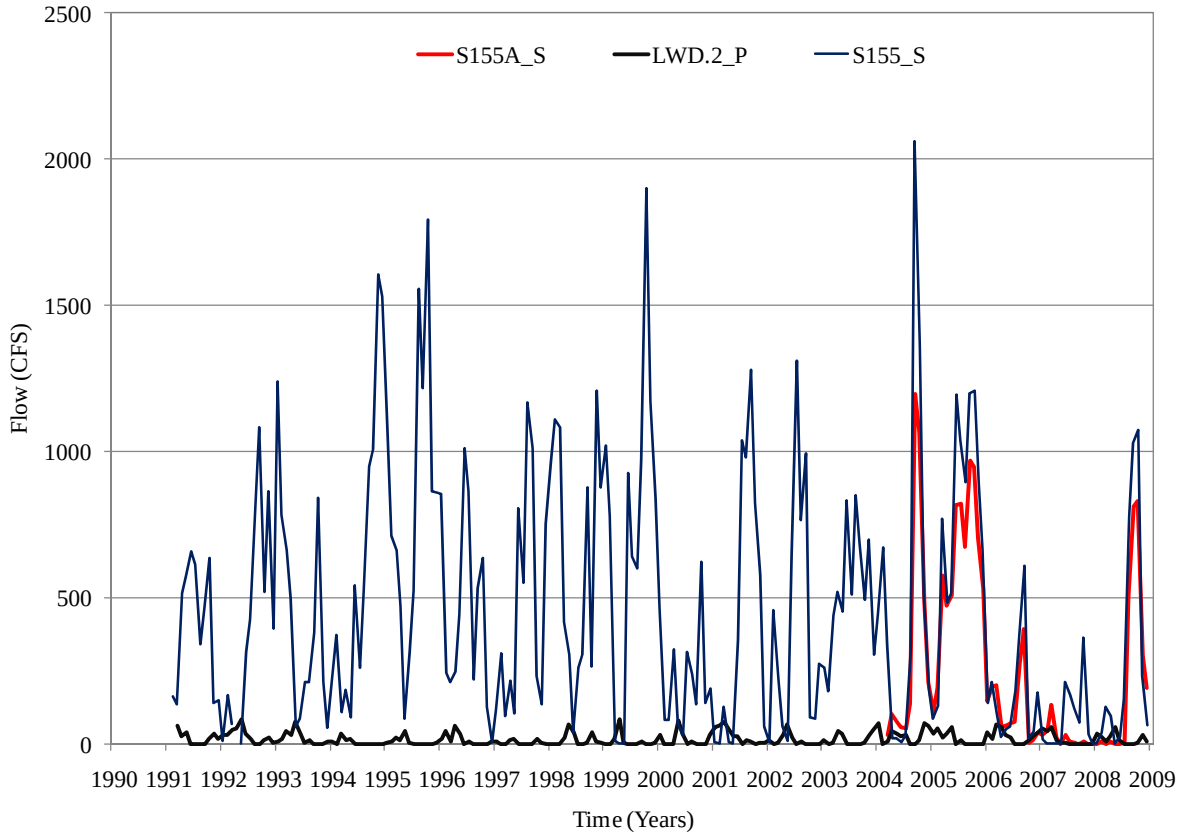

Figure 4.41 Flow Monthly Average for the C-51 East Basin Stations

4.2.4.3 Water Quality Data Analysis

Figure 4.42 through 4.51 shows the 1990 and 2008 water quality monthly averages measured at the 70 stations located in the C-51 East basin (Figure 3.3, Appendix C). Figure 4.42 shows 10 pH samples collected between 1990 and 2008 in the C-51 East canal exceed the F.A.C. 62-302 rule surface water quality standards for pH (6– 8.5 su). Figure 4.28 shows that 127 out of 348 DO samples fall below the F.A.C. 62-302 rule standard.

Taylor Engineering found very little BOD (Figure 4.29) and COD (Figure 4.30) data for the C-51 East basin. BOD values varied between 0 and 8 mg/l; COD values varied between 0 and 100 mg/l.

Figure 4.46 shows an increase of the concentrations of NO_2 + NO_3 during 2002 and 2003. TKN (Figure 4.47) shows the same increase, except it spans between 2001 and 2004. TKN values reported during those years exceed 1.89 mg/l (total nitrogen median reported for the C-51 Canal in the 2005 F.A.C. 62-303(d) impaired waters list). With the exception of three samples, after 2005, TKN concentrations fall below the 1.89 mg/l value reported. However, because TKN is only a fraction of TN (TN = TKN + NO_2 + NO_3), the values reported suggest that nitrogen concentrations are an issue in the basin. The concentrations of NO_2 + NO_3 also show the sample with elevated values (above 0.5 mg/l). As discussed in McPherson and Halley (1996), a value of 0.5 mg/l for this component is quite high.

Figures 4.48 and 4.49 show available data for OPO_4 and TP for stations within the C-51 West basin. Most values fall below 0.5 mg/l. McPherson and Halley (1996) data suggest that phosphorus concentrations above 0.05 indicate water quality degradation.

Figure 4.50 shows the TSS for the C-51 East basin. Most of the data reported fall below 14 mg/l. Figure 4.51 shows the TDS values reported for the C-51 East basin. The few data reported data from this basin fall below the Class I waters criteria of 1000 mg/l TDS (FDEP, 2008).

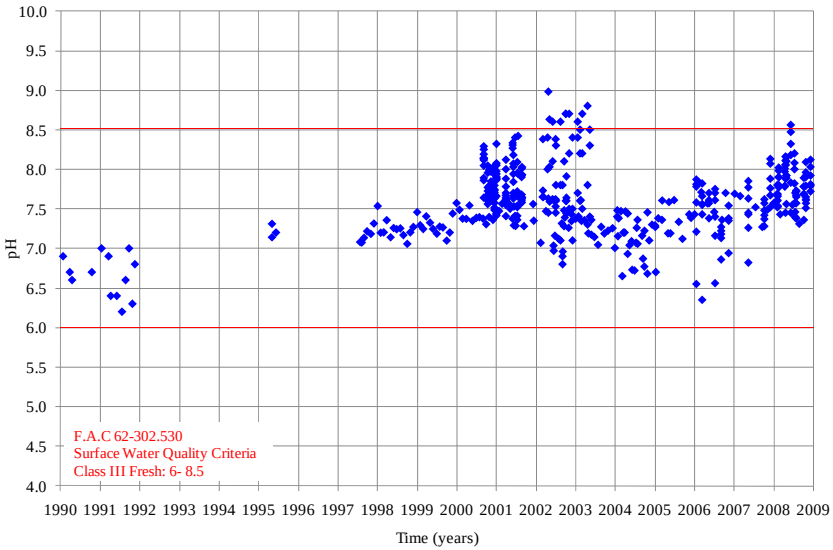

Figure 4.42 pH Monthly Averages for the C-51 East Basin Stations

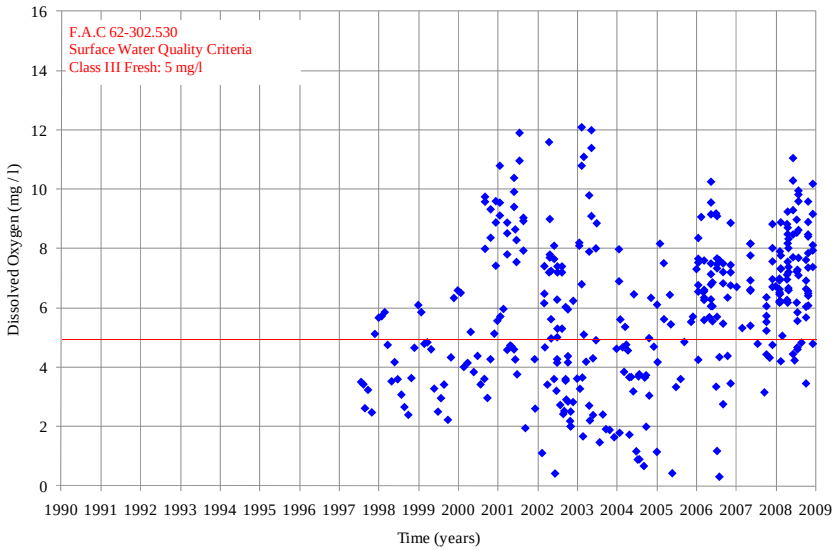

Figure 4.43 DO Monthly Averages for the C-51 East Basin Stations

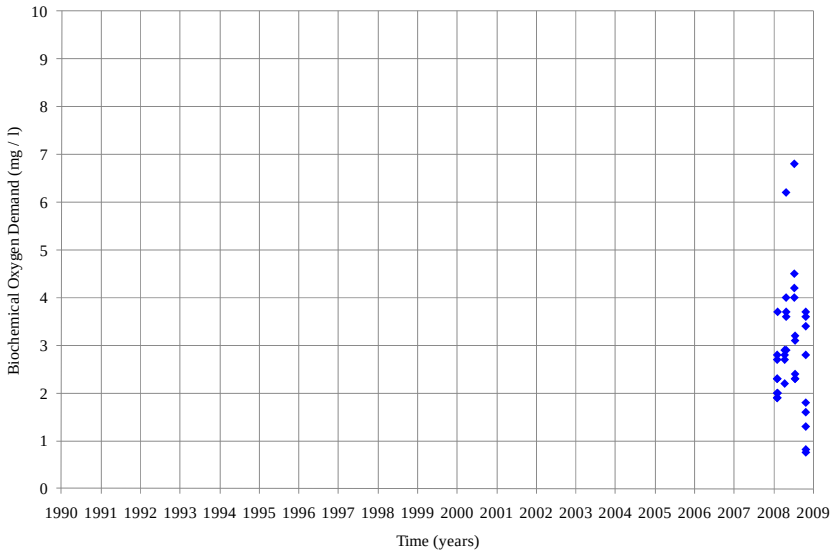

Figure 4.44 BOD Monthly Averages for the C-51 East Basin Stations

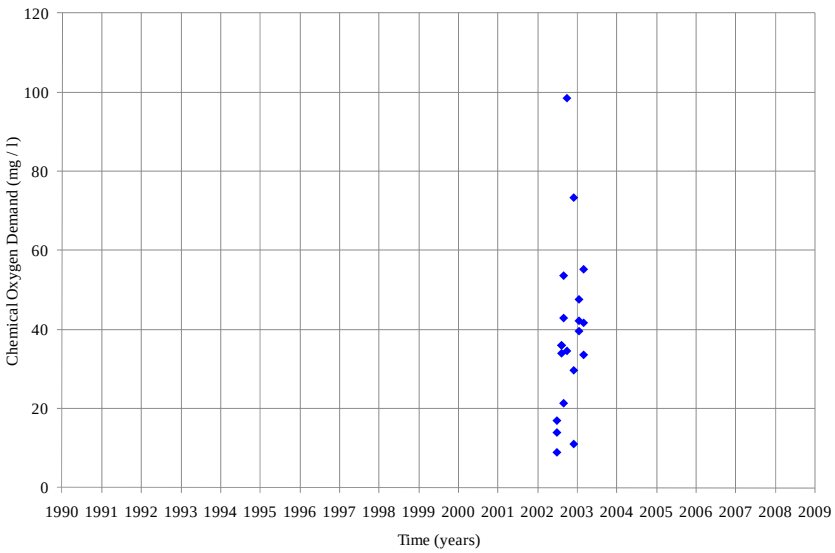

Figure 4.45 COD Monthly Averages for the C-51 East Basin Stations

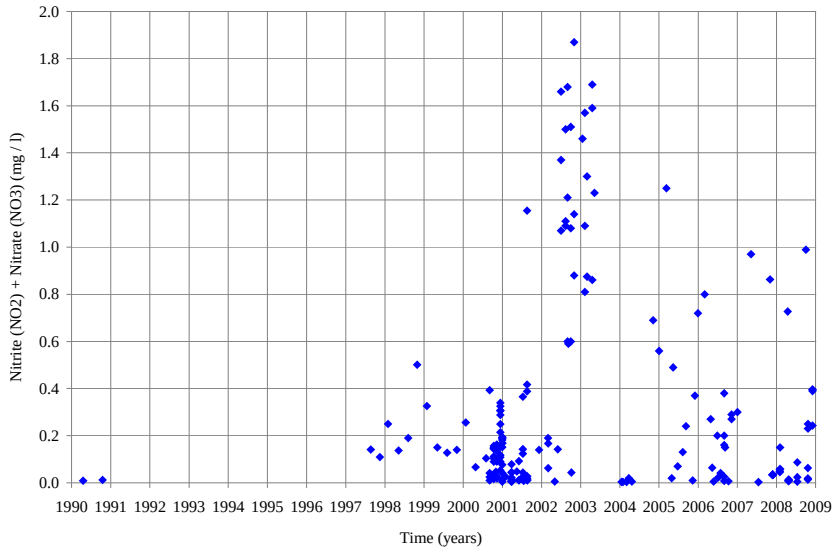

Figure 4.46 NO_2+NO_3 Monthly Averages for the C-51 East Basin Stations

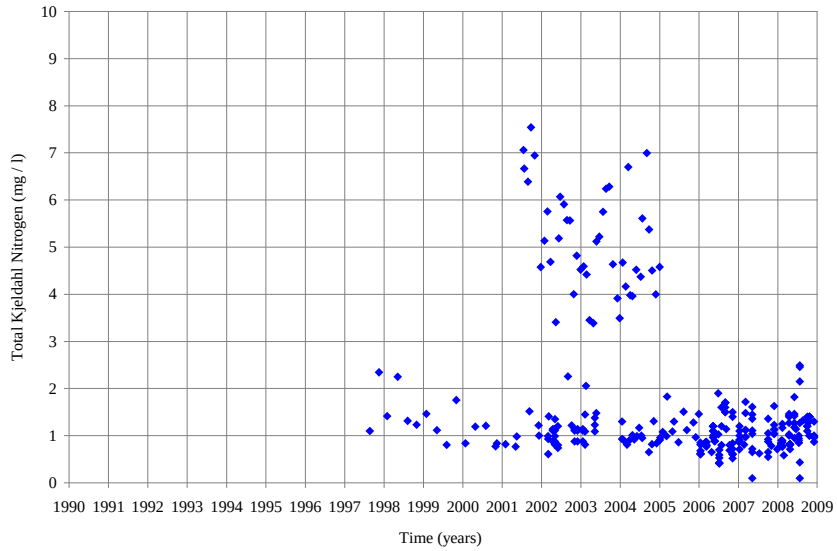

Figure 4.47 TKN Monthly Averages for the C-51 East Basin Stations

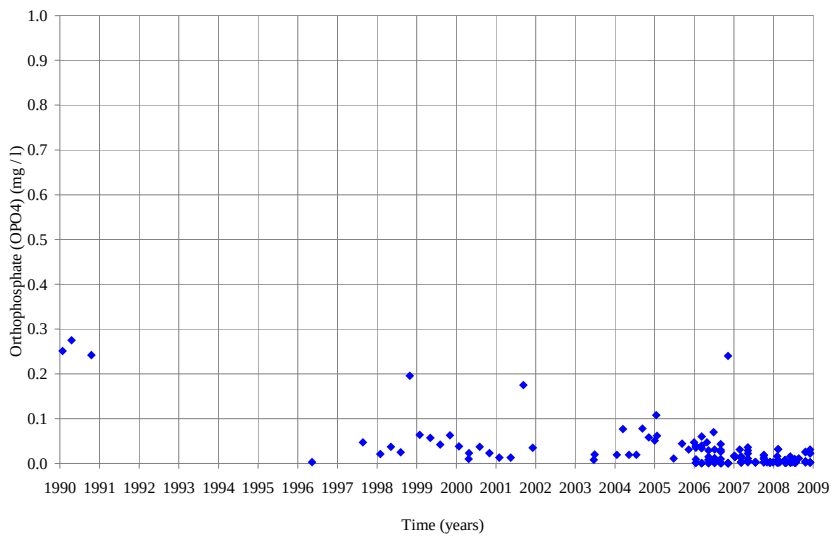

Figure 4.48 OPO_4 Monthly Averages for the C-51 East Basin Stations

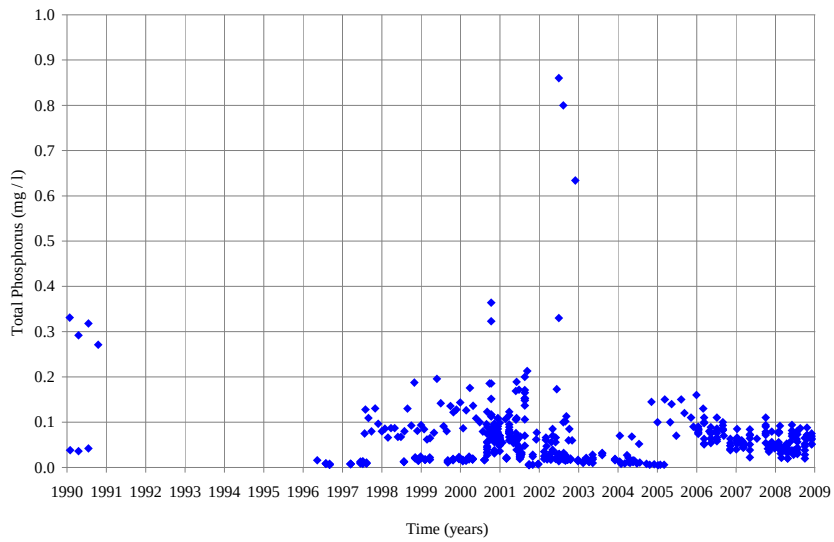

Figure 4.49 TP Monthly Averages for the C-51 East Basin Stations

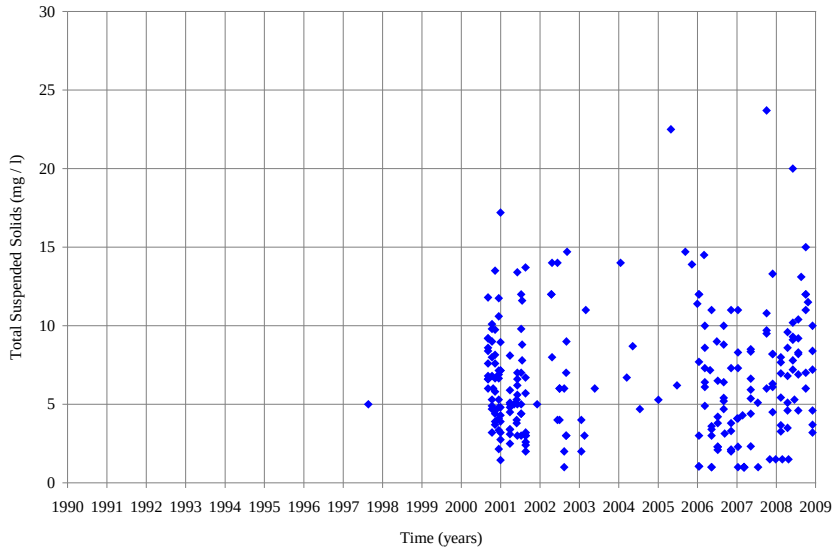

Figure 4.50 TSS Monthly Averages for the C-51 East Basin Stations

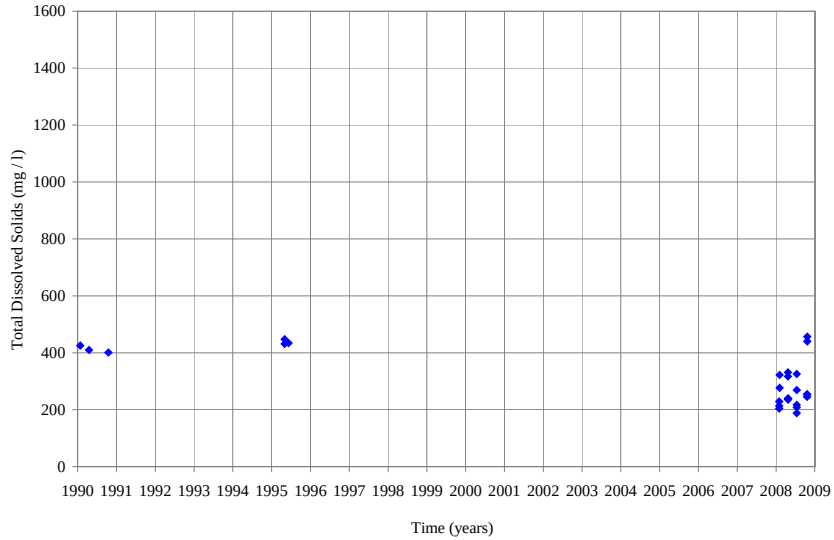

Figure 4.51 TDS Monthly Averages for the C-51 East Basin Stations

4.2.5 Acme B Basin

Acme B, one of two primary drainage basins within the Acme Improvement District (AID), covers 9.3 square miles. The City of Wellington in the C-51 West basin (Acme A basin) is the second basin. The Acme B basin is located on the southeast side of the Arthur R. Marshall Loxahatchee National Wildlife Refuge boundary, on the west end of the LWL watershed, south of the C-51 West basin. The Acme Improvement District manages the basin canals whose waters drain to the C-51 Canal. Acme B basin also discharges south to the Water Conservation Area 1 (WCA-1), at the L-40 Levee. According to the USACE & SFWMD (2003) report

> Six gravity structures … permit gravity discharges between the two basins. Under normal operating conditions, gravity flows through the structures may occur from Basin B to Basin A, particularly during dry periods for the transfer of supplemental water to Basin A. During some rainfall events, the boards are manually removed from these structures allowing gravity discharges from Basin A to Basin B in an effort to reduce flooding in the heavily developed Basin A.

The 2004 – 2005 land use classification (Figure 3.4) shows agriculture, pasture, croplands (stables and horse ranches, some tree nurseries, and row crops) as the predominant land use in the basin. Urban/residential land use occupies over 29.4% of the urbanized land in the basin. Other development includes commercial land uses (6.7%), recreational (2.7%), and transportation and utility (2.3%) land uses. Other land use percentages include undeveloped land (2.7%) in the form of upland forest (pine flat woods and other coniferous forest), wetlands (3.5%), and water (7.1%).

4.2.5.1 Meteorological Data Analysis

Reported daily rainfall amounts for each in station in the Acme B basin vicinity were summed to obtain a monthly total for each station. Totals for each month for each station were then averaged to provide an average basin rainfall for each month. Figure 4.52 shows the rainfall monthly averages between 1990 and 2008 for the three rainfall stations (Figure 3.1, Appendix A) in the Acme B basin vicinity. Years with rainfall events above 15 inches included 1995, 1999, 2001, and 2004.

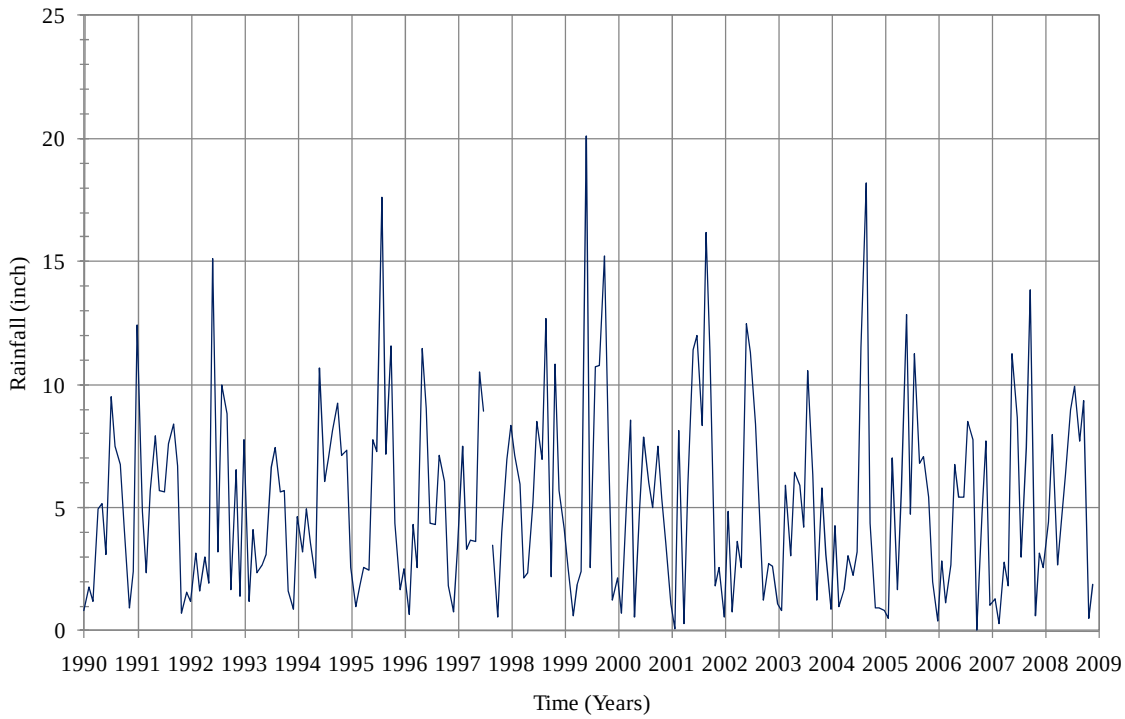

Figure 4.52 Monthly Average Rainfall for the Acme B Basin Stations

4.2.5.2 Hydrological Data Analysis

Figure 4.53 shows the monthly flow averages between 1990 and 2008 measured at pump Station ACME 1 (Figure 3.2, Appendix B) in the Acme B basin. Peak flows, registered during 1994, 1995, 1999, 2001, and 2004, coincided (for the most part) with high rainfall events.

4.2.5.3 Water Quality Data Analysis

Figures 4.54 through 4.59 show water quality monthly averages between 1998 and 2008 measured at the 14 stations located in the Acme B basin (Figure 3.3, Appendix C). Figure 4.54 shows the majority of the pH samples collected between 1998 and 2008 in the Acme B basin fell within the F.A.C. 62-302 rule surface water quality standards for pH (6 – 8.5 su). Figure 4.55 shows that 68 out of 125 DO samples collected in the basin fall below the F.A.C. 62-302 rule surface water quality standards for DO (5 mg/l). Taylor Engineering found no BOD or COD data for the Acme B basin for the study period of record (1990 to 2008).

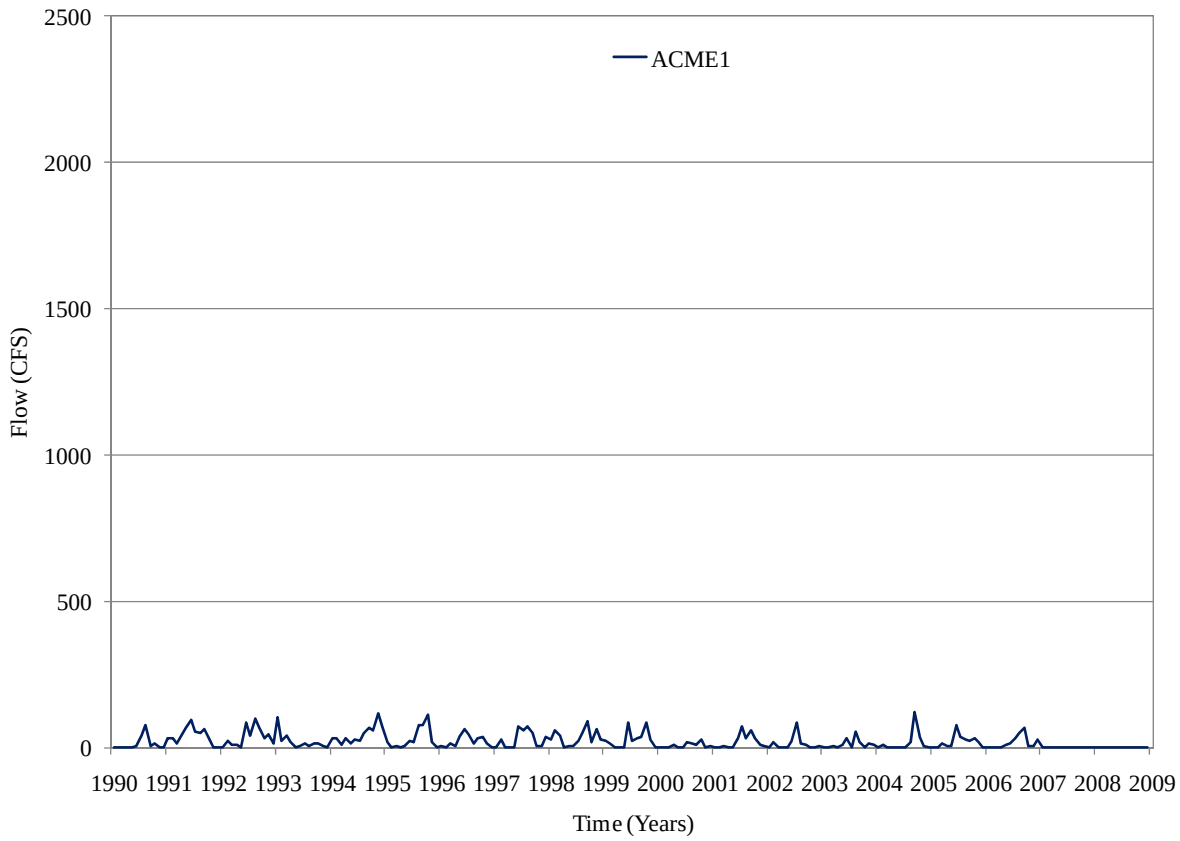

Figure 4.53 Flow Monthly Averages for the Acme B Basin Station ACME1

Figures 4.56 and 4.57 suggest a larger contribution of TKN to the nitrogen inputs into the Acme B basin than from NO_2+NO_3. The majority of the NO_3+NO_2 (Figure 4.56) values reported for the basin fall below 0.35 mg/l, while the majority of the TKN (Figure 4.57) values reported in the basin exceed 0.5 mg/l. However, the more biologically available NO_3 and NO_2 likely have a greater impact on long-term water quality. Figure 4.58 shows the OPO_4 inorganic phosphorus reported for the Acme B basin. Most of the data reported exceed 0.1 mg/l. Taylor Engineering did not find any TP data for the basin. Figure 4.59 shows the TSS data for the basin. The majority of the TSS data reported fall below 20 mg/l. Taylor Engineering found no TDS data for Acme B basin.

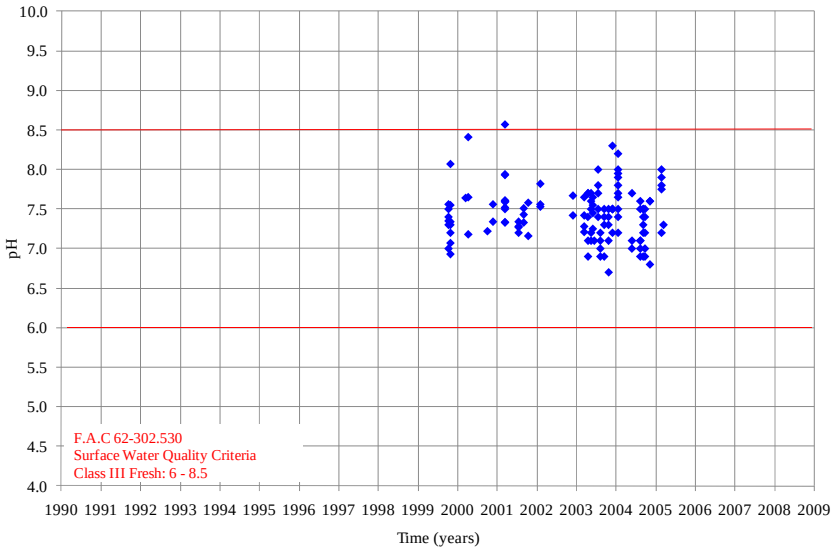

Figure 4.54 pH Monthly Averages for the Acme B basin Stations

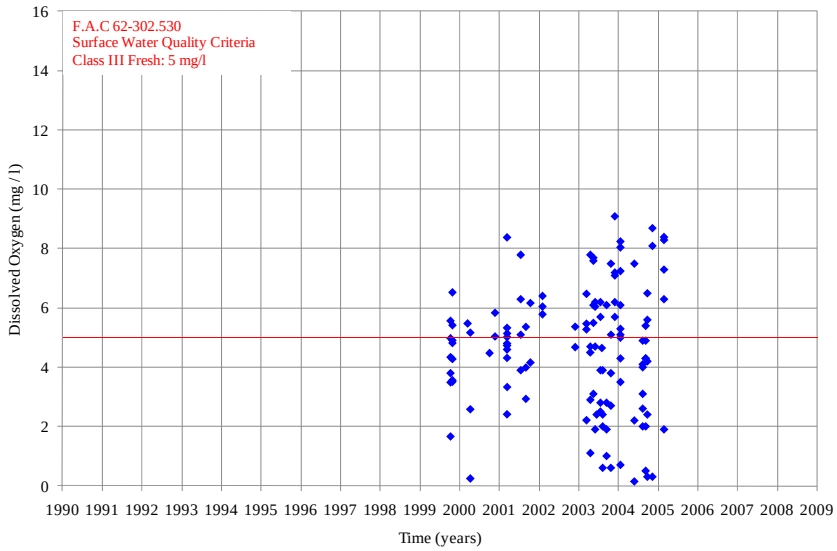

Figure 4.55 DO Monthly Averages for the Acme B basin Stations

No data found

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BOD Monthly Averages for the Acme B basin Stations

COD Monthly Averages for the Acme B basin Stations

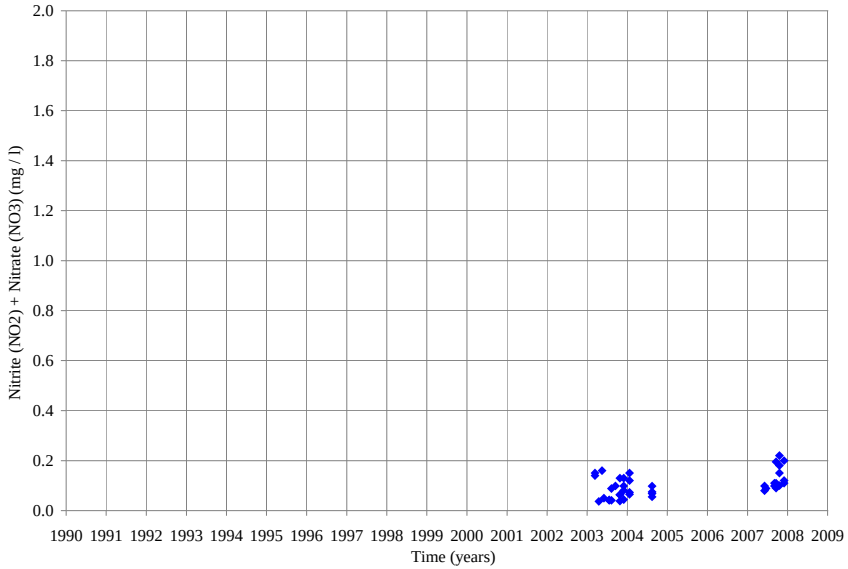


Figure 4.56 NO_2+NO_3 Monthly Averages for the Acme B basin Stations

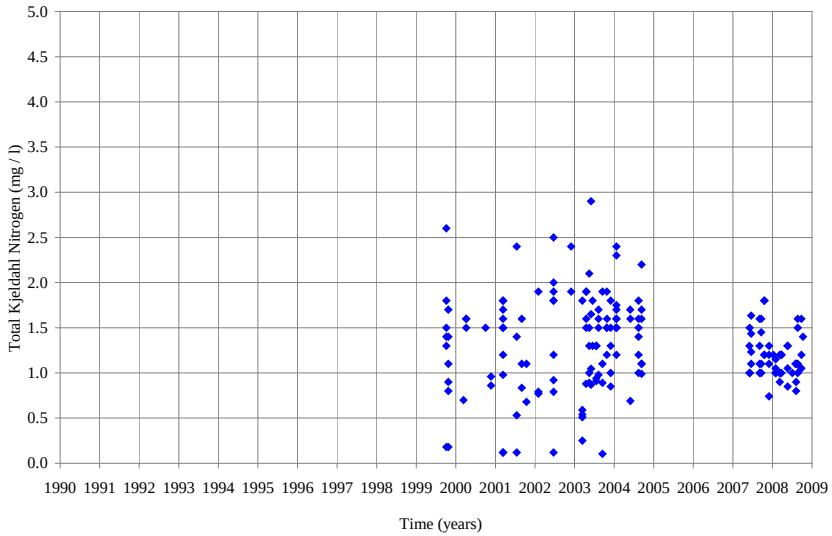


Figure 4.57 TKN Monthly Averages for the Acme B basin Stations

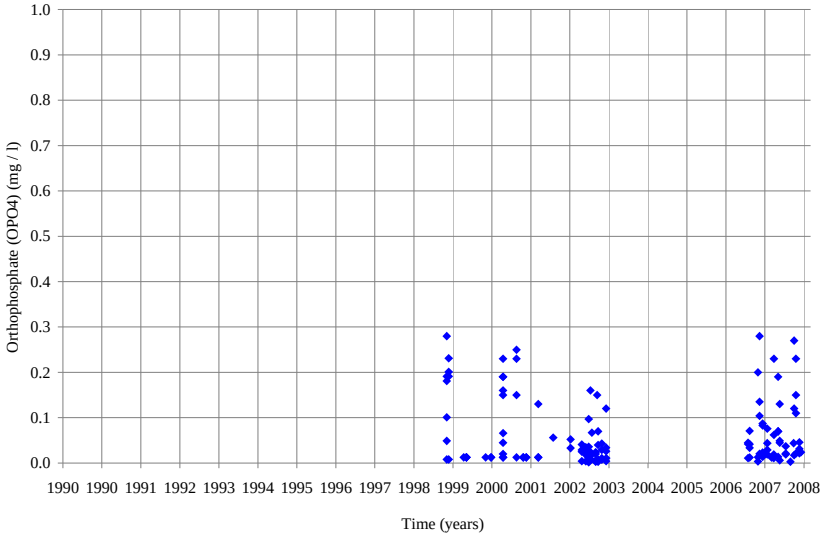


Figure 4.58 OPO_4 Monthly Averages for the Acme B basin Stations

No data found

TP Monthly Averages for the Acme B basin Stations

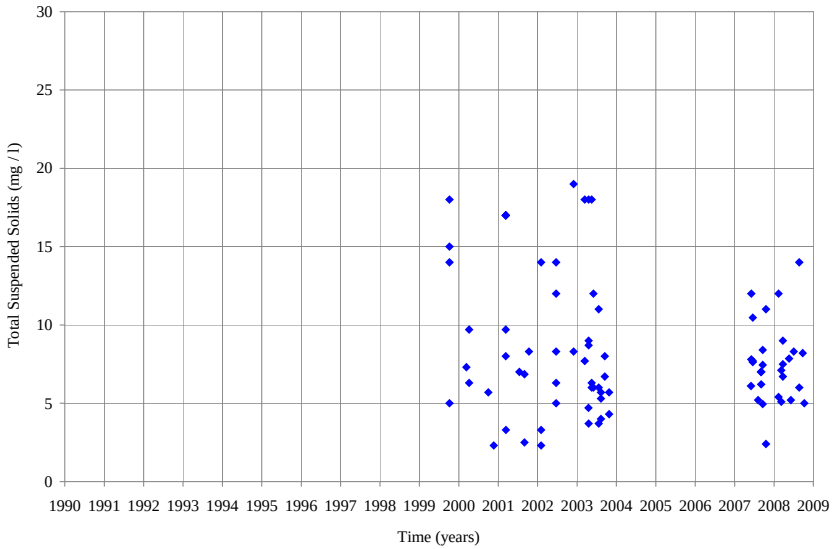


Figure 4.59 TSS Monthly Averages for the Acme B basin Stations

No data found

TDS Monthly Averages for the Acme B basin Stations

4.2.6 C-16 North Basin

The C-16 North basin is located in east central Palm Beach County, south of the Acme B basin, and adjacent to the western boundary of the C-16 basin. The C-16 North basin includes the Boynton Canal, which links to the C-16 Canal (Section 4.2.7). For the most part, the C-16 North basin, approximately 11.7 square miles, lies within the jurisdiction of the Lake Worth Drainage District. The Water Conservation Area to the west receives most of the runoff from the C-16 North basin. No incorporated areas occur within the C-16 North basin.

Based on the 2004 – 2005 land use classification (Figure 3.4), wetlands (57.3%) are the predominant land use in the basin. Agriculture, pasture, and croplands (mainly row crops and ornamentals) occupy 18.5% of the basin. Urban development includes residential (8.6%), commercial (0.6%), transportation and utilities (1.4%). In addition to the wetlands, other undeveloped lands in the form of forest, rangeland and barren lands (mostly upland forest) occupy 8%; water occupies approximately 4.1% of the total basin area.

4.2.6.1 Meteorological Data Analysis

No rainfall stations operate in the C-16 North basin.

4.2.6.2 Hydrological Data Analysis

No flow stations operate in the C-16 North basin.

4.2.6.3 Water Quality Data Analysis

Figures 4.60 through 4.66 show the water quality monthly averages between 1997 and 2008 measured at the 15 stations located in the C-16 North basin (Figure 3.3, Appendix C). Figure 4.56 shows that 13 pH samples collected between 1990 and 2008 in the C-16 North canal were lower than 6.5 and below the F.A.C. 62-302 rule surface water quality standards for pH (6.5 – 8.5 su). Figure 4.61 shows that 132 out of 203 DO samples collected in the basin exceed the F.A.C. 62-302 rule surface water quality standard of 5 mg/l for DO.

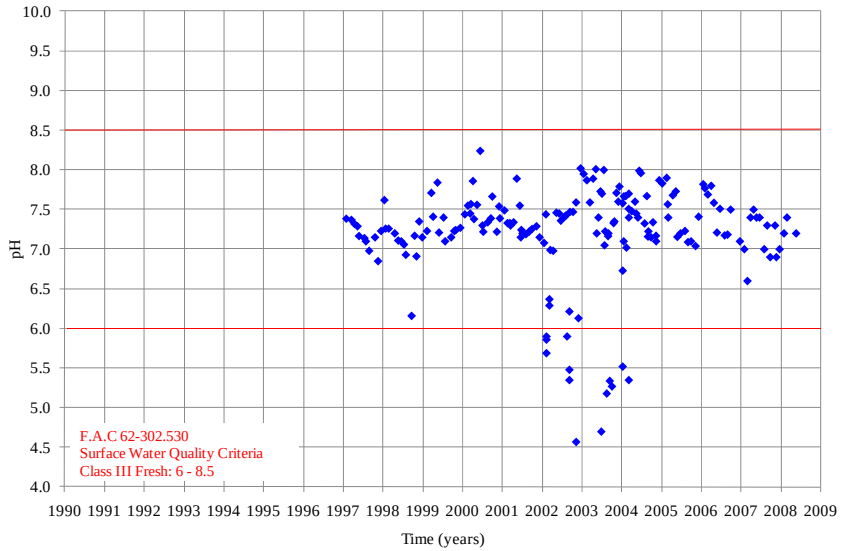


Figure 4.60 pH Monthly Averages for the C-16 North Basin Stations

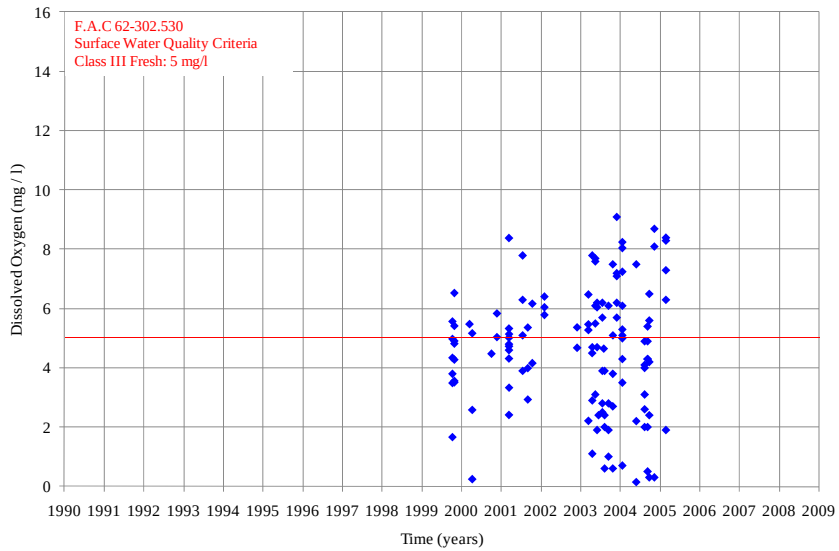


Figure 4.61 DO Monthly Averages for the C-16 North Basin Stations

No data found

No data found

BOD Monthly Averages for the C-16 North Basin Stations

COD Monthly Averages for the C-16 North Basin Stations

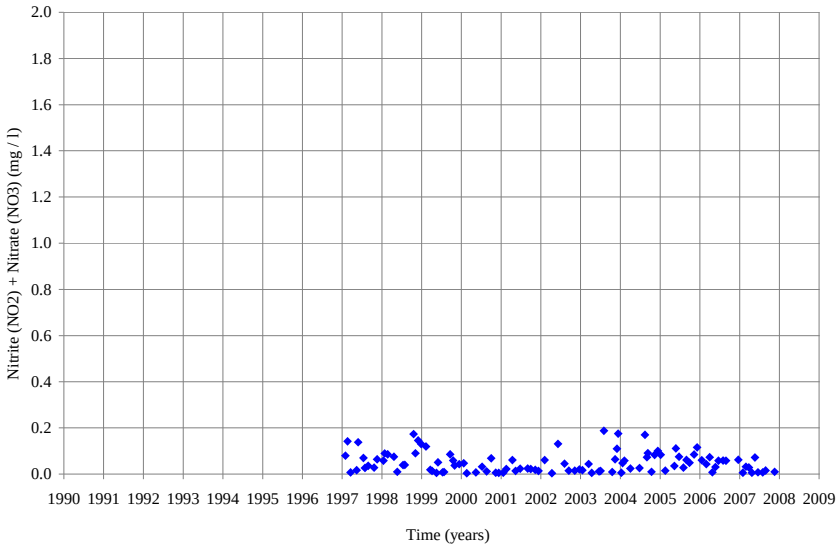


Figure 4.62 NO_2+NO_3 Monthly Averages for the C-16 North Basin Stations

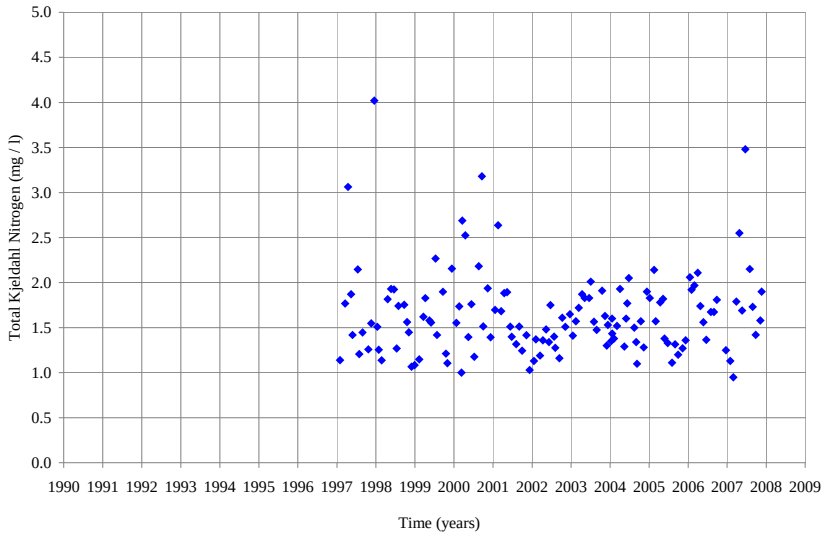


Figure 4.63 TKN Monthly Averages for the C-16 North Basin Stations

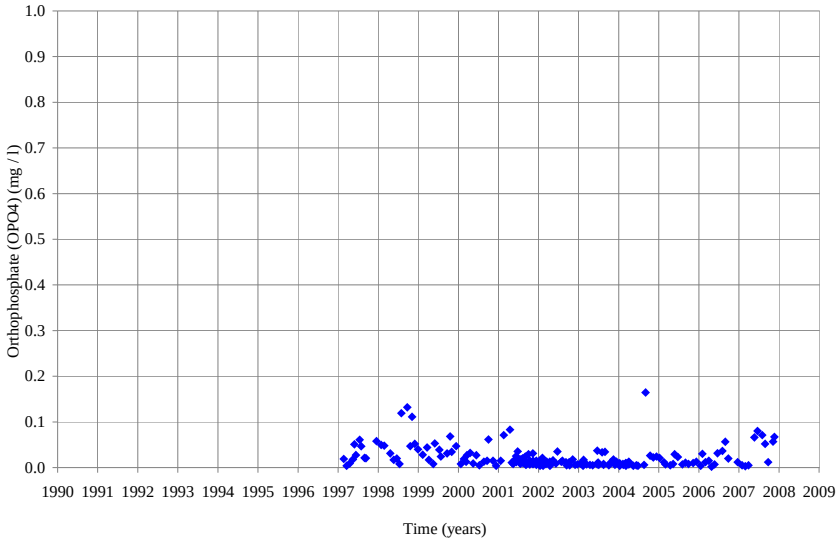


Figure 4.64 OPO4 Monthly Averages for the C-16 North Basin Stations

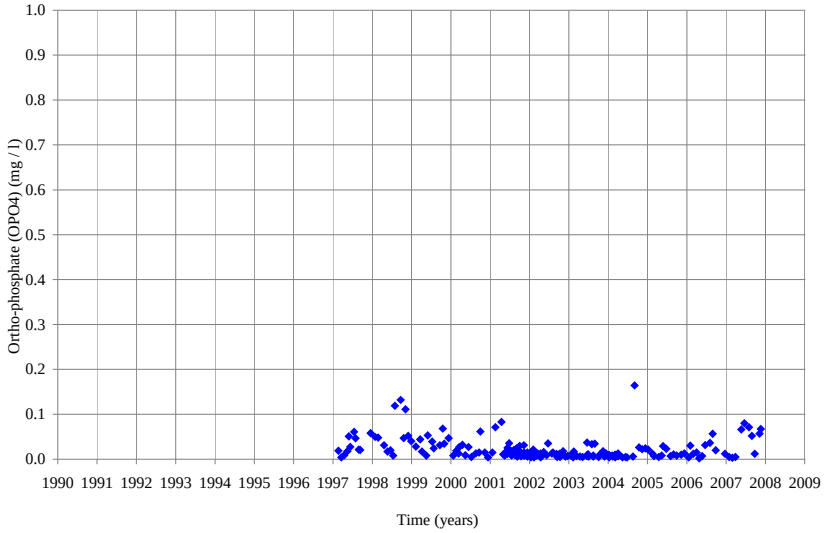


Figure 4.65 TP Monthly Averages for the C-16 North Basin Stations

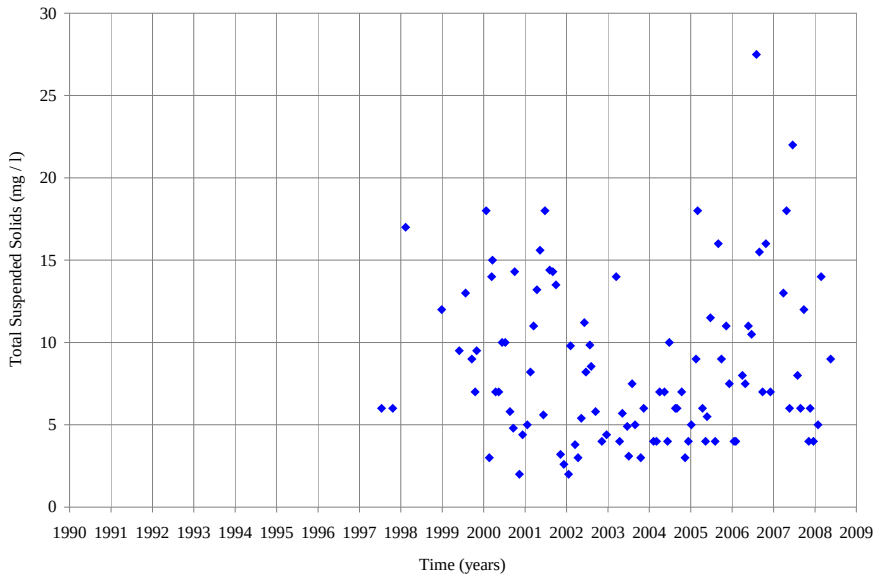


Figure 4.66 TSS Monthly Averages for the C-16 North Basin Stations

No data

TDS Monthly Averages for the C-16 North Basin Stations

Taylor Engineering found no BOD or COD data for the C-16 North basin. Figures 4.62 and 4.63 suggest a strong contribution from TKN to the TN in the C-16 North basin, as the majority of the NO_3+NO_2 (Figure 4.62) values reported in the basin fall below 0.2 mg/l. basin, and the TKN values reported in the basin exceed 1 mg/l.

