FINAL

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Water Resource Management, Bureau of Watershed Management

SOUTH DISTRICT • EVERGLADES WEST COAST BASIN •

TMDL Report
Nutrient, Un-ionized Ammonia, and DO TMDLs for Lake Trafford (WBID 3259W)

Woo-Jun Kang, Ph.D.
and
Douglas Gilbert

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Acknowledgments

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For additional information on the watershed management approach and impaired waters in the Southwest Coast Planning Unit of the Everglades West Coast Basin, contact:

Pat Fricano
Florida Department of Environmental Protection
Bureau of Watershed Management
Watershed Planning and Coordination Section
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400
pat.fricano@dep.state.fl.us
Phone: (850) 245-8559
Fax: (850) 245-8434

Access to all data used in the development of this report can be obtained by contacting:

Douglas Gilbert, Environmental Manager
Florida Department of Environmental Protection
Bureau of Watershed Management
Watershed Assessment Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
douglas.gilbert@dep.state.fl.us
Phone: (850) 245-8450
Fax: (850) 245-8536

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Identification of Impaired Surface Waters Rule

https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-303

STORET Program

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

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Basin Status Report for the Everglades West Coast Basin

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Assessment Report for the Everglades West Coast Basin

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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the TMDLs for nutrients, un-ionized ammonia, and dissolved oxygen for Lake Trafford, located in the Everglades West Coast Basin, Southwest Coast Planning Unit. Lake Trafford was verified as impaired by excessive nutrients, un-ionized ammonia, and low dissolved oxygen using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303, Florida Administrative Code), and was included on the Verified List of impaired waters for the Everglades West Coast Basin that was adopted by Secretarial Order on June 3, 2008. These TMDLs establish the allowable loadings to the lake that would restore the waterbody so that it meets its applicable water quality narrative criteria for nutrients, un-ionized ammonia, and dissolved oxygen.

1.2 Identification of Waterbody

Lake Trafford (~center at Latitude 26°25'38.25", Longitude 81°29'22.4") is located just south of SR 82 in Collier County, Florida (**Figure 1.1**). Lake Trafford is the largest freshwater lake southwest of Lake Okeechobee. The estimated surface area of the lake is about 1522 acres and the average depth is about 7 ft. Lake Trafford receives the drainage from its subbasin surface water drainage area, with elevations of about 25-30 ft National Geodetic Vertical Datum (NGVD). This subtropical lake has no defined tributaries, with typically little outflow (Flaig, 2000). The lake is the headwaters to the Corkscrew marsh and at high water level during the wet season it drains south through Fakahatchee strand to Southern Golden Gate Estates Critical Project Area, ultimately arriving in the Ten Thousand Islands (Ashley, 2004). There are no hydraulic control structures in the planning unit to alter the flow direction.

For assessment purposes, the Department has divided the Everglades West Coast Basin into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each water segment or stream reach. Lake Trafford has been given the WBID number of 3259W. The Lake Trafford WBID and its sampling/monitoring stations are illustrated in **Figure 1.2**.