Figure 4.64 and 4.65 show OPO_4 and TP data for the C-16 North basin. That the majority of the OPO_4 values are similar to the reported TP values suggests that a large fraction of the phosphorus inputs to the basin are in the form of OPO_4, the most biologically active form of phosphorus. Figure 4.66 shows the TSS for the C-16 North basin. The majority of the data reported fall below 100 mg/l. Taylor Engineering found no TDS data for the basin.

4.2.7 C-16 Basin

The C-16 basin, the second most developed basin in the LWL watershed (FDEP, 2006), is located in east central Palm Beach County, south of the C-51 basin. It covers approximately 58 square miles. Incorporated areas in the C-16 basin include Atlantis, Boynton Beach, Lantana, Greenacres City, and Lake Worth. The majority of the basin lies within the Lake Worth Drainage District. Rainfall and water pumped from the WCA-1 supply water to the C-16 basin. The C-16 basin canals, in addition to providing flood protection and conveying storm water, also support recreational uses such as sport fishing.

The 2004 – 2005 land use classification (Figure 3.4) shows residential as the predominant land use (approximately 60%) in the basin. Other urban land use percentages include urban development commercial (5.7%), industrial (0.7%), recreational (7.2%), and transportation and utilities (4.2%). Agricultural land uses (mainly row crops, ornamentals, and horse farms) account for approximately 7.8% of the basin. Other land uses include undeveloped land (4.2%) in the form of upland forest, wetlands 0.6%, and water 10.1%.

The C-16 Canal, an extension of the Boynton Canal, runs east from the WCA-1 to the southern end of the LWL and provides drainage, flood protection, and saltwater intrusion protection for the C-16 basin. The C-16 Canal discharges excess water to the LWL at the S-41 control structure. Lake Worth Drainage District Canals E-1, E-2, E-3, and E-4 drain to and intersect the C-16 Canal, and transfer water between the C-16/C-16 North, C-15, and Hillsboro Canal basins, where no control structures such as the S-41 operate.

The E-4 Canal, which connects the lakes in the Chain of Lakes in the C-51 East basin (Pine Lake and Lake Clarke), with Lake Osborne in the C-16 basin, is also an important canal in this basin. The 1998 F.A.C. 62-303(d) list of impaired waters listed the Boynton Canal (C-16) and the E-4 Canal waters as impaired due to DO and nutrients (FDEP, 2003). However, the 2005 303(d) list update stated that in spite of the low DO values reported (below F.A.C. 62-302 rule standards), the biological information for the basin indicated that both the E-4 Canal and the Boynton Canal were meeting the aquatic life use criterion (which would otherwise trigger the listing of a water body as impaired). FDEP 2005b delisted both canals from the F.A.C. 62-303(d) impaired waters list on that basis.

Pine Lake and Lake Osborne, two of the four lakes located in the Chain of Lakes along the coastal ridge, are located in the C-16 basin. They are connected to the chain via the E-4 Canal. The 1998 F.A.C. 62-303(d) list included Lake Osborne on the impaired water bodies for DO (FDEP, 2003). The same report states that the lake is "influenced by the increased amount of freshwater inflows coming in from the E-4 and L-14 Canals reducing the amount of DO in the lake." However, the 2005 update of the F.A.C. 62-303(d) list (FDEP, 2005a) notes that high DO levels in the lake are inked to neither TN (median equaled 0.96 mg/l) nor TP (median equaled 0.07 mg/l) between January 1997 and June 2004 [FDEP, 2005b]). FDEP delisted Lake Osborne from the impaired list of water bodies on that basis.

4.2.7.1 Meteorological Data Analysis

Summed daily rainfall amounts for each station in the C-16 basin vicinity provided a monthly total for each station. Monthly totals for each station were then averaged to provide an average basin rainfall for each month. Figure 4.67 shows the rainfall monthly averages between 1990 and 2008 for the four rainfall stations (Figure 3.1, Appendix A) in the C-16 basin vicinity.

4.2.7.2 Hydrological Data Analysis

Figure 4.68 shows monthly flow averages between 1990 and 2008 measured at the two flow stations (Figure 3.2, Appendix B) in the C-16 basin. Pump station LWD.9S-P is located on the Boynton Canal, east of the C-16 Canal. Station S41-S, the most eastern station on the C-16 Canal, is located at the S-41 control structure. S41-S monitors the canal discharges to the LWL. The C-16 Canal flows registered peak levels (above 750 CFS) during 1995, 1999, and 2004 at station S41-S.

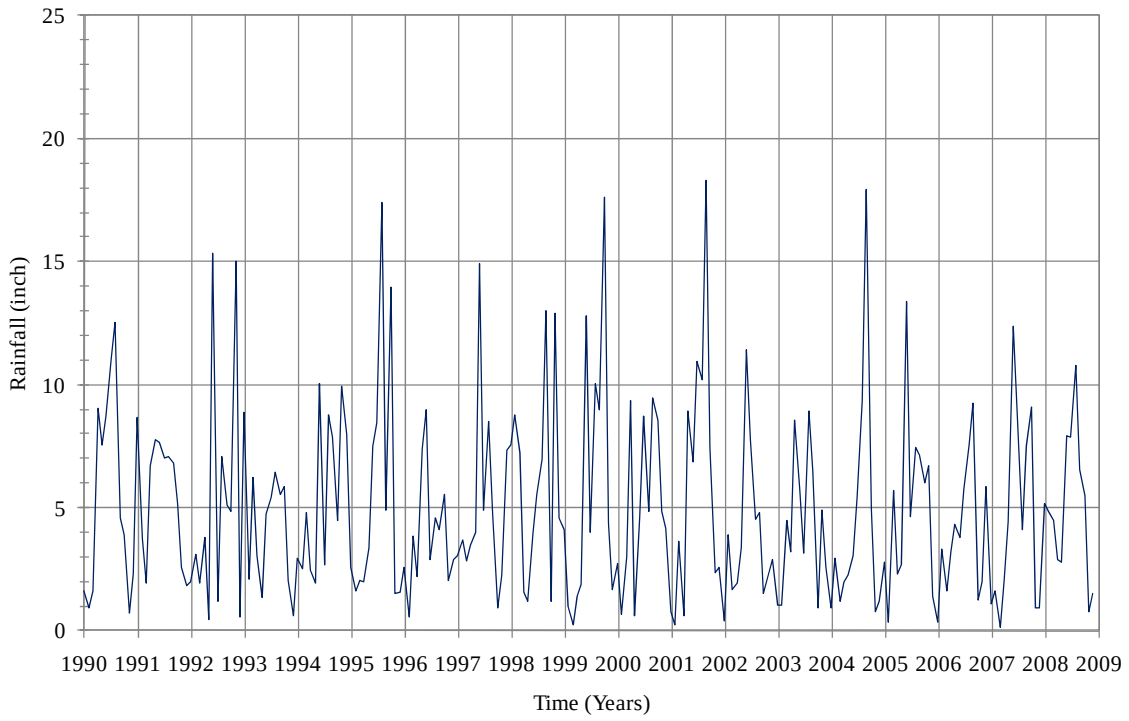


Figure 4.67 Monthly Average Rainfall for the C-16 Basin Stations

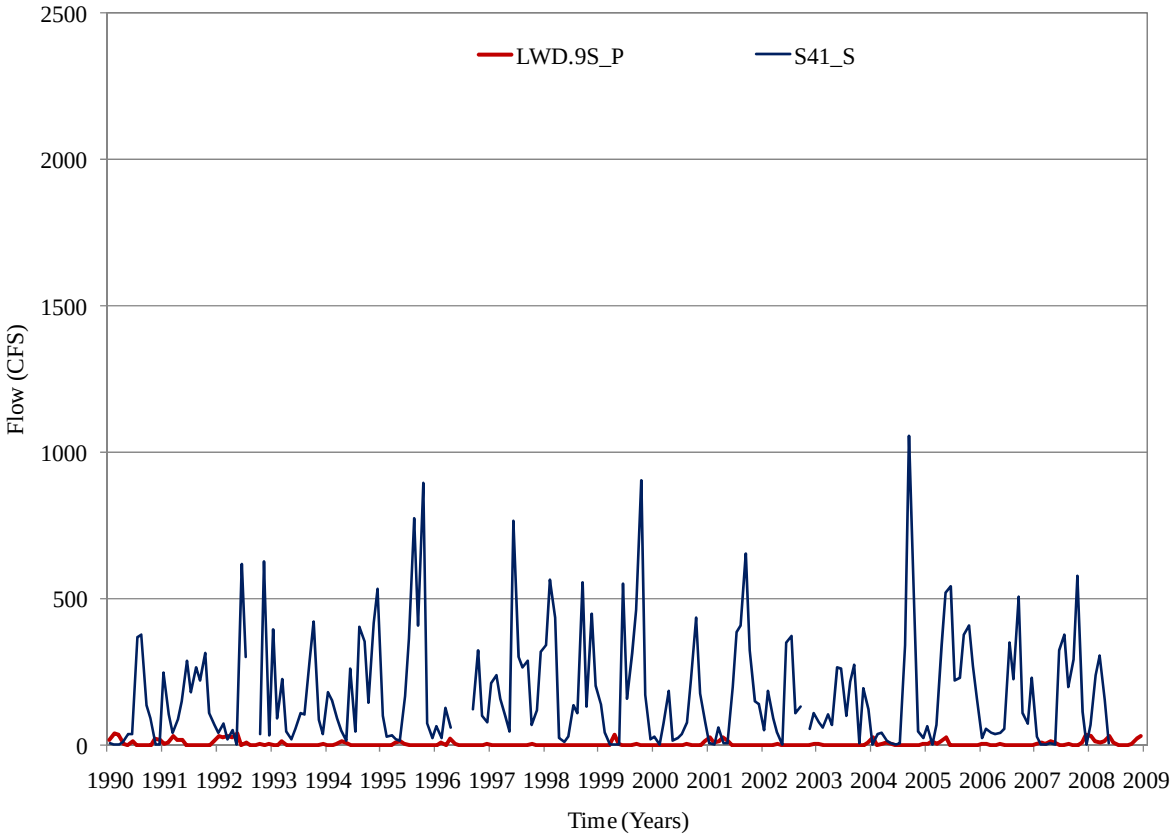


Figure 4.68 Flow Monthly Averages for the C-16 Basin Stations

4.2.7.3 Water Quality Data Analysis

Figures 4.69 through 4.77 show the water quality monthly averages between 1990 and 2008 measured at the 69 stations located in the C-16 basin (Figure 3.3, Appendix C). A total of nine pH samples collected between 1990 and 2008 in the C-16 Canal (Figure 4.69) did not meet the F.A.C. 62-302 rule surface water quality standards for pH (6 – 8.5 su).

Figure 4.70 shows that 82 of 353 DO samples collected in the basin exceed the F.A.C. 62-302 rule surface water quality standards (5 mg/l), and that in recent years (after 2004) only 27 samples fell below 5 mg/l. The increase in DO suggest improved basin water quality starting in 2004. Taylor Engineering found very little BOD data (Figure 4.71) and no COD data for the C-16 Canal. BOD values varied between 1 and 76 mg/l.

Figures 4.72 and 4.73 suggest a strong contribution from TKN to the C-16 Canal, as the majority of the NO_3+NO_2 values reported in the basin (Figure 4.72) fall below 1 mg/l, and most of the TKN values reported for the same time period exceed 2 mg/l, particularly in recent years. Figures 4.74 and 4.75 show OPO_4 and TP data collected for the C-16 basin. While most of the reported values fall below 0.1 mg /l for both OPO_4 and TP, the numerous samples with values well above 0.1 mg/l suggest that phosphorus discharges from this basin should receive further evaluation.

Figure 4.76 shows the TSS data for the C-16 basin. The majority of the values reported fall below 15 mg/l. Figure 4.77 shows the TDS data for the C-16 basin, with values below 300 mg/l. These values are lower than the more stringent Class I waters F.A.C. 62-302 rule requirements of a maximum of 1000 mg/l (FDEP, 2008). Accordingly, TDS is likely not an issue in this basin.

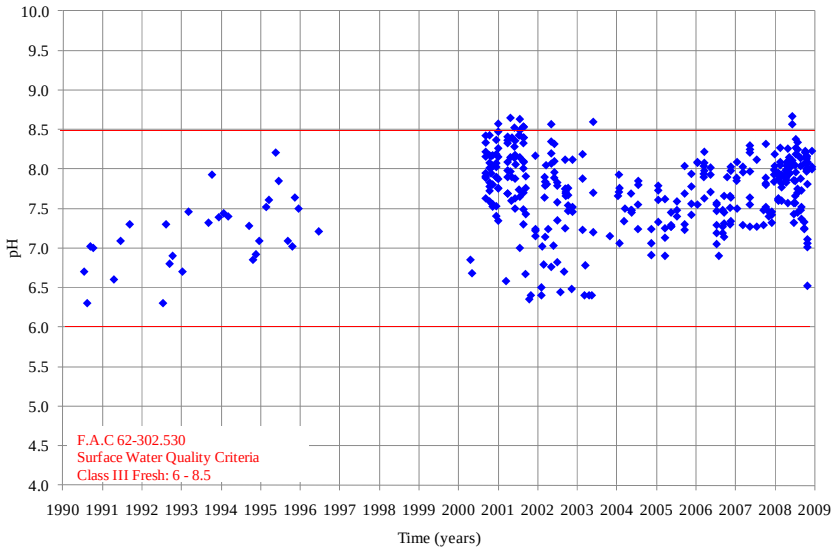


Figure 4.69 pH Monthly Averages for the C-16 Basin Stations

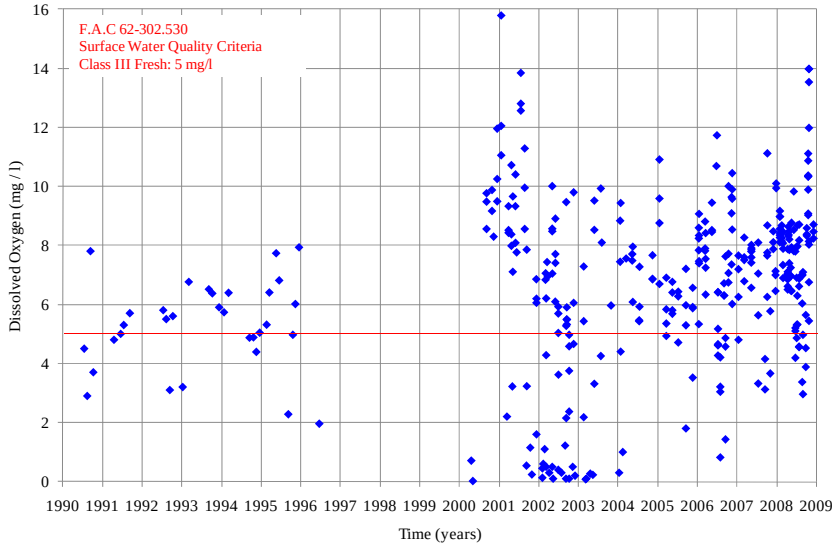


Figure 4.70 DO Monthly Averages for the C-16 Basin Stations

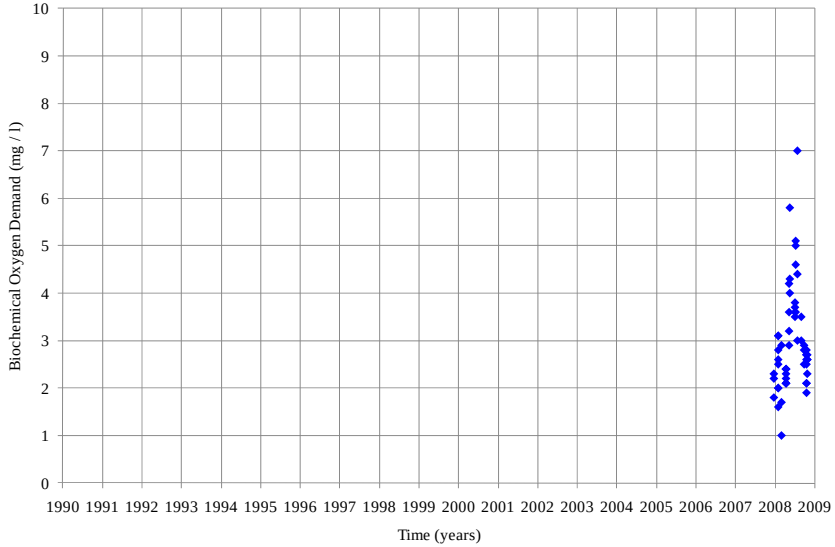


Figure 4.71 BOD Monthly Averages for the C-16 Basin Stations

No data

COD Monthly Averages for the C-16 Basin Stations

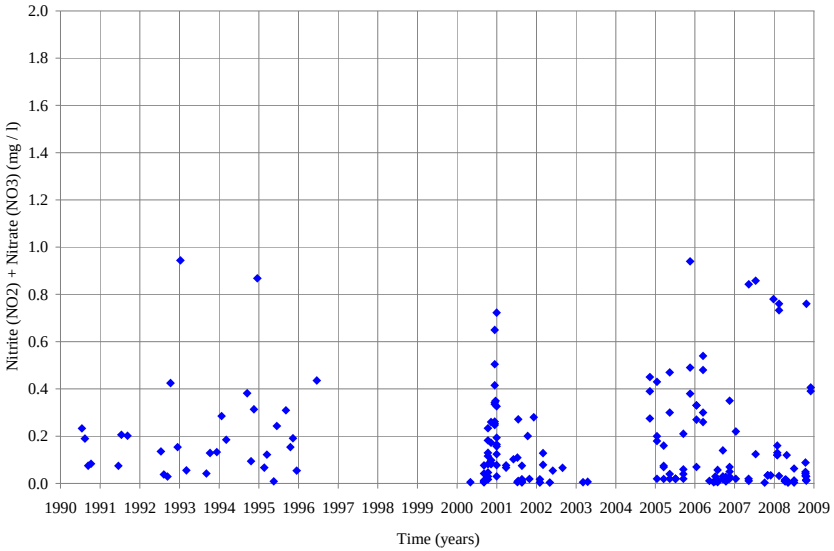


Figure 4.72 NO_2+NO_3 Monthly Averages for the C-16 Basin Stations

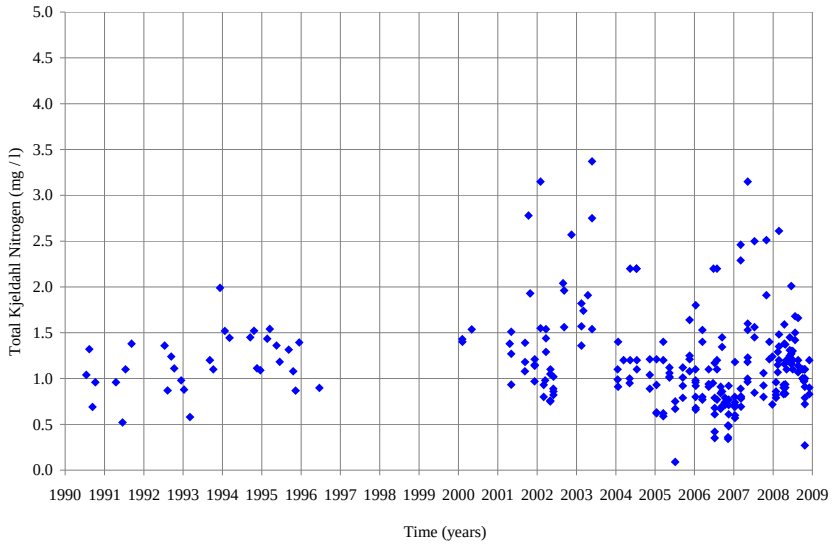


Figure 4.73 TKN Monthly Averages for the C-16 Basin Stations

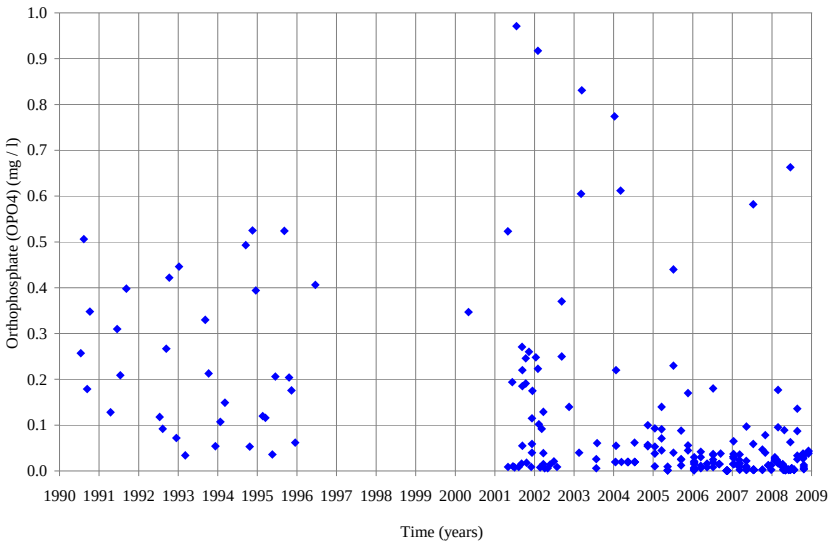


Figure 4.74 OPO_4 Monthly Averages for the C-16 Basin Stations

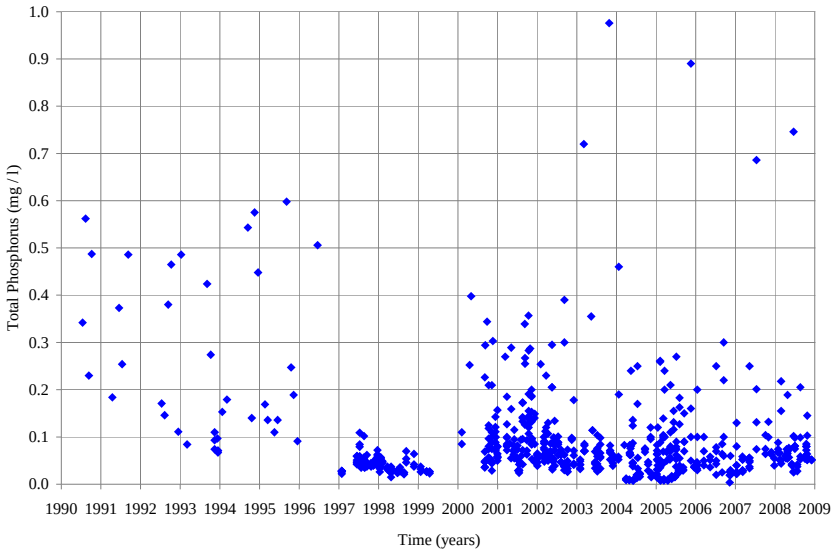


Figure 4.75 TP Monthly Averages for the C-16 Basin Stations

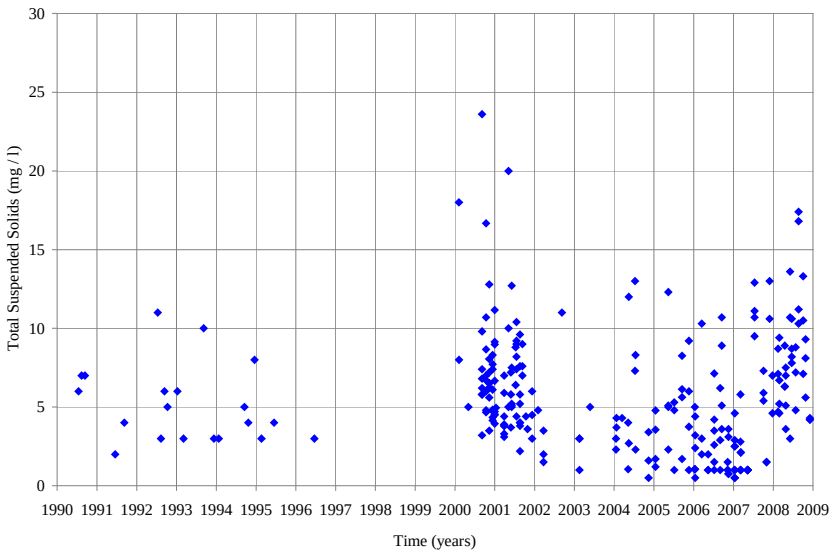


Figure 4.76 TSS Monthly Averages for the C-16 Basin Stations

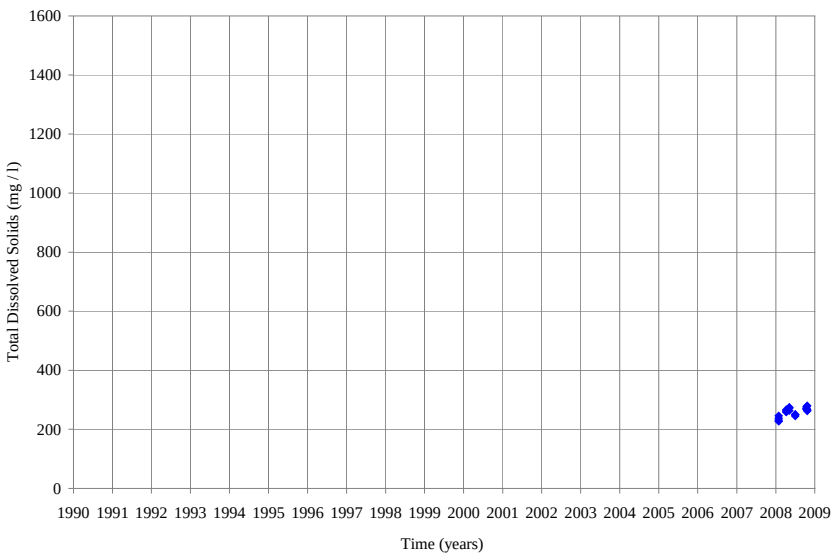


Figure 4.77 TDS Monthly Averages for the C-16 Basin Stations

4.2.8 Lake Worth Lagoon Basin

The LWL basin covers about 61 square miles of the LWL watershed and includes the north and central section of the LWL. These sections extend from just south of Jupiter Inlet in northern Palm Beach County to the Broward County line. The LWL basin, located east of the C-17, C-51 East, and C-16 basins, receives large inflows of fresh water from regional canals. The C-17 Canal discharges to the upper segment of the LWL. Canals C-51 and C-16 discharge to the middle and lower segments of the LWL.

The LWL basin, the fourth most developed basin in the LWL watershed, includes several incorporated municipalities (FDEP 2006): Jupiter, Palm Beach Gardens, and North Palm Beach, Riviera Beach, West Palm Beach, Palm Beach, Lake Worth, and Boynton Beach.

The 2004 – 2005 land use classification (Figure 3.4) show that the urban land use categories occupy approximately 65.6% of the basin. Predominant urban land uses in this category include medium- and high-density residential (approximately 30.5% and 15.5% respectively), with low density residential (1.8%), commercial (10.8%), and recreational (5.5%, including golf courses, parks, and athletic fields). comprising most of the rest. Transportation, including major roadways and utilities, accounts for approximately 3.1% of the total land cover. The most predominant natural land cover is upland forest (approximately 6.1%), most of which is identified as pine flatwoods, wetlands (1.4%), and water (22.8%).

Excessive fresh water downstream inflows from the C-16/Boynton Canal and (more predominantly) from the C-51/West Palm Beach Canal have affected the central and south segments of the LWL (FDEP, 2006). Fresh water inputs to the basin have increased over the years. Several agencies have expressed concerns (FDEP 2003, 2006) that the fresh water inputs are lowering the pH in the LWL (freshwater pH is typically lower than marine pH) (FDEP, 2003, 2006) and carrying increasing amounts of sediment into the LWL.

Nine out of 28 permitted wastewater treatment facilities in the basin have permits to discharge to the LWL. The two domestic wastewater facilities, Wellington Arms Condominiums and Ocean Maisonettes, operate package plants that provide advanced treatment to wastewater and discharge directly to the LWL. Five facilities within the LWL basin discharge cooling water to the LWL. One facility has a permit to discharge to the LWL in case of emergency only.

4.2.8.1 Meteorological Data Analysis

No rainfall stations operate in the LWL basin.

4.2.8.2 Hydrological Data Analysis

No flow stations operate in the LWL basin

4.2.8.3 Water Quality Data Analysis

Figures 4.78 through 4.86 show the water quality monthly medians between 1990 and 2008 measured at the 83 stations located in the LWL basin (Figure 3.3, Appendix C). Figure 4.78 shows seven pH samples exceeded the F.A.C. 62-302 rule surface water quality standards for pH (6.5 – 8.5 su). Two samples ranged above and five fell below the standard range) The data plotted in Figure 4.78 do not appear to support agency concerns for decreases in the pH of the lagoon (as cited in FDEP, 2006).

Figure 4.79 shows that 150 of 430 DO samples collected in the basin exceed the F.A.C. 62-302 surface water quality standards rule for DO of 4 mg/l. The segment of the LWL just north and south of the discharge point of the C-17 Canal (Structure S-44 in Figure 3.2) was listed in the 1998 (303d) list of impaired waters for DO but it was removed in the 2005 update, most likely due to the improvement in the DO levels in the LWL.

Taylor Engineering found very little BOD data (Figure 4.80) and no COD data for the LWL basin. BOD values varied between 0 and 5 mg/l. The majority of the NO_3+NO_2 samples fall below 0.5 mg/l (Figure 4.81) while the majority of the TKN samples (Figure 4.82) fall below 1.5 mg/l. Figures 4.74 and 4.85 show OPO_4 and TP data for the LWL basin. In an obvious reporting error, total phosphorus values are often lower than OPO_4 values collected on the same date. All sample locations (stations) with OPO_4 data differ from the locations with TP data. Independently of location, most of the phosphorus sample values remain below 0.10 mg/L, and the maximum values for the two parameters fall below 0.4 mg/L.

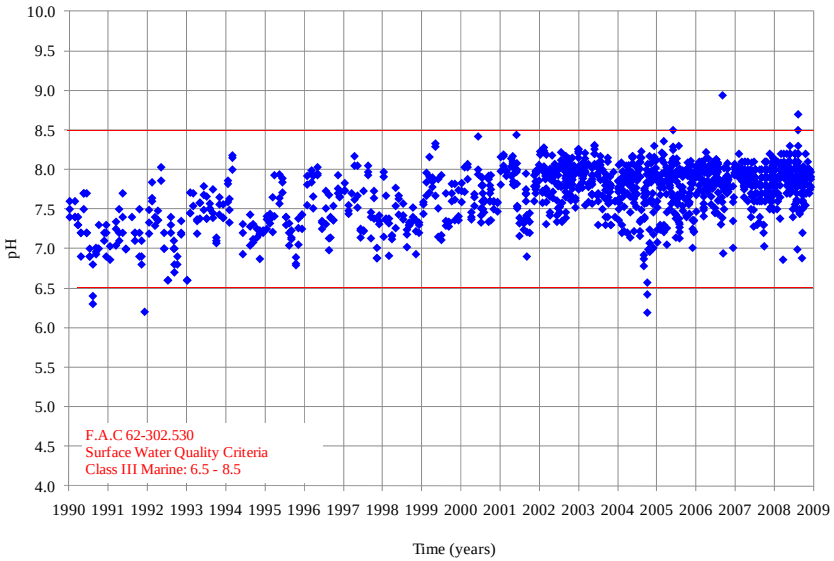


Figure 4.78 pH Monthly Averages for the LWL Stations

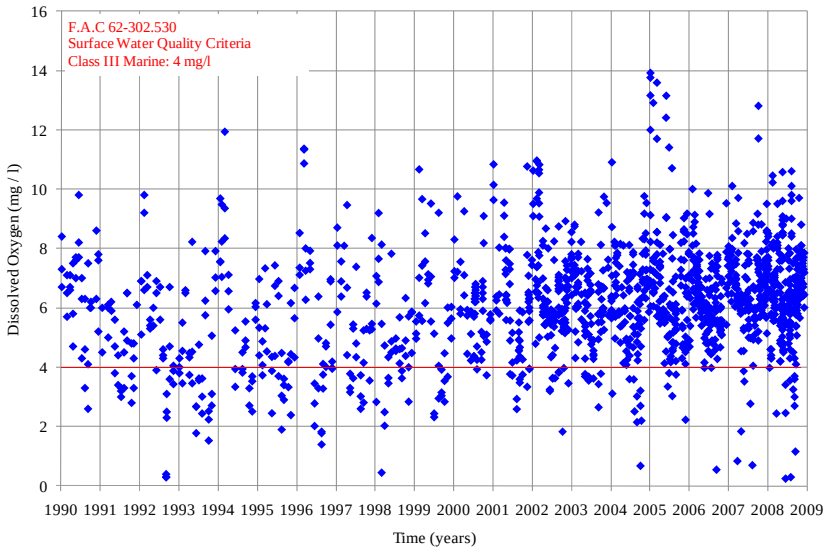


Figure 4.79 DO Monthly Averages for the LWL Stations

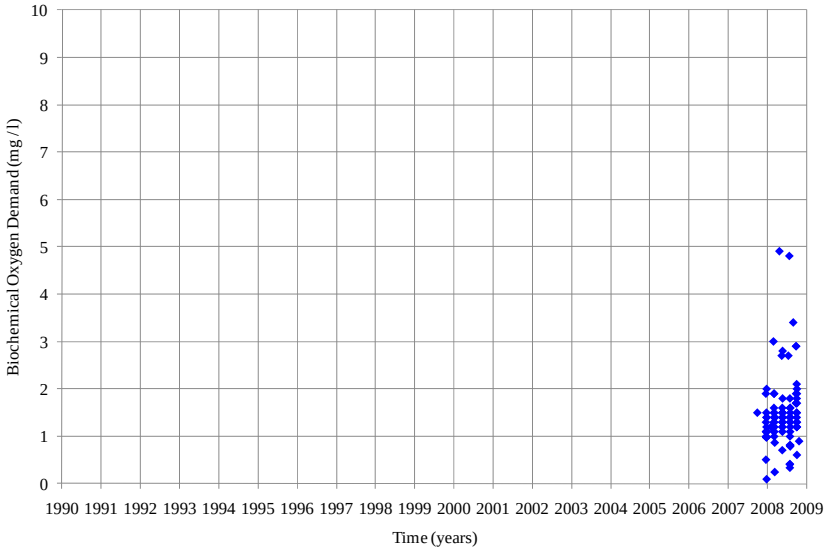


Figure 4.80 BOD Monthly Averages for the LWL Stations

No data found

COD Monthly Averages for the LWL Stations

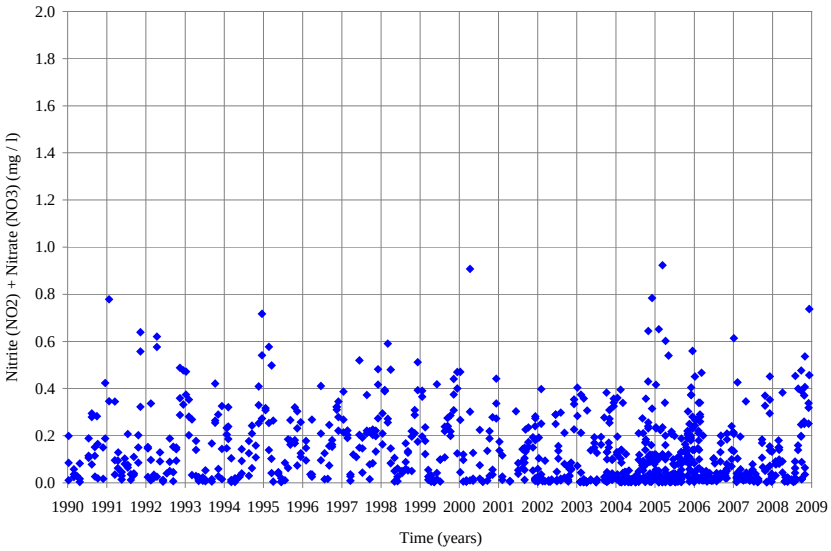


Figure 4.81 NO_2+NO_3 Monthly Averages for the LWL Stations

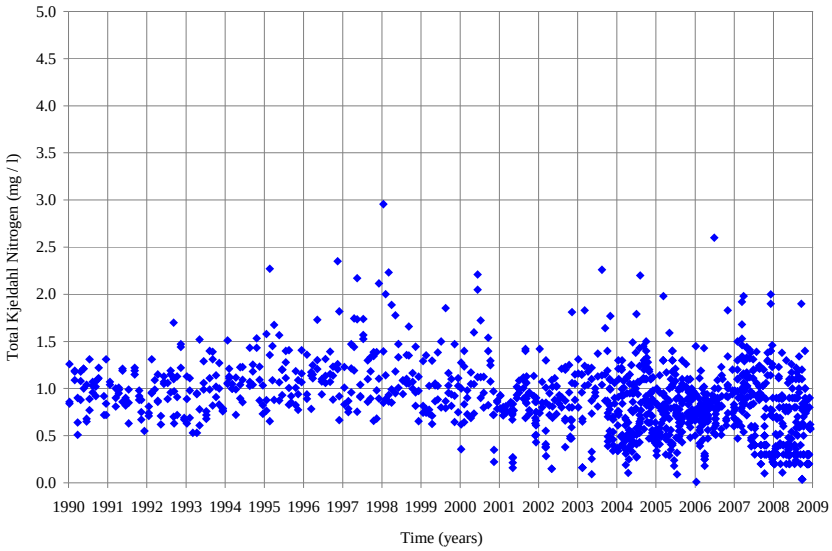


Figure 4.82 TKN Monthly Averages for the LWL Stations

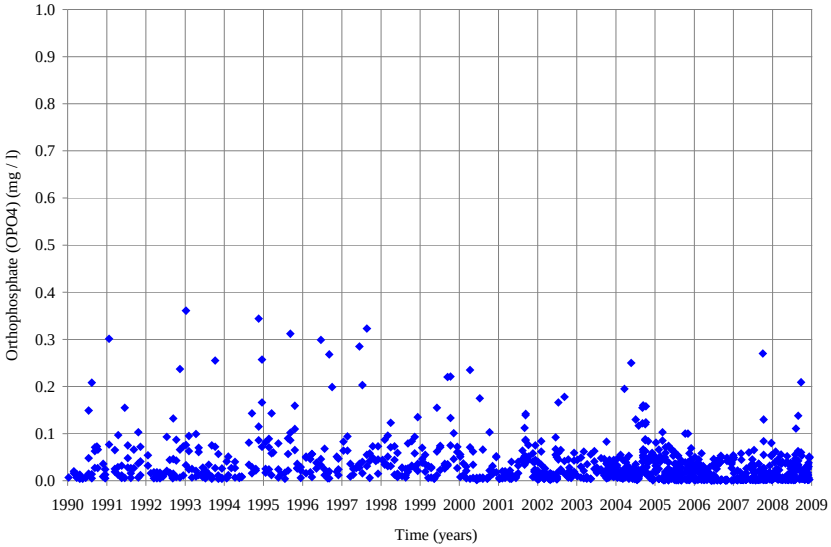


Figure 4.83 OPO_4 Monthly Averages for the LWL Stations

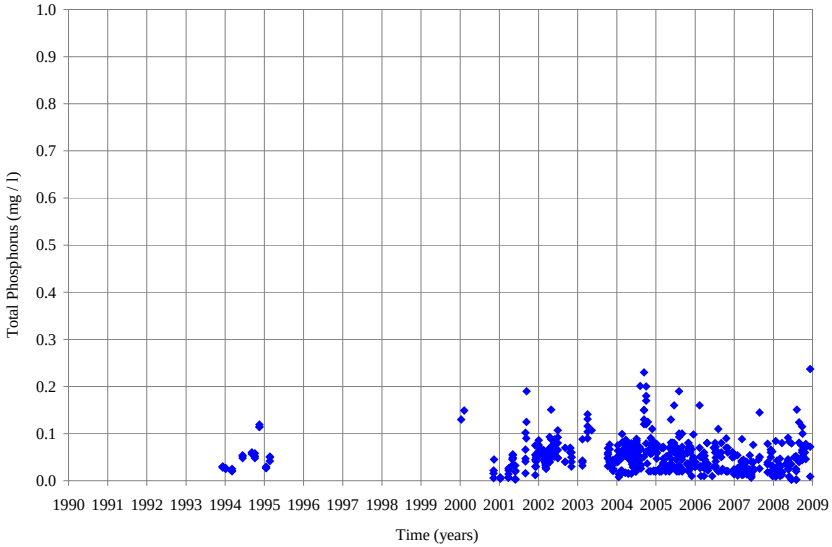


Figure 4.84 TP Monthly Averages for the LWL Stations

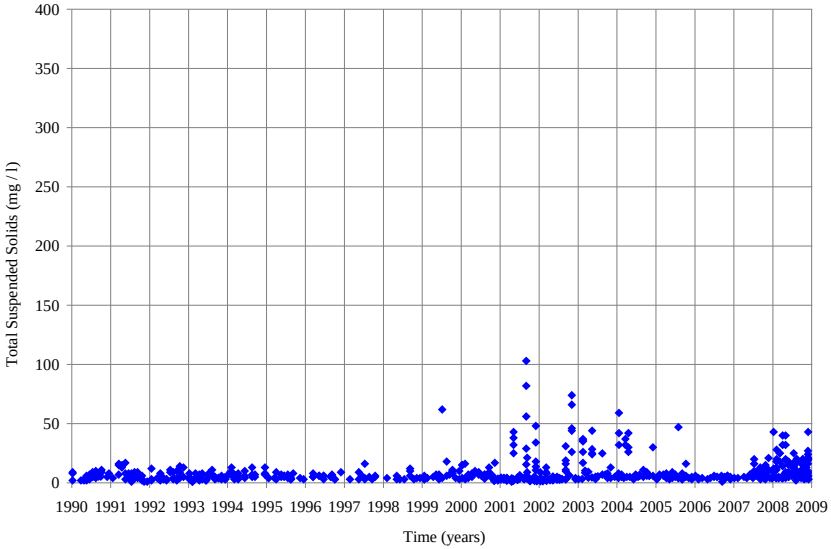


Figure 8.85 TSS Monthly Averages for the LWL Stations

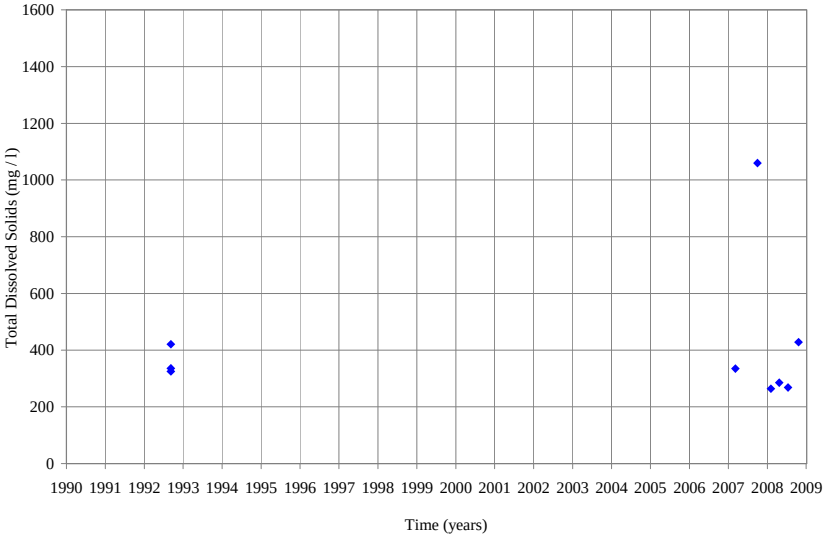


Figure 4.86 TDS Monthly Averages for the LWL Stations

Figure 4.85 shows the TSS for the LWL basin. The majority of the data reported fall below 20 mg/l. Between 2001 and 2005, and during 2008, TSS concentrations measured in the lagoon increased dramatically. Figure 4.86 shows the TDS data for the LWL basin. These values suggest the potential for TSS-related water quality issues and may confirm the concerns stated in the 2006 FDWP water quality assessment report regarding an increase in sediment loads to the LWL. Albeit from a very limited data set, the five samples collected during 2008 fell below 600 mg/l.

5. SEASONAL ANALYSIS

To quantify the seasonal variability of the water quality data, Taylor Engineering segregated the data collected between 1995 and 2008 into seasaonl sets: data collected during the dry season (November to April), and data collected during the wet season (May to October). This analysis included stations from the lakes and canals in each basin, and data from the Lake Worth Lagoon. Data for individual stations received the same weight, regardless of the number of samples available for each station, or the month they were collected.

Tables in Appendix E show data statistics of each season for all stations in each basin and the dataset period. The box and whisker plots for each parameter (Figures 5.1 through 5.10) show the extremes (maximum and minimum) and the quartiles (25%, 50%, and 75%), of the recorded concentrations for all basins in the watershed for all water quality parameters reviewed. These parameters include dissolved oxygen (DO), alkalinity (pH), orthophosphate (OPO_4), total phosphorus (TP), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrite plus nitrate (NO2 + NO3), total Kjeldahl nitrogen (TKN), total suspended solids (TSS), and total dissolved solids (TDS).

Figure 5.1 shows the box and whisker plot for dry and wet season pH data from each of the eight basins in the LWL watershed. The figure reflects data collected through 2008 for seven basins and data collected from 1999 through 2005 for the Acme B basin (Appendix E). For the period of record for each basin, the dry season pH median generally exceeds the wet season median. However, the median value for all basins falls well within the F.A.C. 62-302 rule surface water quality standards for pH (6 – 8.5 su).

Figure 5.2 shows wet and dry season box and whisker plots for DO samples from the eight basins in the LWL watershed. The figure reflects data collected through 2008 for seven basins and data collected from 1999 through 2005 for the Acme B basin (Appendix E).

With one exception (C-16 North), the dry season DO medians greatly exceeded the wet season medians. For the lone exception, the DO median difference equals 0.1 mg/l. With the exception of the C-16 basin, the dry season medians for all other basins exceed the F.A.C. 62-302 rule surface water quality standards for DO (5 mg/l for fresh water and 4 mg/l for marine waters), indicating that low DO is not an issue in those basins during the dry season.