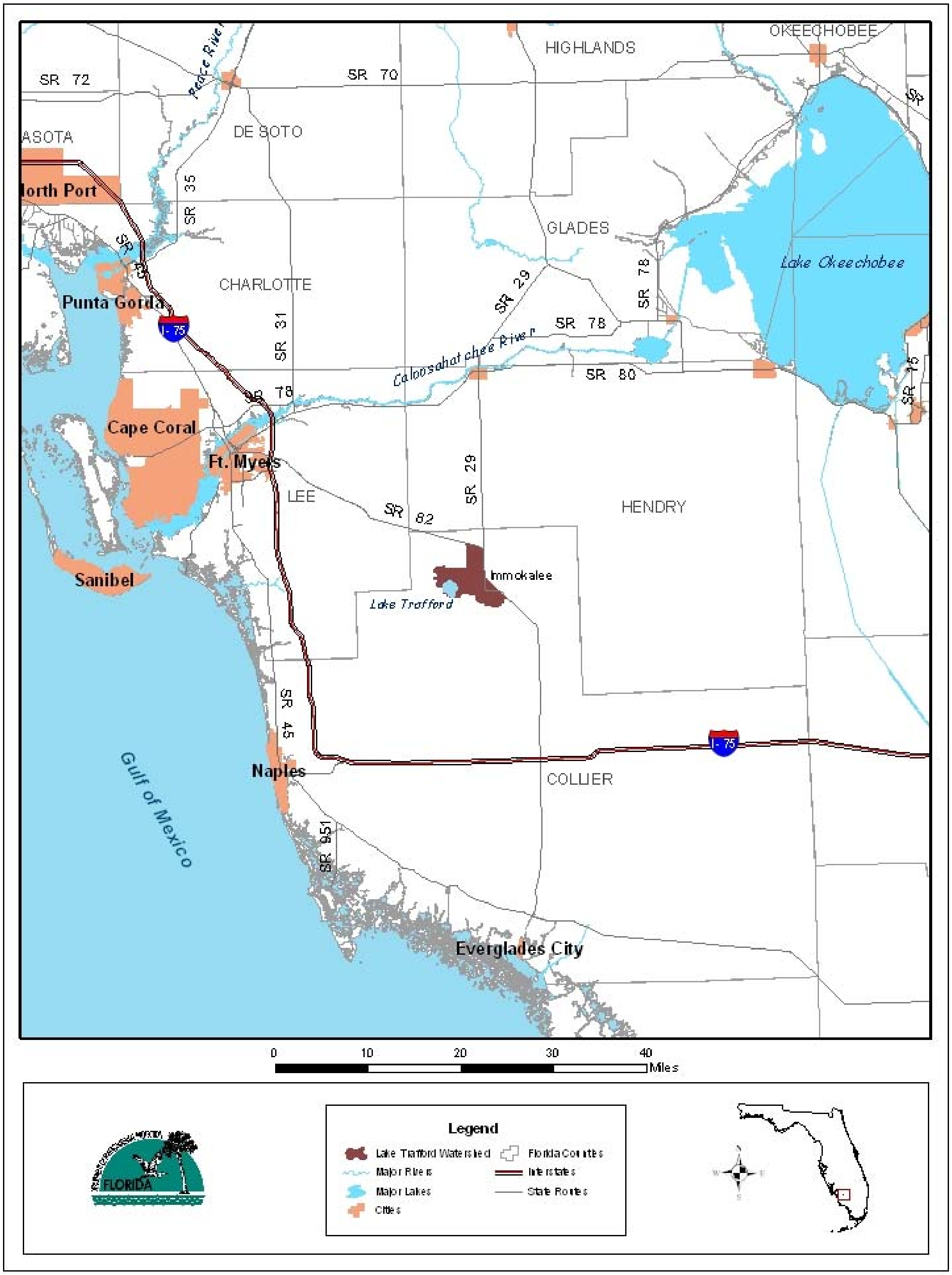


Figure 1.1. Area Map Adjacent to Lake Trafford and its Watershed

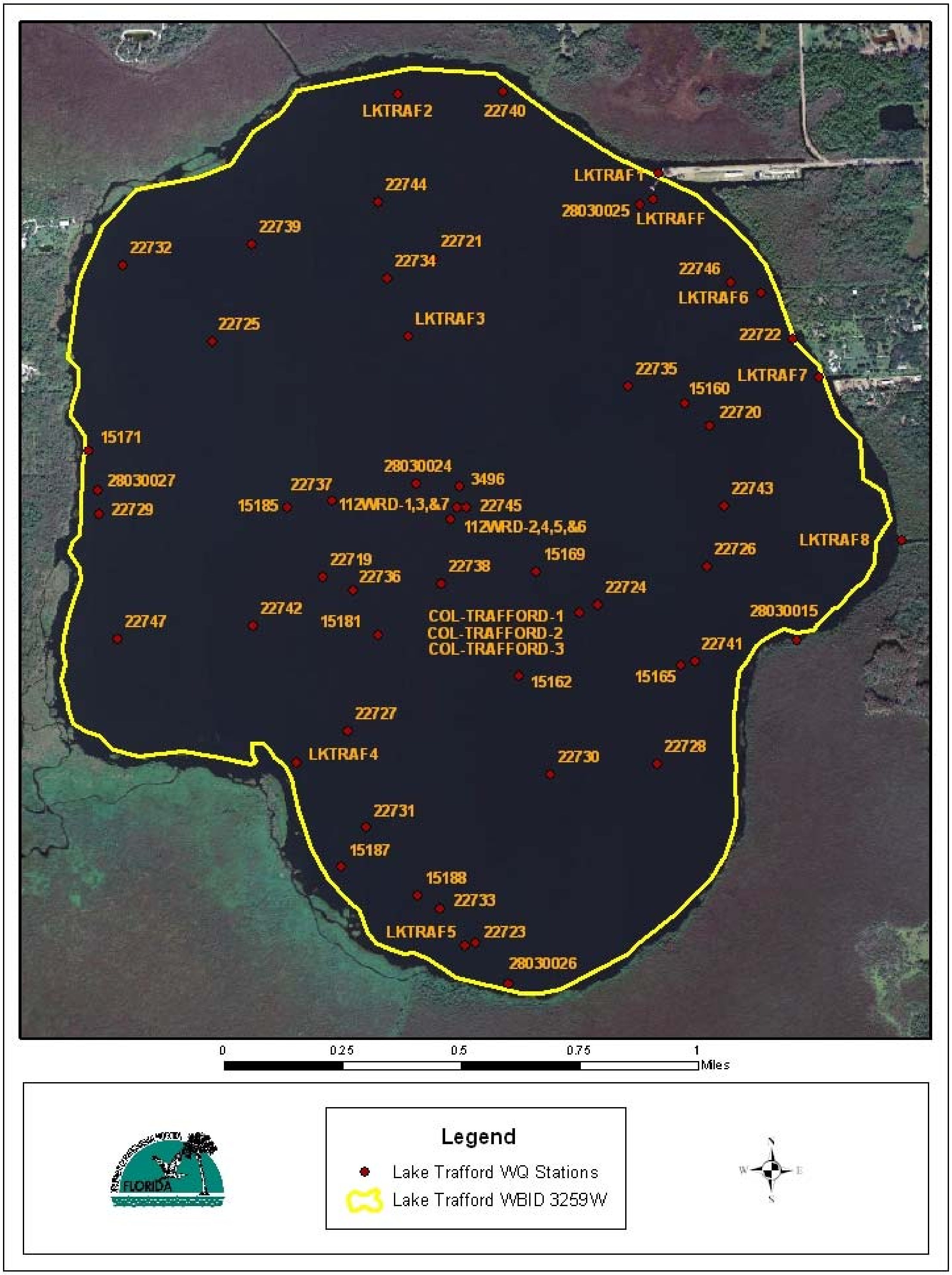


Figure 1.2 Lake Trafford WBID and Water Quality Sampling Stations Listed in the Florida STORET (STOrage and RETrieval).

1.3 Lake Trafford Water Quality Trends

Long-term water quality data between 1972 and 2004 obtained from Florida STORET for Lake Trafford are presented in **Figures 1.3** through **1.8**. The Lake Trafford Watershed is depicted on **Figure 1.9**. It should be noted that the water quality data collected from the county's sampling stations between 2004 and 2008 were provided by Collier County via electronic mail. Water quality stations and individual water quality measurements (raw data) for total nitrogen (TN), total phosphorus (TP), chlorophyll a (Chla), and dissolved oxygen (DO) used in this report are available upon request. A total of 63 water quality sampling stations are listed in Florida STORET. Some limited TN, TP, and DO data were recorded back to 1972; however, monthly measurements for Chla, TN, TP, and DO were not made until the county began sampling for water quality in 1996.

In general, the historical water quality trends of TN and TP concentrations as shown in **Figures 1.3** and **1.4** indicate that in-lake concentrations of TN and TP have increased over the 26-yr period of observation from 1972 to 2007. In the early 1970s, the lake exhibited TN and TP concentrations of about 2.0 mg/L and 0.05 mg/L, respectively. This indicates that the TN/TP ratio was about 40 and the lake was limited by phosphorus for phytoplankton growth. Dramatic changes in the TN and TP concentrations were observed in the 1990s, with a wide range of concentrations, especially in TP. Peak concentrations of TN and TP appeared in May 1999 and February 1990, respectively. The earliest observations for Chla were made in 1988. As seen on **Figure 1.5**, the concentrations for 1988-1989 ranged between 5.5 μg/L and 33 μg/L, with a mean value of 18.8 μg/L. Significant increases in Chla were found in the late 1990s, with the peak concentration of about 244 μg/L in December 1999. **Figure 1.6** illustrates the TN to TP ratio over the period of record (1972 – 2008). The data indicate a reduction in the degree of TP limitation over time. As shown on **Figure 1.7**, the relationship between Chla concentrations and TN/TP ratios indicates that concentrations of Chla are greater when the lake is co-limited by both TN and TP. Conversely, the Chla concentration was found to be less than 50 when the lake was phosphorus-limited. This finding can be an important index for the future management efforts on the status of nutrients in a restored lake.

Table 1.1 shows summary statistics of historical water quality variables observed over the period from 1972 to 1989. Although the Chla data were collected only for two years (1988 and 1989), most of the other water quality variables were collected beginning in the 1970s. During this period, the concentrations of TN averaged about 1.87 ± 0.78 mg/L (n = 36) while concentrations of TP averaged 0.088 ± 0.077 mg/L (n = 39). As a result, the TN/TP ratios were found to be greater than 30 in many observations in the 1970s (**Figure 1.6**), with an average of 32 ± 24 over the period (n = 35). These older data indicate that the lake was alternating between phosphorus-limiting and co-limiting. In comparison, recent (1998-2005) observations for water quality variables are summarized in **Table 1.2**. Concentrations of TN over the period of 1998-2005 have increased by a factor of two, ranging from 1.19 to 6.81 mg/L with an average of 2.69 ± 0.99 mg/L (n = 82). Similarly, TP concentrations also have increased, exhibiting an average of 0.221 ± 0.122 mg/L (n = 90). Recent increases in Chla concentrations by three-fold are most likely associated with increased TN and TP concentrations in the lake. **Figure 1.8** shows that while DO values less than the 5 mg/L criterion have occurred throughout the period of record, the majority of the results are greater than the criterion. Over time, it appears that the range in DO has been increasing (lower lows and higher highs). This report will evaluated the relationship between the current nutrient loading from the watershed and the observed concentrations in the lake and propose the load reductions required for Lake Trafford to meet water quality standards.