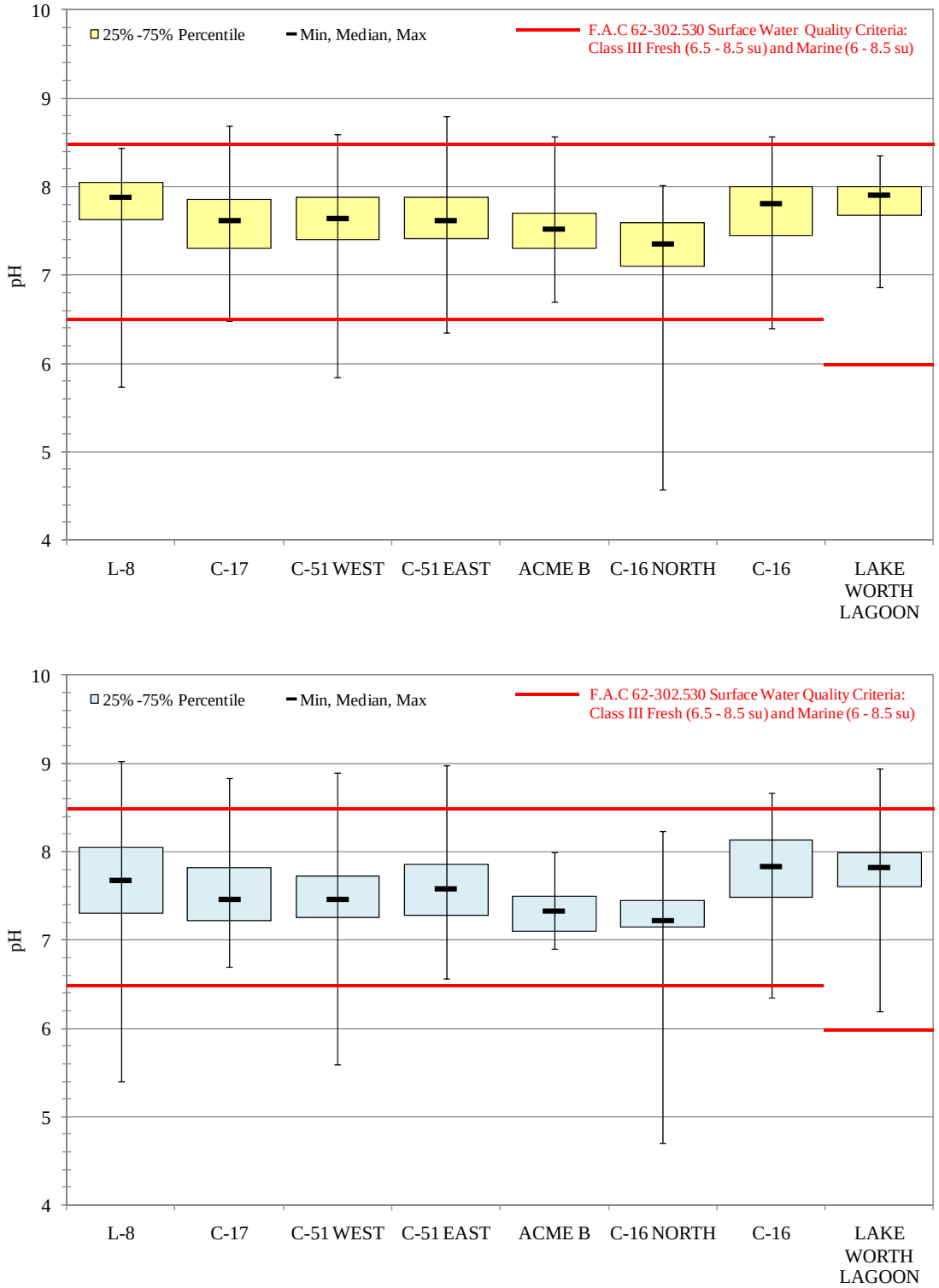


Figure 5.1 pH Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

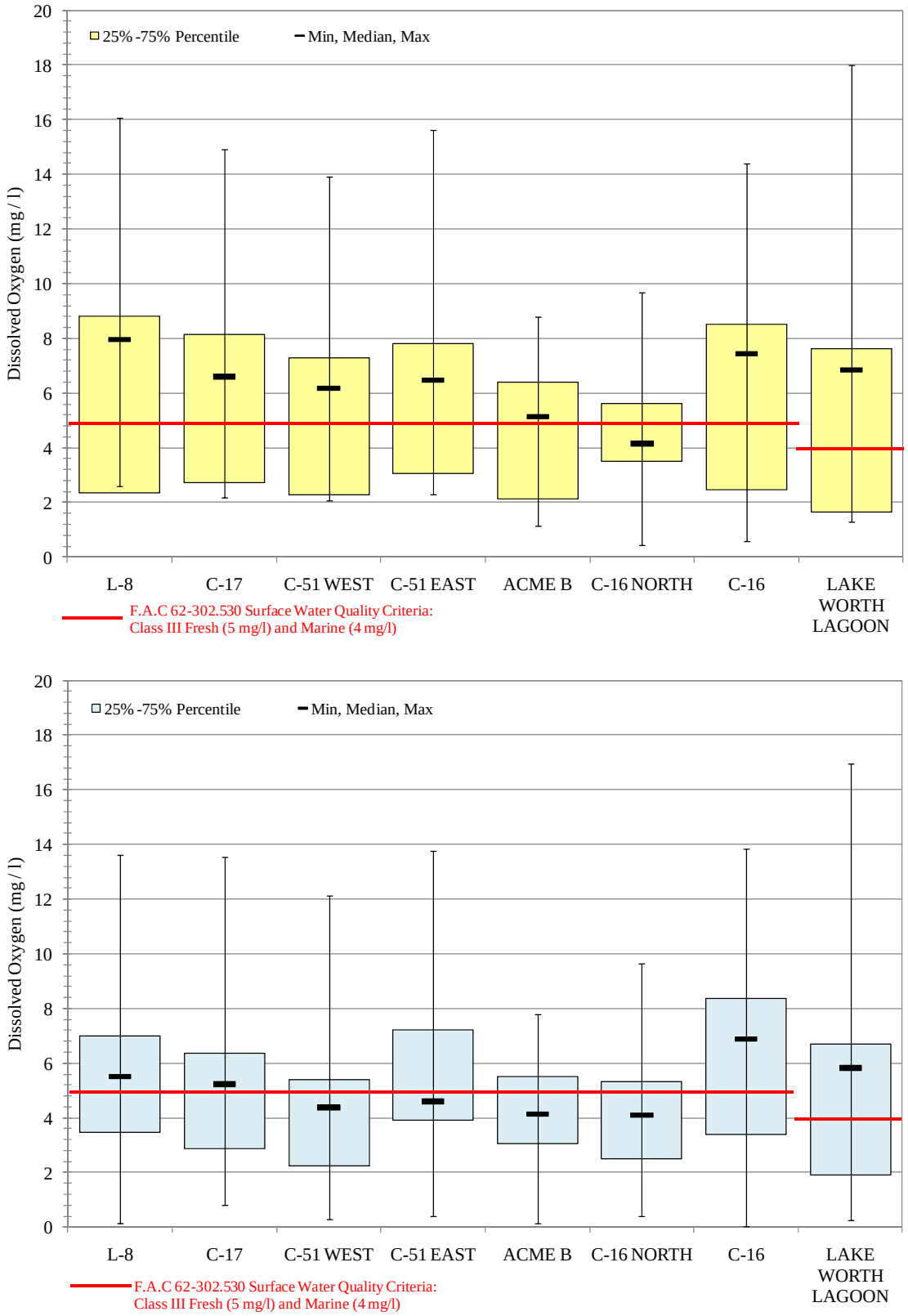


Figure 5.2 DO Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

For the wet season, the C-51 East, C-51West, Acme B, and C-16 North basins have DO lower that the minimum standard of 5 mg/l, indicating poor water quality during the wet season. The Lake Worth Lagoon median exceeds 4 mg/l, and the L-8 and the C-16 medians exceed 0.5 mg/l, suggesting that DO is not an issue during the wet season in those basins.

Biochemical oxygen demand (BOD) represents the amount of oxygen consumed during decomposition of organic matter by microorganisms. As BOD increases, DO in the water body tends to decrease. Figure 5.3 shows the box and whisker plot for BOD for six of the eight basins in the LWL watershed. No BOD data was available for the Acme B or the C-16 North basin. The figure reflects data collected through 2008 for five basins and data collected from 2006 through 2007 for the L-8 and C-17 basins (Appendix E). BOD medians for all basins were generally higher during the wet season, which agrees with the lower DO medians during that season.

Figure 5.4 shows the box and whisker plot for COD based on data reported between July 2002 and March 2003 for the C-51 East basin. No COD data was available for any of the other basins.

Figure 5.5 shows the box and whisker plot for NO_2 + NO_3 for the eight basins in the LWL watershed. The figure reflects data collected through 2008 for six basins, data collected from 2003 through 2007 for the Acme B basin, and data collected from 1997 through 2007 for the C-16 North basin (Appendix E). For the period of record for each basin, NO_2 + NO_3 medians for the dry season generally exceed medians for the wet season. L-8, C-51 West, C-16, and C-51 East had the highest (above 0.14 mg/l) NO_2 + NO_3 medians for the dry season. L-8, C-51 East, C-51 West, and Acme B basins had the highest (above 0.9 mg/l) NO_2 + NO_3 medians for the wet season.

Figure 5.6 shows the box and whisker plot for TKN for the eight basins in the LWL watershed. The figure reflects data collected through 2008 for six of the basins. Data collected from 2003 through 2007 the Acme B basin and data collected from 1997 through 2007 for the C-16 North basin (Appendix E) provided the total available datasets for TKN in those basins.

TKN varies little between the dry season and the wet season (Figure 5.6). TKN medians run highest (1.2 – 1.6 mg/l) in basins (C-16 North, L-8, Acme B, and C-51 West) where nitrogen dependent agriculture (sugar cane, orange groves, row crops, and horse farms and pasture) is one of the dominant land uses. TKN medians run the lowest (0.8 – 1.2 mg/l) in the eastern basins where urban development predominates.

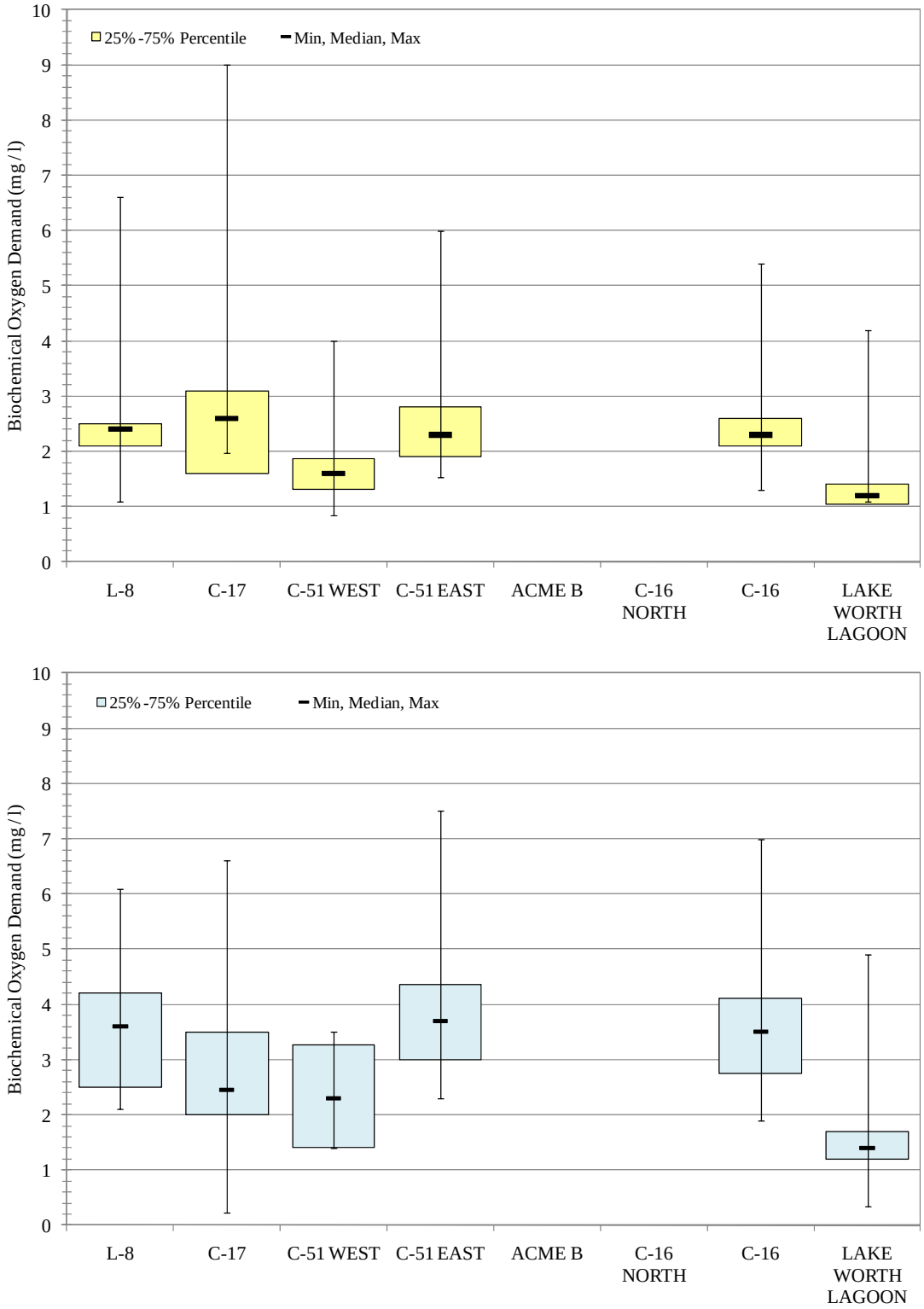


Figure 5.3 BOD Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

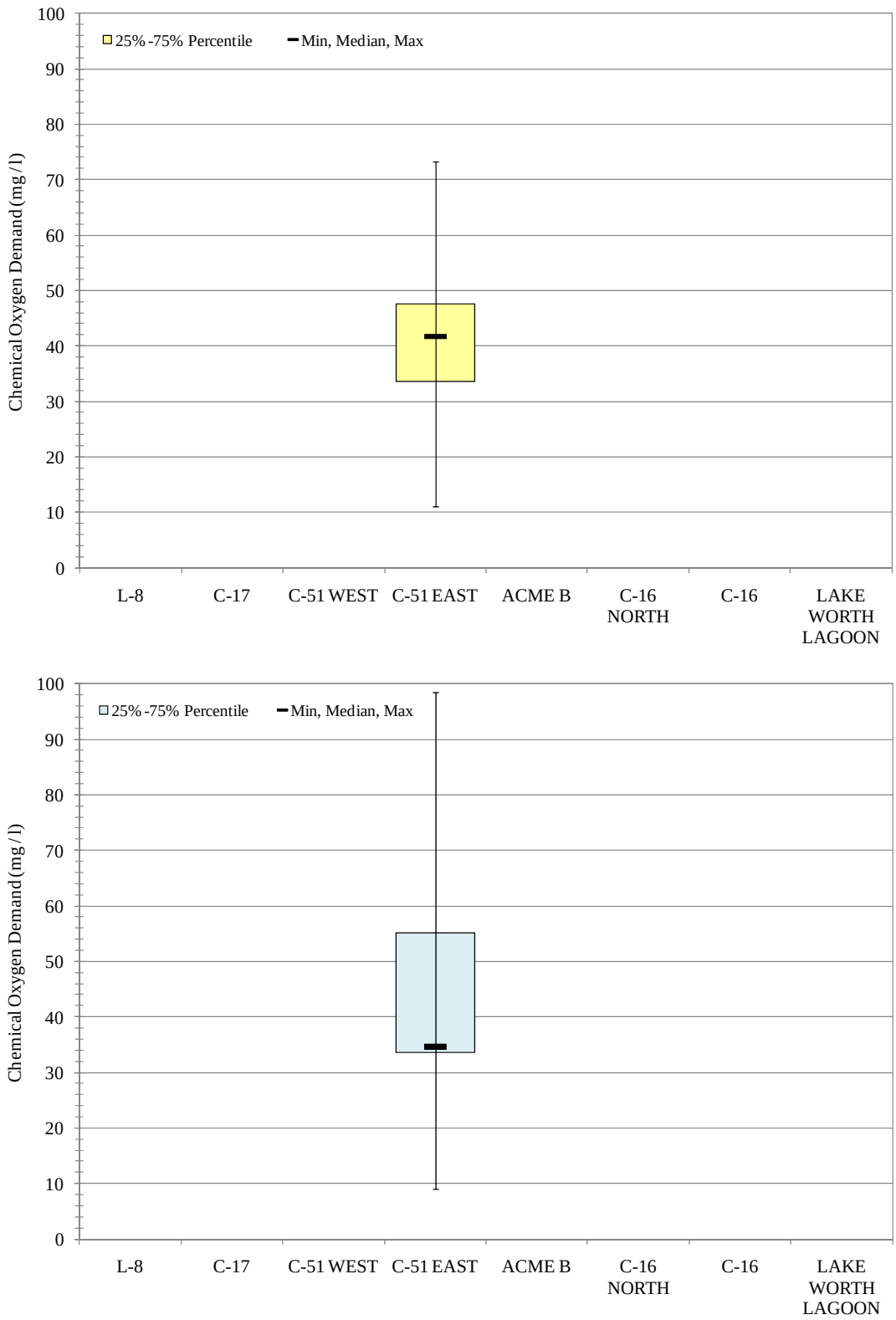


Figure 5.4 COD Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

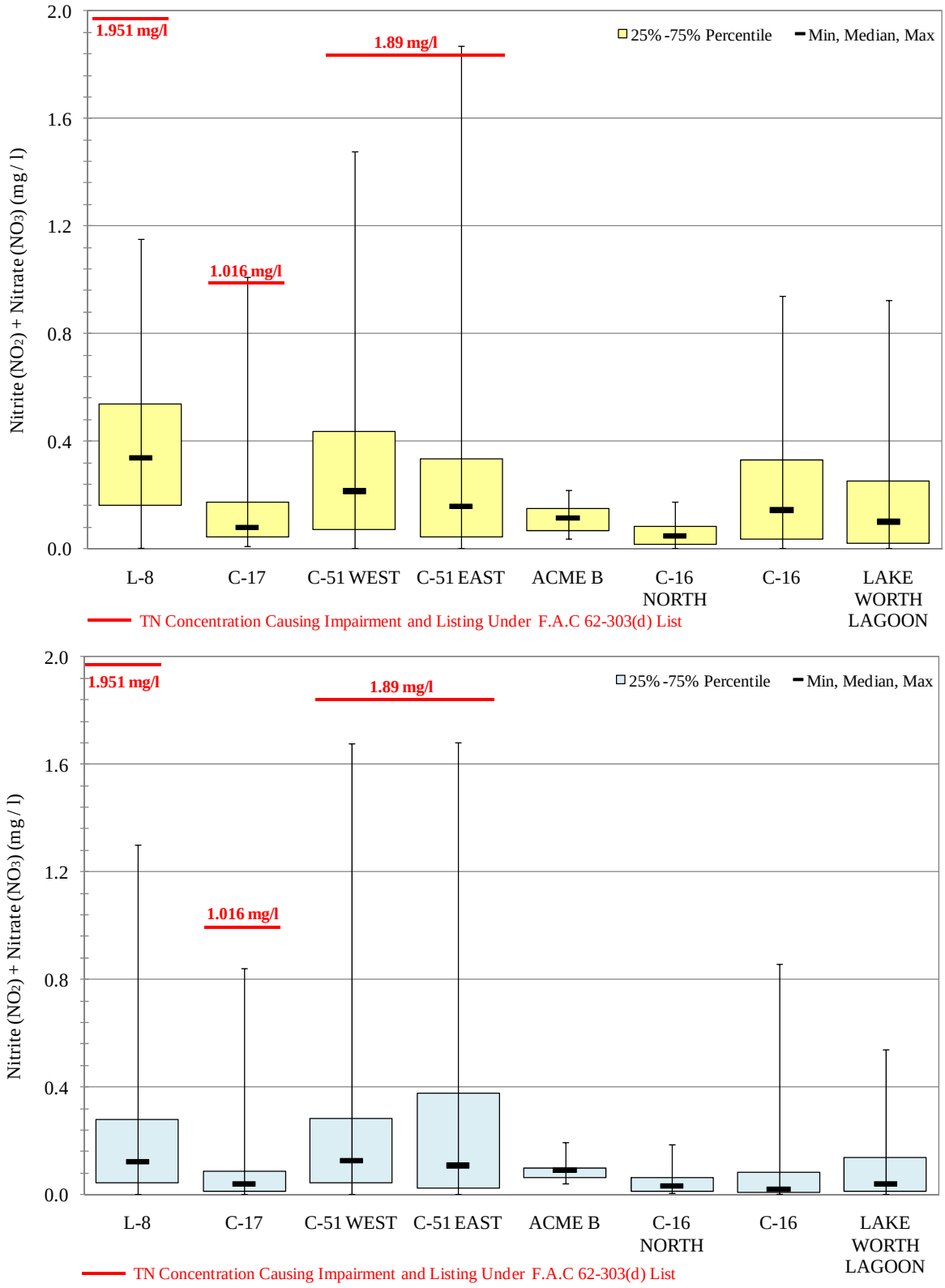


Figure 5.5 NO_2 + NO_3 Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

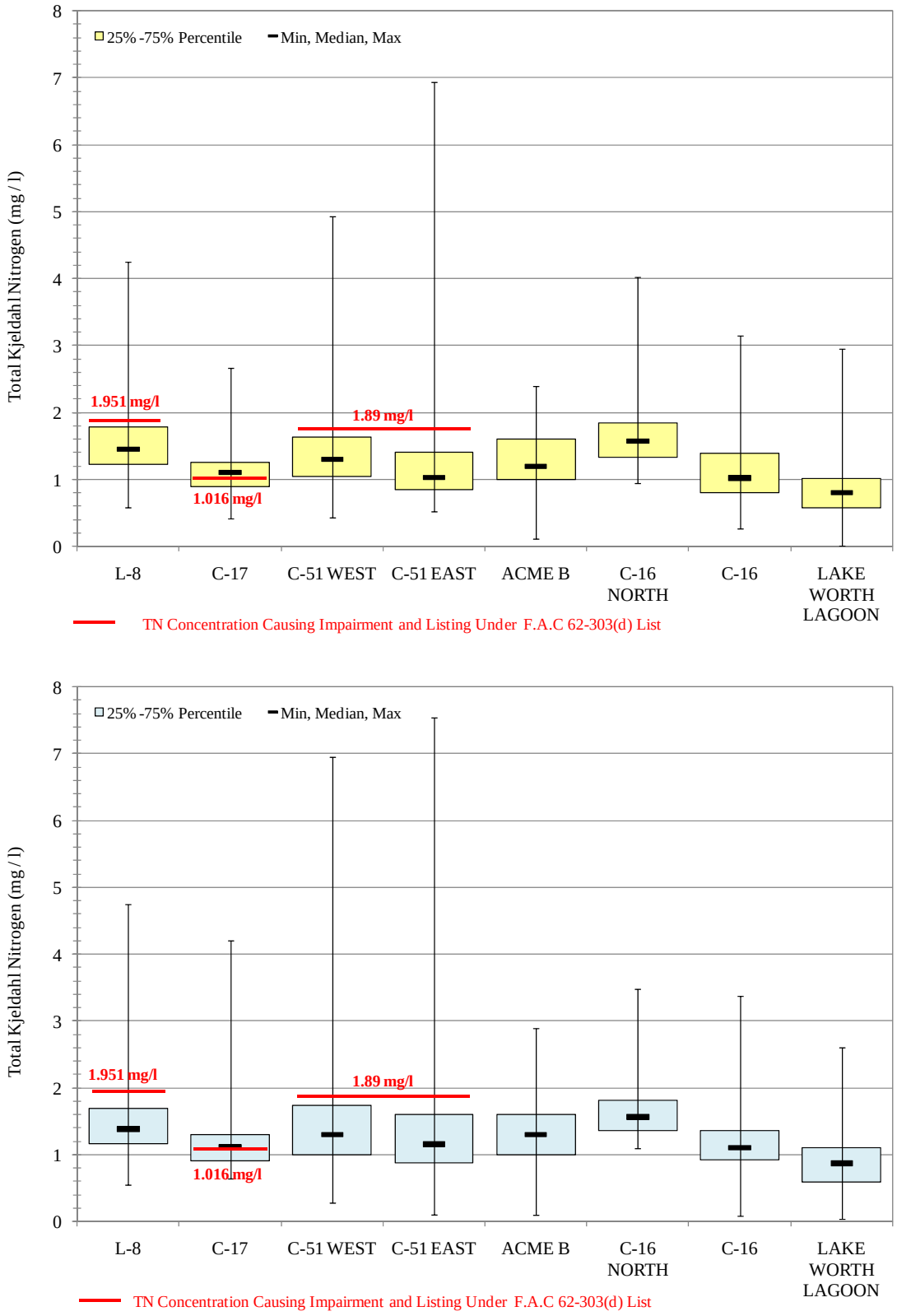


Figure 5.6 TKN Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

Total nitrogen (TN) is composed of NO_2 + NO_3 and TKN. Based on data collected between January 1997 and July 2004, the 2005 update of the F.A.C. 62-303(d) list of impaired waters (FDEP, 2005a) reports TN medians for the L-8 basin (1.951 mg/l), the C-17 basin (1.016 mg/l), and for the C-51 basin (1.89 mg/l). Assuming these TN medians provide a reference value for the basins, TKN medians for the C-17 basin exceed the median values presented in FDEP (2005a) during the dry and wet season. Given the small variation in the medians reported for (TKN) for both seasons; the seasonal difference between the medians reported for the readily available nitrogen (NO_2 + NO_3) seems to drive the total nitrogen medians above impairment values.

Figure 5.7 shows the box and whisker plot for OPO_4 for the eight basins in the LWL watershed. The figure reflects data collected through 2008 for seven of the basins and data collected from 1997 through 2007 for the C-16 North basin (Appendix E). In each basin, the difference between dry season and wet season OPO_4 medians is very small. Median values are highest at the L-8 basin followed by the C-51 West, Acme B, and the C-16 basins. Basins with agriculture as one of the dominant land uses (L-8, C-51 West, and Acme B) have higher median values. In the case of the C-16 basin, residential and recreational (golf courses) land uses may account for the high orthophosphate medians.

Figure 5.8 shows the box and whisker plot for TP for seven of the eight basins in the LWL watershed. The available data did not include TP values for ACME B basin (Appendix E). With the exception of the L-8 and C-51 West basins, dry season TP medians are generally lower than wet season medians. The TP median is highest in the L-8 basin, followed by the C-16 North, C-17, C-16, and the C-51 West basins. Developed basins (C-16 and C-17) or basins where agriculture land uses occupy a large percentage of the land (L-8 C-16 North, and C-51 West) exhibit the highest medians.

The 2005 updated F.A.C. 62-303(d) list of impaired waters (FDEP, 2005a) reports TP median between January 1997 and July 2004 for the C-17 basin as 0.053 mg/l. The C-17 medians (dry and wet season) for the available data period exceeded the F.A.C. 62-303(d) list value.

Based on data collected through 2008, Figure 5.9 shows the box and whisker plot for TSS for the eight basins in the LWL watershed (Appendix E). The L-8, the Acme B, the C-17, and the C-51 West basins exhibit the highest TSS medians for the dry season; the L-8, the C-16, Acme B, and the C-51 East basins exhibit the highest TSS medians for the wet season.

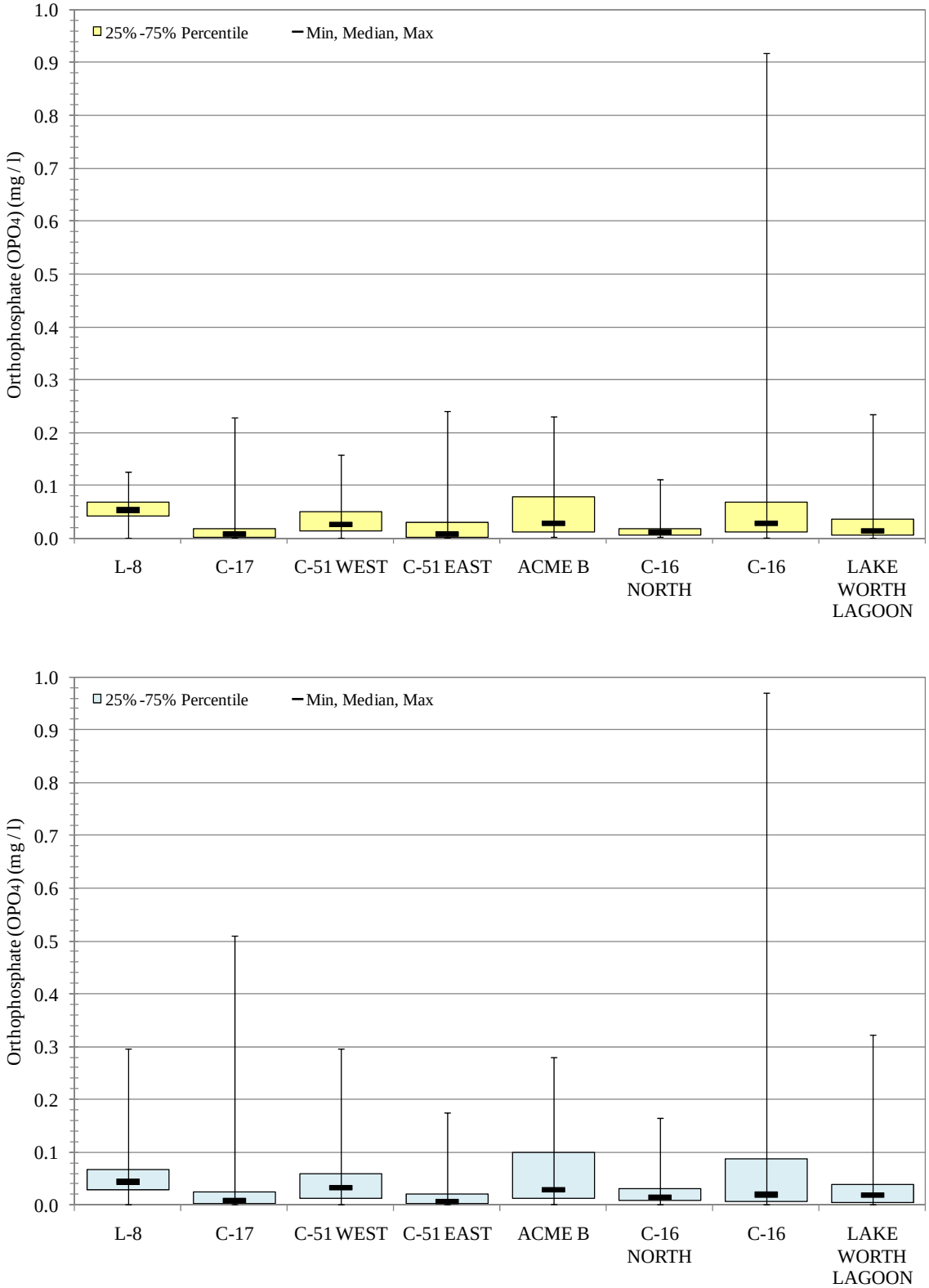


Figure 5.7 OPO_4 Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

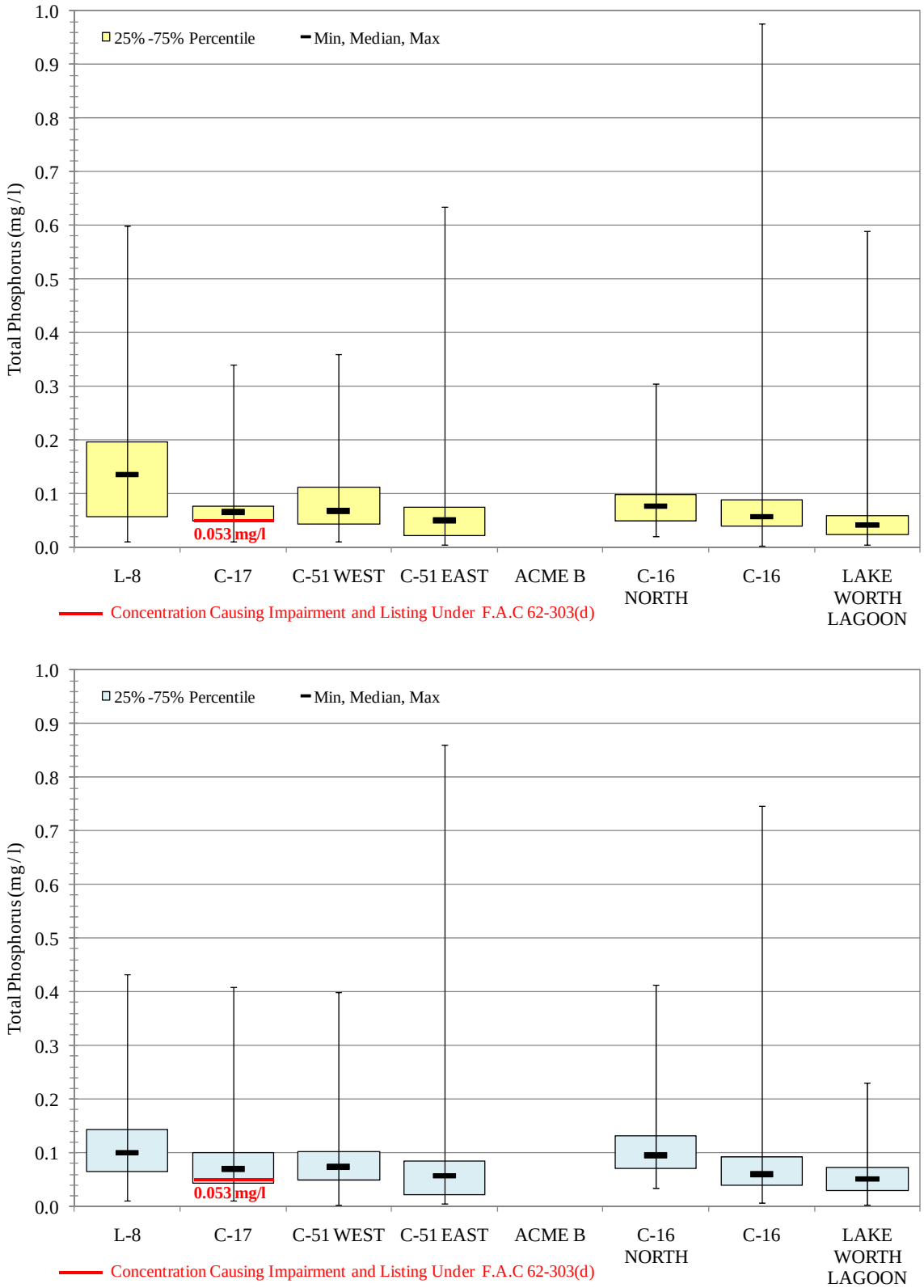


Figure 5.8 TP Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

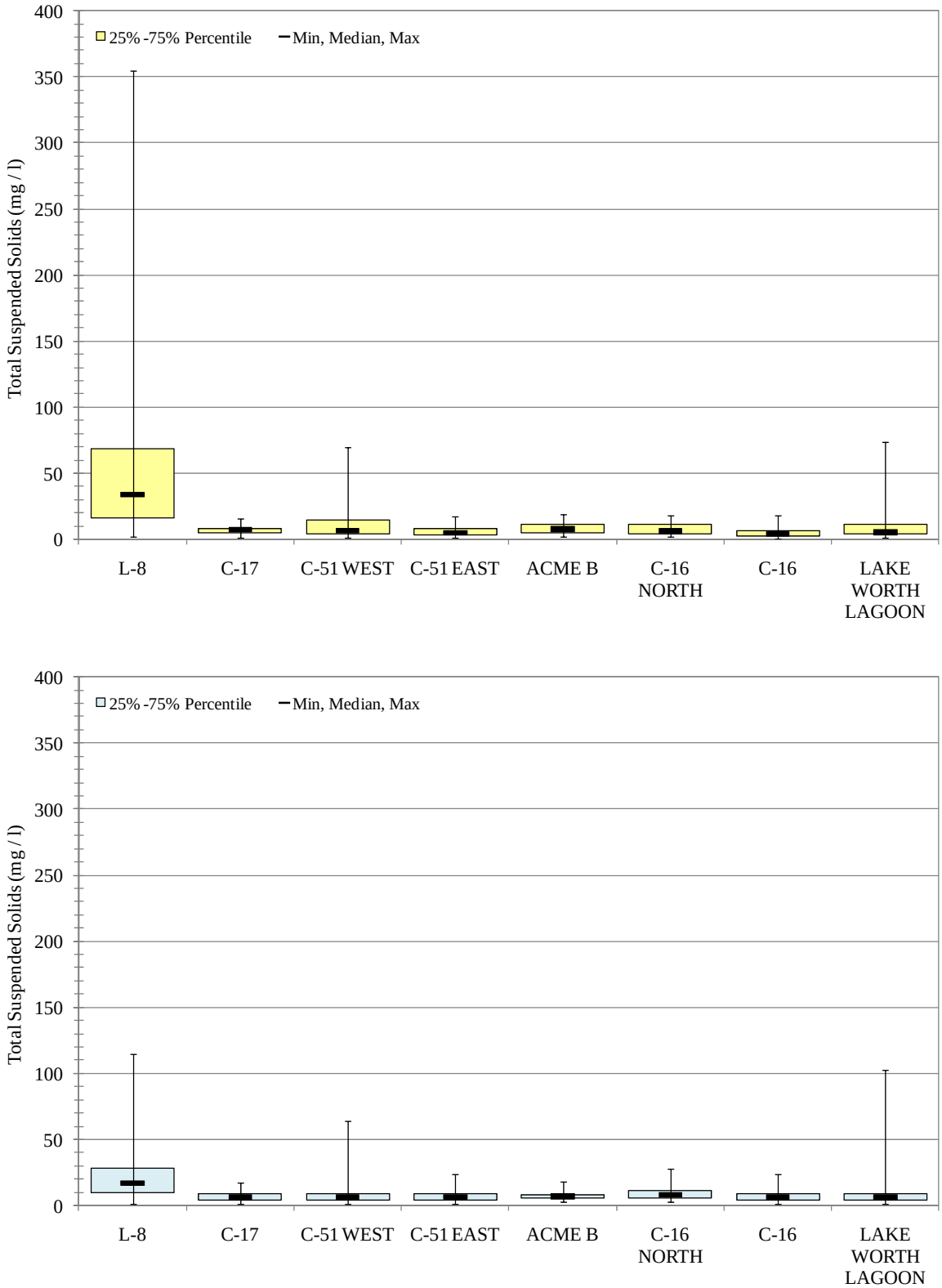


Figure 5.9 TSS Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

Figure 5.10 shows the box and whisker plot for TDS for six of the eight basins in the LWL watershed. The figure reflects data collected through 2008 for the six basins (Appendix E). All basins exhibit similar medians for the period of record.

The seasonal water quality analysis indicated that DO, TKN, OPO_4, and TP are the parameters of concern in the LWL watershed. Based on the 1998 F.A.C. 62-303(d) list data and on the results of this study, basins such as C-51 West, Acme B, and C-16 North clearly demonstrate the relationship between low DO and elevated nutrient inputs (TKN and OPO_4). This relationship could apply to the majority of basins where agriculture uses occupy large areas.

Harper (1994) and Harper and Baker (2003) included literature reviews of TN, OPO4, TP, BOD, and TSS stormwater runoff concentrations for selected land use categories in central, south, and southwest Florida. According to these reports, agriculture (pasture, row crops, and citrus), and medium and high density residential and high density commercial land uses have the highest TN and TP concentrations. Medium and high density residential and high density commercial land uses have the highest BOD concentrations.

High density commercial, industrial, pasture, and high and medium density residential land uses have the highest TSS concentrations. The agriculture lands in the C-51 West, Acme B, or the C-16 North basins include row crops, pasture and horse farms, as well as citrus groves and fruit orchards, and have high medians of TN and TP.

The same reports (Harper, 1994; Harper and Baker, 2003) also support the findings of this study that basins where medium and high density residential land uses are most common (C-17, C-16, C- 51 East, and LWL), elevated nutrient levels may relate to development rather than agriculture. The majority of the developed land uses in these basins are medium and high density residential. In the particular case of the C-17 basin, commercial and industrial are most likely the second most important land use contributor to the elevated nutrient median values. In the case of the C-16 basin, agriculture is most likely the third most important land use contributor to the elevated nutrient median values.

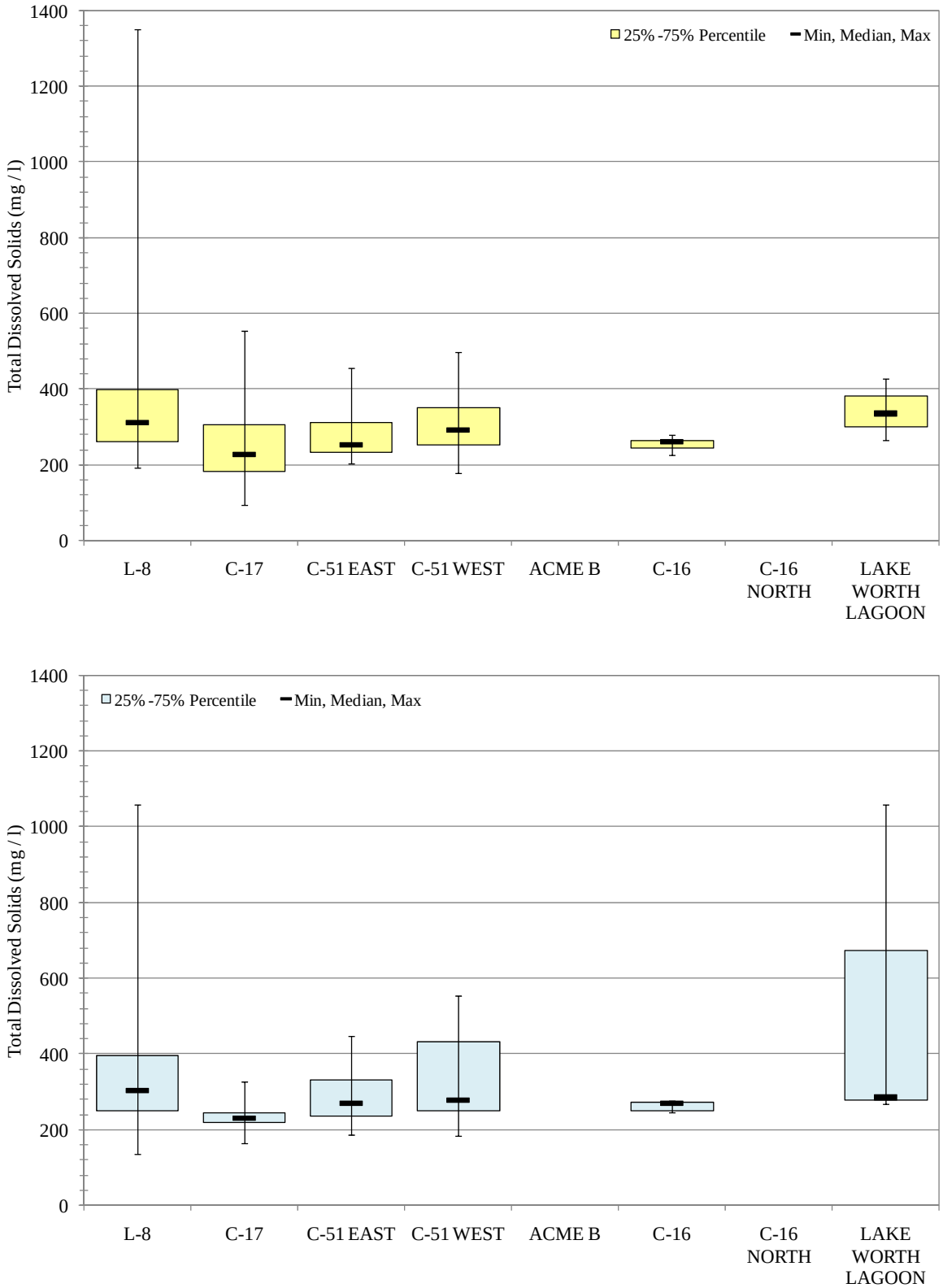


Figure 5.10 TDS Dry (Top) and Wet (Bottom) Season Extremes and Quartiles for the Lake Worth Lagoon Watershed Basins

6. GEOSPATIAL DATA ANALYSIS

The goal of the geospatial analysis was to identify, within each basin, the location of the highest reported annual medians for each water quality parameter, and to assess the location of those data relative to a particular land use category. Linking land use types to areas with poor water quality will help prioritize areas to locate monitoring stations to collect data suitable to calculate EMCs (see Chapter 8).

Using on the monthly average data from the selected stations, Taylor Engineering calculated annual medians for water quality parameters for each station in the LWL watershed (Appendix F). The calculation accounted for stations with more than three data points for the same year. The GIS geodatabase provided with this project includes both the monthly and annual water quality data and statistics between 1990 and 2008.

Data included in this study represent canals, lakes, the LWL lagoon, and wetland areas. To meet the criteria used in this report to include stations in the annual analysis, several agencies, in 2008, increased the number of stations they sampled and the sampling frequency to more than three samples yearly. Thus, the 2008 sampling data may receive more weight in the analysis.

Taylor Engineering used statistical median to show concentrations of each water quality parameter. Depending on the variability of the parameter, the annual medians were grouped into either four or five groups. In the case of pH and DO, the lower limits of some of the groups represented the F.A.C. 62-302 surface water quality standard limits discussed in Chapters 4.

In this chapter, each figure shows changes in concentration for a specific parameter in a basin between 2006 and 2008. Each figure includes a map and table summarizing any changes noted over the three years of evaluation.

The map shows

- Basin land use categories
- Primary and secondary drainage canal locations
- Location and ID of the monitoring stations

- Water quality parameter annual concentration medians ranges for 2006, 2007, and 2008. Note that 2006 – 2008 were dry years. During dry years, stormwater runoff and transported loads were typically lower (see Chapter 4 for basin rainfall and Chapter 7 for load analysis.)
- Color and size coded legend — each symbol color and size combination represents a range of median values for each water quality parameter median grouped to display the information in GIS.

The table includes

- Dominant land use quantities (acres) — the dominant urban, agriculture, undeveloped landuses in the basin
- Sampling effort — number of stations with more than three samples in that year
- Concentration changes — increase and decrease in parameter concentration between 2006 (baseline year) and 2008
- Geographic trend — changes in the parameter concentrations within the basin from north to south (N-S) or west to east (W-E)
- Concentrations of concern — regulatory and literature-based concentrations that determine the status (elevated or not elevated) of the parameter concentration
- Stations of concern — stations reporting elevated concentration for a parameter or stations reporting concentrations in violation of regulatory limits

The last row of the table includes any pertinent comments concerning the data in the table.

Figures 7.1 through Figure 7.49 show the results of the geospatial analysis for all the basins in the LWL watershed in the form of a technical sheet organized by basin and by water quality parameter. This chapter does not present water quality datasheets for biological oxygen demand (BOD), chemical oxygen demand (COD), and total dissolved solids (TDS) because the datasets did not have data for all three years (2006 – 2008) represented in this chapter.