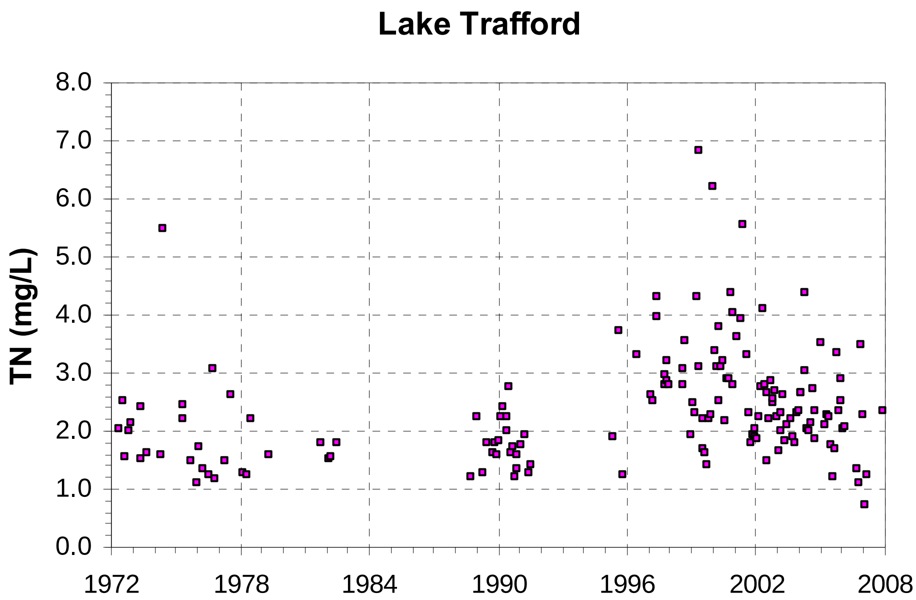
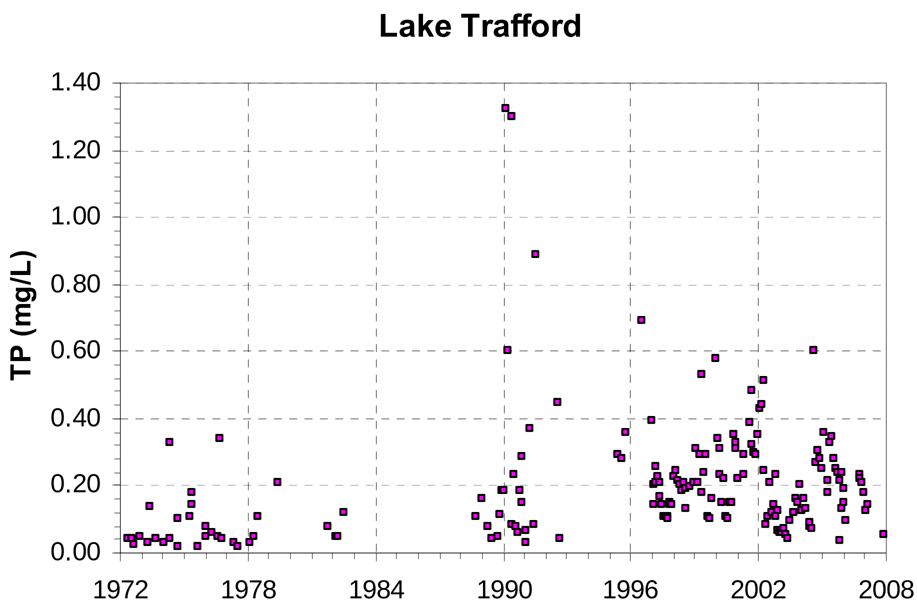


Figure 1.3 Total Nitrogen Concentrations Measured for Lake Trafford from 1972 to 2007