L-8 BASIN

Figures for

Alkalinity (pH)

Dissolved oxygen (DO)

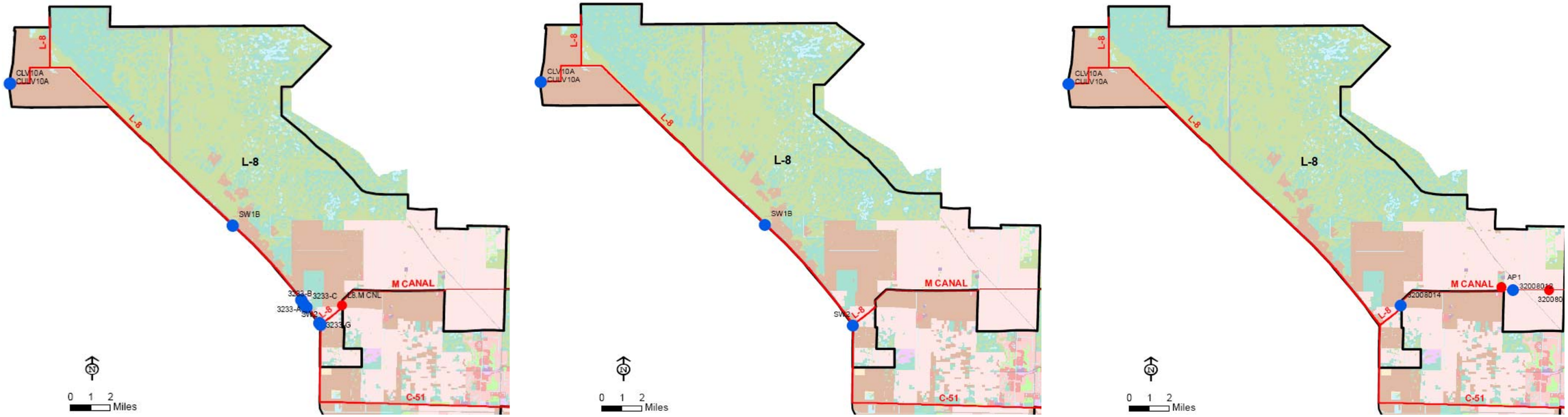
Nitrite plus nitrate (NO_2 + NO_3)

Total Kjeldahl nitrogen (TKN)

Orthophosphate (OPO_4)

Total phosphorus (TP)

Total suspended solids (TSS)



LEGEND

pH Annual Median (mg/l)

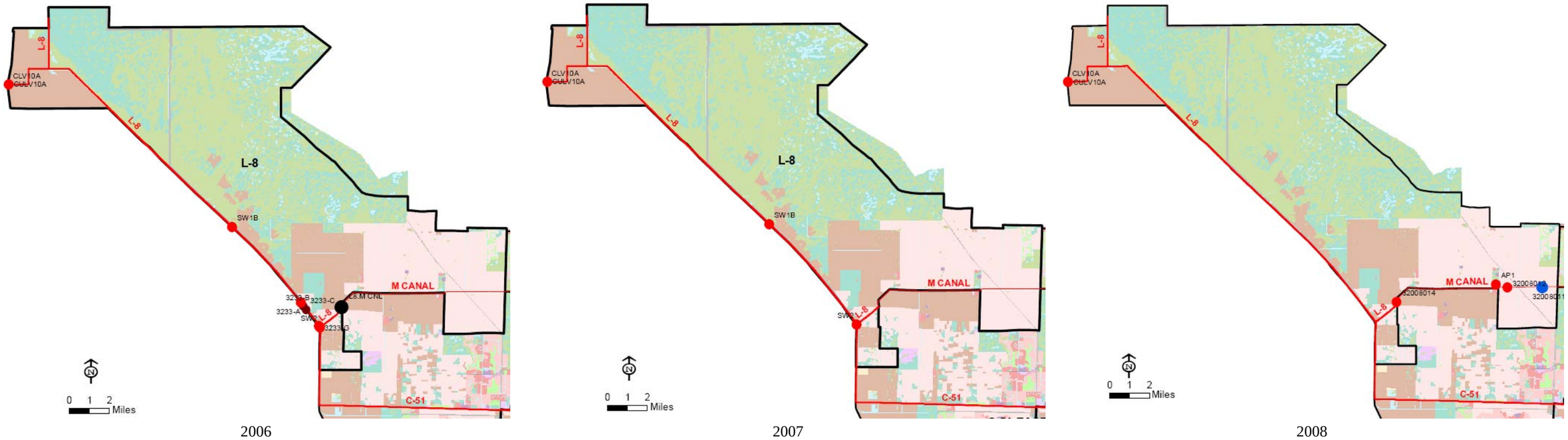
- Less Than 6.0
- 6.1 - 6.5
- 6.6 - 7.5
- 7.6 - 8.5
- More than 8.5

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	9	4	6
Concentration changes	Baseline	No Change	Lower pH in M Canal
Geographic trend	W → E (high → low)	W → E (high →low)	W → E (high → low)
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	All annual median values within F.A.C.62-302 surface water quality standards (see Appendix F for summary data)		

Figure 6.1 pH Medians between 2006 and 2008 for All Stations in the L-8 Canal Basin



LEGEND

DO Annual Median (mg/l)

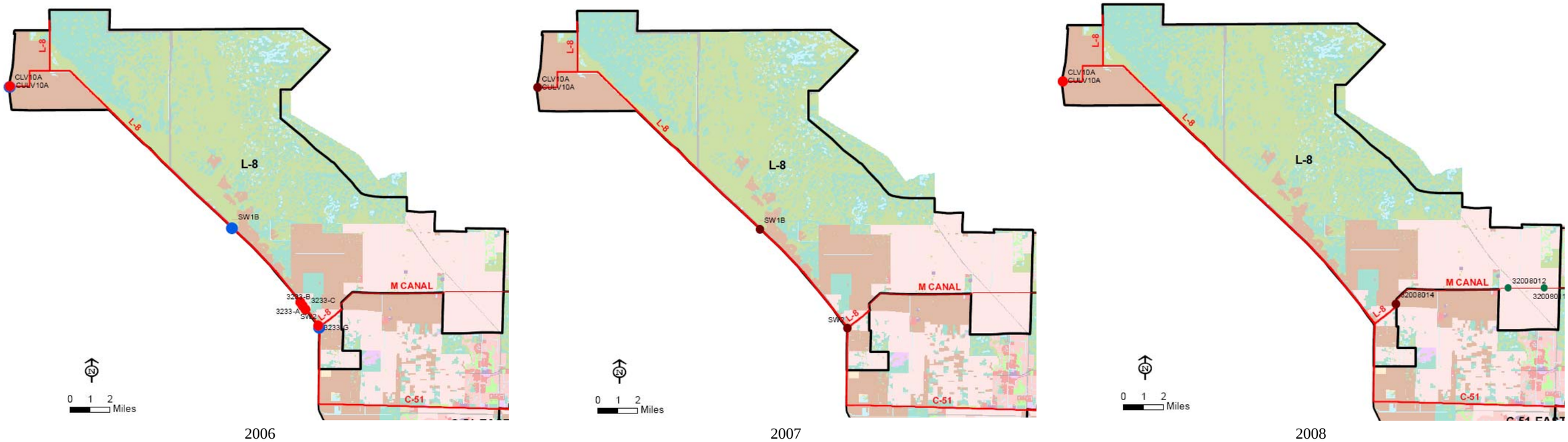
- Less than 4
- 4.1 - 5.0
- 5.1 - 7.5
- 7.6 - 10.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	9	4	6
Concentration changes	Baseline	No change	Increase and Decrease
Geographic trend	N → S (high → low)	None	W → E (low → high)
Concentrations of concern	< 5mg/l	< 5mg/l	< 5mg/l
Stations of concern	L8.M.CNL	Station Inactive	Station Inactive
Comments	Between 2006 and 2009 at the intersection of the L-8 and M Canal, the DO increased from less than 4 to more than 5 mg/l. Station 32008011 DO concentrations exceed the F.A.C.62-302 standards. See Appendix F for summary data.		

Figure 6.2 DO Medians between 2006 and 2008 for All Stations in the L-8 Canal Basin



LEGEND

NO2 + NO3 Annual Median (mg/l)

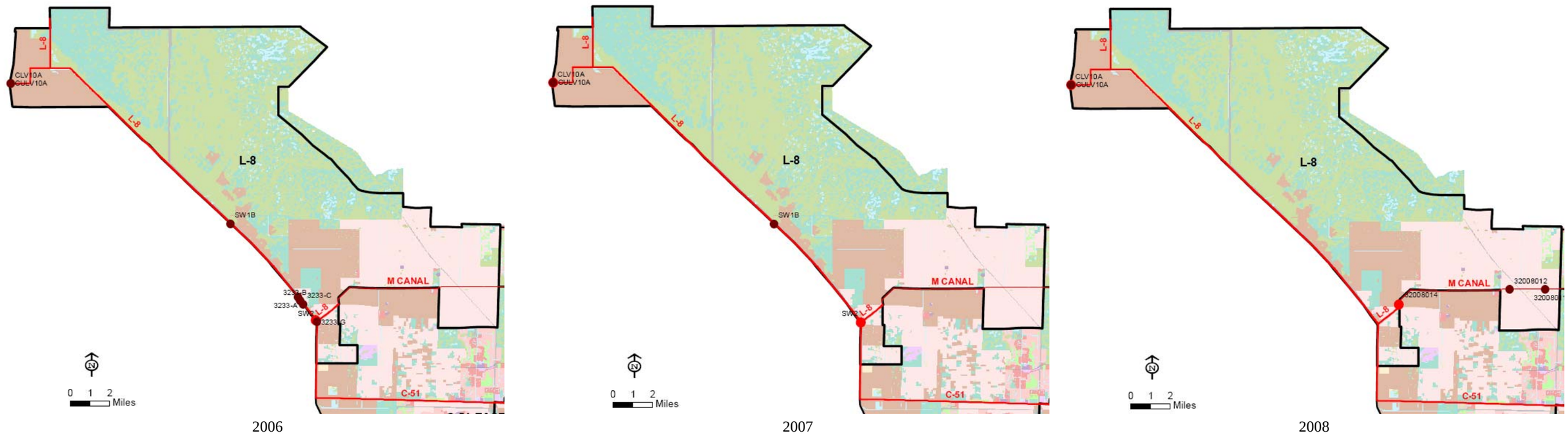
- 0.01 - 0.03
- 0.04 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.45

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	8	4	5
Concentration changes	Baseline	Decrease	Increase / Decrease
Geographic trend	High N → S Low & High W → E Low	High N → S Low & High W → E Low	High N → S Low & High W → E Low
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	Decrease in concentrations between 2006 and 2007, with the concentrations at the stations near Lake Okeechobee increasing back to 2006 levels in 2008. (See Appendix F for summary data).		

Figure 6.3 $NO_2 + NO_3$ Medians between 2006 and 2008 for All Stations in the L-8 Canal Basin



LEGEND

TKN Annual Median (mg/l)

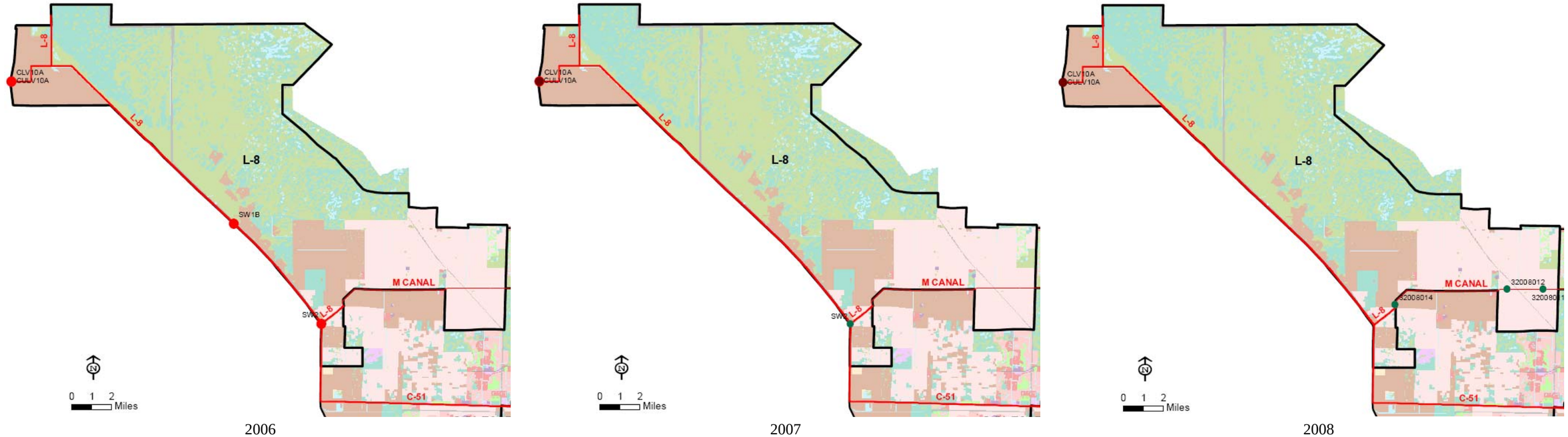
- 0.20 - 0.50
- 0.51 - 1.50
- 1.51 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	8	4	5
Concentration changes	Baseline	No change	Decrease
Geographic trend	Low N→S High	Low N→S High	High N→S Low High W → E Low
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	All concentrations above 0.5 mg /l. (See Appendix F for summary data.)		

Figure 6.4 TKN Medians between 2006 and 2008 for All Stations in the L-8 Canal Basin



LEGEND

OPO4 Annual Median (mg/l)

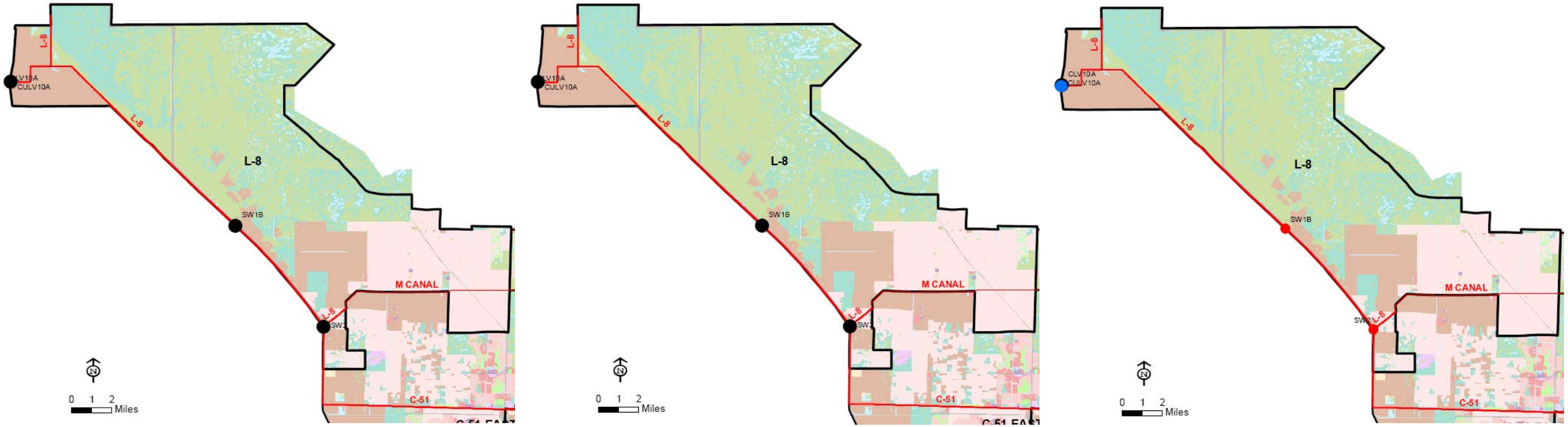
- 0.001 - 0.024
- 0.025 - 0.050
- 0.051 - 0.095
- 0.096 - 0.190
- 0.191 - 0.303

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	4	3	5
Concentration changes	Baseline	Decrease	Decrease
Geographic trend	High N → S Low & High W → E Low	High N → S Low & High W →E Low	High N → S Low & High W → E Low
Concentrations of concern	> 0.05 mg/l	-	-
Stations of concern	All	-	-
Comments	0.05 mg/l baseline based on McPherson and Haley, 1996. (See Appendix F for summary data.)		

Figure 6.5 OPO_4 Medians between 2006 and 2008 for All Stations in the L-8 Canal Basin



LEGEND

TP Annual Median (mg/l)

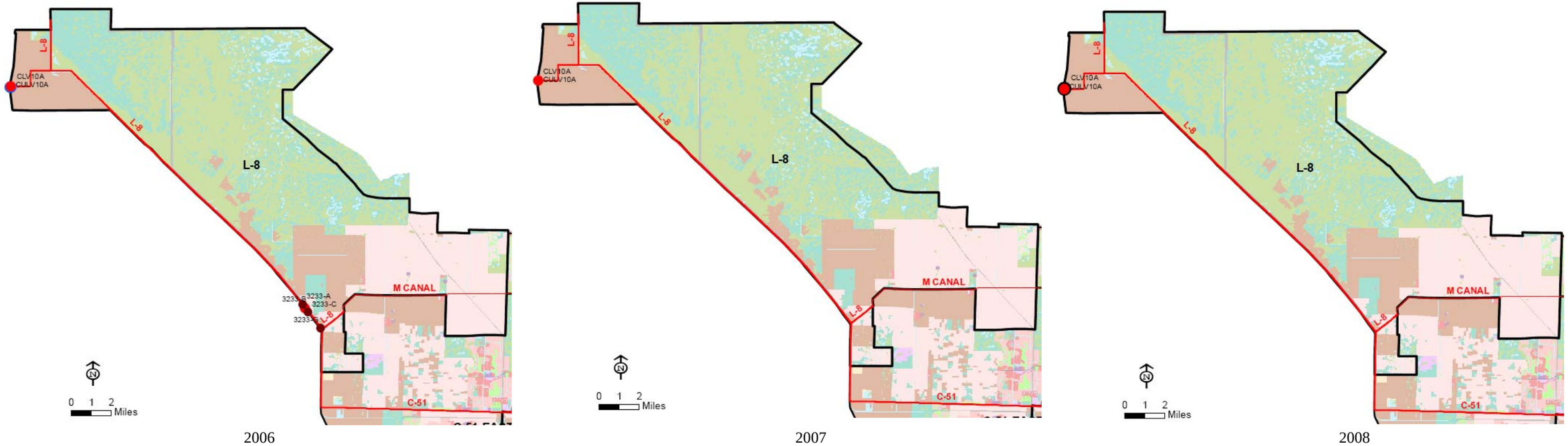
- 0.010 - 0.034
- 0.035 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.172

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	4	4	5
Concentration changes	Baseline	Decrease	Decrease
Geographic Trend	None	None	High N → S Low
Concentrations of concern	> 0.05 mg/l	> 0.05 mg/l	> 0.05 mg/l
Stations of concern	All	All	All
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data.		

Figure 6.6 TP Medians between 2006 and 2008 for All Stations in the L-8 Canal Basin



LEGEND

TSS Annual Median (mg/l)

- 1.0 - 5.8
- 5.9 - 11.0
- 11.1 - 21.0
- 21.1 - 34.0
- 34.1 - 67.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	6	2	2
Concentration changes	Baseline	No Change	No Change
Geographic Trend	None	None	None
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.7 TSS Medians between 2006 and 2008 for All Stations in the L-8 Canal Basin

C-17 CANAL BASIN

Figures for:

Alkalinity (pH)

Dissolved Oxygen (DO)

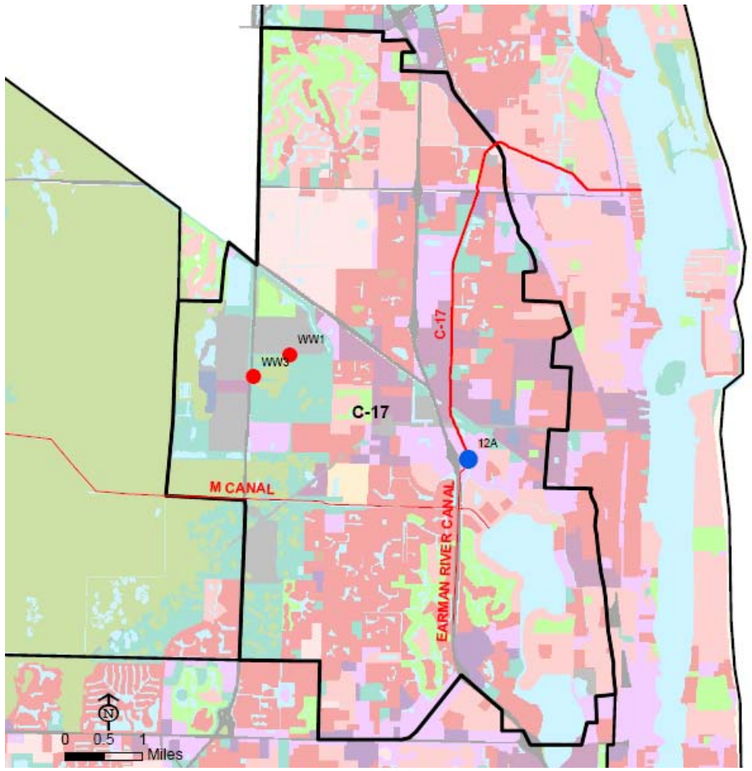
Nitrite plus Nitrate (NO_2 + NO_3)

Total Kjeldahl Nitrogen (TKN)

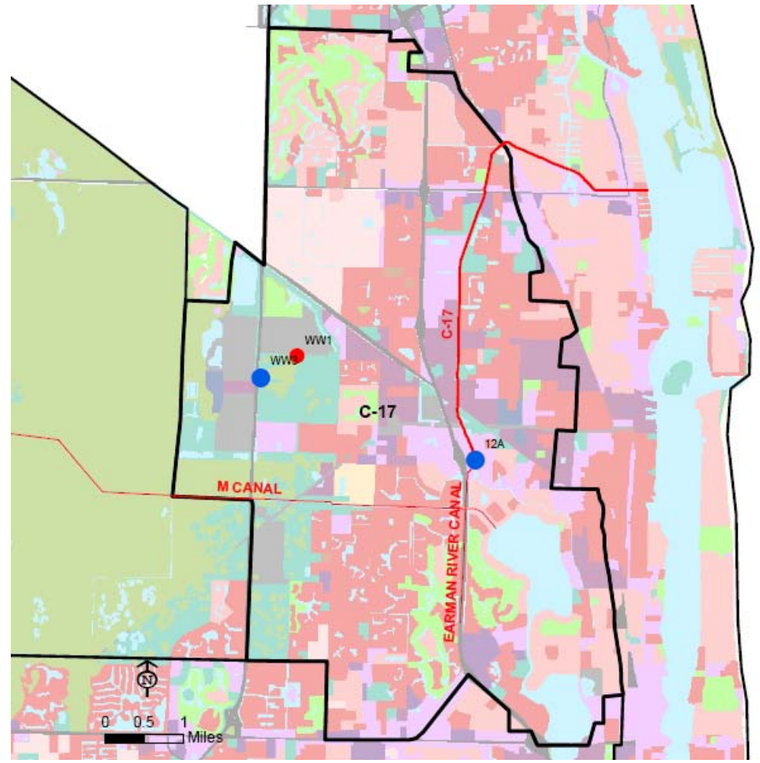
Orthophosphate (OPO_4)

Total Phosphorus (TP)

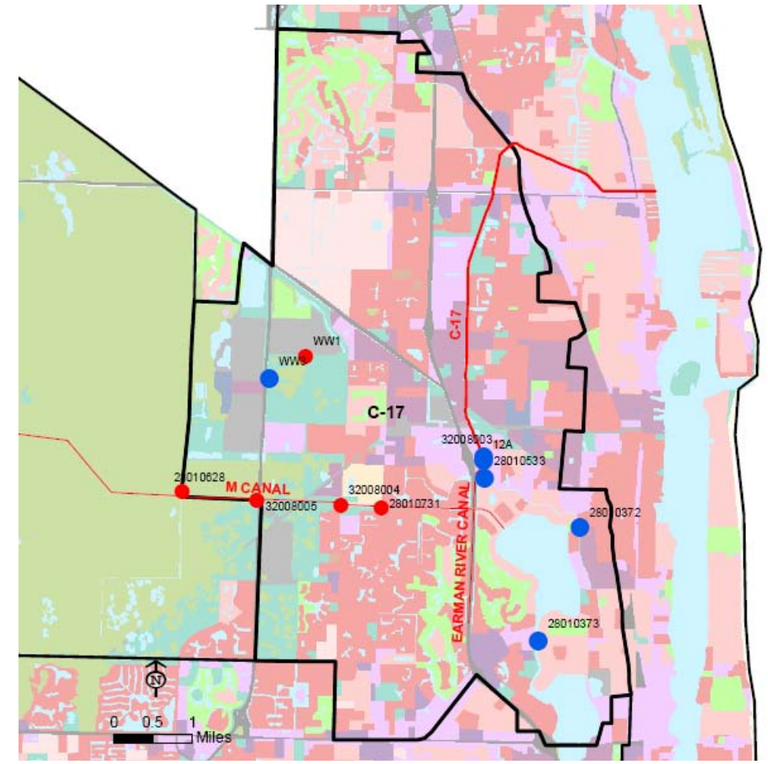
Total Suspended Solids (TSS)



2006



2007



2008

LEGEND

pH Annual Median (mg/l)

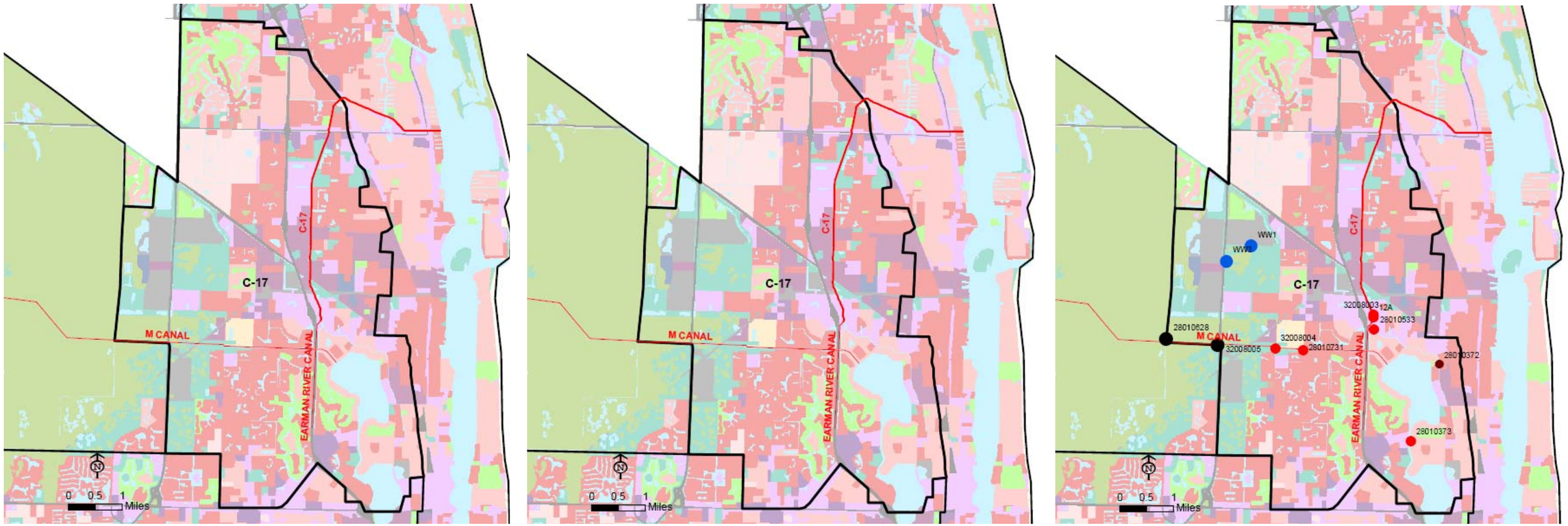
- Less Than 6.0
- 6.1 - 6.5
- 6.6 - 7.5
- 7.6 - 8.5
- More than 8.5

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, Medium, Low Density Residential, Commercial & Industry, Recreation, Wetlands, Forest, Water (lakes)		
Year	2006	2007	2008
Sampling effort	3	3	11
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	Low W → E High	Low W → E High	Low W → E High
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	All annual median values within.A.C.62-302 surface water quality standards Lower pH in the southwestern side of the basin and high in Lake Mangonia and Lake Clarke. See Appendix F for summary data.		

Figure 6.8 pH Medians between 2006 and 2008 for All Stations in the C-17 Canal Basin



2006 2007 2008

LEGEND

DO Annual Median (mg/l)

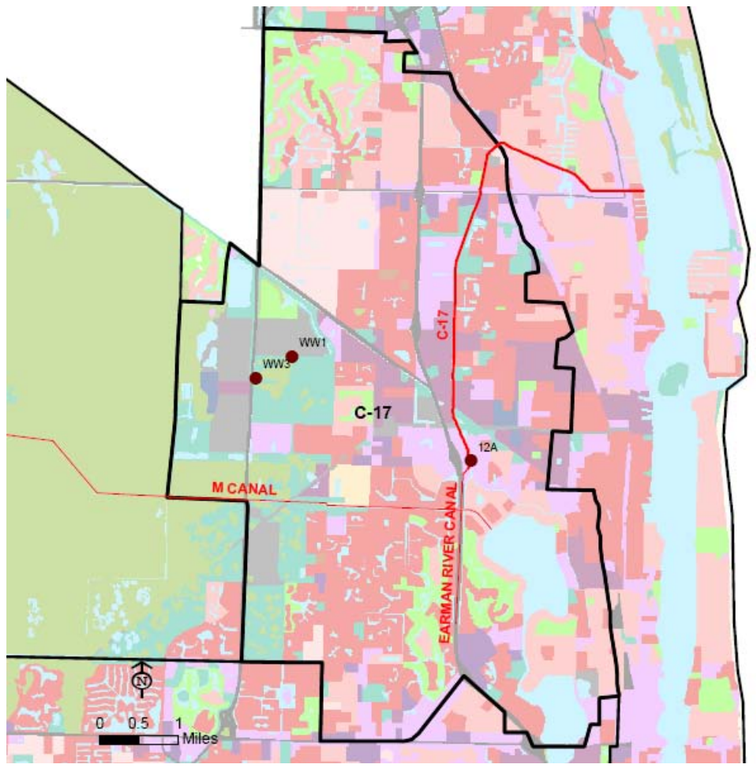
- Less than 4
- 4.1 - 5.0
- 5.1 - 7.5
- 7.6 - 10.0

SFWMD 2004-05 Land Use Land Cover

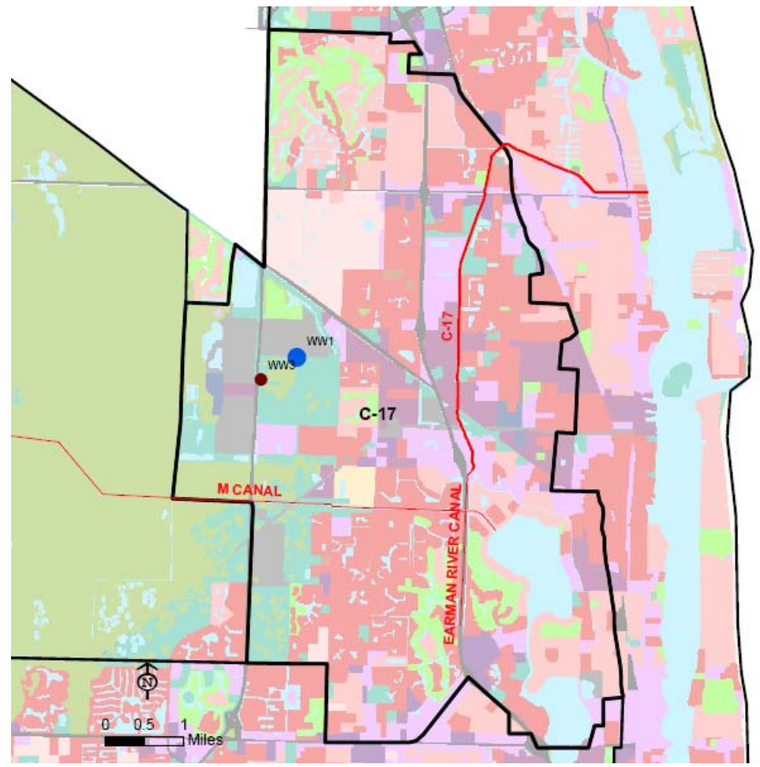
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, Medium, Low Density Residential, Commercial & Industry, Recreation, Wetlands, Forest, Water (lakes)		
Year	2006	2007	2008
Sampling effort	None	None	11
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	No Data	No Data	High W → E Low
Concentrations of concern	No Data	No Data	WW1, WW3, 28010628, 32008005
Stations of concern	No Data	No Data	WW1, WW3, 28010628, 32008005
Comments	The natural areas WW1 and WW3 stations and the station located near the Water Conservation Area at M Canal presented concentrations below the F.A.C. 62-303 water quality standards. See Appendix F for summary data.		

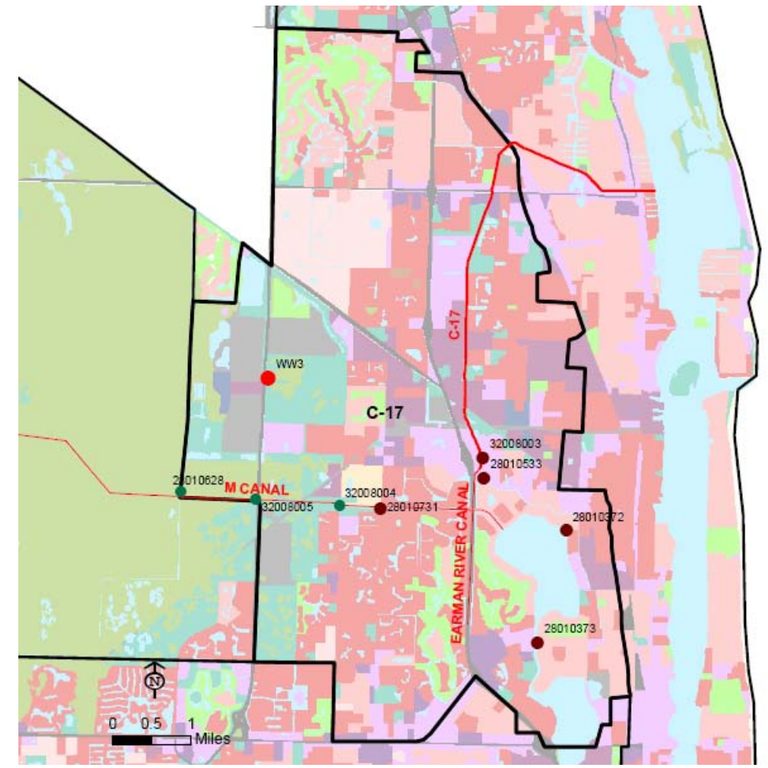
Figure 6.9 DO Medians between 2006 and 2008 for All Stations in the C-17 Canal Basin



2006



2007



2008

LEGEND

NO2 + NO3 Annual Median (mg/l)

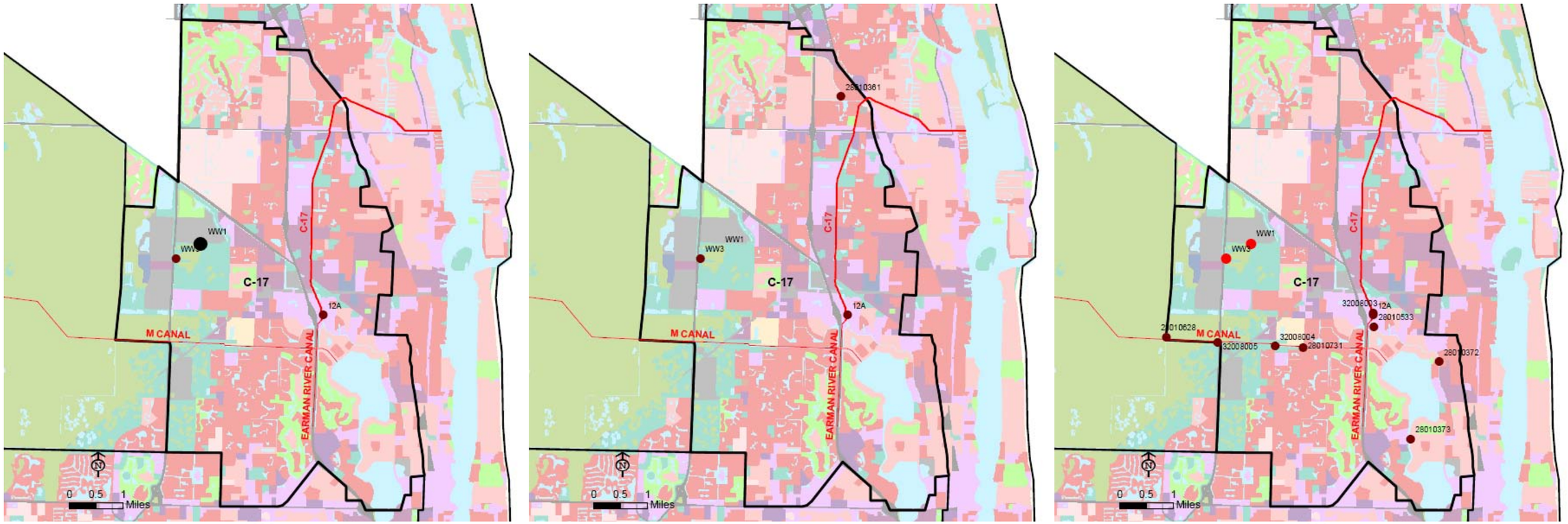
- 0.01 - 0.03
- 0.04 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.45

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, Medium, Low Density Residential, Commercial & Industry, Recreation, Wetlands, Forest, Water (lakes)		
Year	2006	2007	2008
Sampling effort	3	2	9
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	High N → S Low & Low W → E High	High N→S Low & Low W – E High	High N → S Low & Low W→E High
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	With the exception of the stations located in the natural areas all concentrations are below 0.26 mg/l. See Appendix F for summary data.		

Figure 6.10 NO_2 + NO_3 Medians between 2006 and 2008 for All Stations in the C-17 Canal Basin



2006 2007 2008

LEGEND

TKN Annual Median (mg/l)

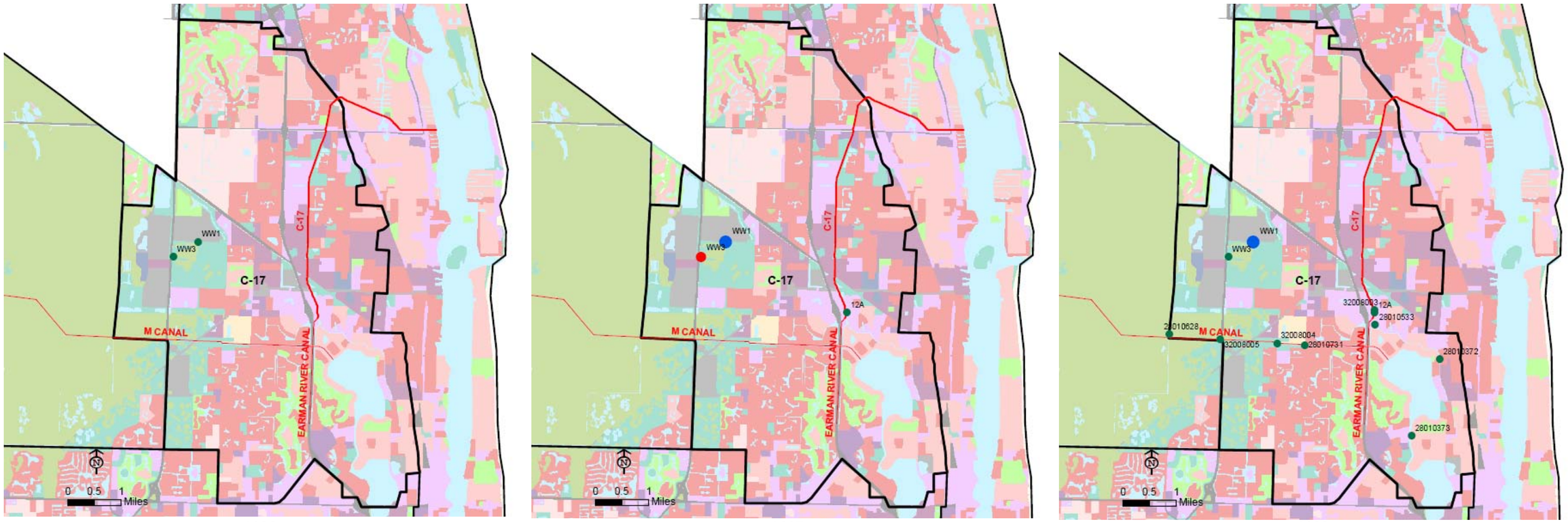
- 0.20 - 0.50
- 0.51 - 1.50
- 1.51 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, Medium, Low Density Residential, Commercial & Industry, Recreation, Wetlands, Forest, Water (lakes)		
Year	2006	2007	2008
Sampling effort	3	4	11
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	Low N → S High	Low N→S High	Low N→S High
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	WW1, WW3	WW1, WW3	WW1, WW3
Comments	With the exception of the stations located in the natural areas all concentrations are above 0.5 mg/l. See Appendix F for summary data.		

Figure 6.11 TKN Medians between 2006 and 2008 for All Stations in the C-17 Canal Basin



2006 2007 2008

LEGEND

OPO4 Annual Median (mg/l)

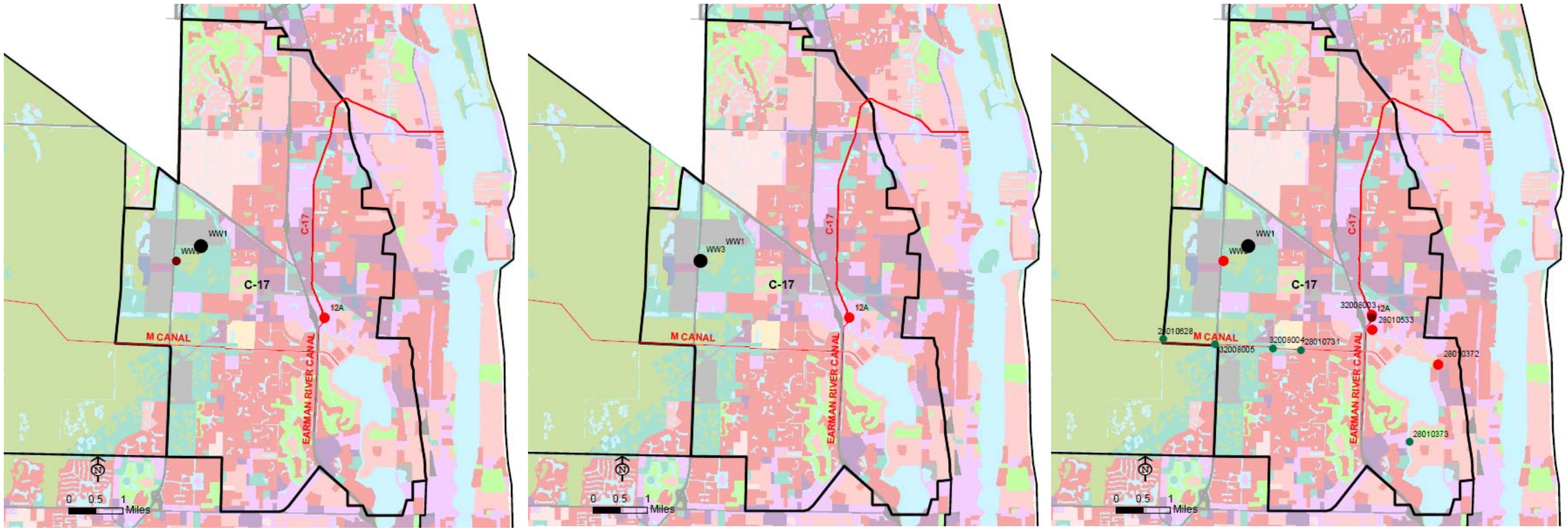
- 0.001 - 0.024
- 0.025 - 0.050
- 0.051 - 0.095
- 0.096 - 0.190
- 0.191 - 0.303

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, Medium, Low Density Residential, Commercial & Industry, Recreation, Wetlands, Forest, Water (lakes)		
Year	2006	2007	2008
Sampling effort	2	3	11
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	Low W → E High	Low W → E High	Low W → E High
Concentrations of concern	0.05 mg/l	0.05 mg/l	0.05 mg/l
Stations of concern	None	WW1, WW2	WW1
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data.		

Figure 6.12 OPO_4 Medians between 2006 and 2008 for All Stations in the C-17 Canal Basin



2006 2007 2008

LEGEND

TP Annual Median (mg/l)

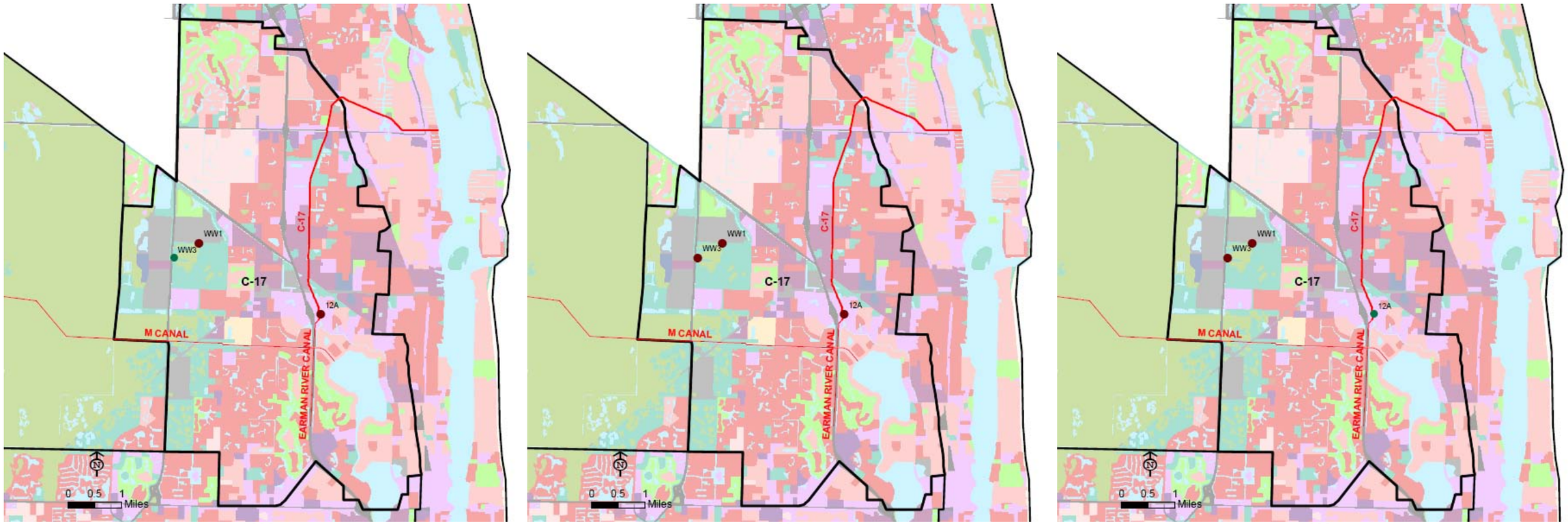
- 0.010 - 0.034
- 0.035 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.172

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, Medium, Low Density Residential, Commercial & Industry, Recreation, Wetlands, Forest, Water (lakes)		
Year	2006	2007	2008
Sampling effort	3	3	11
Concentration changes	Baseline	No Change	No Change
Geographic Trend	Low W → E High	Low W→E High	Low W → E High
Concentrations of concern	>0.05 mg/l	>0.05 mg/l	>0.05 mg/l
Stations of concern	WW1, 12A	WW3, 12A	WW1,12A,28010372, 28010533
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data.		

Figure 6.13 TP Medians between 2006 and 2008 for All Stations in the C-17 Canal Basin



LEGEND

TSS Annual Median (mg/l)

- 1.0 - 5.8
- 5.9 - 11.0
- 11.1 - 21.0
- 21.1 - 34.0
- 34.1 - 67.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, Medium, Low Density Residential, Commercial & Industry, Recreation, Wetlands, Forest, Water (lakes)		
Year	2006	2007	2008
Sampling effort	3	3	3
Concentration changes	Baseline	Increase WW3	Decrease 12 A
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.14 TSS Medians between 2006 and 2008 for All Stations in the C-17 Canal Basin

C-51 CANAL WEST BASIN

Figures for:

Alkalinity (pH)

Dissolved Oxygen (DO)

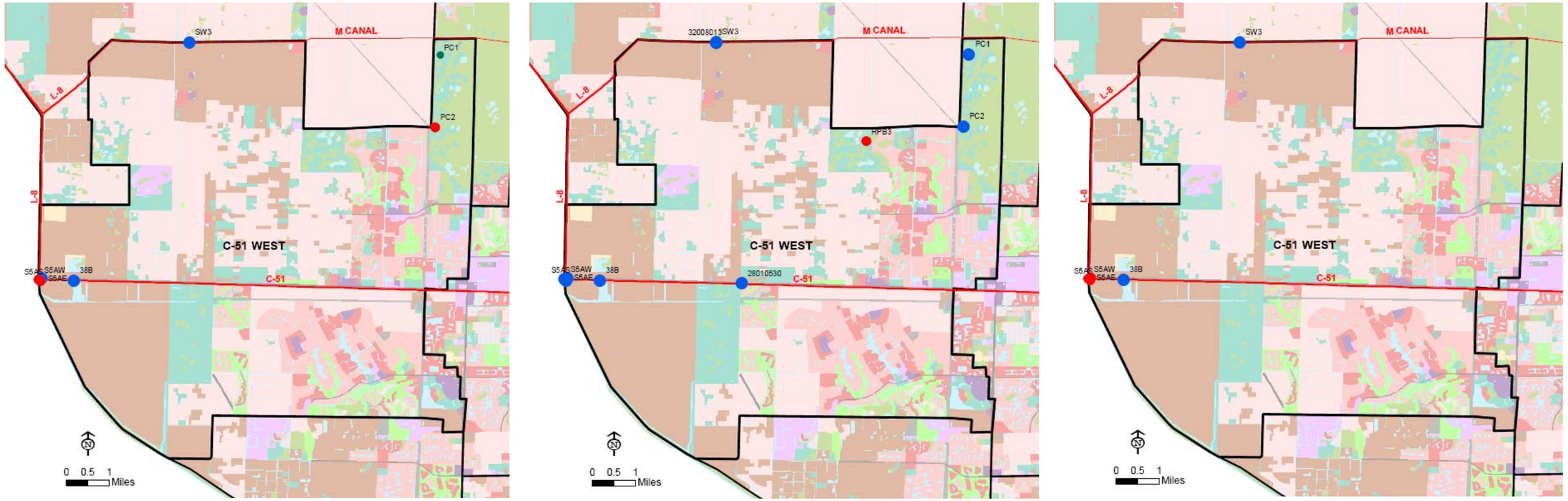
Nitrite plus Nitrate (NO_2 + NO_3)

Total Kjeldahl Nitrogen (TKN)

Orthophosphate (OPO_4)

Total Phosphorus (TP)

Total Suspended Solids (TSS)



LEGEND

pH Annual Median (mg/l)

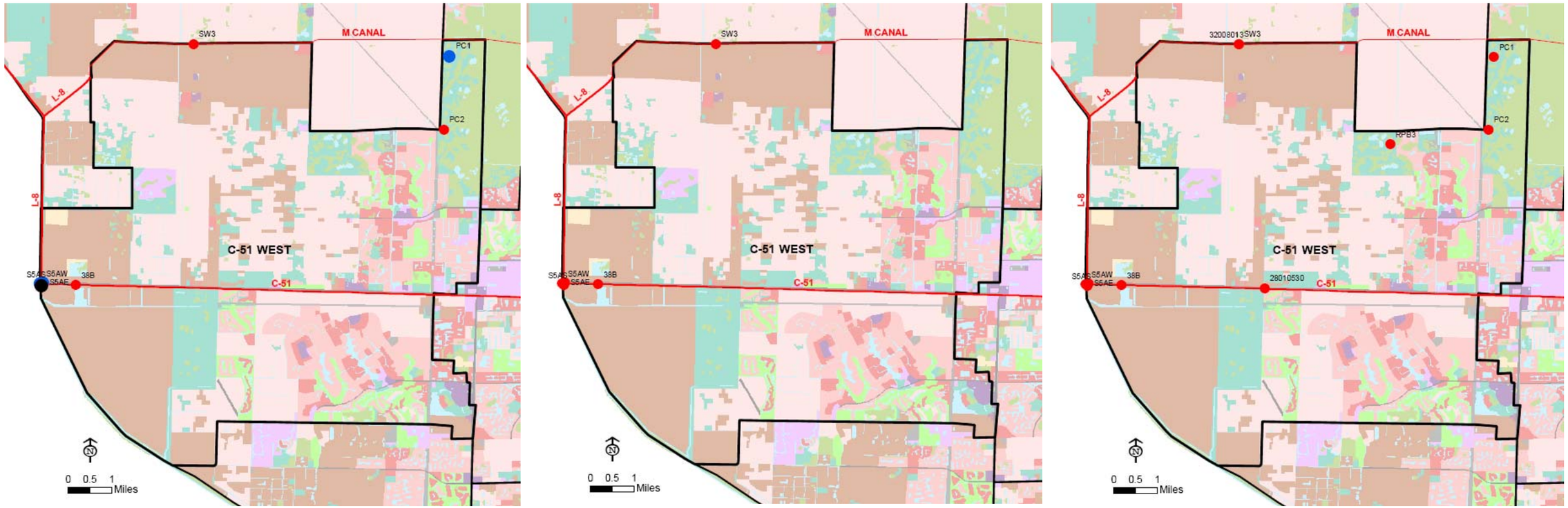
- Less Than 6.0
- 6.1 - 6.5
- 6.6 - 7.5
- 7.6 - 8.5
- More than 8.5

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Agriculture, Low Density Residential, Wetlands		
Year	2006	2007	2008
Sampling effort	10	5	11
Concentration changes	Baseline	No Change	No Change
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	All annual median values within F.A.C.62-302 surface water quality standards. See Appendix F for summary data.		

Figure 6.15 pH Medians between 2006 and 2008 for All Stations in the C-51 Canal West Basin



2006 2007 2008

LEGEND

DO Annual Median (mg/l)

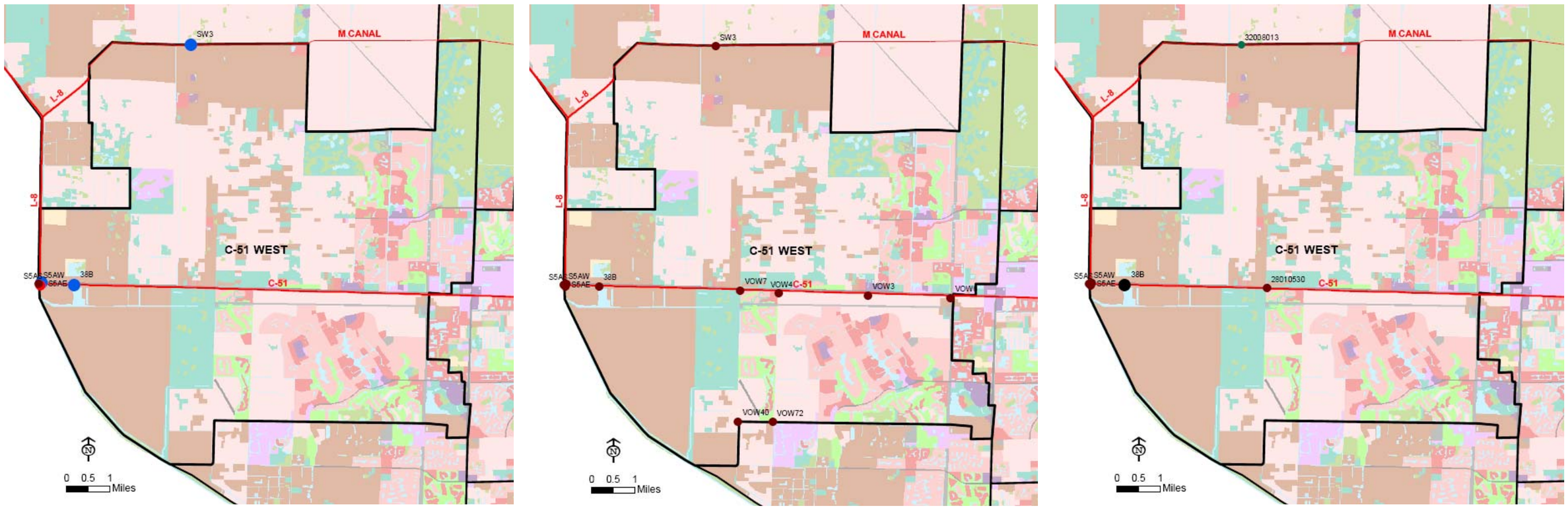
- Less than 4
- 4.1 - 5.0
- 5.1 - 7.5
- 7.6 - 10.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highwa

Dominant land use	Agriculture, Low Density Residential, Wetlands		
Year	2006	2007	2008
Sampling effort	7	5	11
Concentration changes	Baseline	No Change	Increase
Geographic Trend	W → E (high → low)	W →E (high → low)	W → E (high → low)
Concentrations of concern	S5A, PC1	None	None
Stations of concern	S5A, PC1	None	None
Comments	All annual median values within F.A.C.62-302 surface water quality standards. See Appendix F for summary data.		

Figure 6.16 DO Medians between 2006 and 2008 for All Stations in the C-51 Canal West Basin



2006 2007 2008

LEGEND

NO2 + NO3 Annual Median (mg/l)

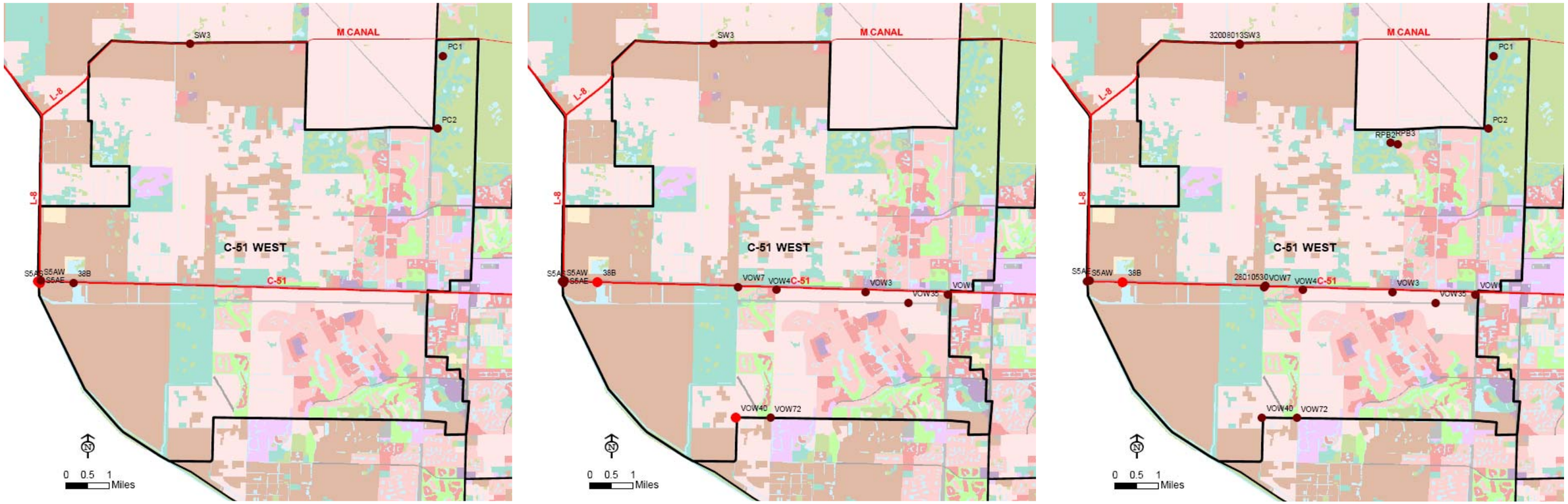
- 0.01 - 0.03
- 0.04 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.45

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Agriculture, Low Density Residential, Wetlands		
Year	2006	2007	2008
Sampling effort	5	11	6
Concentration changes	Baseline	No Change	Increase 38B
Geographic Trend	W → E (high → low) N → S (high → low)	W → E (high → low) N → S (high → low)	W → E (high → low) N → S (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.17 $NO_2 + NO_3$ Medians between 2006 and 2008 for All Stations in the C-51 Canal West Basin



2006 2007 2008

LEGEND

TKN Annual Median (mg/l)

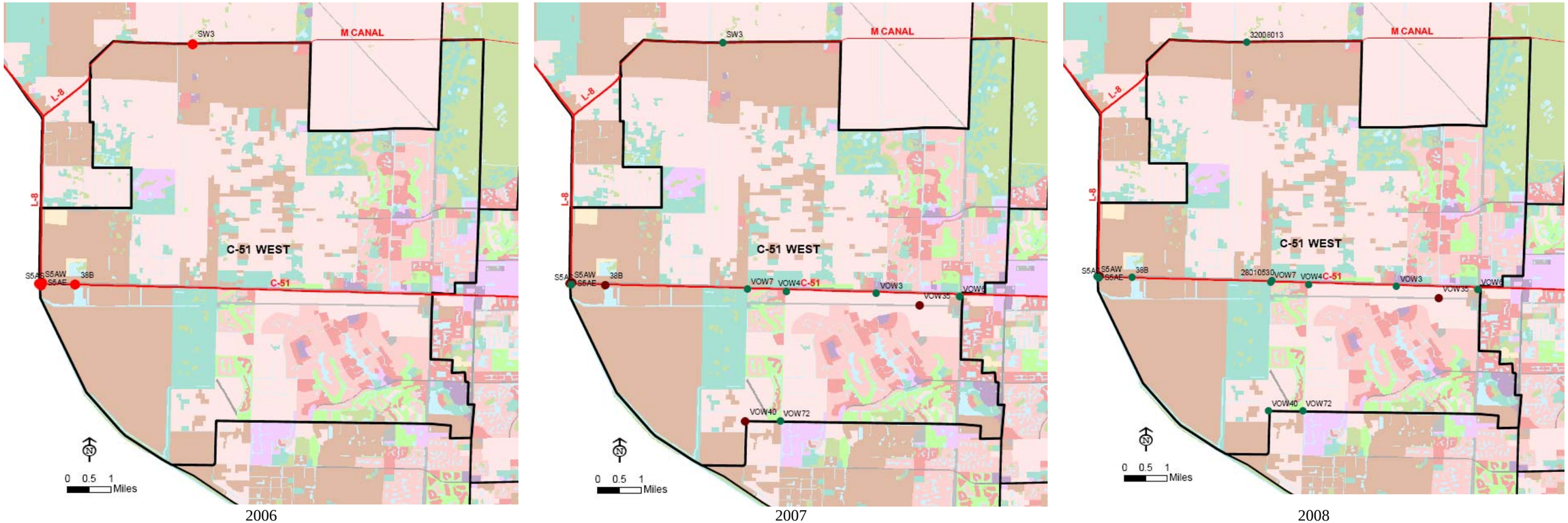
- 0.20 - 0.50
- 0.51 - 1.50
- 1.51 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Agriculture, Low Density Residential, Wetlands		
Year	2006	2007	2008
Sampling effort	7	12	17
Concentration changes	Baseline	Increase 38B	Decrease vow 40
Geographic Trend	W → E (high → low) N → S (high → low)	W → E (high → low) N → S (high → low)	W → E (high → low) N → S (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.18 TKN Medians between 2006 and 2008 for All Stations in the C-51 Canal West Basin



LEGEND

OPO4 Annual Median (mg/l)

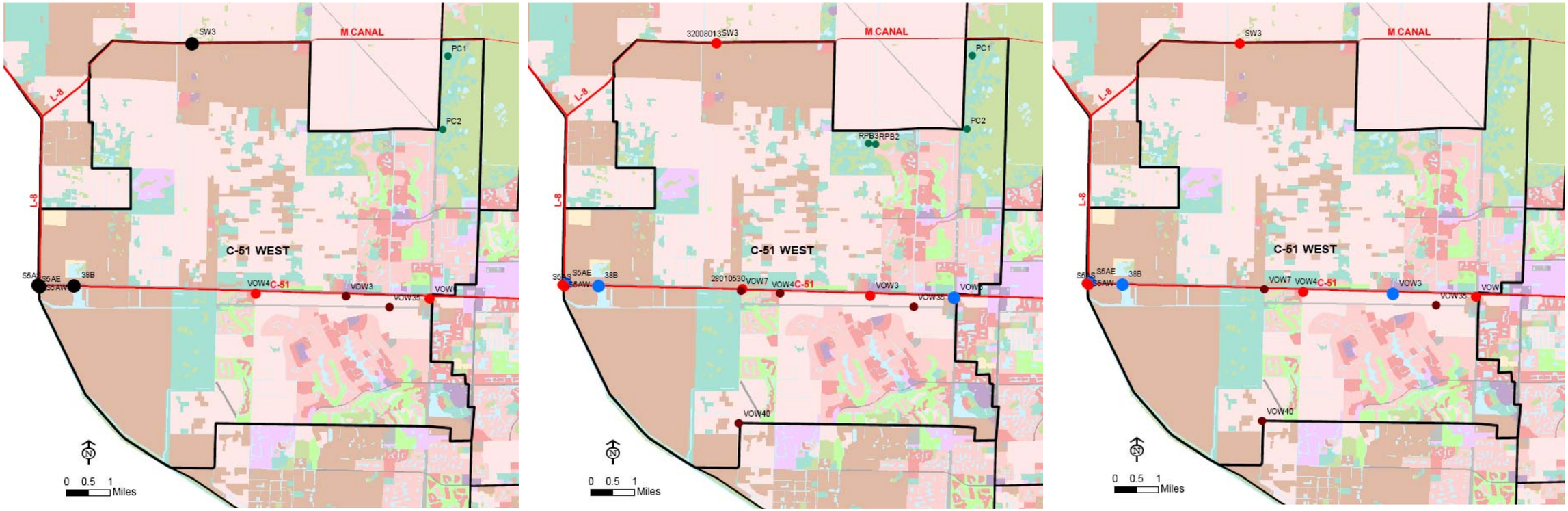
- 0.001 - 0.024
- 0.025 - 0.050
- 0.051 - 0.095
- 0.096 - 0.190
- 0.191 - 0.303

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Agriculture, Low Density Residential, Wetlands		
Year	2006	2007	2008
Sampling effort	5	12	13
Concentration changes	Baseline	Decrease West Stations	Decrease 38B
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	>0.05 mg/l	None	None
Stations of concern	S5A, 38B	None	None
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data.		

Figure 6.19 OPO_4 Medians between 2006 and 2008 for All Stations in the C-51 Canal West Basin



LEGEND

TP Annual Median (mg/l)

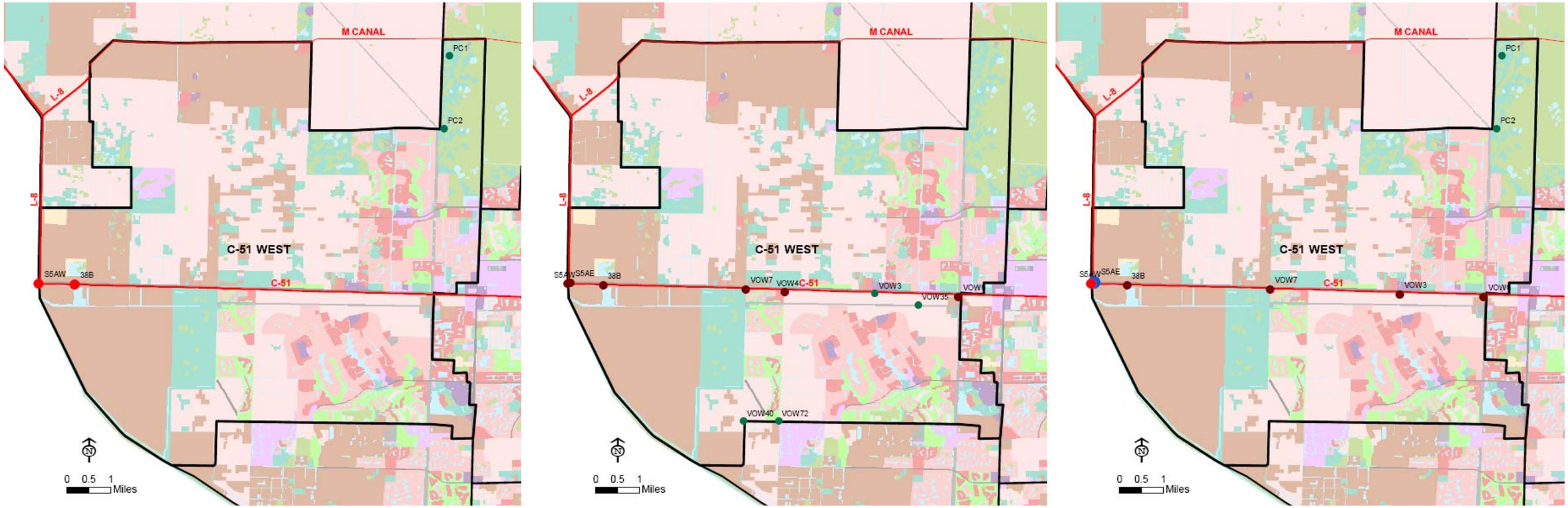
- 0.010 - 0.034
- 0.035 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.172

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highway

Dominant land use	Agriculture, Low Density Residential, Wetlands		
Year	2006	2007	2008
Sampling effort	11	11	17
Concentration changes	Baseline	Decrease	Increase
Geographic Trend	W – E (high – low)	W – E (high – low)	W – E (high – low)
Concentrations of concern	>0.05 mg/l	>0.05 mg/l	>0.05 mg/l
Stations of concern	S5A,38B, VOW4	S5A,38B, VOW3	S5A,38B, VOW35
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data.		

Figure 6.20 TP Medians between 2006 and 2008 for All Stations in the C-51 Canal West Basin



2006 2007 2008

LEGEND

TSS Annual Median (mg/l)

- 1.0 - 5.8
- 5.9 - 11.0
- 11.1 - 21.0
- 21.1 - 34.0
- 34.1 - 67.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Agriculture, Low Density Residential, Wetlands		
Year	2006	2007	2008
Sampling effort	4	10	8
Concentration changes	Baseline	Decrease	Increase
Geographic Trend	W – E (high – low)	W – E (high – low)	W – E (high – low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.21 TSS Medians between 2006 and 2008 for All Stations in the C-51 Canal West Basin

C-51 CANAL EAST BASIN

Figures for:

Alkalinity (pH)

Dissolved Oxygen (DO)

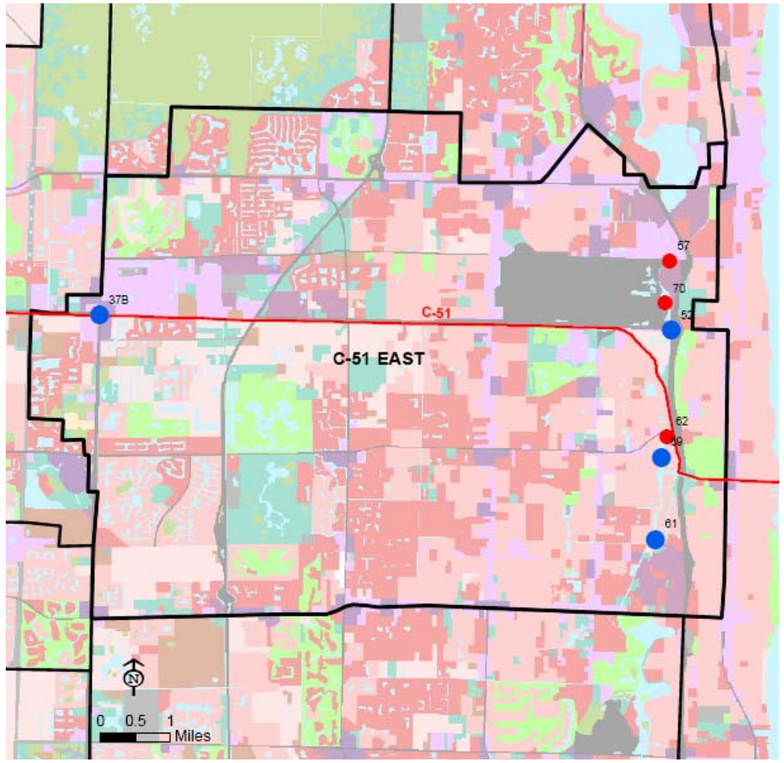
Nitrite plus Nitrate (NO_2 + NO_3)

Total Kjeldahl Nitrogen (TKN)

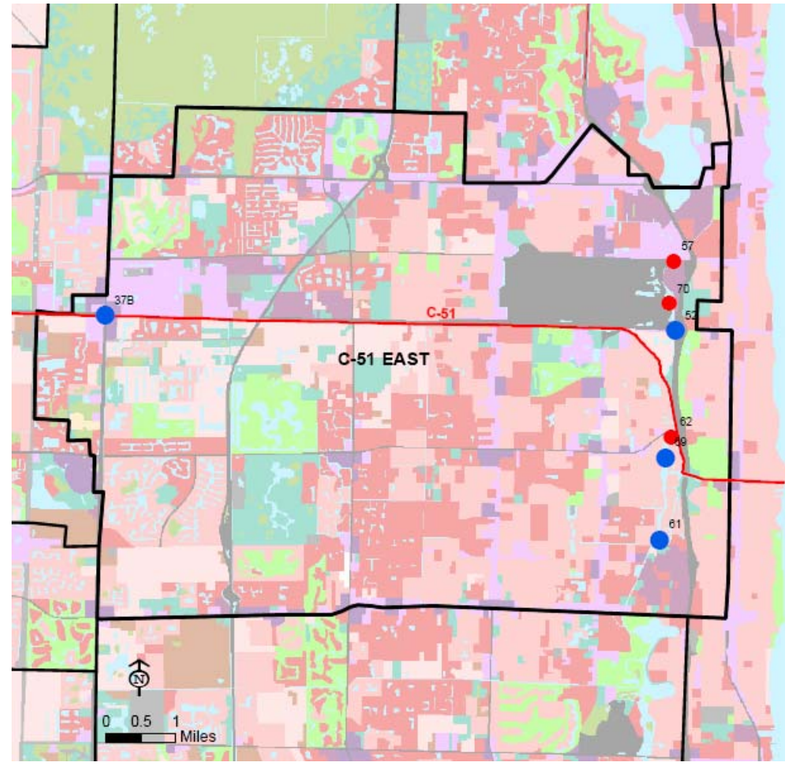
Orthophosphate (OPO_4)

Total Phosphorus (TP)

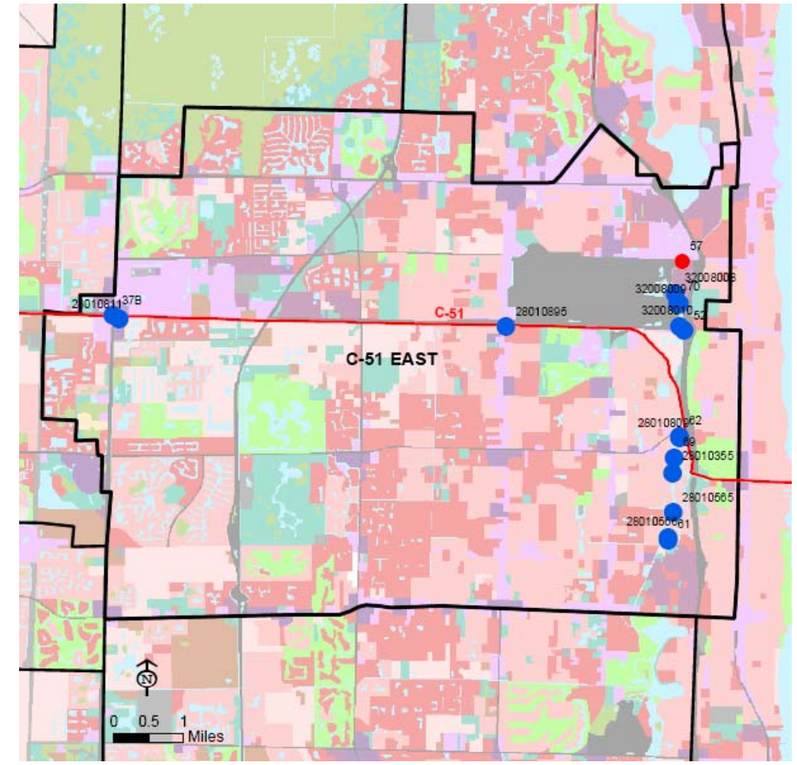
Total Suspended Solids (TSS)



2006



2007



2008

LEGEND

pH Annual Median (mg/l)

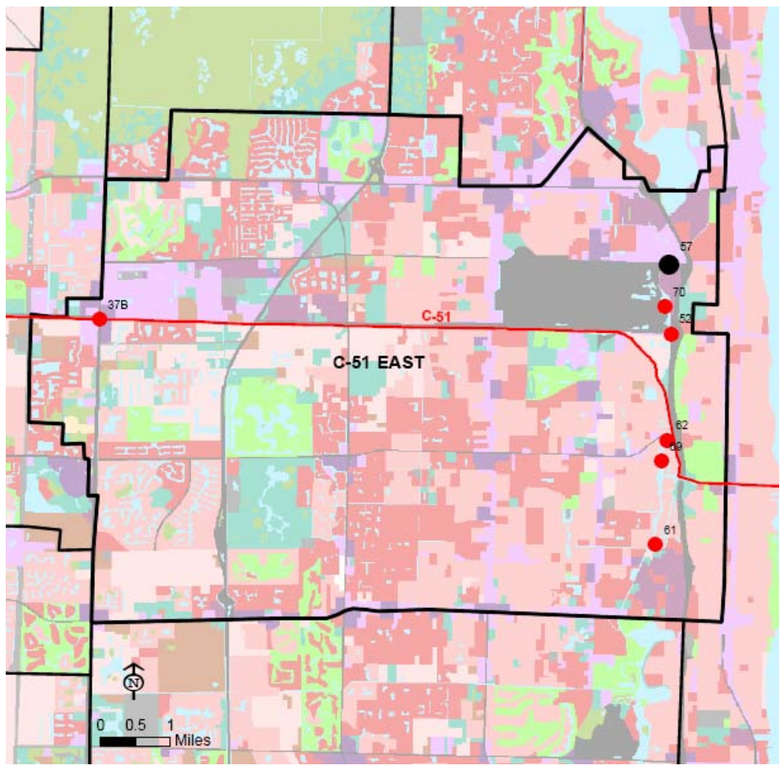
- Less Than 6.0
- 6.1 - 6.5
- 6.6 - 7.5
- 7.6 - 8.5
- More than 8.5

SFWMD 2004-05 Land Use Land Cover

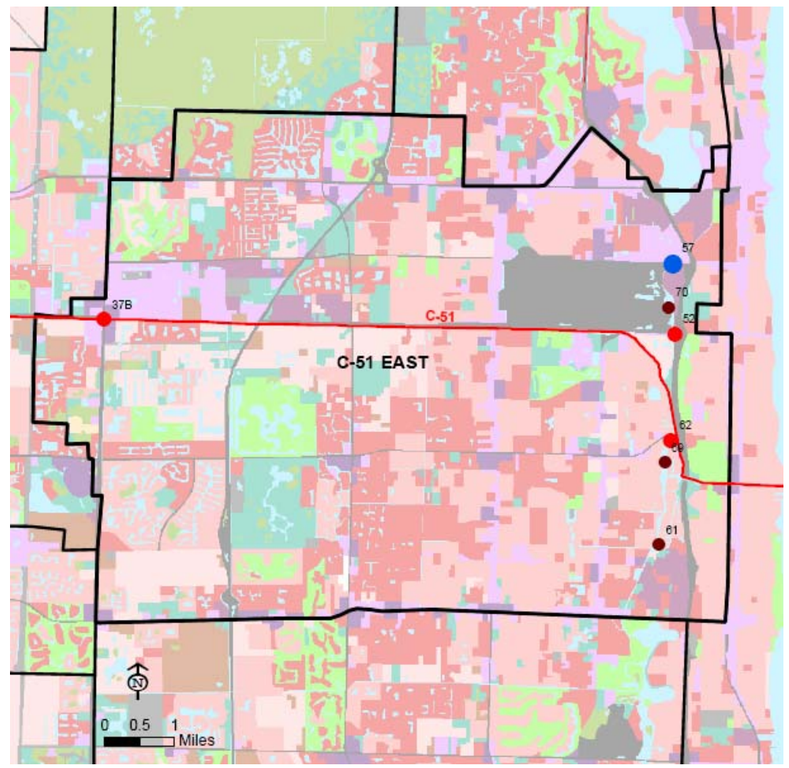
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, medium, low density residential, commercial, recreation, infrastructure		
Year	2006	2007	2008
Sampling effort	7	7	17
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	W → E & N → S (low – high)	W → E & N → S (low – high)	W → E & N → S (low – high)
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	2006 to 2007 increase in concentration did not result in F.A.C.62-202 surface water quality standards violations. See Appendix F for summary data.		

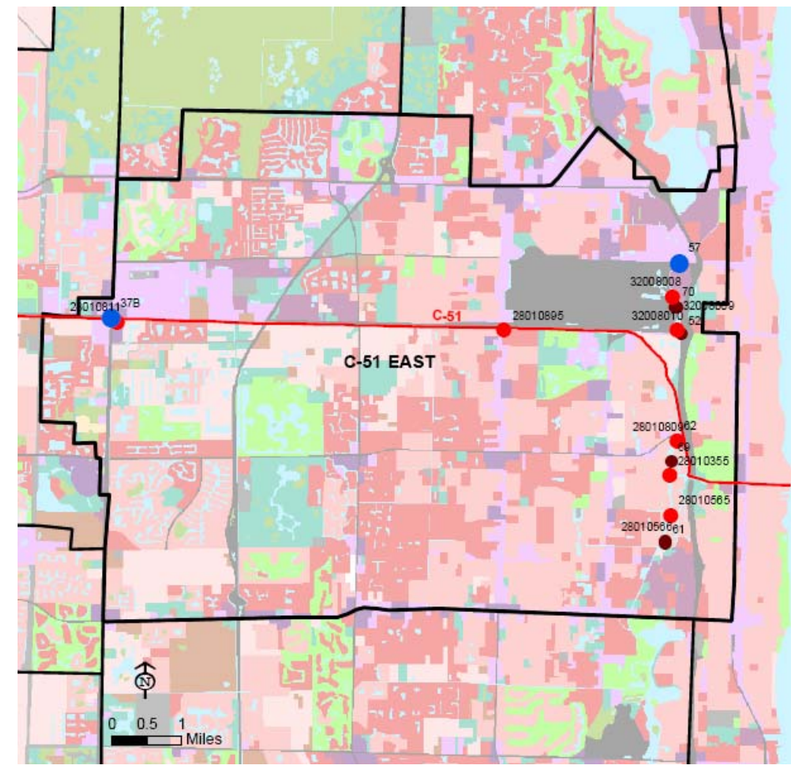
Figure 6.22 pH Medians between 2006 and 2008 for All Stations in the C-51 Canal East Basin



2006



2007



2008

LEGEND

DO Annual Median (mg/l)

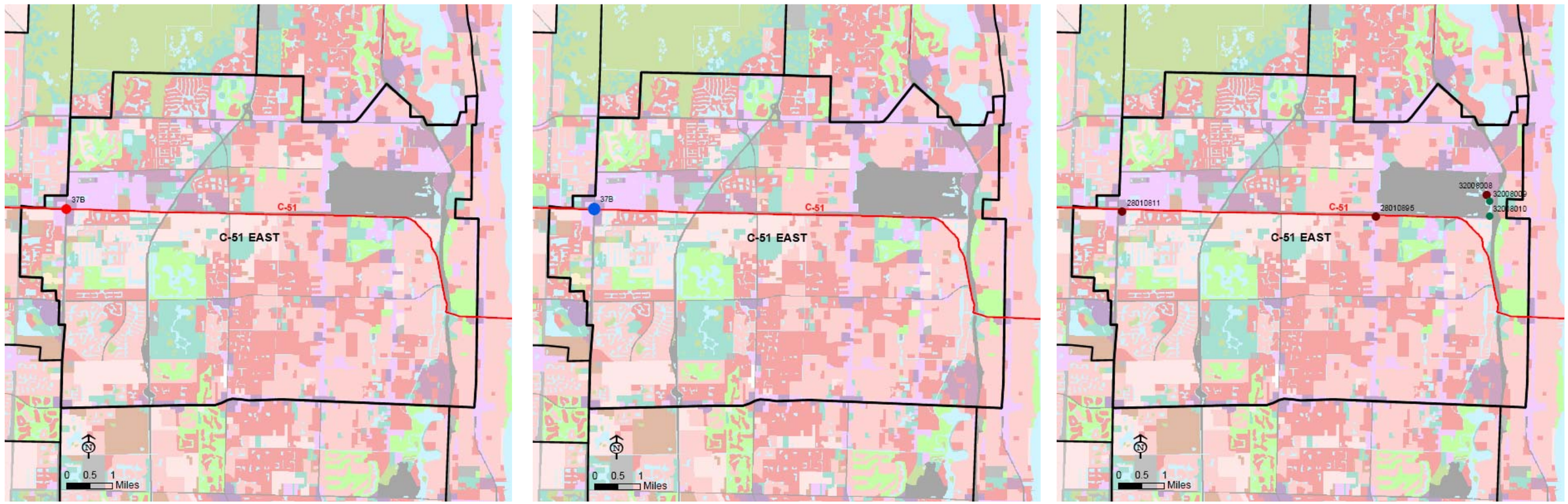
- Less than 4
- 4.1 - 5.0
- 5.1 - 7.5
- 7.6 - 10.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, medium, low density residential, commercial, recreation, infrastructure		
Year	2006	2007	2008
Sampling effort	11	10	17
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	W → E & N → S (low – high)	W → E & N → S (low – high)	W → E & N → S (low – high)
Concentrations of concern	>5 mg/l	None	None
Stations of concern	57	None	None
Comments	2007 to 2008 decrease in concentration did not result in F.A.C.62-202 surface water quality standards violations. See Appendix F for summary data.		

Figure 6.23 DO Medians between 2006 and 2008 for All Stations in the C-51 Canal East Basin



2006 2007 2008

LEGEND

NO2 + NO3 Annual Median (mg/l)

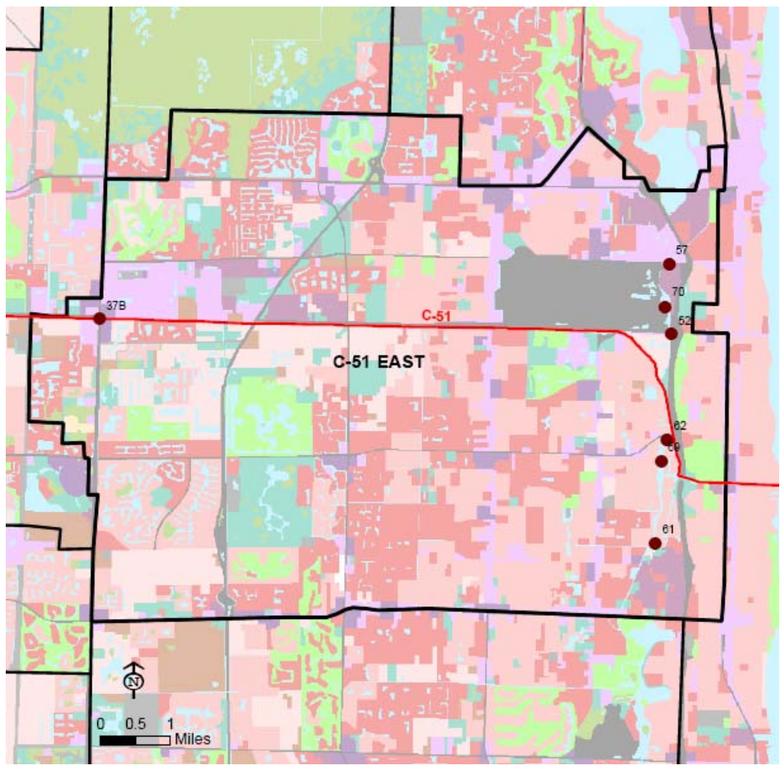
- 0.01 - 0.03
- 0.04 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.45

SFWMD 2004-05 Land Use Land Cover

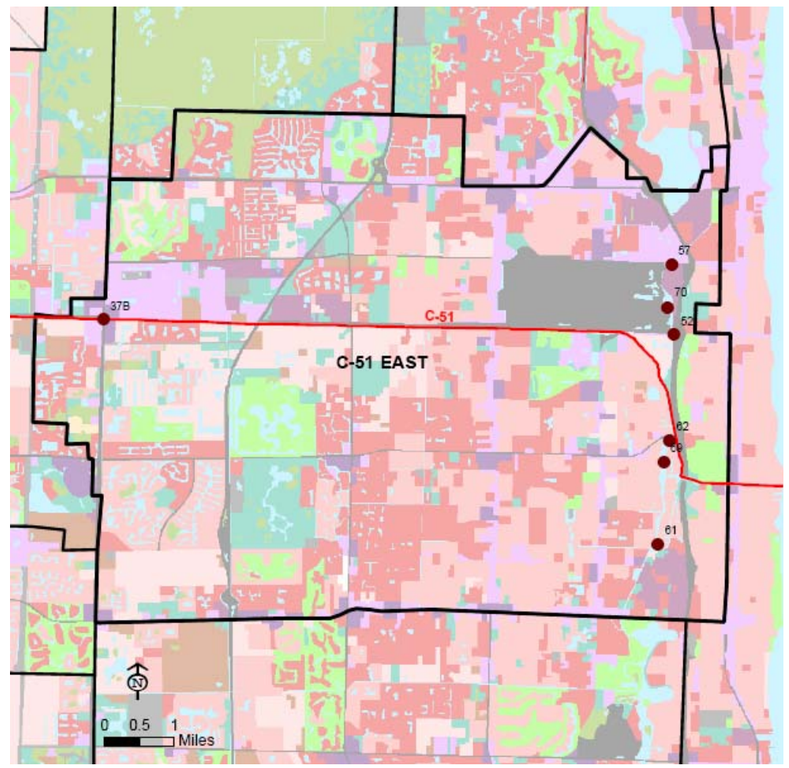
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, medium, low density residential, commercial, recreation, infrastructure		
Year	2006	2007	2008
Sampling effort	1	1	5
Concentration changes	Baseline	Increase	Decrease
Geographic Trend	None	None	None
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

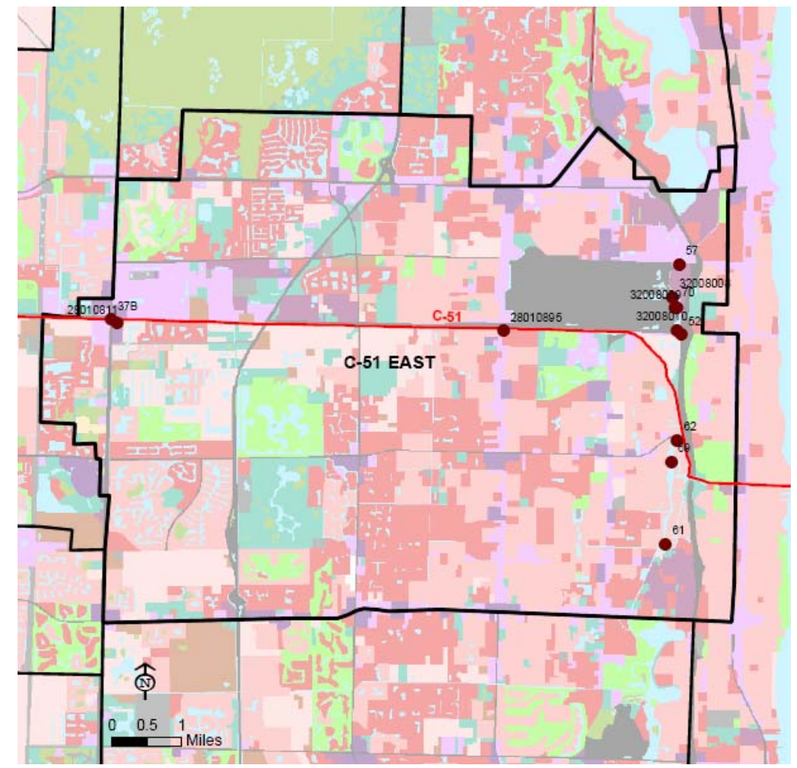
Figure 6.24 NO_2 + NO_3 Medians between 2006 and 2008 for All Stations in the C-51 Canal East Basin



2006



2007



2008

LEGEND

TKN Annual Median (mg/l)

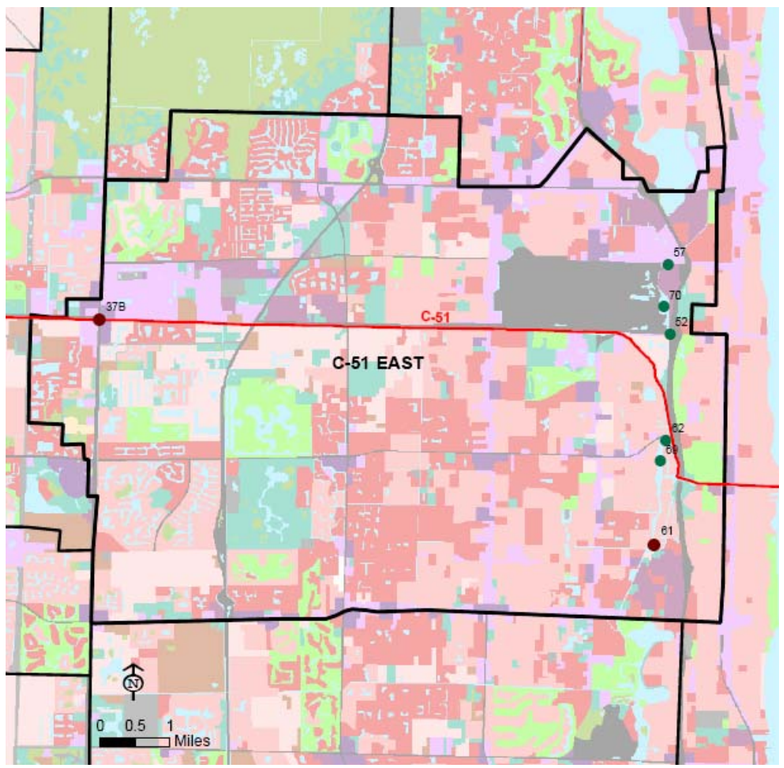
- 0.20 - 0.50
- 0.51 - 1.50
- 1.51 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50

SFWMD 2004-05 Land Use Land Cover

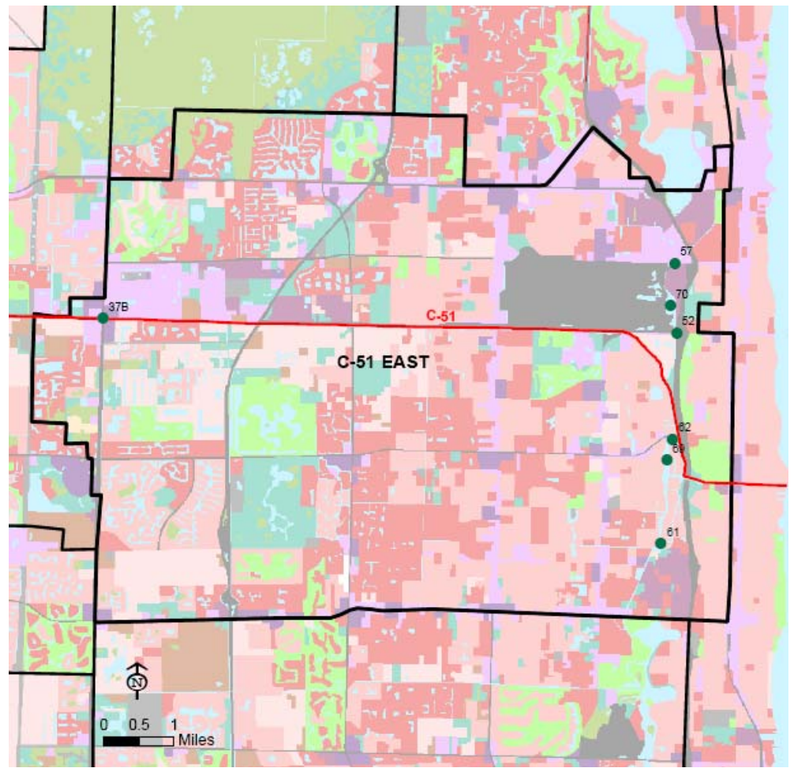
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, medium, low density residential, commercial, recreation, infrastructure		
Year	2006	2007	2008
Sampling effort	7	7	12
Concentration changes	Baseline	No Change	No Change
Geographic Trend	None	None	None
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

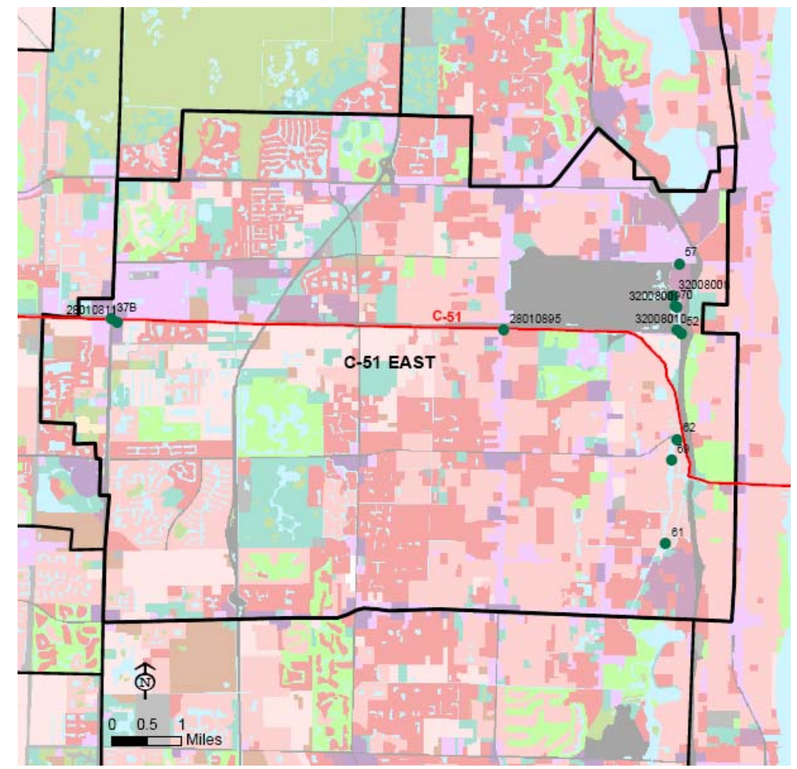
Figure 6.25 TKN Medians between 2006 and 2008 for All Stations in the C-51 Canal East Basin



2006



2007



2008

LEGEND

OPO4 Annual Median (mg/l)

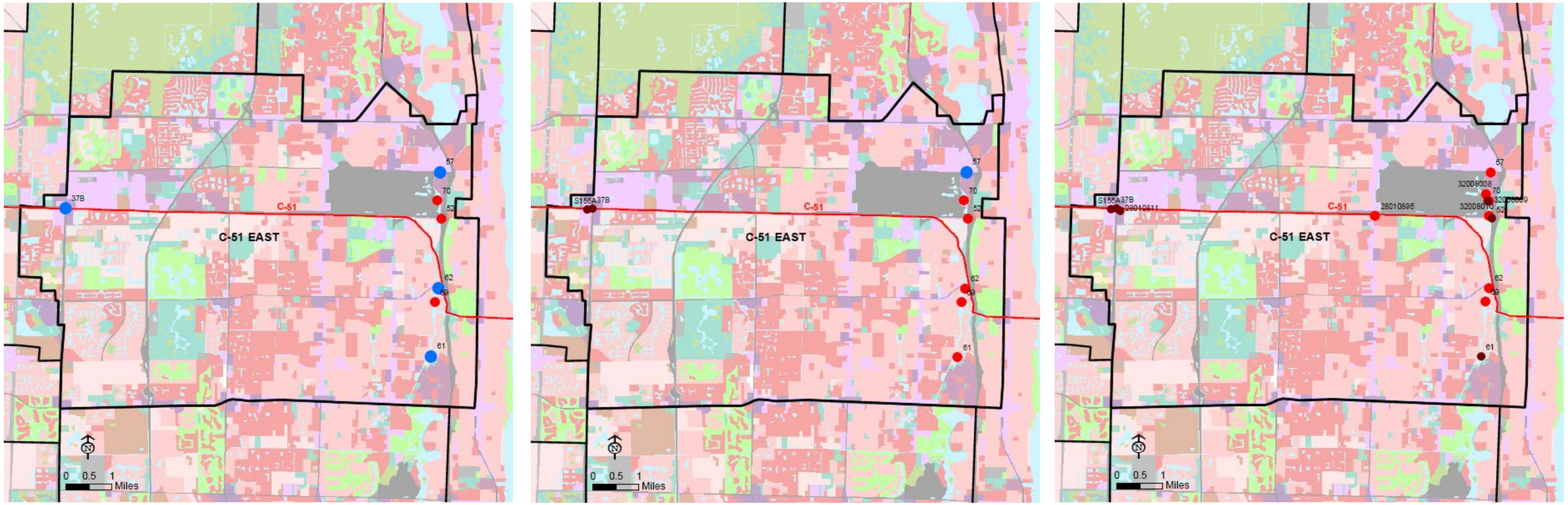
- 0.001 - 0.024
- 0.025 - 0.050
- 0.051 - 0.095
- 0.096 - 0.190
- 0.191 - 0.303

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, medium, low density residential, commercial, recreation, infrastructure		
Year	2006	2007	2008
Sampling effort	7	7	12
Concentration changes	Baseline	Decrease 61	Decrease
Geographic Trend	None	None	None
Concentrations of concern	>0.05 mg/l	>0.05 mg/l	>0.05 mg/l
Stations of concern	None	None	None
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data. See Appendix F for summary data.		