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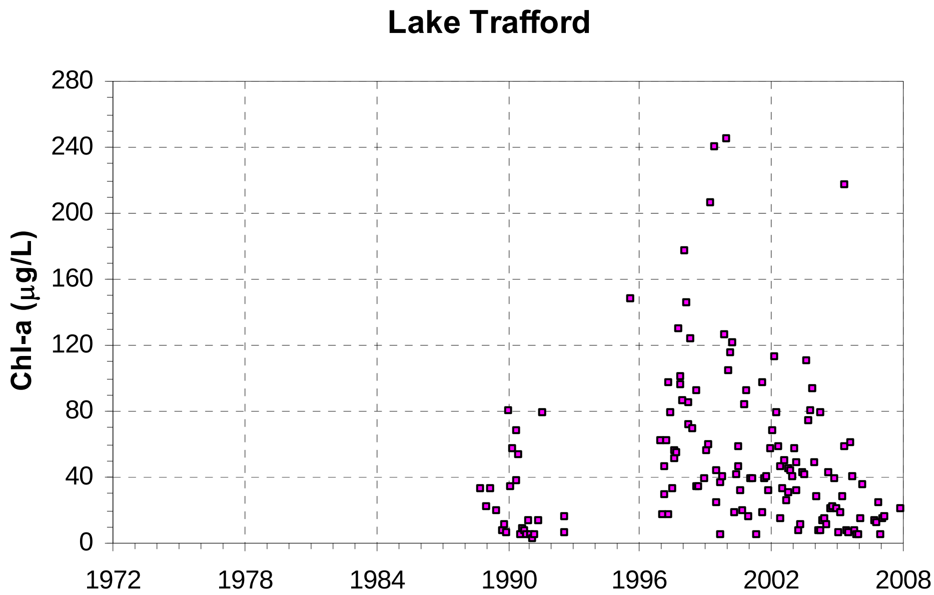

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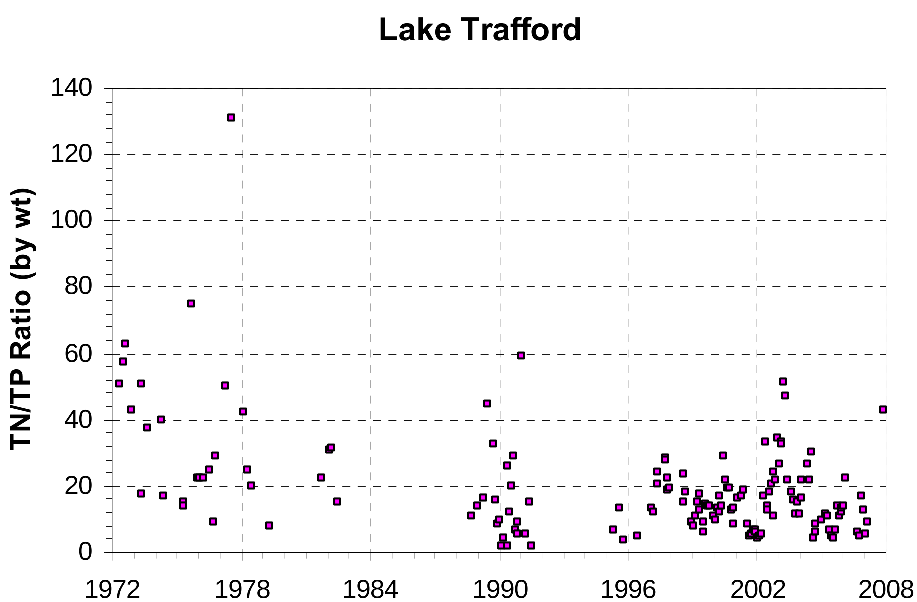

Figure 1.6 Ratios of Total Nitrogen to Total Phosphorus (by wt.) for Lake Trafford from 1972 to 2007