Figure 6.26 OPO_4 Medians between 2006 and 2008 for All Stations in the C-51 Canal East Basin



2006 2007 2008

LEGEND

TP Annual Median (mg/l)

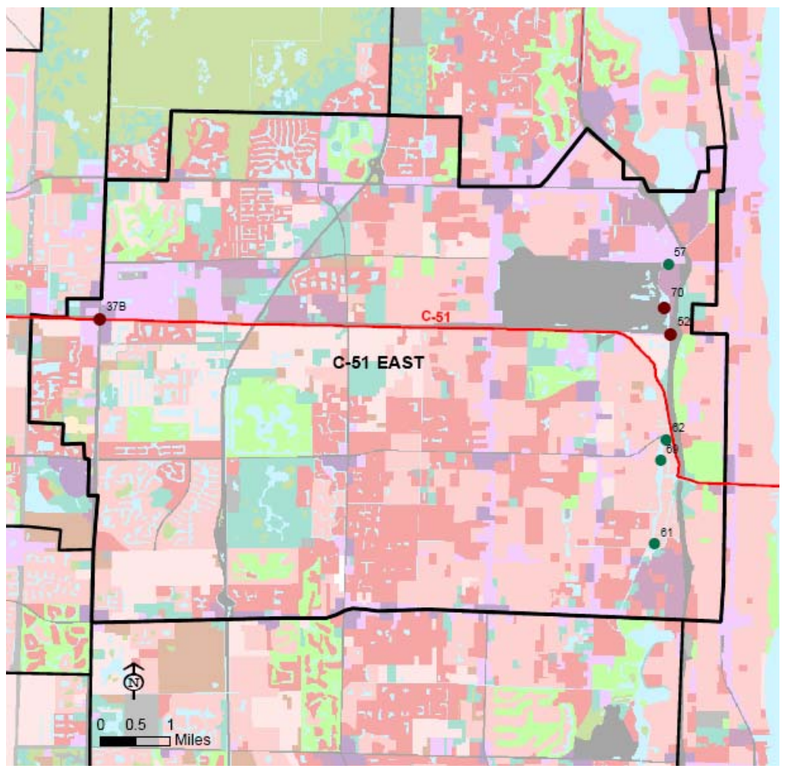
- 0.010 - 0.034
- 0.035 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.172

SFWMD 2004-05 Land Use Land Cover

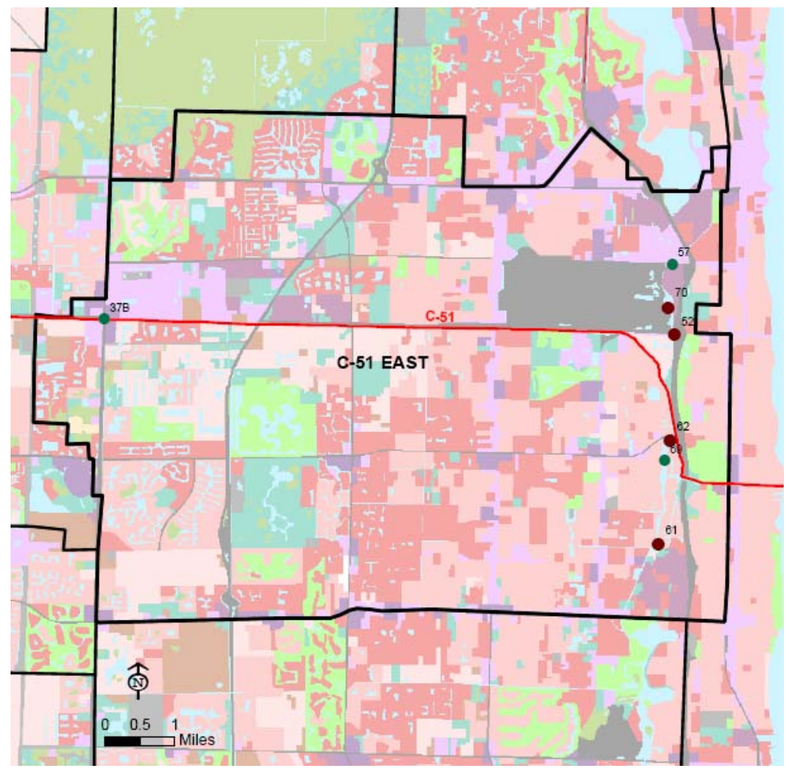
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, medium, low density residential, commercial, recreation, infrastructure		
Year	2006	2007	2008
Sampling effort	7	8	13
Concentration changes	Baseline	Decrease	Decrease
Geographic Trend	W → E & N → S (low – high)	W → E & N → S (low – high)	W → E & N → S (low – high)
Concentrations of concern	>0.05 mg/l	>0.05 mg/l	>0.05 mg/l
Stations of concern	37B,52,57,61,62,69,70	52,57,61,62,69,70	57,62,69
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data. See Appendix F for summary data.		

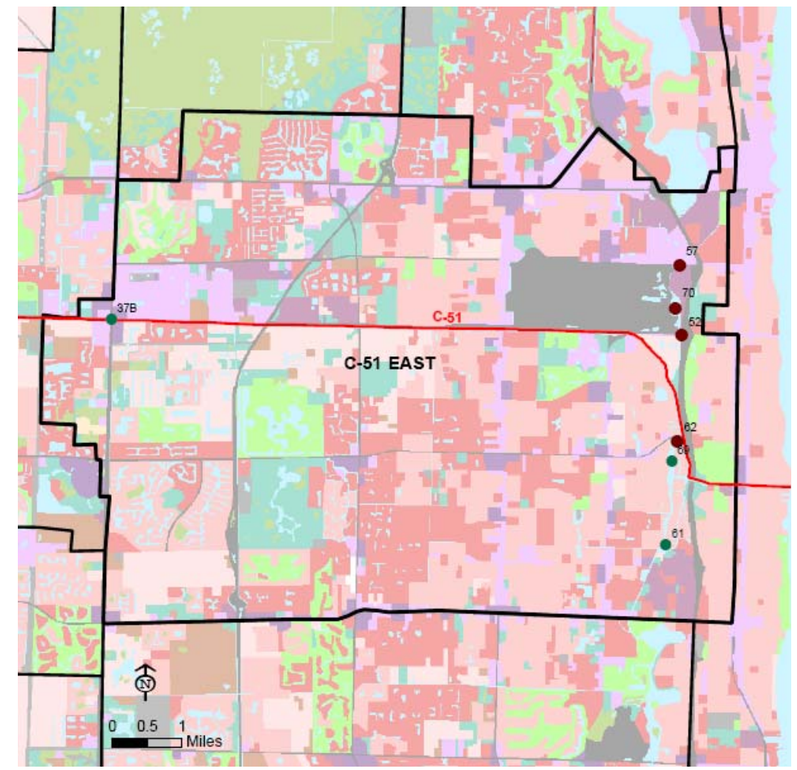
Figure 6.27 TP Medians between 2006 and 2008 for All Stations in the C-51 Canal East Basin



2006



2007



2008

LEGEND

TSS Annual Median (mg/l)

- 1.0 - 5.8
- 5.9 - 11.0
- 11.1 - 21.0
- 21.1 - 34.0
- 34.1 - 67.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	High, medium, low density residential, commercial, recreation, infrastructure		
Year	2006	2007	2008
Sampling effort	7	7	7
Concentration changes	Baseline	Decrease West and Increase East	Decrease West and South, and Increase North East
Geographic Trend	N → S (Low →High)	N → S (Low →High)	N → S (Low →High)
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.28 TSS Medians between 2006 and 2008 for All Stations in the C-51 Canal East Basin

ACME B AND C-16 CANAL NORTH BASINS BASIN

Figures for:

Alkalinity (pH)

Dissolved Oxygen (DO)

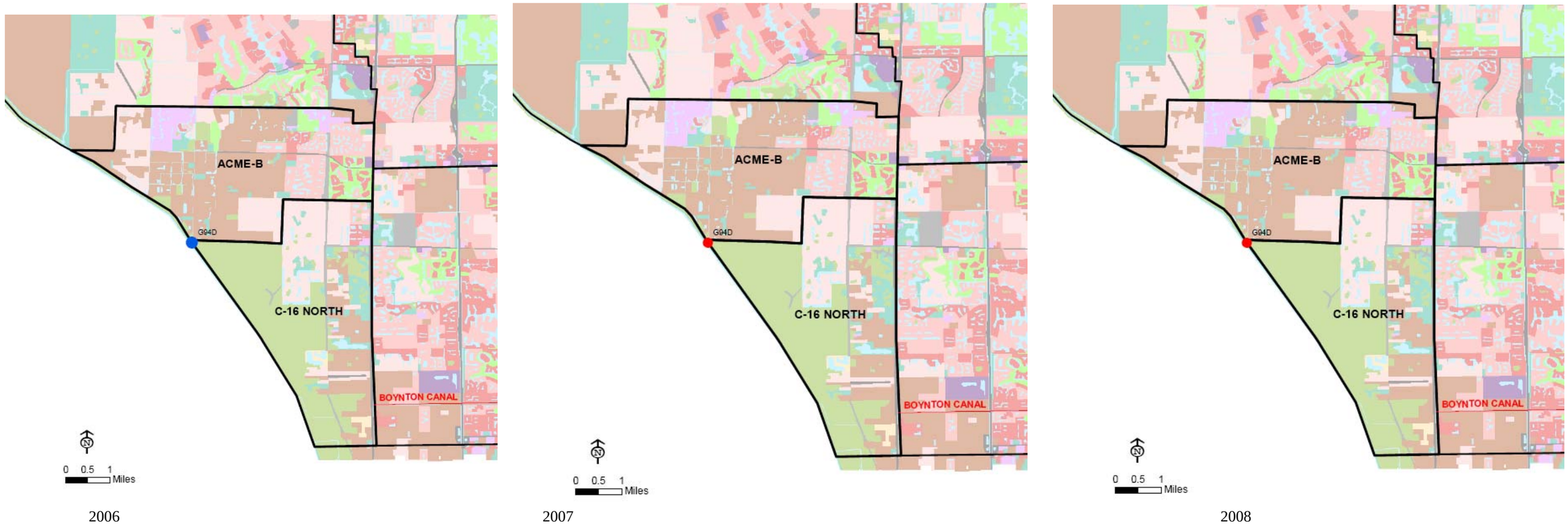
Nitrite plus Nitrate (NO_2 + NO_3)

Total Kjeldahl Nitrogen (TKN)

Orthophosphate (OPO_4)

Total Phosphorus (TP)

Total Suspended Solids (TSS)



LEGEND

pH Annual Median (mg/l)

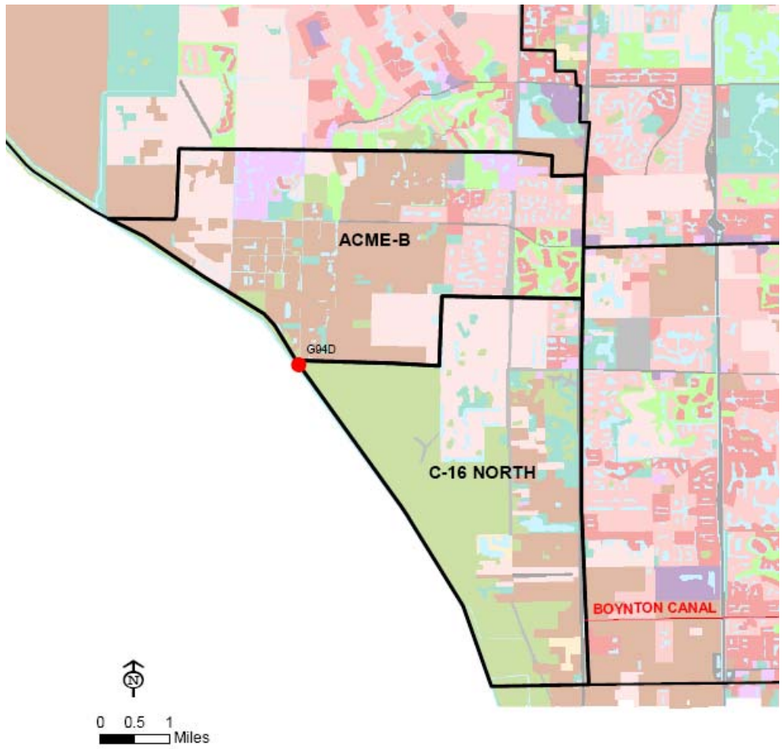
- Less Than 6.0
- 6.1 - 6.5
- 6.6 - 7.5
- 7.6 - 8.5
- More than 8.5

SFWMD 2004-05 Land Use Land Cover

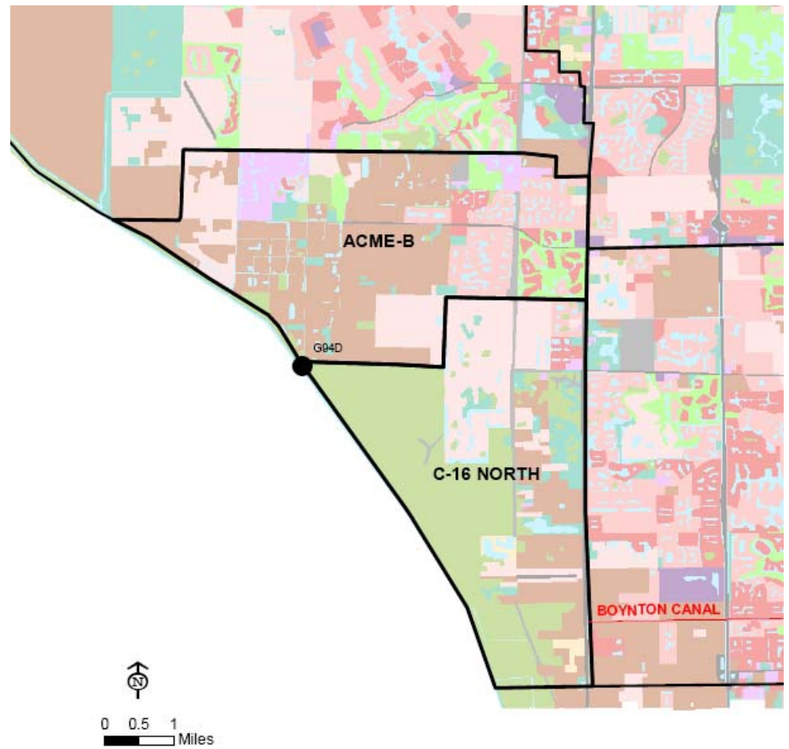
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	1	1	1
Concentration changes	Baseline	No Change	No Change
Geographic Trend	None	None	None
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	All annual median values within.F.A.C.62-302 surface water quality standards. See Appendix F for summary data.		

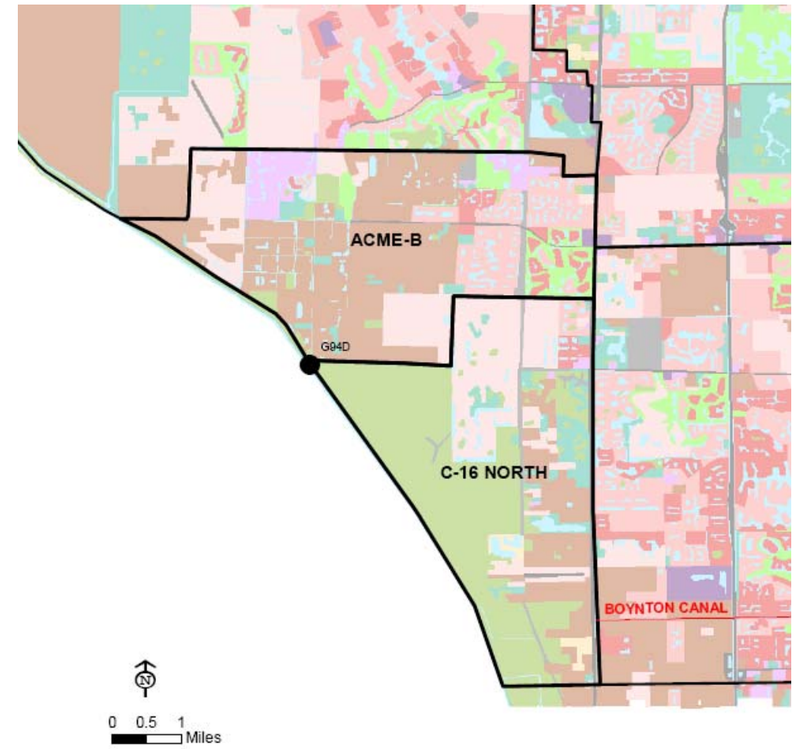
Figure 6.29 pH Medians between 2006 and 2008 for All Stations in the ACME B and C-16 Canal North Basins



2006



2007



2008

LEGEND

DO Annual Median (mg/l)

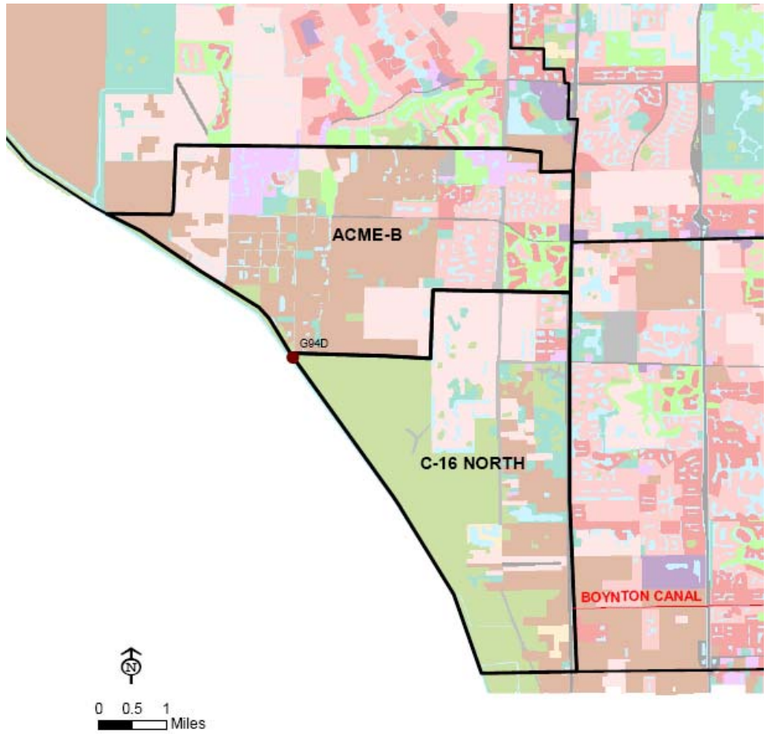
- Less than 4
- 4.1 - 5.0
- 5.1 - 7.5
- 7.6 - 10.0

SFWMD 2004-05 Land Use Land Cover

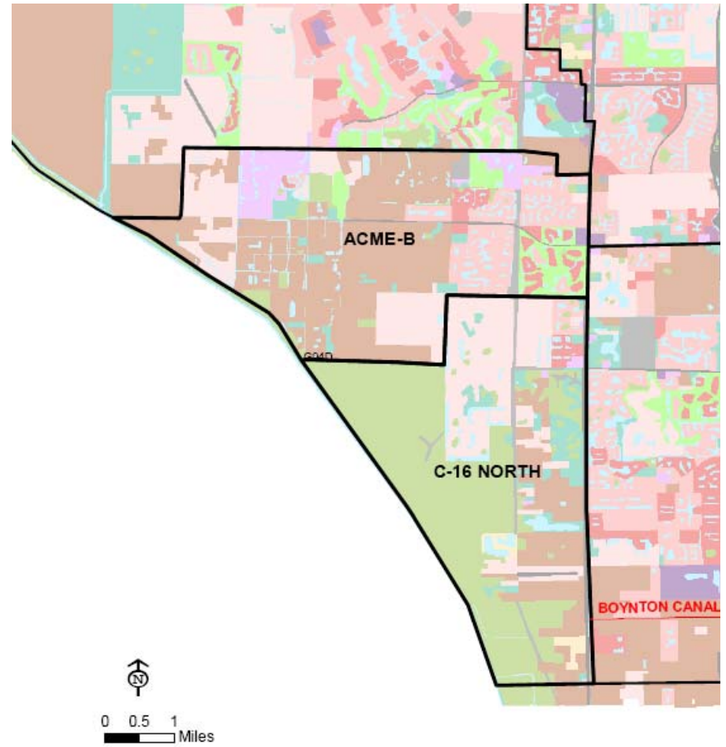
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	1	1	1
Concentration changes	Baseline	Increase	No Change
Geographic Trend	None	None	None
Concentrations of concern	< 5 mg/l	< 5 mg/l	< 5 mg/l
Stations of concern	G94D	G94D	G94D
Comments	See Appendix F for summary data.		

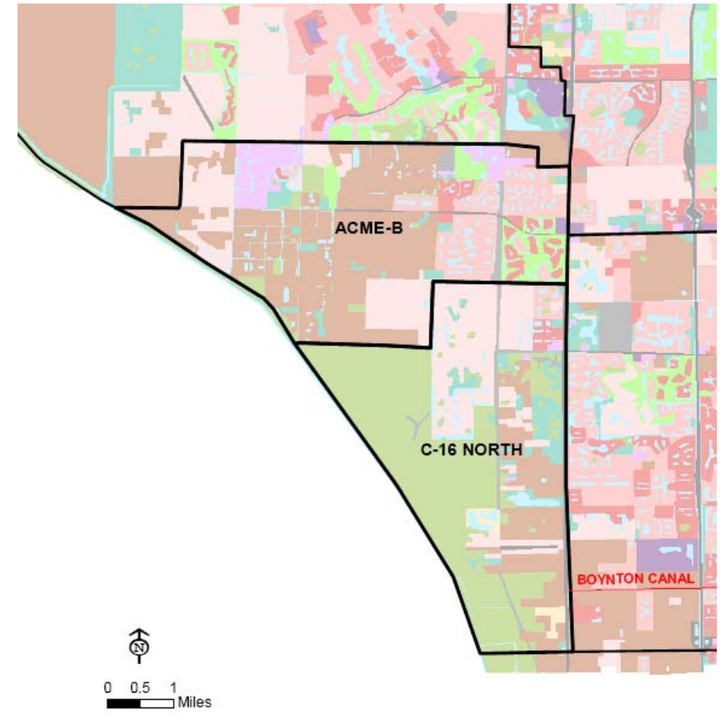
Figure 6.30 DO Medians between 2006 and 2008 for All Stations in the ACME B and C-16 Canal North Basins



2006



2007



2008

LEGEND

NO2 + NO3 Annual Median (mg/l)

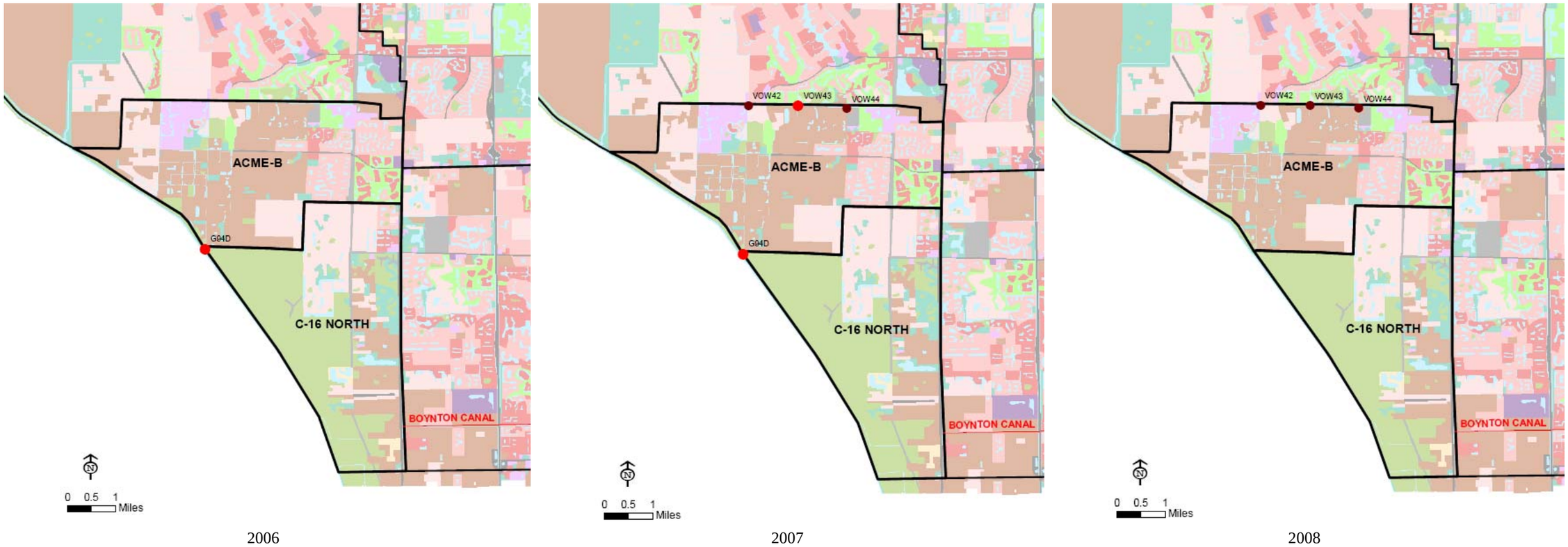
- 0.01 - 0.03
- 0.04 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.45

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	1	1	0
Concentration changes	Baseline	No Data	No Data
Geographic Trend	None	None	None
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.31 NO_2 + NO_3 Medians between 2006 and 2008 for All Stations in the ACME B and C-16 Canal North Basins



LEGEND

TKN Annual Median (mg/l)

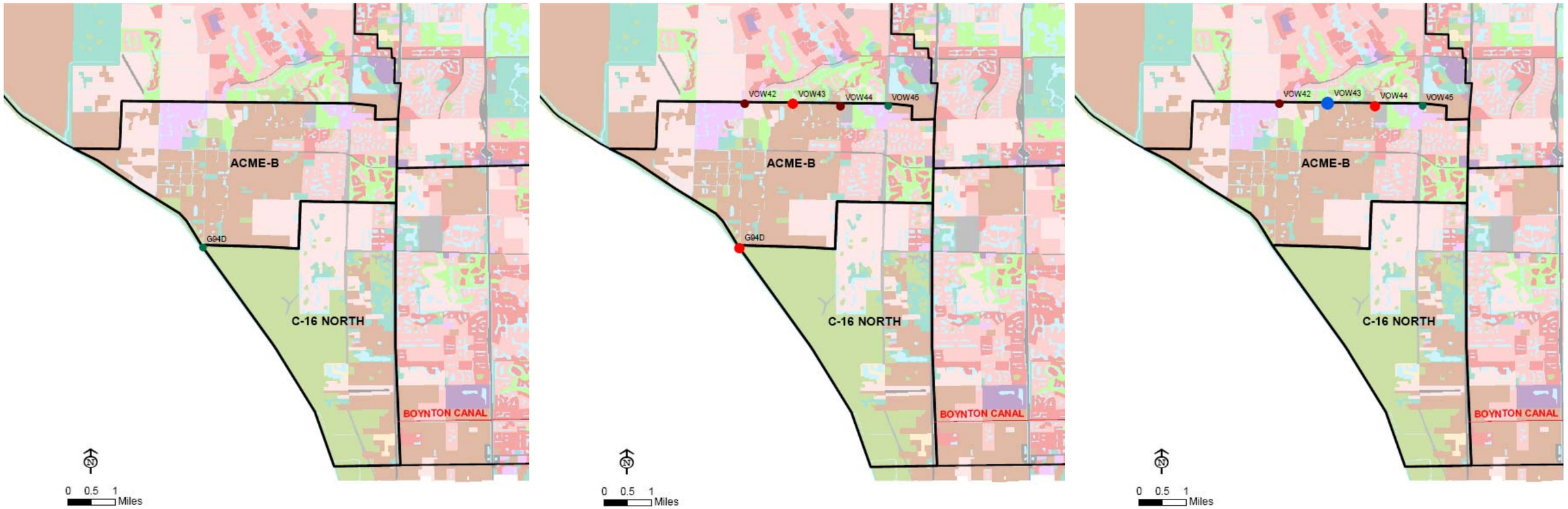
- 0.20 - 0.50
- 0.51 - 1.50
- 1.51 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	1	4	3
Concentration changes	Baseline	No Change	Decrease North
Geographic Trend	None	None	W → E (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.32 TKN Medians between 2006 and 2008 for All Stations in the ACME B and C-16 Canal North Basins



LEGEND

OPO4 Annual Median (mg/l)

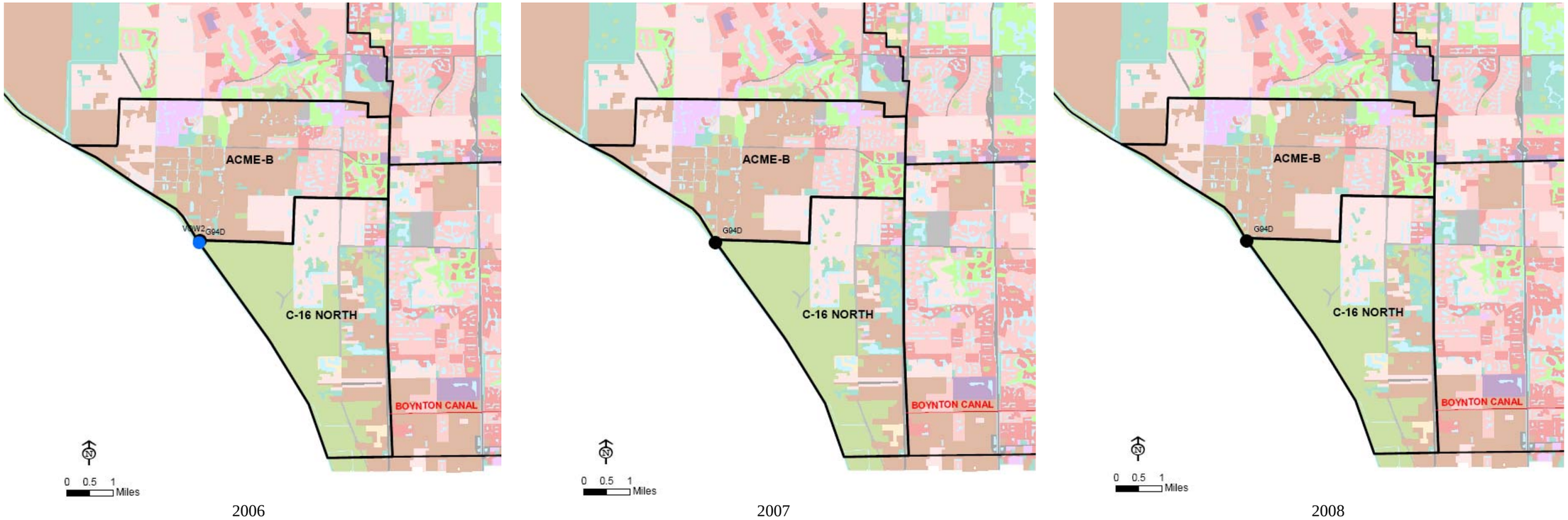
- 0.001 - 0.024
- 0.025 - 0.050
- 0.051 - 0.095
- 0.096 - 0.190
- 0.191 - 0.303

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	1	5	4
Concentration changes	Baseline	Increase (Station G94D)	Increase
Geographic Trend	W → E (high → low)	W → E (high – low)	W → E (high → low)
Concentrations of concern	0.05 mg/l	0.05 mg/l	0.05 mg/l
Stations of concern	None	G94D	vow43, vow45
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data. See Appendix F for summary data.		

Figure 6.33 OPO_4 Medians between 2006 and 2008 for All Stations in the ACME B and C-16 Canal North Basins



LEGEND

TP Annual Median (mg/l)

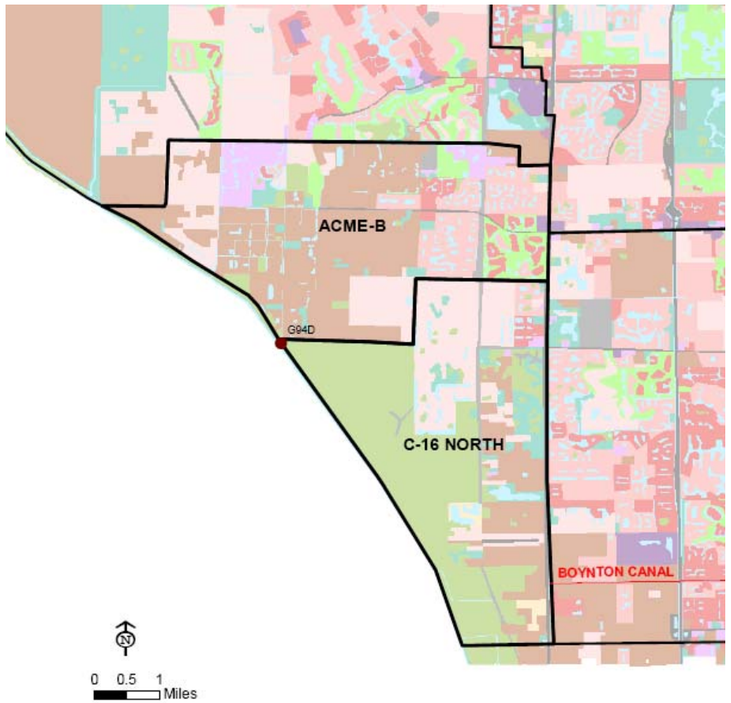
- 0.010 - 0.034
- 0.035 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.172

SFWMD 2004-05 Land Use Land Cover

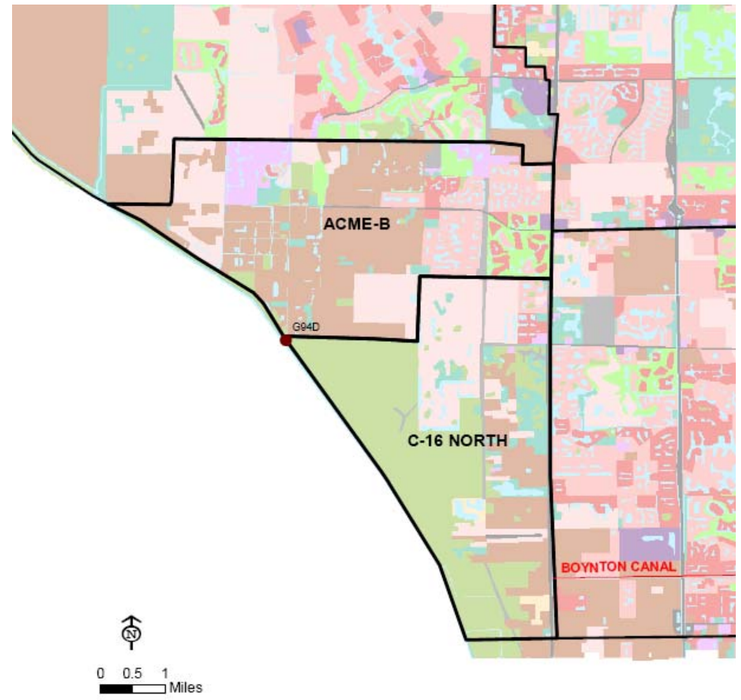
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	2	1	1
Concentration changes	Baseline	Increase	No Change
Geographic Trend	None	None	None
Concentrations of concern	0.05 mg/l	0.05 mg/l	0.05 mg/l
Stations of concern	G94D	G94D	G94D
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data. See Appendix F for summary data.		

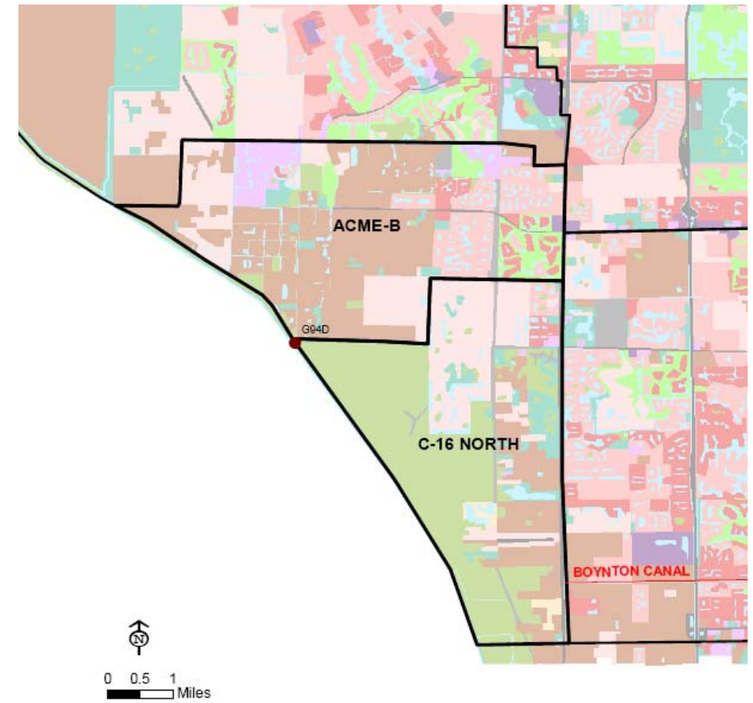
Figure 6.34 TP Medians between 2006 and 2008 for All Stations in the ACME B and C-16 Canal North Basins



2006



2007



2008

LEGEND

TSS Annual Median (mg/l)

- 1.0 - 5.8
- 5.9 - 11.0
- 11.1 - 21.0
- 21.1 - 34.0
- 34.1 - 67.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Hig

Dominant land use	Wetlands, Agriculture, Low Density Residential		
Year	2006	2007	2008
Sampling effort	1	1	1
Concentration changes	Baseline	No Change	Non Change
Geographic Trend	None	None	None
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.35 TSS Medians between 2006 and 2008 for All Stations in the ACME B and C-16 Canal North Basins

C-16 CANAL BASIN

Figures for:

Alkalinity (pH)

Dissolved Oxygen (DO)

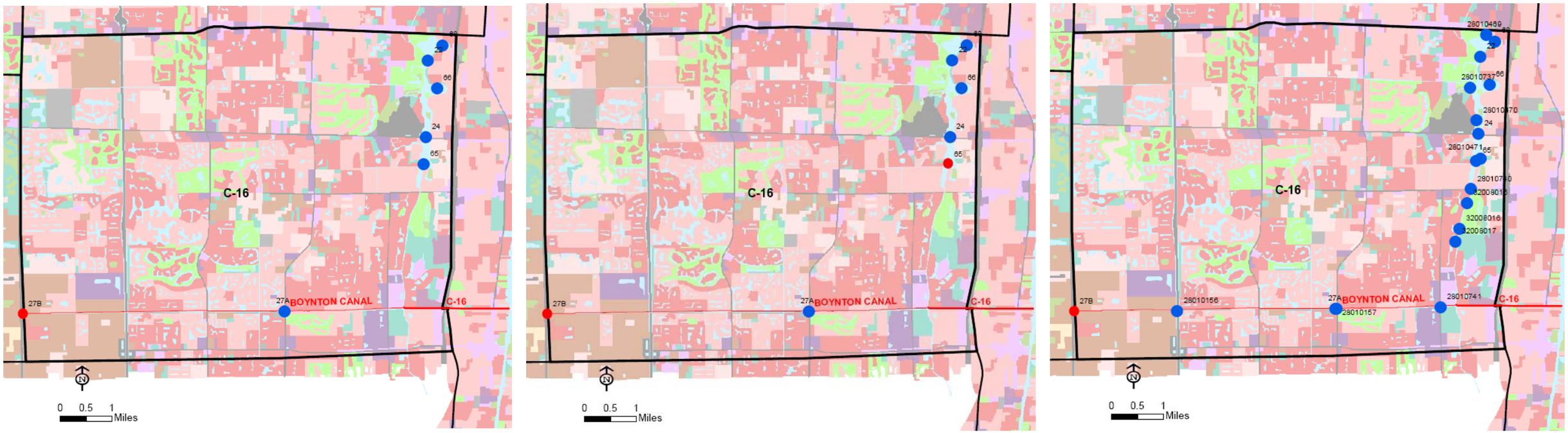
Nitrite plus Nitrate (NO_2 + NO_3)

Total Kjeldahl Nitrogen (TKN)

Orthophosphate (OPO_4)

Total Phosphorus (TP)

Total Suspended Solids (TSS)



LEGEND

pH Annual Median (mg/l)

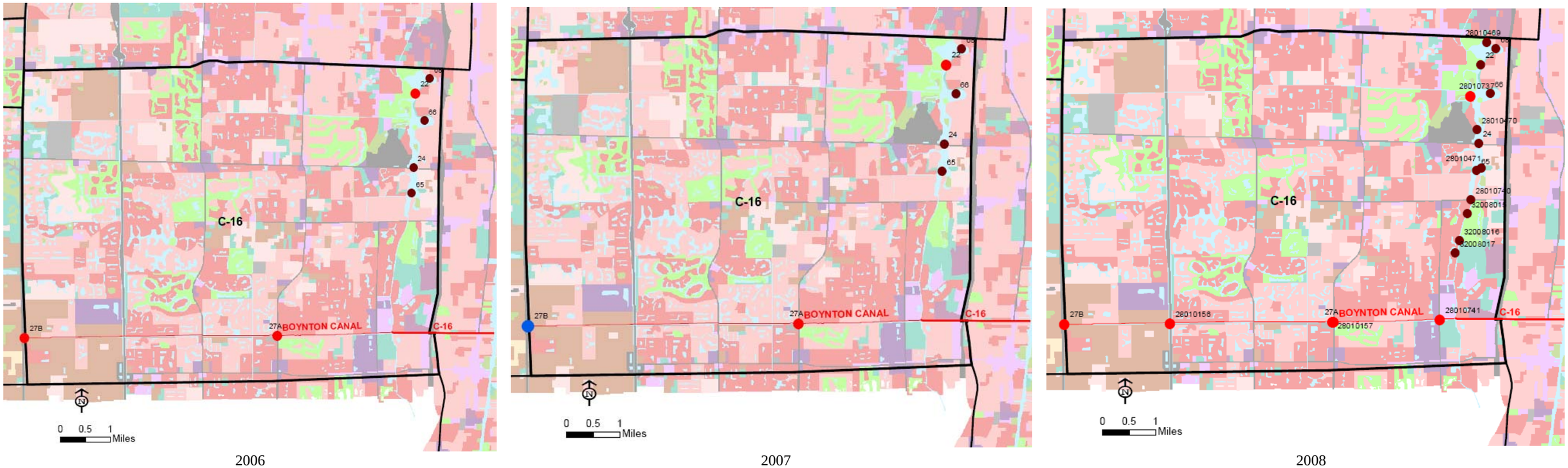
- Less Than 6.0
- 6.1 - 6.5
- 6.6 - 7.5
- 7.6 - 8.5
- More than 8.5

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Recreation, and Agriculture		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	No Change	Decrease (Station 22)
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	All annual median values within.F.A.C.62-302 surface water quality standards. See Appendix F for summary data.		

Figure 6.36 pH Medians between 2006 and 2008 for All Stations in the C-16 Canal Basin



LEGEND

DO Annual Median (mg/l)

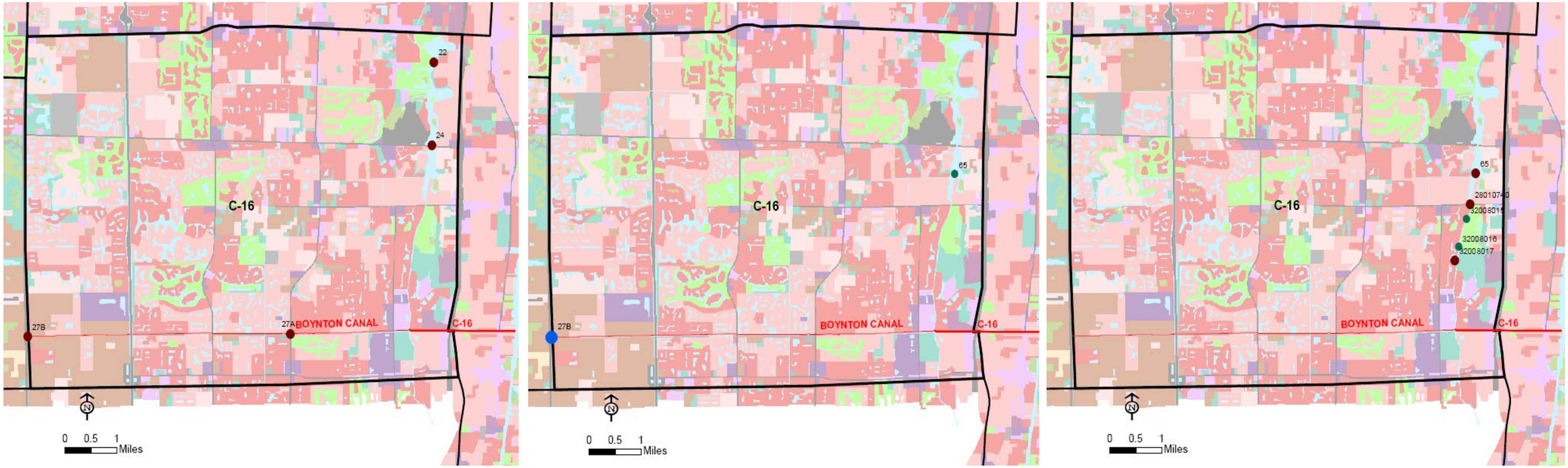
- Less than 4
- 4.1 - 5.0
- 5.1 - 7.5
- 7.6 - 10.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Recreation, and Agriculture		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Decrease (Station 27B)	Increase (Station 27B)
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	5 mg/l	5 mg/l	5 mg/l
Stations of concern	None	27B	None
Comments	All annual median values within.A.C.62-202 surface water quality standards Decreases See Appendix F for summary data.		

Figure 6.37 DO Medians between 2006 and 2008 for All Stations in the C-16 Canal Basin



LEGEND

NO2 + NO3 Annual Median (mg/l)

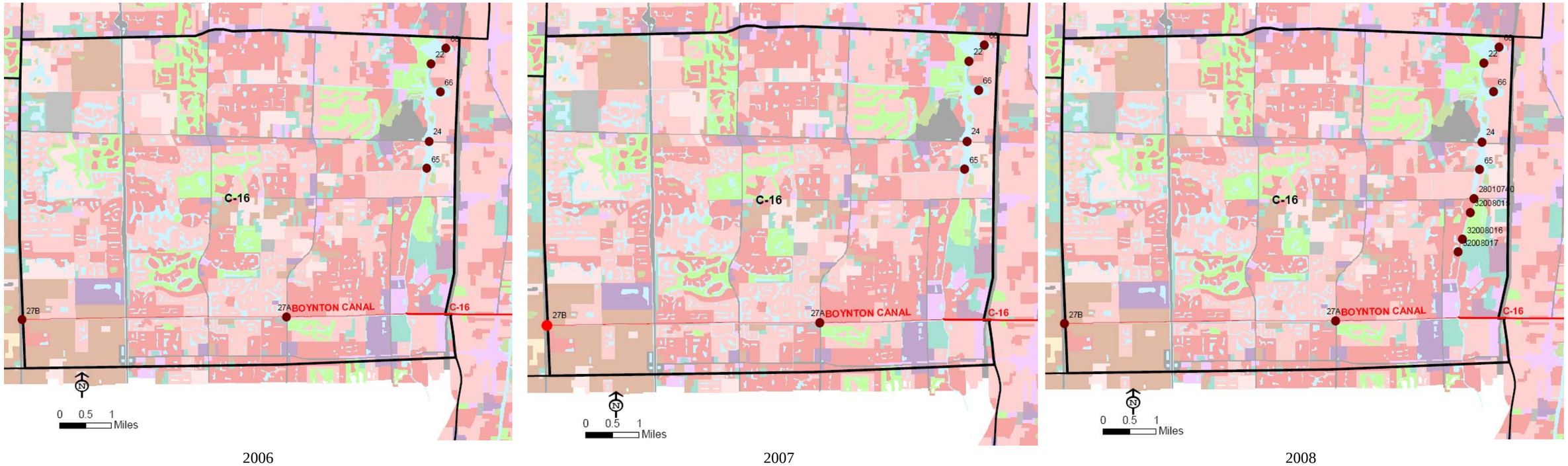
- 0.01 - 0.03
- 0.04 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.45

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and H

Dominant land use	Medium and High Density Residential, Recreation, and Agriculture		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Increase	Increase (Station 65)
Geographic Trend	W → E (high → low)	W → E (high → low)	W →E (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.38 $NO_2 + NO_3$ Medians between 2006 and 2008 for All Stations in the C-16 Canal Basin



LEGEND

TKN Annual Median (mg/l)

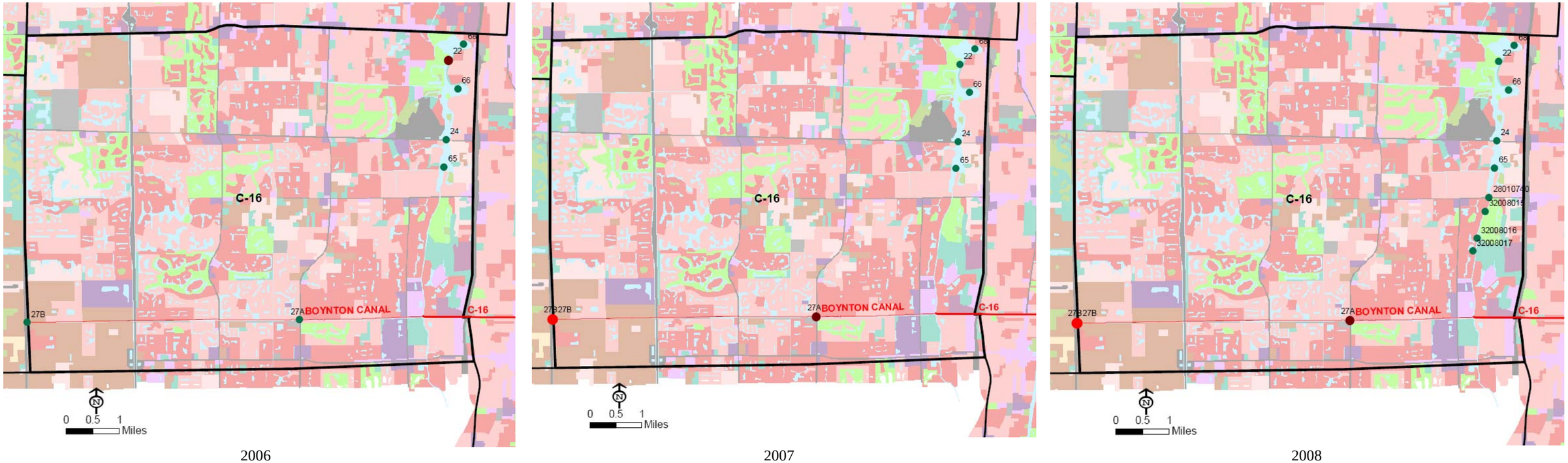
- 0.20 - 0.50
- 0.51 - 1.50
- 1.51 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Recreation, and Agriculture		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Increase (Station 27B)	Decrease (Station 27B)
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary of data.		

Figure 6.49 TKN Medians between 2006 and 2008 for All Stations in the C-16 Canal Basin



LEGEND

OPO4 Annual Median (mg/l)

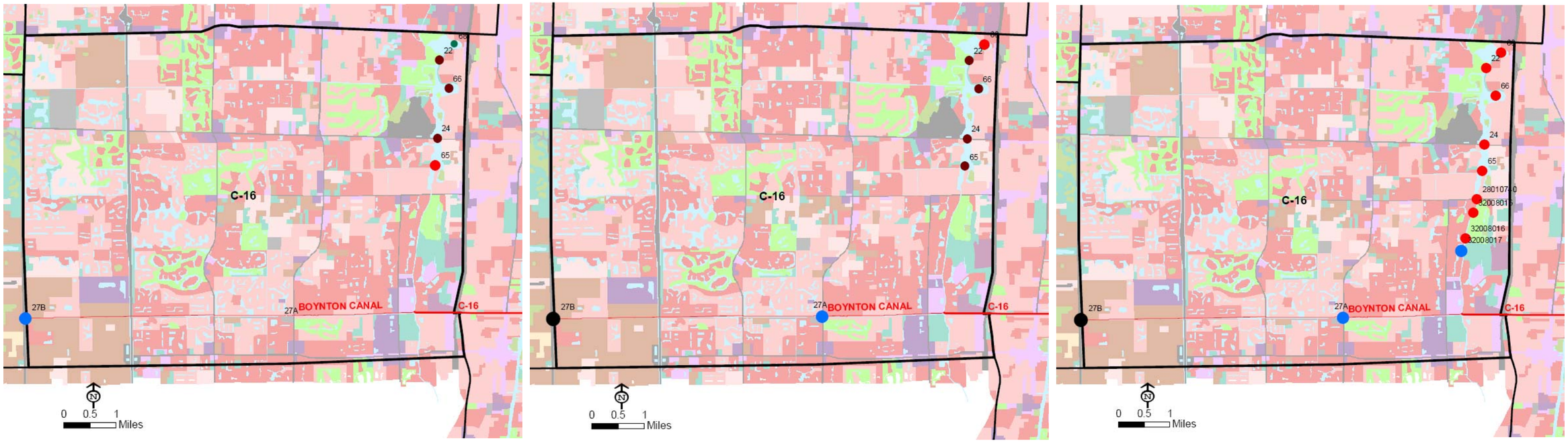
- 0.001 - 0.024
- 0.025 - 0.050
- 0.051 - 0.095
- 0.096 - 0.190
- 0.191 - 0.303

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Recreation, and Agriculture		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Increase (Station 27B)	No Change
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	0.05 mg/l	0.05 mg/l	0.05 mg/l
Stations of concern	None	27B	None
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data.		

Figure 6.40 OPO_4 Medians between 2006 and 2008 for All Stations in the C-16 Canal Basin



LEGEND

TP Annual Median (mg/l)

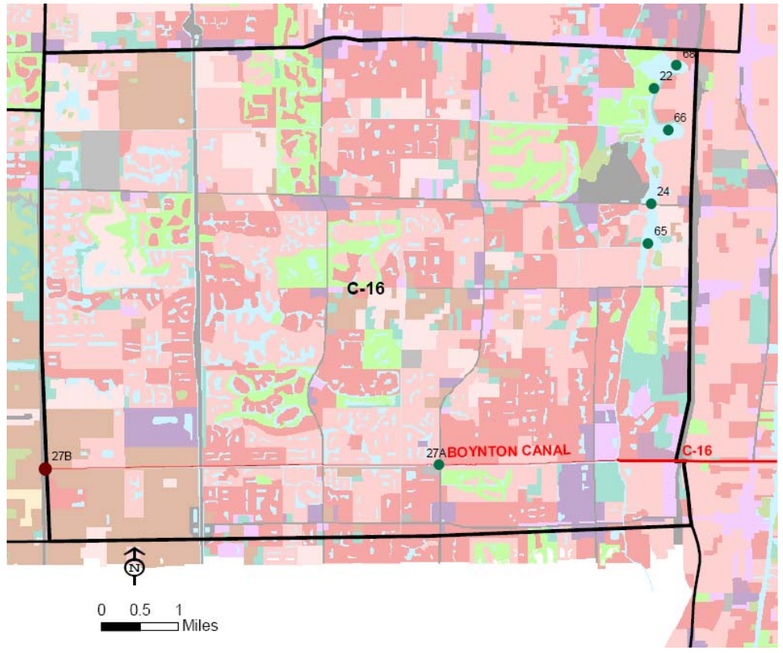
- 0.010 - 0.034
- 0.035 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.172

SFWMD 2004-05 Land Use Land Cover

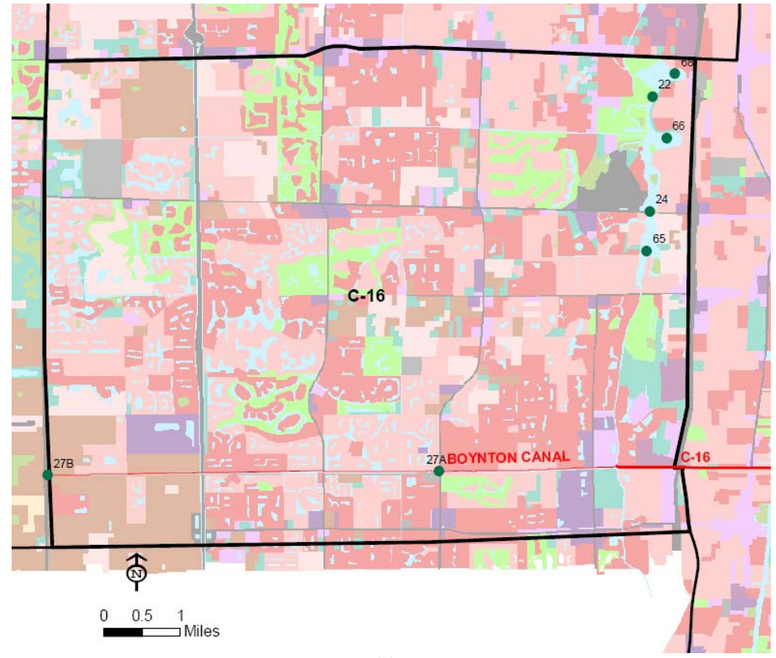
- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Recreation, and Agriculture		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Increase	Increase
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	0.05 mg/l	0.05 mg/l	0.05 mg/l
Stations of concern	27B, 65	All	All
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data.		

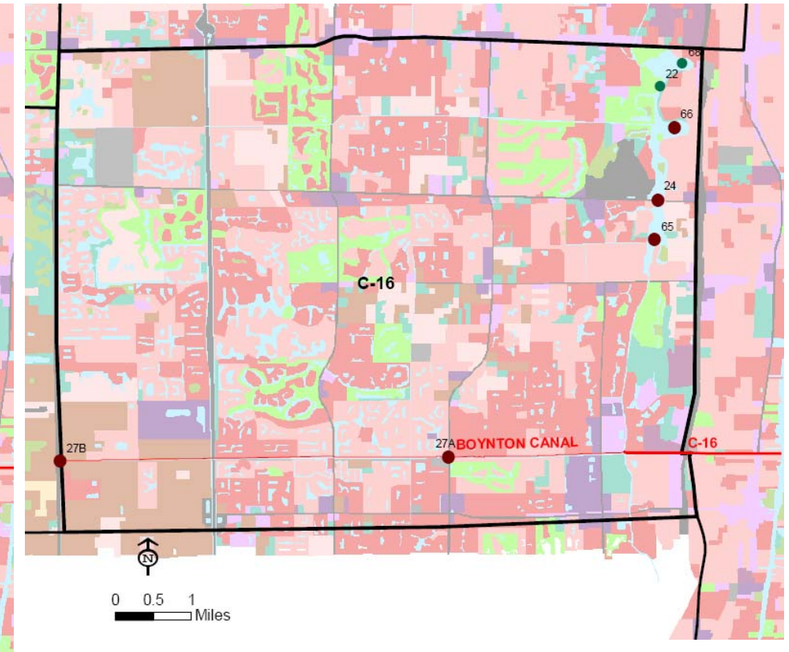
Figure 6.41 TP Medians between 2006 and 2008 for All Stations in the C-16 Canal Basin



2006



2007



2008

LEGEND

TSS Annual Median (mg/l)

- 1.0 - 5.8
- 5.9 - 11.0
- 11.1 - 21.0
- 21.1 - 34.0
- 34.1 - 67.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Recreation, and Agriculture		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Decrease (Station 27B)	Increase
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high —→low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.42 TSS Medians between 2006 and 2008 for All Stations in the C-16 Canal Basin

LAKE WORTH LAGOON BASIN

Figures for:

Alkalinity (pH)

Dissolved Oxygen (DO)

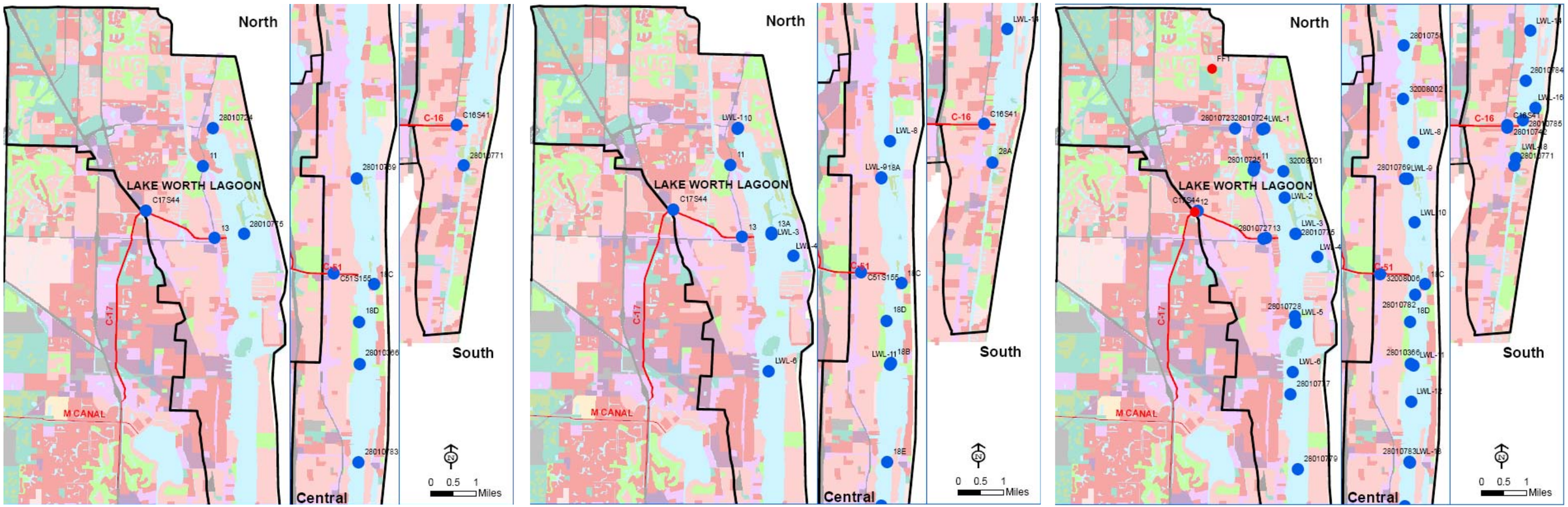
Nitrite plus Nitrate (NO_2 + NO_3)

Total Kjeldahl Nitrogen (TKN)

Orthophosphate (OPO_4)

Total Phosphorus (TP)

Total Suspended Solids (TSS)



LEGEND

pH Annual Median (mg/l)

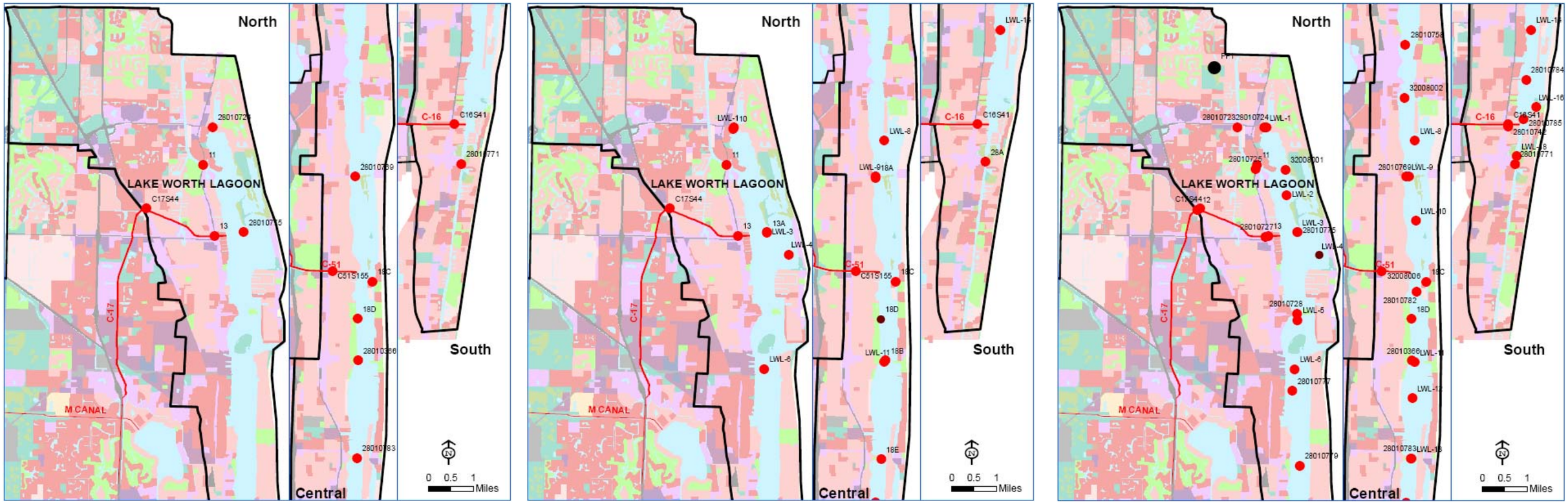
- Less Than 6.0
- 6.1 - 6.5
- 6.6 - 7.5
- 7.6 - 8.5
- More than 8.5

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Commercial, and Water		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	No Change	No Change
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	None	None	None
Stations of concern	None	None	None
Comments	All annual median values within.A.C.62-202 surface water quality standards See Appendix F for summary data.		

Figure 6.43 pH Medians between 2006 and 2008 for All Stations in the Lake Worth Lagoon Basin (Figure Shows the Lagoon Divided in Three Sections: North, Central, and South)



LEGEND

DO Annual Median (mg/l)

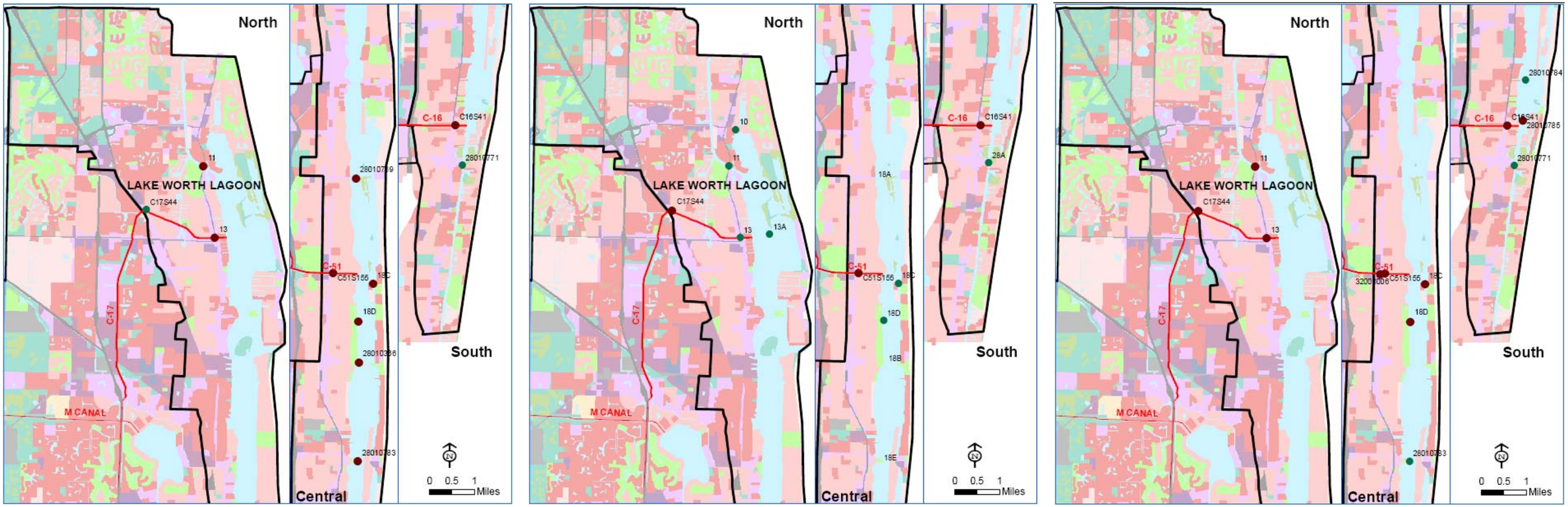
- Less than 4
- 4.1 - 5.0
- 5.1 - 7.5
- 7.6 - 10.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Commercial, and Water		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	No Change	No Change
Geographic Trend	N → S (high → low)	N→ S (high → low)	N → S (high → low)
Concentrations of concern	None	None	None
Stations of concern	None	None	FF1
Comments	All annual median values within F.A.C.62-302 surface water quality standards See Appendix F for summary data.		

Figure 6.44 DO Medians between 2006 and 2008 for All Stations in the Lake Worth Lagoon Basin (Figure Shows the Lagoon Divided in Three Sections: North, Central, and South)



LEGEND

NO2 + NO3 Annual Median (mg/l)

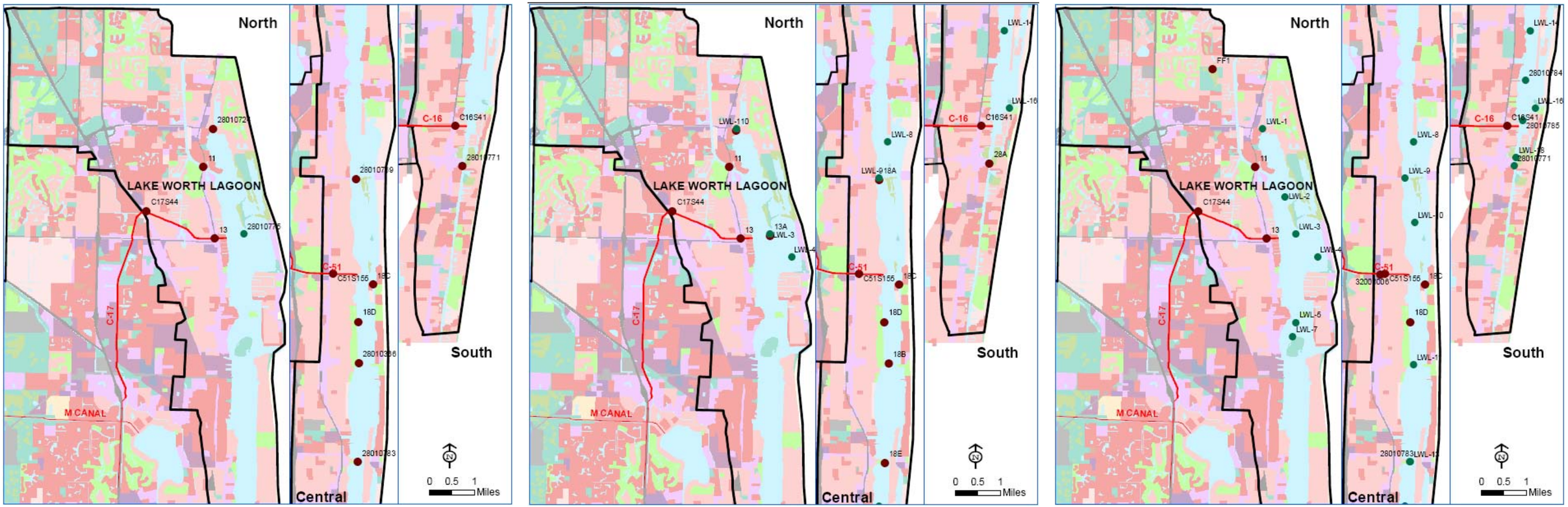
- 0.01 - 0.03
- 0.04 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.45

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Commercial, and Water		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Decrease	Increase
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	Higher concentrations at discharge points of the main canals. See Appendix F for summary data.		

Figure 6.45 $NO_2 + NO_3$ Medians between 2006 and 2008 for All Stations in the Lake Worth Lagoon Basin (Figure Shows the Lagoon Divided in Three Sections: North, Central, and South)



LEGEND

TKN Annual Median (mg/l)

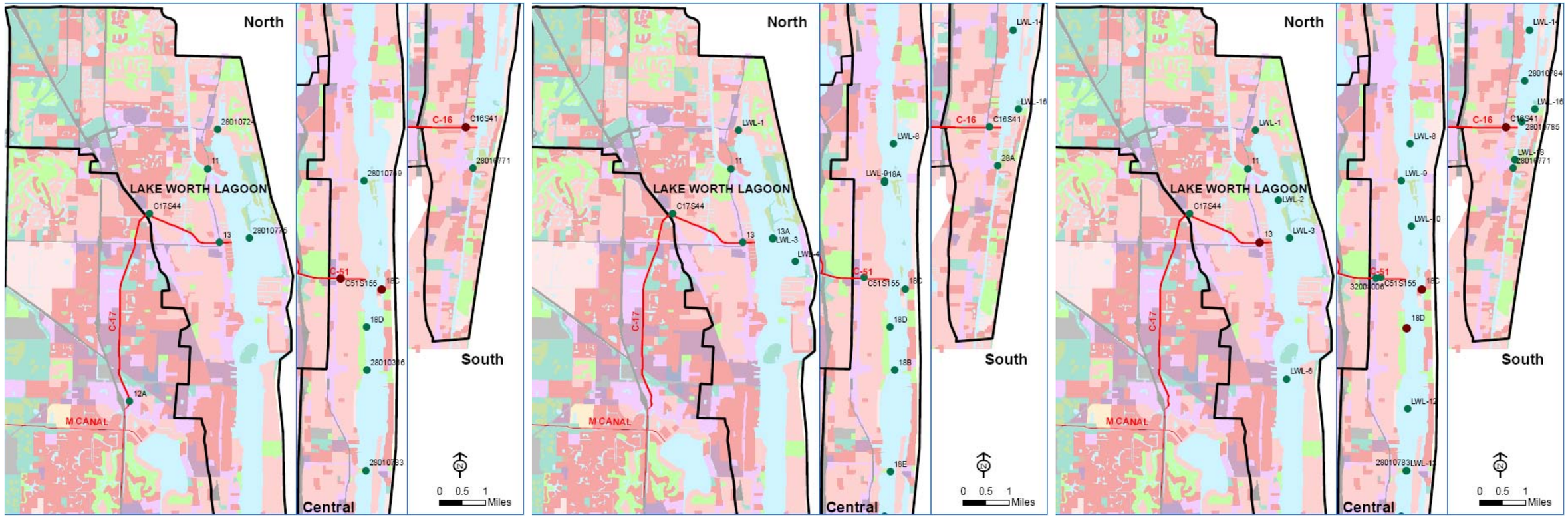
- 0.20 - 0.50
- 0.51 - 1.50
- 1.51 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Commercial, and Water		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Decrease	Decrease
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	Higher concentrations at discharge points of the main canals.See Appendix F for summary data.		

Figure 6.46 TKN Medians between 2006 and 2008 for All Stations in the Lake Worth Lagoon Basin (Figure Shows the Lagoon Divided in Three Sections: North, Central, and South)



LEGEND

OPO4 Annual Median (mg/l)

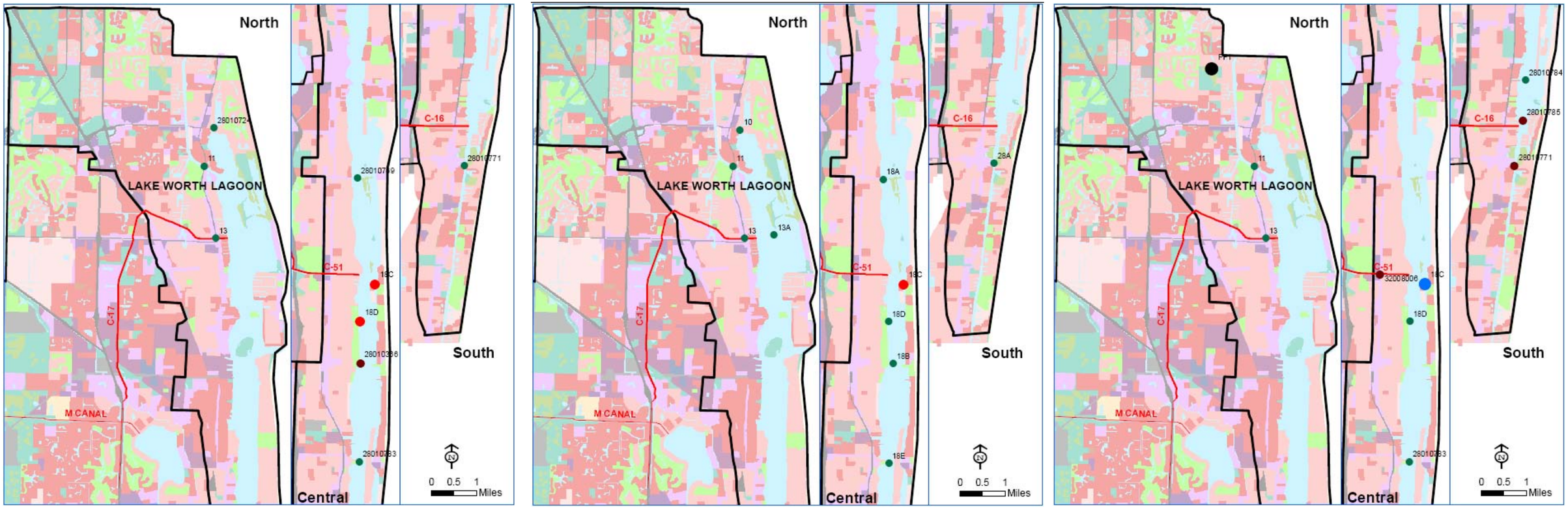
- 0.001 - 0.024
- 0.025 - 0.050
- 0.051 - 0.095
- 0.096 - 0.190
- 0.191 - 0.303

D 2004-05 Land Use Land Cover

- each
- griculture, Pasture, and Cropland
- orest, Rangeland, and Barren Lands
- Vater
- Vetlands
- ow Density Residential
- Iedium Density Residential
- igh Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Commercial, and Water		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Decrease Main Canal Exits	Increase Main Canal Exits
Geographic Trend	W → E (high → low)	W → E (high → low)	W → E (high → low)
Concentrations of concern	0.05 mg/l	0.05 mg/l	0.05 mg/l
Stations of concern	None	None	None
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data. Higher concentrations at discharge points of the main canals. All stations below 0.05 mg/l. See Appendix F for summary data.		

Figure 6.47 OPO_4 Medians between 2006 and 2008 for All Stations in the Lake Worth Lagoon Basin (Figure Shows the Lagoon Divided in Three Sections: North, Central, and South)



LEGEND

TP Annual Median (mg/l)

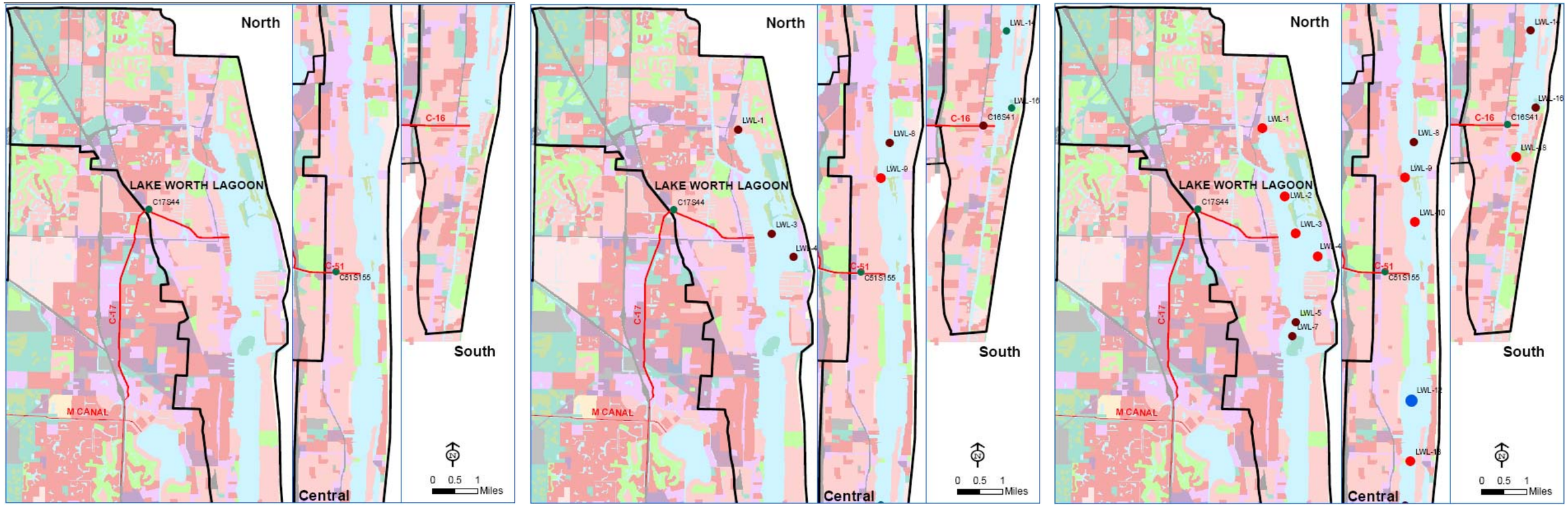
- 0.010 - 0.034
- 0.035 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.172

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Commercial, and Water		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	Increase	Increase
Geographic Trend	W – E (high – low)	W – E (high – low)	W – E (high – low)
Concentrations of concern	0.05 mg/l	0.05 mg/l	0.05 mg/l
Stations of concern	18C, 18D	18C	FF1, 18C
Comments	0.05 mg/l baseline based on McPherson and Haley 1996. See Appendix F for summary data. Higher concentrations at discharge points of the main canals. All stations below 0.05 mg/l. See Appendix F for summary data.		

Figure 6.48 TP Medians between 2006 and 2008 for All Stations in the Lake Worth Lagoon Basin (Figure Shows the Lagoon Divided in Three Sections: North, Central, and South)



LEGEND

TSS Annual Median (mg/l)

- 1.0 - 5.8
- 5.9 - 11.0
- 11.1 - 21.0
- 21.1 - 34.0
- 34.1 - 67.0

SFWMD 2004-05 Land Use Land Cover

- Beach
- Agriculture, Pasture, and Cropland
- Forest, Rangeland, and Barren Lands
- Water
- Wetlands
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Low Density Commercial
- High Density Commercial
- Extrative
- Light Industrial
- Heavy Industrial
- Recreational
- Utilities
- Transportation, Roads, and Highways

Dominant land use	Medium and High Density Residential, Commercial, and Water		
Year	2006	2007	2008
Sampling effort	10	5	6
Concentration changes	Baseline	-	-
Geographic Trend	W – E (high – low)	W – E (high – low)	W – E (high – low)
Concentrations of concern	No Baseline	No Baseline	No Baseline
Stations of concern	None	None	None
Comments	See Appendix F for summary data.		

Figure 6.49 TSS Medians between 2006 and 2008 for All Stations in the Lake Worth Lagoon Basin (Figure Shows the Lagoon Divided in Three Sections: North, Central, and South)

In the L-8 basin, samples are located in the L-8 Canal and in the M Canal (Figures 6.1 through 6.7). Two large land use areas (low density and agriculture land uses) on the eastern side of the basin may contribute to the low DO concentrations in the M Canal. Chapter 8, the EMC Monitoring Plan, suggests further examination of these two areas for potential location of EMC monitoring stations. Nutrient concentrations were generally higher or the L-8 canal, and lower towards the east along the M Canal. Overall concentrations either remain unchanged or decreased between 2006 and 2008. In the particular case of TP, 2008 showed a steep decrease in total phosphorus concentrations in 2008 in the station along the L-8 Canal.

In the C-17 basin, samples are located in the M Canal, C-17 Canal, in Lake Mangonia and Clark, and in some of the natural areas in the basin.C-51 west basin has samples mostly in the C-51 Canal (Figures 6.8 through 6.14). DO concentrations (Figure 6.9) were lower on the western side of the basin, along the M Canal and in the natural areas closer to the Water Conservation Area. The nutrient concentrations were also higher on the west side of the basin, specifically in the natural areas in the northwestern side of the basin, and at the beginning of the C-17 Canal. Decreases or increases between within the three years were minimal.

In the C-51 West basin stations are located mostly along the M Canal and the C-51 Canal. Some stations are in the naturals areas within the basin (Figures 6.15 through 6.21). Generally, nutrient concentrations decreased from west to east with the exception of TP. TP concentrations in the western side of the C-51 canal decreased between 2006 and 2008 while the concentrations along the same canal near areas of low density residential land uses increased.

In the C-51 East basin, stations are located mostly along the C-51 Canal, near the airport, and within the two first lakes of the Chain of lakes: Pine Lake and Lake Clarke (Figures 6.22 through 6.28). Overall DO concentrations (Figure 6.23) by 2008 were all above the F.A.C 62-302 standards, with the exception of one station on the western side of the C-51 Canal (Station 37B) and one station on the north eastern side of the basin near the airport (Station 57). NO2 + NO3 (Figure 6.24) is higher on the west side of the basin, where near the water release structure that controls the release of water from the C-51 West basin to the C-51 East basin. TKN and OPO4 did not show changes in the past three years (Figure 6.25 and 6.26).TP values included concentrations above 0.05 mg/l at the majority of the stations through 2008. Literature showed that levels of total phosphorus in Florida are usually lower than 0.05 mg/l (McPherson and Halley, 1996).

The Acme B basin or within the C-16 North basin (Figures 6.30 through 6.36) had very few stations with more than three samples a year. Beginning in 2007, the Village of Wellington has monitored for nutrients (NO2 +NO3, TKN, and OPO4), on the northern boundary of the ACME B basin. Data from these stations showed a general increase from west to east, in particular for OPO4 values in the areas where the adjacent land uses are include a golf course (to the north) and agriculture (to the south).

The C-16 basin stations are located mostly in the Boynton and C-16 Canals and in the Lake Osborne, the fourth third lake of the Chain of Lakes. Overall nutrient concentrations on the lakes are lower than stations in the Boynton canal. All stations in the basin however presented total phosphorus concentrations above 0.05 mg/l, which indicate water degradation (McPherson and Halley, 1996).

Lake Worth Lagoon includes samples all over the estuary, and at the three Canal exits: C-17 drains to the north section, C-51 to the central section, and C-16 to the most southern section. Parameter concentrations are higher closer to the exits of the canals. A multi-dimensional circulation/ water quality model of the lagoon would help understand the impacts of the discharges in all areas of lagoon, and possibly help identify means to manage the discharge flows into the LWL for improved water quality.

This analysis is just an example of what the SFWMD can accomplish with the ArcGIS geodatabase provided with this project. Since this analysis used estimated annual medians calculated from any year that had a minimum of three samples) the interpretations of the results of this analysis should be viewed only as a general representation of the basin. A similar analysis using the monthly averages may provide a more detailed insight on a particular basin of interest of at an individual station.

Continuing analyzing data from the current sampling programs at the district or at the county will help continuing monitor each basin on a large scale. An EMC monitoring program will provide the district with data to quantify storm water run off contribution for the watershed from particular land uses.

7. LAKE WORTH LAGOON PRELIMINARY LOADS CALCULATIONS

7.1 Yearly Volumes

Three canals that drain the LWL watershed basins discharge directly to the LWL: C-17 Canal (C-17), C-51 Canal (C-51) and C-16 Canal (C-16) (FDEP, 2006). The SFWMD maintains flow, rain, and the water quality data collection at or near the three structures relatively close to the end of the canals at the open waters of LWL (Figure 7.1, Table 7.1).

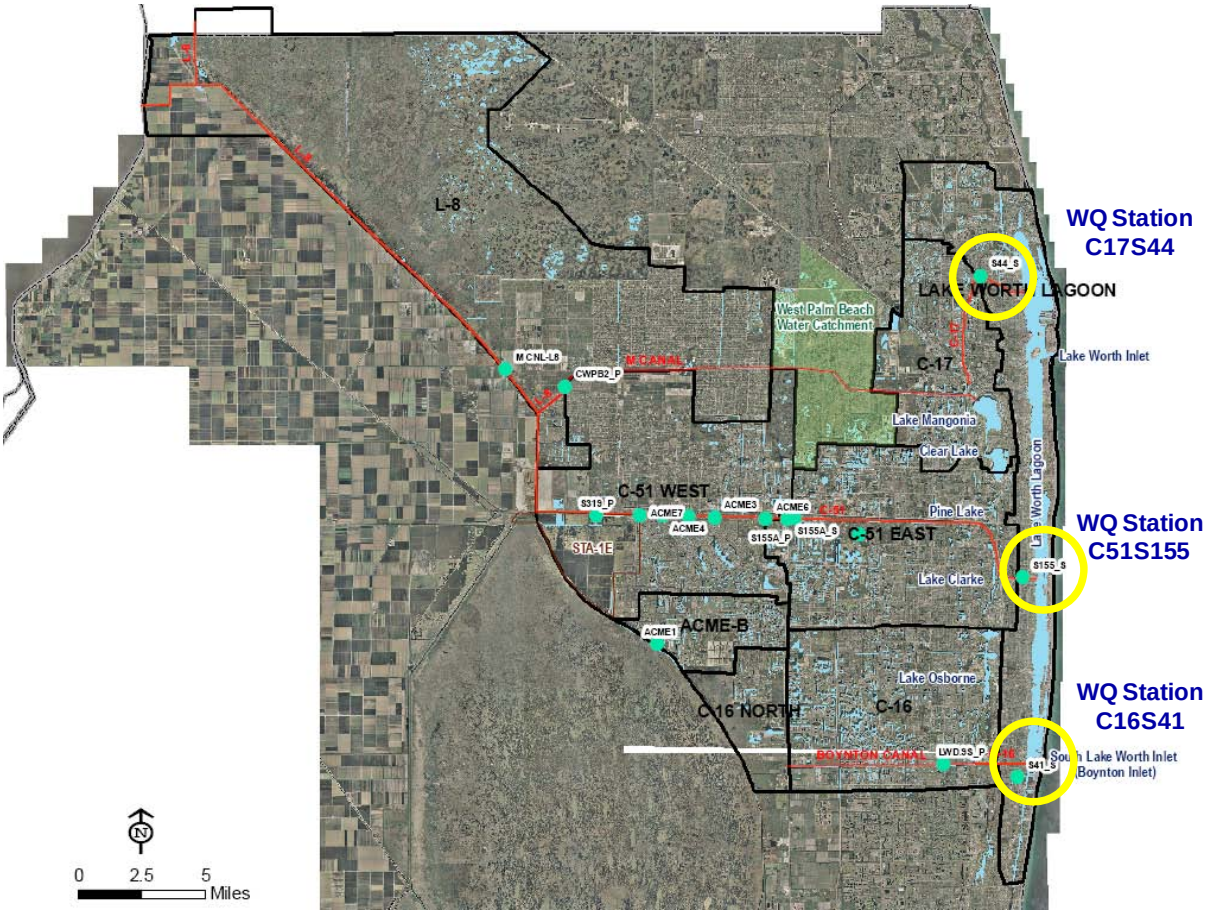


Figure 7.1 Selected Stations to Calculate Preliminary Loads to the LWL

Table 7.1 Flow and Water Quality Stations at the C-17, C-51, and C-16 LWL Discharge Structures

Basin	Flow Station	Water Quality Stations
C-17	S-44	C17S44
C-51 East	S-51	C51S155
C-16	S-41	C16S41

Based on the time series of daily average flows for the C-17, C-51, and C-16 hydrologic data collection stations (Table 7.1), Taylor Engineering calculated the annual flow volumes for the three canals. Figure 7.2 shows the volume of water (millions of liters) discharged annually to LWL since 1990 from C-17, C-51, and C-16. Table 7.2 ranks the discharge flow from low to highest for the period of record (1990 to 2008)

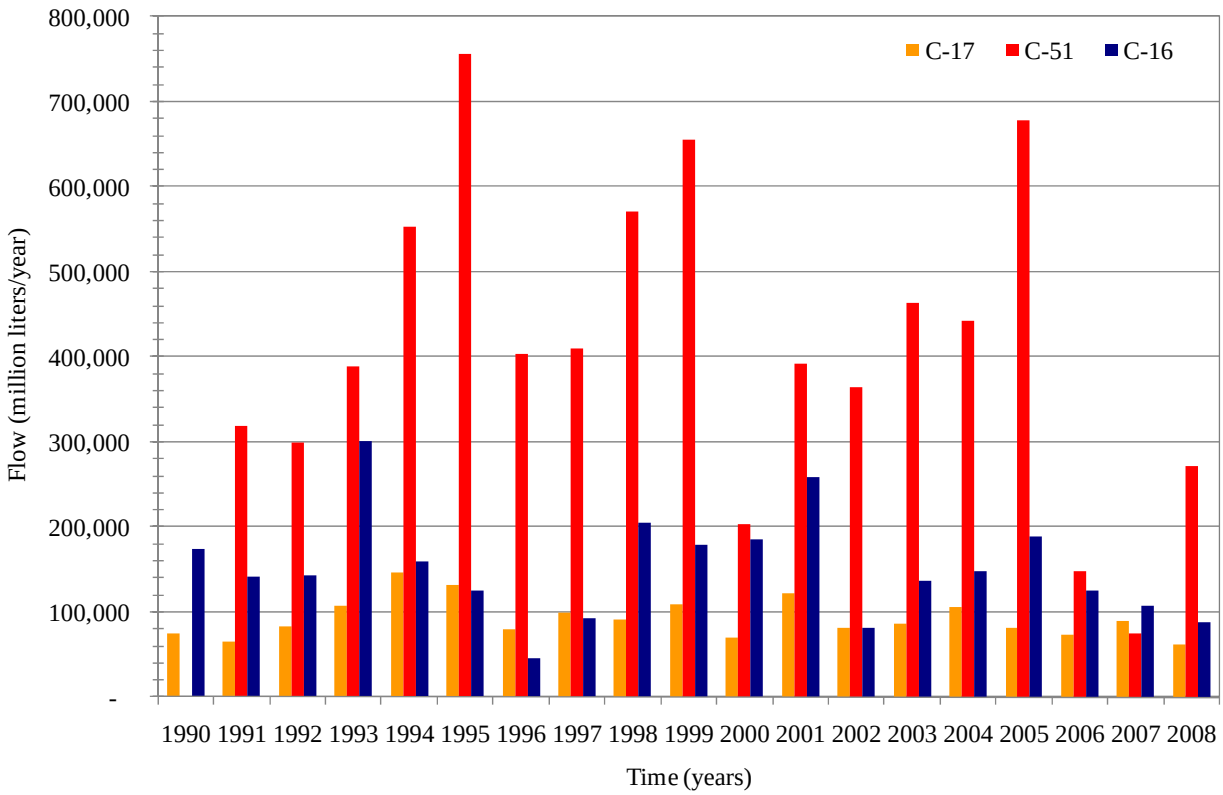


Figure 7.2 Annual Flow Discharges from the C-17, C-51, and C-16 Canals to the LWL (1990 – 2008)

Table 7.2 Ranked Discharge Flow for the C-17, C-155, and C-16 Canal

	C-17 (S44_S)		C-51 (S155_S)		C-16 (S41_S)	
Rank	**Year**	**Flow (million l/yr)**	**Year**	**Flow (million l/yr)**	**Year**	**Flow (million l/yr)**
1	2008	62,075	2007	74,190	1996	45,012
2	1991	64,656	2006	147,509	2002	81,268
3	2000	69,314	2000	202,710	2008	87,877
4	2006	73,426	2008	271,164	1997	93,228
5	1990	74,720	1992	299,857	2007	107,677
6	1996	79,505	1991	318,197	1995	124,904
7	2005	81,128	2002	364,869	2006	125,485
8	2002	81,618	1993	388,673	2003	137,363
9	1992	82,141	2001	392,495	1991	141,891
10	2003	86,970	1996	403,178	1992	143,489
11	2007	88,979	1997	409,588	2004	148,403
12	1998	90,694	2004	442,499	1994	158,867
13	1997	99,401	2003	464,226	1990	174,439
14	2004	106,430	1994	552,500	1999	178,554
15	1993	107,602	1998	570,250	2000	185,101
16	1999	109,523	1999	654,735	2005	188,471
17	2001	121,823	2005	678,496	1998	204,510
18	1995	131,101	1995	756,088	2001	258,696
19	1994	146,563	1990	no data	1993	300,246
Statistics						
Minimum		62,075		74,190		45,012
1st Quartile		77,113		304,442		116,290
Median		86,970		397,837		143,489
3rd Quartile		107,016		530,431		181,828
Maximum		146,563		756,088		300,246

C-51 discharges the highest volume of the three canals, because C-51 serves two of the largest basins in the watershed — C-51 West (66,560 ac) and C-51 East (46,720 ac). C-17 serves the smallest basin (22,551 ac) and accordingly discharges the smallest annual volumes. C-16 drains a 34,256 ac basin, and most often produces significantly larger annual volumes than C-17. Table 7.2 data do not appear to show any overall increase or decrease in discharges through time, and different basins show quite different year rank values.

7.2 Preliminary Loads for Individual Canals

Richards (1998) described a simple methodology to calculate preliminary loads from a river or stream: multiply the volume of water that passes by a specific location in a period of time by a chemical concentration for that period.

Load (metric tons/year) = Volume/Year (liter / year) x Concentration/Volume (mg / liter)

Taylor Engineering calculated preliminary loads to the LWL by multiplying the annual median concentration of each water quality parameter by the total volume of water passing through the monitoring stations during the same year. Figures 7.3 through 7.6 show the calculated preliminary loads from each of the three canals between 1990 and 2008 for total suspended solids (TSS), Nitrite + Nitrate (NO2 + NO3), total Kjeldahl nitrogen (TKN), and orthophosphate (OPO_4) Annual loads are presented in units of metric tons (mt).

Tables 7.3 through 7.6 present minimum, mid range and maximum loads from the three canals. Data are presented as total annual metric tons (mt) loads and as per acre loadings (total load divided by basin area) (mt/acre/yr). The mid range value was defined bas the value ninth of the all years' values ranked from 1 as the lowest value (18 years for C51, 19 years for C17 and C16).

7.2.1 Total Suspended Solids (TSS)

Minimum annual TSS loads from the three canals (Figure 7.3, Table 7.3) varied by less than a factor of 2, with the C-51 canal providing almost one-half the total loading to the LWL. Minimum, mid range and maximum annual per-acre loadings (Table 7.3) did not vary widely and did not reflect strongly the differences in total areas drained by the canals. Note also that the minimum, maximum, and mid-point loadings did not occur in the same years for the different basins. The other annual loadings summaries below also show this same characteristic – minimum, mid, and maximum value loadings occur in different years in different basins.

The number of TSS samples reported per year varied between three and twelve for the C-17 (no data for 1997) and C-51 (no data for 2003) canals and between four and twelve for the C-16 canals (no data for 2006). Appendix F (Table F.8g) includes TSS concentrations annual statistics for all stations with more than three samples per year.

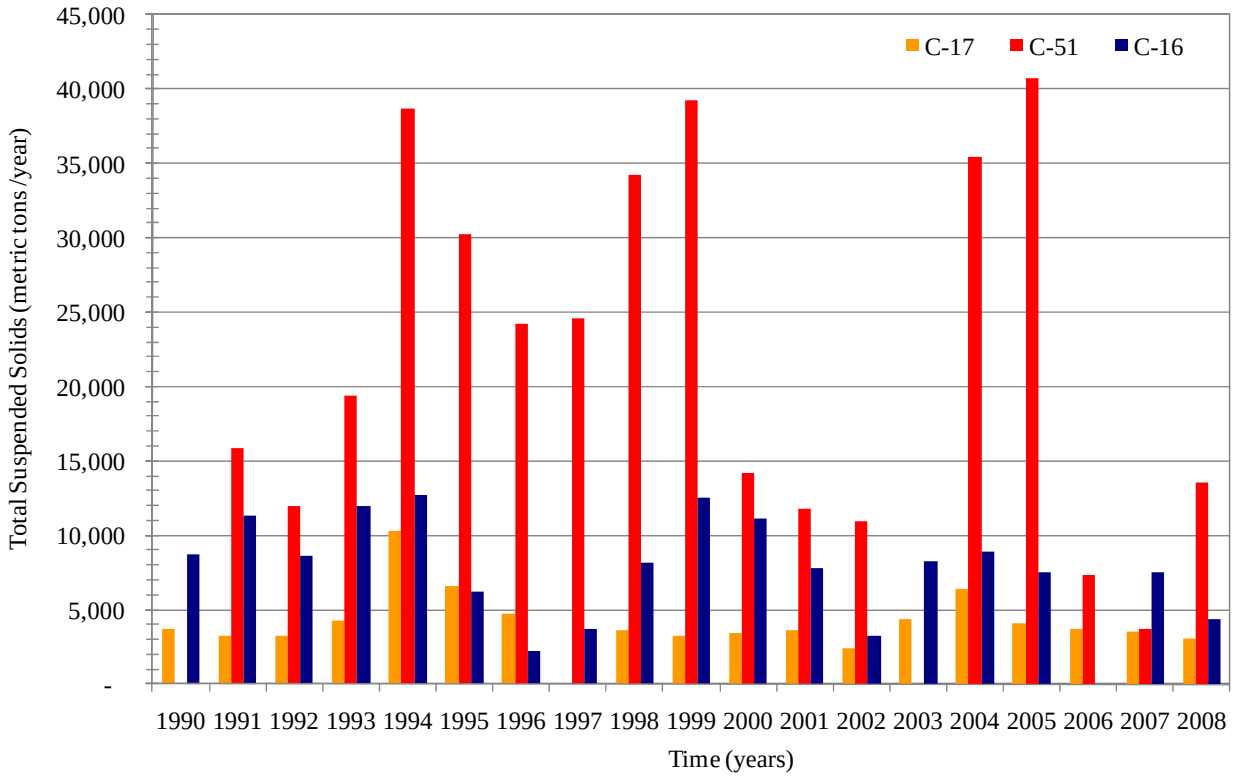


Figure 7.3 Total Suspended Solids Annual Load to LWL from the C-17, C-51 and C-16 Canals

Table 7.3 Total Suspended Solids (TSS) Load Summary for C-17, C51, and C-16: Total Annual Loads, Unit Area Loads, and Year

	Minimum Load		**Mid-Range of Loads**		**Maximum Load**	
Canal	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**
C-17	2002	2,449 (0.109)	2001	3,655 (0.162)	1994	10, 259 (0.455)
C-51	2007	3,709 (0.033)	1993	19,434 (0.172)	2005	40,710 (0.359)
C-16	1996	2,251 (0;066)	1998	8,180 (0.239)	1999	12,709 (0.371)

7.2.2 Nitrite plus Nitrate (NO_2+NO_3)

NO_2+NO_3 minimum and maximum loads ranged much more widely than did TSS loads from the same canal (Table 7.4). While TSS loads differed at most by a factor of 10 (Table 7.2), NO_2 + NO_3 loads for each basin discharge varied by more than a factor of 10 and C-51 NO_2 + NO_3 maximum load was 35 times the minimum load. Minimum per-acre NO_2 + NO_3 loads varied little while maximum per acre NO_2

+ NO_3 loads varied greatly. These patterns imply that total annual storm runoff more strongly influences NO_2 + NO_3 loadings than TSS loadings.

The available NO_2 + NO_3 concentration data varied between nine and twelve samples per year from the C-17 Canal and between eight and twelve samples per year from the C-51 and C-16 canals. Appendix F (Table F.8e) includes the NO_2 + NO_3 annual concentrations statistics for all stations with more than three samples per year.

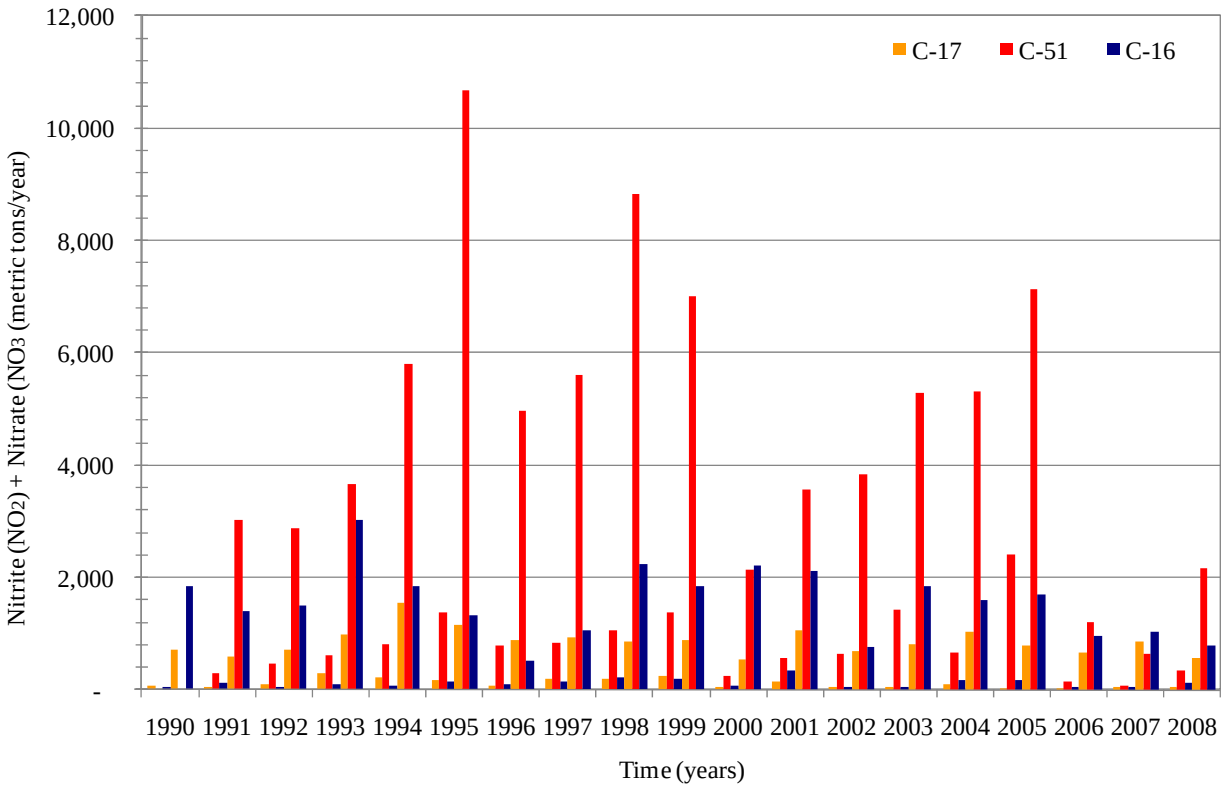


Figure 7.4 Nitrite + Nitrate Annual Load to LWL from the C-17, C-51 and C-16 Canals

Table 7.4 Nitrite plus Nitrate (NO++NO_3) Load Summary for C-17, C51, and C-16: Total Annual Loads, Per-Acre Loads, and Year

	Minimum Load		Mid-Range of Loads		Maximum Load	
Canal	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**
C-17	2006	15 (0.001)	1990	86 (0.004)	1993	284 (0.013)
C-51	2007	68 (0.001)	2002	635 (0.006)	2005	2,402 (0.021)
C-16	2007	38 (0.001)	1993	99 (0.003)	2001	341 (0.010)

7.2.3 Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen loading in all basins (Figure 7.5, Table 7.4) showed a pattern of increased per acre loading rates with increased total load. Minimum total TKN loads from the three canals were very similar, while per-acre loads ranged relatively widely. As loading increased, per acre loads became more similar. Maximum total loads reflected the sizes of the drainage basins and maximum per acre loads varied relatively little.

The number of total Kjeldahl nitrogen samples per year varied between ten and twelve for the C-17 Canal, between seven and twelve for the C-51 Canal, and between nine and twelve for the C-16 Canal. Appendix F (Table F.8f) includes total Kjeldahl nitrogen annual concentrations statistics for all stations with more than three samples per year.

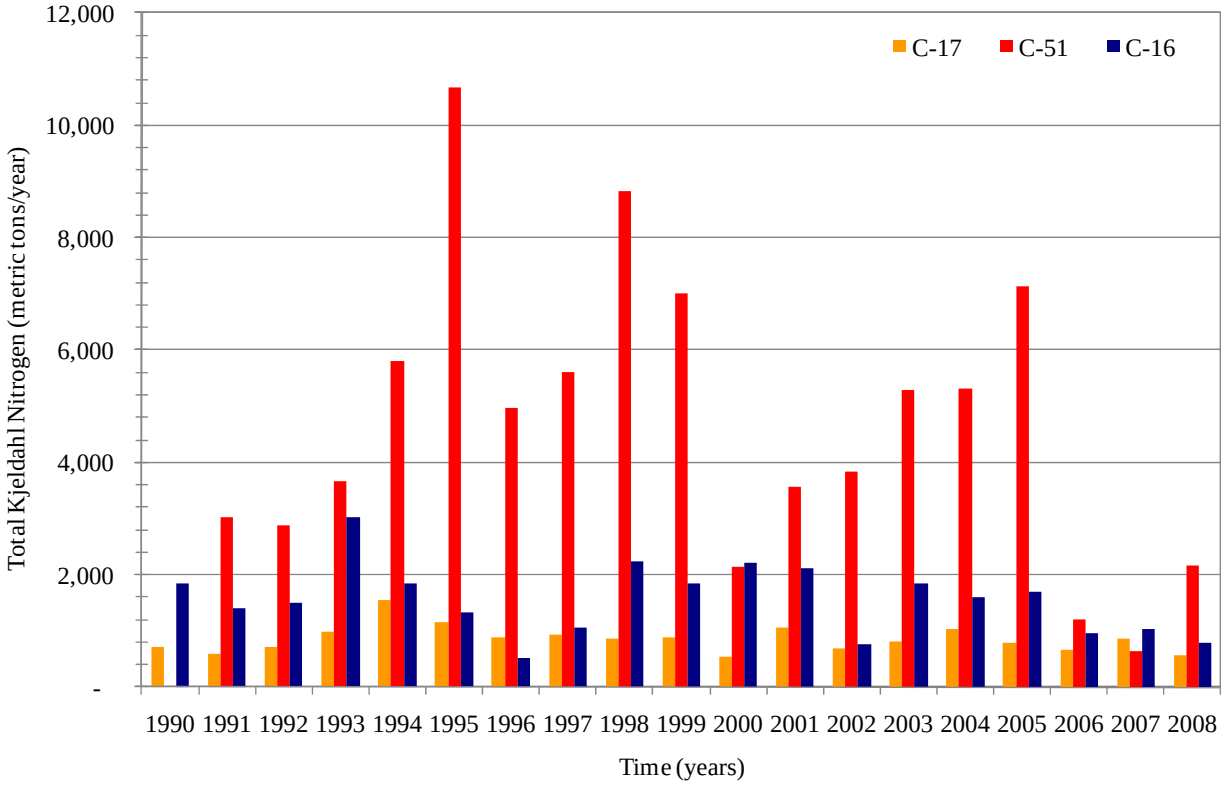


Figure 7.5 Total Kjeldahl Nitrogen Annual Load to LWL from the C-17, C-51 and C-16 Canals

Table 7.5 Total Kjeldahl Nitrogen (TKN) Load Summary for C-17, C51, and C-16: Total Annual Loads, Unit Area Loads, and Year

	Minimum Load		Mid-Range of Loads		Maximum Load	
Canal	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**
C-17	2000	534 (0.024)	1998	862 (0.038)	1994	1,539 (0.068)
C-51	2007	638 (0.006)	2002	3831 (0.034)	1995	10,661 (0.094)
C-16	1996	504 (0.015)	2004	1603 (0.047)	1993	3,032 (0.089)

7.2.4 Orthophosphate (OPO_4)

Orthophosphate loading patterns (Figure 7.6, Table 7.5) were more similar to NO_2 + NO_3 and TKN loading patterns than to TSS. Per acre loading increased with increased total load. The orthophosphate data also included the largest difference between minimum and maximum total annual loads and per acre loads (Table 7.5: C-51 data).

The number of orthophosphate samples per year varied between six and twelve for the C-17 Canal, between eight and twelve for the C-51 Canal, and between nine and twelve for the C-16 Canal. Appendix F (Table F.8f) includes OPO_4 annual concentrations statistics for all stations with more than three samples per year.

7.3 Preliminary Loads for the LWL

The C-17, C-51 and C-16 Canals are the major contributors of fresh water and associated material loads to the LWL. Accordingly adding the loads of the three canals together constitutes a minimum estimate of the total load from the LWL watershed to the waters of the LWL. Additional loads to LWL basin result from storm water runoff from the upland portion of the basin and aerial deposition on the basin waters.

The statistics of total annual loads for the several parameters (Table 7.7) indicate that total loading to LWL receiving waters varies considerably less than loadings from individual canals. The wider range of inorganic constituent (NO_2 + NO_3 and OPO_4) loads reflects their greater transport with increased flows.

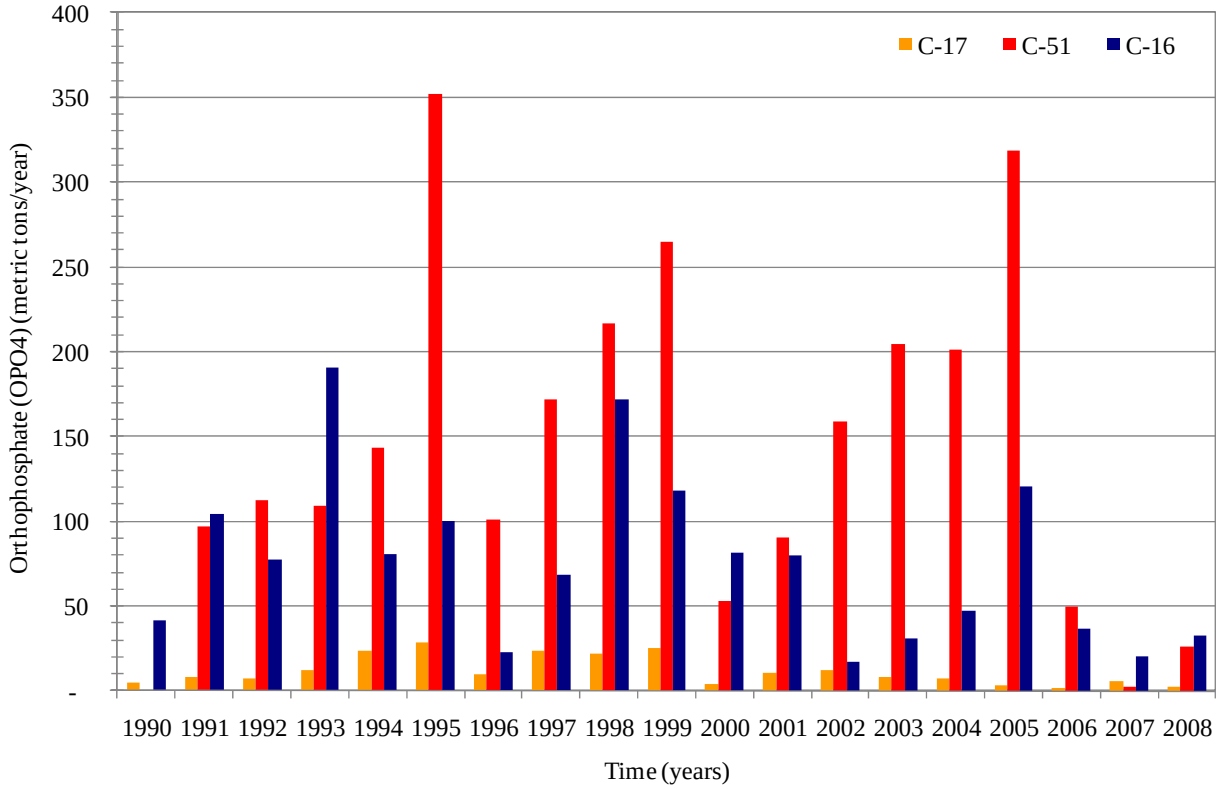


Figure 7.6 Orthophosphate Annual Load to LWL from the C-17, C-51 and C-16 Canals

Table 7.6 Orthophosphate (OPO4) Load Summary for C-17, C51, and C-16: Total Annual Loads, Unit Area Loads, and Year

	Minimum Load		Mid-Range of Loads		Maximum Load	
Canal	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**	**Year**	**mt (mt / ac / yr)**
C-17	2006	1 (0.0001)	1991	7.8 (0.0003)	1995	29 (0.001)
C-51	2007	2 (0.00002)	1992	112 (0.001)	1995	352 (0.003)
C-16	2002	17 (0.0005)	1992	77 (0.002)	1993	191 (0.006)

Tables 7.7 through 7.10 show the individual and total annual loads contributions to the LWL from each canal for the four water quality parameters analyzed: TSS, NO2 + NO3 , TKN, and OPO_4.

Table 7.7 Statistics of Summed Annual loads of TSS, NO_2 + NO_3, TKN, and OPO_4 to Lake Worth Lagoon from C-17, C-51, and C-16

Statistic	TSS (mt)	NO_2+NO_3 (mt)	TKN (mt)	OPO_4 (mt)
Minimum	11,047	131	2,544	28
1st Quartile	18,851	502	4,950	136
Median	28,762	946	6,753	209
3rd Quartile	44,533	1,325	8,564	288
Maximum	61,644	2,613	13,151	481

Table 7.8 TSS Annual Loads to the LWL from the C-17, C51, and C-16 Canals

Year	C-17 (mt)	C-51 (mt)	C-16 (mt)	Total Load (mt)
1990	3,736	no data	8,722	12,458
1991	3,233	15,910	11,351	30,494
1992	3,286	11,994	8,609	23,889
1993	4,304	19,434	12,010	35,748
1994	10,259	38,675	12,709	61,644
1995	6,555	30,244	6,245	43,044
1996	4,770	24,191	2,251	31,212
1997	no data	24,575	3,729	28,304
1998	3,628	34,215	8,180	46,023
1999	3,286	39,284	12,499	55,069
2000	3,466	14,190	11,106	28,762
2001	3,655	11,775	7,761	23,190
2002	2,449	10,946	3,251	16,645
2003	4,349	no data	8,242	12,590
2004	6,386	35,400	8,904	50,690
2005	4,056	40,710	7,539	52,305
2006	3,671	7,375	no data	11,047
2007	3,559	3,709	7,537	14,806
2008	3,104	13,558	4,394	21,056

Table 7.9 $NO_2 + NO_3$ Annual Loads to the LWL from the C-17, C51, and C-16 Canals

Year	C-17 (mt)	C-51 (mt)	C-16 (mt)	Total Load (mt)
1990	86	no data	45	131
1991	61	302	122	486
1992	93	459	43	595
1993	284	606	99	989
1994	232	812	81	1,125
1995	173	1,384	137	1,694
1996	76	782	86	945
1997	203	836	136	1,174
1998	199	1,061	217	1,476
1999	249	1,368	205	1,822
2000	48	257	74	379
2001	141	577	341	1,060
2002	44	635	55	734
2003	37	1,430	60	1,528
2004	110	659	177	946
2005	28	2,402	183	2,613
2006	15	149	51	215
2007	43	68	38	148
2008	52	339	127	518

Table 7.10 TKN Annual Loads to the LWL from the C-17, C51, and C-16 Canals

Year	C-17 (mt)	C-51 (mt)	C-16 (mt)	Total Load (m.t.)
1990	717	no data	1,849	2,566
1991	588	3,023	1,405	5,016
1992	723	2,879	1,507	5,108
1993	979	3,654	3,032	7,665
1994	1,539	5,801	1,843	9,183
1995	1,154	10,661	1,336	13,151
1996	890	4,959	504	6,354
1997	924	5,611	1,053	7,589
1998	862	8,839	2,250	11,950
1999	887	7,006	1,839	9,732
2000	534	2,128	2,221	4,883
2001	1,060	3,572	2,121	6,753
2002	694	3,831	772	5,297
2003	800	5,292	1,841	7,933
2004	1,032	5,310	1,603	7,945
2005	779	7,124	1,696	9,599
2006	668	1,210	966	2,844
2007	872	638	1,034	2,544
2008	559	2,169	791	3,519

Tables 7.11 OPO_4 Annual Loads to the LWL from the C-17, C51, and C-16 Canals

Year	C-17 (mt)	C-51(mt)	C-16 (mt)	Total Load (mt)
1990	5		42	47
1991	8	97	104	209
1992	7	112	77	197
1993	12	109	191	312
1994	23	144	81	248
1995	29	352	101	481
1996	10	101	23	133
1997	23	172	68	263
1998	22	217	172	411
1999	25	265	118	408
2000	4	53	81	138
2001	10	90	80	181
2002	12	159	17	188
2003	8	204	31	243
2004	7	201	47	256
2005	3	319	121	443
2006	1	49	36	87
2007	5	2	20	28
2008	2	26	33	61

8. THREE YEAR EMC MONITORING PLAN

Data useful for EMC calculations result from specific water quality collection protocols. Adherence to these protocols (detailed in subsequent sections of this Chapter) allow engineers and scientists to develop a relationship between the water quality sample and the volume of storm water associated with that sample; failure to follow these protocols yields data inappropriate for EMC calculations. Unfortunately, available data on the Lake Worth Lagoon (LWL) watershed fall into the latter category.

Brief review of the 2005 Palm Beach County NPDES compliance report (Mock, Roos & Associates, 2005) indicated scarcity of water quality information suitable to calculate EMCs for the LWL watershed. The data gathered for this report support the findings of the 2005 Mock, Roos & Associates report. There isn't suitable data to calculate EMCs for the Lake Worth Lagoon Watershed because:

- The water quality data available for the LWL watershed consists of grab samples collected on a monthly or weekly schedule, and do not include sufficient information to allow development of a water quality-discharge relationship.
- The available water quality samples do not include any sets sampled over the period associated with a distinct storm event.
- Most of the water quality sampling stations and hydrologic monitoring stations in the LWL watershed are located in canals that drain and integrate runoff from other canals and from a variety of land use types.

The very nature of EMCs and the substance of what they communicate to environmentalists help to explain the importance of data collection protocols. The EMC "represents the concentration of a specific pollutant in the storm water runoff from a particular land use type within a watershed" (Chow and Yusop, 2008). The Environmental Protection Agency (EPA) recommends use of EMC values for several purposes: to calculate pollutant loads from watersheds to receiving water bodies; as a parameter in land use-based pollution prediction models; or even estimation of the effectiveness of the implementation of best management practices (BMPs) for water quality improvement. Mock and Roos (2005) presents some examples of these applications.

EMC calculation requires, among other parameters, flow-weighted water quality concentrations, and associated discharge records for a known area associated primarily or wholly with a specific land use. This chapter describes the means to collect such information through storm event sampling in the LWL. The objective of storm event sampling for EMC calculation is to obtain a water quality data set representative of the whole storm event. This Chapter outlines protocols for collection of water quality and discharge data necessary for EMC calculation. This Chapter describes sampling location selection and sampling methods necessary to provide the data for EMC calculation. It also includes a description of the equation used to calculate the EMC values.

8.1 Sampling Location Selection

The objective of EMC sampling is to capture runoff from each of the dominant land use types that contribute to pollutant loading in the study watershed. Selection of particular locations with specific land use characteristics thus comprises the first step in collecting EMC data. Taylor Engineering analyzed available land use cover data for the LWL and reviewed the associated flow and water quality data for all the existing water quality station locations (Chapter 4). Location of stations and associated summary water quality data plotted on recent aerial photographs and over land use information provided the means to assess the usefulness of existing stations and available data for EMC sampling (Chapter 6). Development of EMC data will require additional sampling stations located immediately downstream of areas with predominance of a single land use category (e.g. agriculture).

Section 4.1 of this report describes the land use analysis performed for this study. The final land use categories may be grouped into three major categories: developed (residential, recreation, commercial, and industrial), agriculture, and undeveloped (forest, wetlands, and water). Finding locations exclusively draining some of the land use types covering a very minor portion of the LWL (e.g., commercial and industrial development) may not prove practical. Furthermore, little or no practical value would accrue from sampling open water. The lagoon, which is the receptor of the storm water runoff from LWL represents most of the open water landuse area; other open water areas, such as canals or small lakes also act as receptors and integrators of storm water from various sources rather than as primary pollutant sources for a particular land use category.

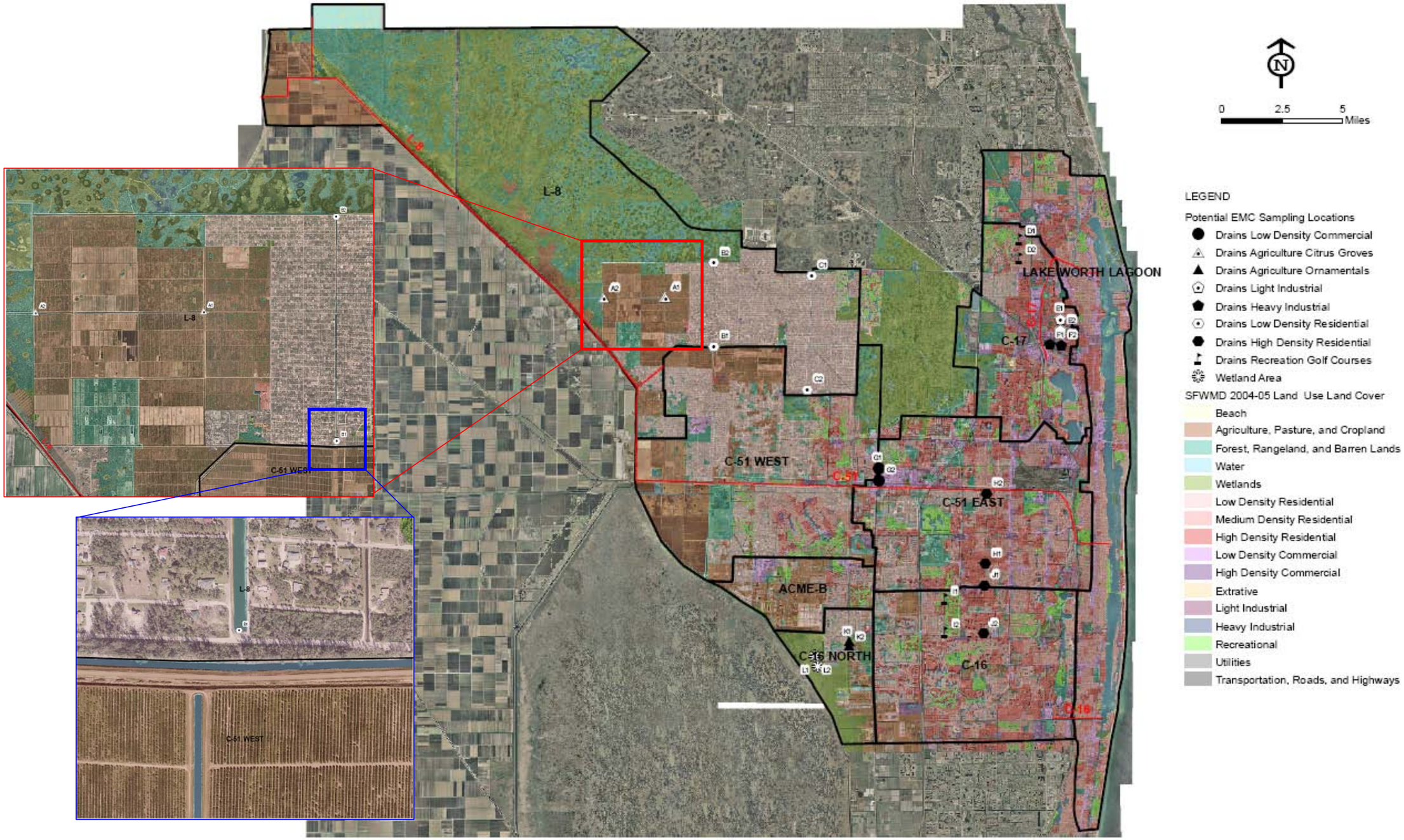
Figure 8.1 provides potential LWL locations for sampling stations downstream of single predominant land uses. We selected these potential sampling locations by visually locating large patches of single land use types on the land use cover map, and by looking at the water quality parameter median values for the selected areas. Areas where the median values indicate poor water quality took priority in the selection.

We then examined the aerial photograph underlying the selected areas for possible sampling locations. Each of these locations appears to include a stable cross section sufficient space for location of equipment, and accessibility (assuming land owners allow it) (Figure 8.1). The locations associated with most of the land uses likely include adjacent power sources. Agricultural land use sites may or may not provide a local power source. In addition, the agricultural locations likely locate on private property, while the other locations appear to locate on public right of way or adjacent to public roadways.

This approach provides potential sites. SFWMD should perform their own search and refine site selection based field survey of the site to verify that the site and associated drainage area provide appropriate conditions, appropriate access, location of stream gauging sites, etc.

Ideal locations would include the following features:

- A stable cross section at the sampling location (essential)
- A conveyance channel draining an area in which a single land use accounts for 66% or more of the land use
- A control structure (e.g., weir) or other feature (such as a bridge or culvert) — Technical data attendant to such structures may include rating curves or other information such as channel cross sections. Access to this data would reduce the effort necessary to estimate the relationship between stage and discharge volume at that site. Sites with a control structure may also allow easier manual sampling and may provide public space for placement of equipment. If necessary, a survey of the conveyance channel cross section at the sampling location would provide the basis to develop hydraulic / hydrologic models to predict the stage-discharge relationship necessary to collect samples related to discharge volumes.



Figures 8.1 Potential EMC Sampling Locations

- A power source (electric line) for operation of the sampling station equipment — In the absence of an electric grid power source, battery operated equipment or manual sampling provide reasonable alternatives to equipment that relies on electric power. Refrigerated autosamplers would likely require more energy than the energy available from a battery system.
- Sufficient space to place and protect the required equipment, which may include refrigerated autosampler, automated stage recorder, automated rainfall gauge, and SCADA (supervisory control and data acquisition) system

8.2 Sampling Methods

Sampling method alternatives include manual collection or automatic collection via sampling equipment. The choice of manual collection and automated collection methods for a site should occur in the context of an overall plan. Site conditions may dictate the appropriate approach. Project objectives may differ for different land use types. Data collection from only a few storms for minor land use types may warrant a manual sampling approach, while collection from multiple storms over a long period for major land use types may warrant an automated sampling approach.

8.2.1 Manual Sampling

Manual sampling requires anticipation of storm events, rapid preparation for sample collection, and the capability to remain at a site for an indefinite period while the storm passes. Locations available for manual sampling are first limited by the time required for the technician to reach the site in anticipation of a storm. Sampling from more than one site during a storm will present significant difficulties because sample collection based on stage changes requires the continued presence of the sampling technician for best sample collection. U.S. EPA (1992) states that for manual collection of only one sample per storm, sampling should occur in the first half-hour of storm discharge, as a significant portion of the total pollutants discharges during this part of the storm flow. Use of data collected only during the first half-hour of a storm may likely overestimate the pollutant land transported during the entire storm, as pollutant concentrations typically decrease over the course of a storm. The sampling technician could remain on site for the duration of the storm and collect samples based on a pre-defined schedule. Alternatively, an autosampler could collect the samples while the technician went to another location.

For manual sampling, a staff gauge provides the minimum equipment necessary to collect appropriately timed samples. The sampling technician should record the corresponding water stage and the time of each collection. Comparison of the sampling record to the stage-discharge curve provides the means to estimate the discharge volume fraction related to each water quality sample. Records from a local rain gauge will support a better understanding of the actual runoff behavior.

8.2.2 Automated Sampling

Given the uncertainties associated with the manual sampling approach, Taylor Engineering recommends development of an automatic sampling system for this project since automatic sampling equipment provides a means to collect volume-related samples with greater accuracy and predictability.

To obtain a full suite of nutrients and other water quality and accurate hydrologic data, each sampling station would ideally include the following equipment:

- Rain gauge
- Stage recorder
- Refrigerated autosampler with data logging equipment with programming capabilities
- SCADA system

Development of a hydrologic / hydraulic model of the drainage area upstream of the sampling station will provide the basis for storm flow sampling. The rain gauge and stage recorder will provide the autosampler data inputs necessary to initiate sampling, to cause the autosampler to collect water at appropriate flood elevations (water stages),and to gain a better understanding of storm flow characteristics for the drainage area upstream of the sampling station.

After completion of storm sampling, comparison of the hydraulic/hydrologic model results to the measured stages during storm flow will allow refinement of the sampling frequency. A refrigerated autosampler provides the most effective means to ensure appropriate sample preservation before laboratory analysis. Autosamplers that allow rainfall or stage data to initiate sampling ensure effective sampling along the storm hydrograph. A SCADA system will signal the project staff that the storm event has begun, that sampling is occurring, and will allow timely transport of samples to the laboratory Some SCADA systems also have the capability to signal the operational status of the equipment.

8.2.3 Pumped Discharge Sampling

Manual or automated pump station operations may control water levels and discharges on some land use types, such as agricultural lands. For pumped discharge locations, sampling should coincide with operation of the pump. Depending on the drainage system design, a sampling protocol might have to consider the volume of standing water in the system, with the sampler programmed to delay start of sampling until that the pump had discharged the standing volume. At that point, a sample collected periodically while the pump operated would provide sufficient samples.

If a pump operates automatically (e.g., based on water elevation changes), the SFWMD sampling system could operate on the same stage changes. SFWMD will likely install its own stage monitoring equipment for this purpose. Automated pump discharges are often electrical, which could provide an electricity source for SFWMD sampling equipment.

Manual discharge pump operation would not alter the basic sampling approach. A change in water elevation recorded by SFWMD equipment would trigger sample collection. The number of samples collected would depend on site characteristics including the size of the pump system, the drainage area, and an understanding of the operation protocol for the pump.

8.3 Sample Storm Characteristics

Data for EMC calculation should come from storm events as defined in EPA National Pollutant Discharge Elimination System (NPDES) Storm Water Sampling Guidance Document (U.S. EPA, 1992). The guidance for the NPDES program recommends the following criteria to identify storm events:

- Rainfall must exceed 0.1 inch to produce storm water runoff discharge for sampling purposes.
- At least 72 hours (3 days) of dry weather should precede water quality collection to allow for pollutant build-up in land.
- Where feasible, the depth of rain and duration of the event should not vary by more than 50% from the average depth and duration (i.e., the monitored storm event should yield no more than 50% more rain and last no longer than 1.5 times the length of an average storm).

In Florida, the average storm yields about 0.8 inch of rain and lasts about 6.4 hours (U.S. EPA 1992). Harper and Baker (2003) analyzed rainfall event data from 1960 — 1993 for the Ft. Meyers,

Florida area. They found that about 75% of the storms released less than 0.4 inch of rain in less than 3 hours. About 20% of the storms produced 0.4 to 1.5 inches of rainfall; those storms lasted between 3 and 9 hours. The remaining annual storm fraction, representing high volume storms, occurs very infrequently. Based on the above information, a reasonable storm sampling protocol could expect to produce samples from several storms that meet EPA guidelines each year. Experience in operating the sampling system should result in a record of improved data. Collection of samples from all available storms will provide the greatest opportunity to develop a sample size sufficient to produce accurate EMCs. The project manager can decide after collection whether the samples from a particular storm should undergo laboratory analysis. Ultimately, the final dataset should allow analysts to understand which storm datasets provide the most error-free and representative data.

A typical Florida thunderstorm has a diameter of less than 15 miles (National Weather Service 2009). The LWL (excepting the westward extension of the L8 basin) extends about 30 miles north to south and about 25 miles east to west. Given these dimensions and the size of a Florida thunderstorm, any part of the LWL might only experience one-half the storms that occur within the LWL. Any location in Florida typically experiences between about 70 and 90 thunderstorms per year (Encyclopedia Britannica, 2009; Gremillion and Orville, 1999; National Weather Service, 2009). Therefore, any site in the LWL watershed may experience at least 7 to 9 storms (20% of one-half of 70 to 90 storms) per year with sufficient flow for sampling purposes and experience one to a few more very large storms.

Rainfall in South Florida includes a distinct seasonal trend, with about 73% of the rainfall occurring between May and October, with only 27% falling November through April (Ali and Abtew, 1999). SFWMD should apportion sampling efforts to collect the majority of the storm events in the wet season.

The sampling program should also include wet season and dry season base flow sampling. Base flow quality will occur more than 72 hours after the end of a storm of the scale proposed here for sample collection. Base flow samples collected after a longer period without a storm would provide additional confidence that the water contained typical chemical concentrations. An equal number of samples for each season should provide sufficiently accurate information. Manual sampling timed to represent typical long-term base flow conditions in each season should provide sufficient data collected relatively inexpensively.

8.4 Event Sample Collection Frequency

The selected sampling point must locate at a stable cross section of a storm water conveyance channel. Stage-discharge characteristics developed from hydrologic/hydraulic models of the drainage area will provide the basis of the initial sampling regime. A rain gauge may provide the means to initiate sample collection, at least for the first storm. With sufficient confidence in the relationship between stage and discharge characteristics, stage change may provide the trigger to initiate sampling.

Taylor Engineering recommends that the autosampler start sampling when accumulative rainfall depth reaches 0.1 inch, (i.e., when water starts to flow into the stream), and stop sampling either when rain stops or sample containers become full. As technicians develop a better understanding of the site, adjustment to the value that initiates sampling and development of a rating curve will help optimize sample collection at that station.

Sampling frequency selection typically requires a compromise between sampling and analysis costs and estimated accuracy of resulting EMC data. Shorter intervals between samples provide more flow-related data at a greater cost. Without a relationship between stage and discharge volume, an initial sampling regime should specify collecting a sample every 15 minutes during the first 30 minutes of a storm followed by sample collection each subsequent 30 minutes through the end of the storm. For a 9-hour storm, this would lead to the collection of about 20 samples, assuming collection of three samples in the first half-hour (0, 15, and 30 minutes) and a sample every 30 minutes for the remaining 8.5 hours. Review of the water quality and flow data may allow refinement of the sampling regime to increase cost effectiveness.

If based on the predictions of a stage-discharge model, an appropriately equipped autosampler program will collect samples based on changes in stage reported to the autosampler. Again, the determination of sampling frequency amounts to a trade-off between sampling cost and accuracy. A single sample should account for 5% of the cumulative discharge volume based on changes in stage. Analysis of data from the first storm would allow redesign of the sampling protocol for more cost-effective performance. For a 9-hour storm, this would result in collection of about 20 samples.

8.5 Calculation of Event Mean Concentration (EMC) Values

The basis of the EMC calculation is a pollutant concentration multiplied by the estimated volume of storm water discharge associated with the concentration to produce a pollutant load (amount in kg or pounds) transported with the estimated volume of storm water. The sum of all the loads calculated for each storm divided by the total storm volume equals the EMC value for that pollutant for the sampled land use. Each sampled storm provides the data to calculate an EMC value. The number of samples collected during the storm and the accuracy of the associated storm volume associated with those samples determine the accuracy of the EMC.

The EMC calculation follows the following equation:

$$EMC = \overline{C} = \frac{M}{V} = \frac{\int C(t)\,Q(t)dt}{\int Q(t)dt}$$

where

$\overline{C}$ is the mean concentration over the event

C(t) is the concentration of a constituent at time t

Q(t) is storm water discharge at time t,

M and V are pollutant mass and runoff volumes during the storm event

In discrete form, using the data collected from the sampling program, this equation simplifies to

$$EMC = \overline{C} = \frac{\sum_{i=1}^{n} \overline{C}_i\ \overline{Q}_i\ \Delta t_i}{\sum_{i=1}^{n} \overline{Q}_i\ \Delta t_i}$$

Where

n is the total number of samples taken for a storm event

Δt_i is the time interval between two consecutive samples, i.e., $\Delta t_i = t_i - t_{i-1}$

$\overline{C}_i$ is the mean concentration of a constituent over the time interval Δt_i, i.e.,

$$\overline{C}_i = \frac{C(t_i) + C(t_{i-1})}{2}$$

$\overline{Q}_i$ is the mean storm water discharge over the time interval Δt_i, i.e.,

$$\overline{Q}_i = \frac{Q(t_i) + Q(t_{i-1})}{2}$$

8.6 Project Period

As seen from the equation for the EMC calculation, the number of EMC values calculated for a pollutant cannot exceed the number of storm events sampled from each land use sampling station. Each complete EMC dataset (EMC values for all pollutants of interest for each dominant land use in the LWL) thus represents a very significant level of sampling effort. Collection of a statistically significant dataset for any pollutant may require a multi-year program. As part of project planning, SFWMD should identify an EMC dataset target and reassess that target and associated costs after the first rainy season sampling effort. While 8 to 10 storms may occur in any year, sampling efforts (rarely perfect) will likely include failure to sample some storms and failure to sample other storms completely.

8.7 Summary

Collection of EMC data requires identification of appropriate sampling sites, design of sampling stations to fit site conditions, and selection of sampling methodology to fit available budgets and sampling site characteristics. Selection of sampling sites will require fieldwork to identify sampling site conditions and to verify the conditions in and boundaries of the drainage area of interest.

For a given site, development of a stage-discharge volume relationship for the drainage area will provide the basis for an appropriate storm sampling schedule. Without such information, sampling — either only at the beginning of a storm or at fixed time intervals throughout a storm — will provide less accurate data for EMC calculation.

Each sampling methodology presents advantages and disadvantages. Manual data collection presents a less equipment-intensive approach and avoids issues of equipment failure. However, the manual collection approach likely reduces the number of storms sampled and potentially reduces the data accuracy. Manual sampling problems center on the difficulty of reaching a particular site at the appropriate time and collecting all the necessary samples at the appropriate time for several storm events. Thus, manual sampling will reduce the likelihood of collecting a large number of samples effectively.

The automation approach provides greater opportunity to collect more samples from a greater number of storm events in a more precise fashion. Automation provides a greater likelihood that project efforts will result in the highest possible data quality. However, this approach comes with significantly greater costs for equipment, site construction, and subsequent maintenance. An automated system for

many of the project sampling sites may present the only realistic opportunity to collect high quality data from multiple storms and multiple sites

Regardless of the collection method, development of an EMC dataset carries a significant cost. The SFWMD should develop an EMC dataset target and budget for the cost expected to meet that target. After the first rainy season sampling effort, assessment of the EMC dataset produced by the effort to date and the project cost to date will provide the basis to reassess those targets and make recommendations to revise the collection methodology for the two following years.

9. FINAL CONSIDERATIONS AND RECOMMENDATIONS

The SFWMD desires to assess pollutant loadings to the Lake Worth Lagoon from LWL watershed (LWL) land uses. The WMD goals for this study were to characterize the types and magnitude of pollutants in storm water runoff from contributing land uses within the LWL watershed; to calculate the event mean concentrations (EMC) for selected water pollutants in the storm water runoff that discharges to the LWL; and to prepare a 3-year watershed EMC monitoring plan.

Data review and exploratory analysis of the water quality data indicated that DO, TKN, OPO_4, and TP are the parameters of concern in the LWL watershed. Water quality samples from basins L-8, C-51 West, Acme B, or the C-16 North, where agriculture uses comprise a large fraction of the total land use typically showed elevated nutrient inputs (NO_2+NO_3, TKN, OPO_4 and TP). These findings agree with the literature on storm water quality, which suggests that agriculture (pasture, row crops, and citrus) are among the land uses that produce high concentration of TN and TP.

Basins where medium and high density residential land uses are most common (C-17, C-16, C-51 East, and LWL), also showed elevated nutrient levels. The C-17 basin, where commercial and industrial land uses are most common, values of TKN (a component of TN) are among the highest reported. These findings also agree with the available literature which suggests that medium and high density residential, and high density commercial land uses are among the land uses that produce high concentration of TN and TP.

The data review and exploratory analysis determined that the available data (hydrologic and water quality data) provided insufficient information to characterize peak pollution loads from storm water discharges that may occur during storm events, and revealed that the data collection intervals did not allow the calculation of land use EMCs. Almost all the water quality samples were monthly grab samples. These data, while sufficient for long-term characterization of the general water quality in the watershed, were not timed to coincide with peak flows, or storm events.

Collection of EMC data requires identification of appropriate sampling sites, design of sampling stations to fit site conditions, and selection of sampling methodology to fit available budgets and sampling site characteristics. Selection of sampling sites will require fieldwork to identify sampling site conditions and to verify the conditions in and boundaries of the drainage area of interest.

The use of existing active stations for this effort may require the SFWMD to re-evaluate current monitoring frequencies, consider the possibility of adding new equipment, and determine how to develop particular stations for EMC sampling within the overall operational plan of the particular station. Many sampling programs (and related stations) are developed for compliance with regulatory requirements; sampling protocols related to those requirements cannot be modified.

The location of new monitoring stations will require a more detail study of the areas identified in this report. The land use data used as the basins for the analysis of these reports was published in 2005. Areas that were not build up at the time may now have different uses, which may contribute significantly to the increase or decrease of the concentrations reported. In addition new BMPs continue to be implemented through out the County, and these may also prove to have a significant impact on the future nutrient inputs to the LWL watershed.

The development of an EMC dataset carries a significant cost. Taylor Engineering recommends the SFWMD consider a phased approach to prioritize EMC sampling based on basins and land use types that provide the greatest loadings and present the greatest likely opportunities for implementation of best management practices. Annual review of all program aspects and adaptive management strategies will help maintain cost-effective and successful program performance.

The available data allowed calculation of preliminary annual stormwater loads (without respect to specific land uses) from the three main canals (C-17, C-51, C-16) that drain different parts of the basin and discharge to LWL. The annual loads from each canal varied significantly by year. Year to year differences in annual loads did not vary consistently among the canals. These two results suggest that rainfall patterns within the basin as well as land use differences affected annual pollutant loading from different locations within the basin.

SFWMD and their watershed communities will continue to focus on water quality improvement to restore Lake Worth Lagoon. Determination of land-use related EMCs will provide a basis to developing cost-effective best management practices (BMPs) for stormwater treatment in the LWL watershed. As EMC development goes forward, planning studies to evaluate the types, performance characteristics, location requirements, and costs of BMPs that could be employed in different land use settings should also begin.

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