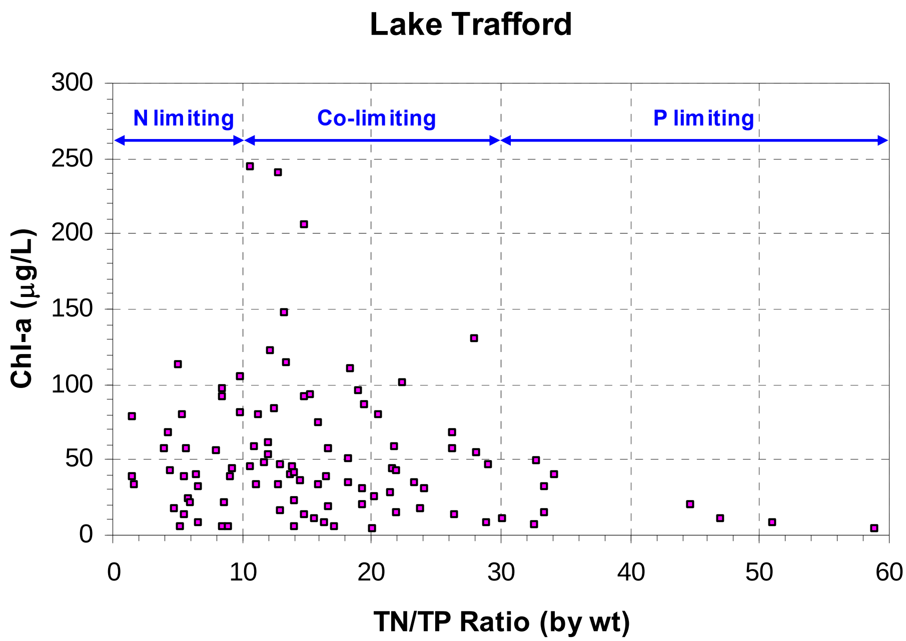

Figure 1.7 Relationship between Corrected Chlorophyll *a* Concentration versus TN/TP Ratio Observed for Lake Trafford.

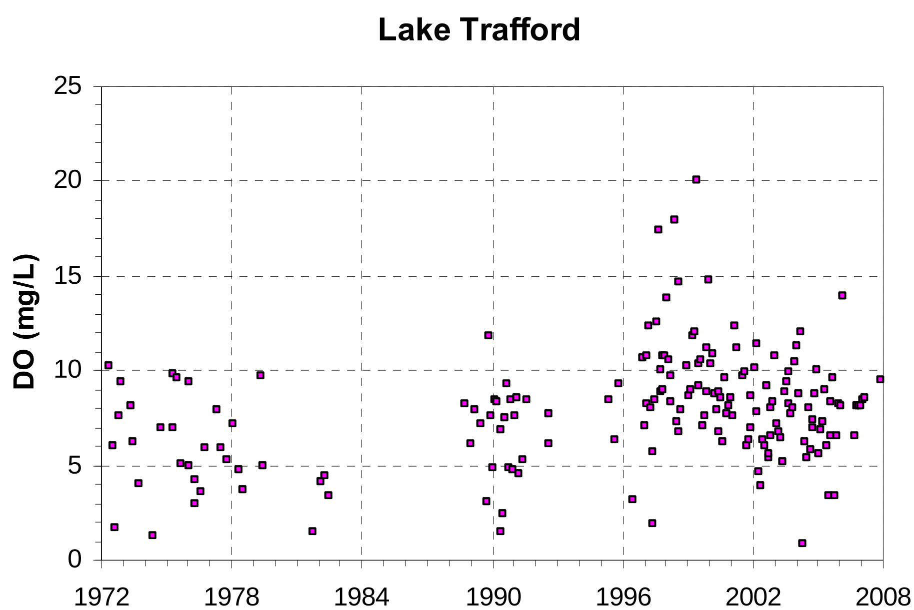

Figure 1.8 Concentrations of Dissolved Oxygen measured for Lake Trafford from 1972 to 2007

Table 1.1 Summary Statistics of Water Quality Variables in Lake Trafford over the Period of 1972-1989.

Water Quality Variable	Unit	Number of Observation	Mean	Standard Deviation	Minimum	Maximum	Coefficient Variation
Chlorophyll a	µg/L	7	18.8	11.5	5.5	33.0	61.0%
Total Nitrogen	mg/L	36	1.87	0.776	1.107	5.5	41.5%
Total Phosphorus	mg/L	39	0.088	0.077	0.019	0.340	87.1%
DO	mg/L	39	6.1	2.6	1.3	11.9	42.6%
BOD	mg/L	22	3.01	1.76	0.90	8.60	58.3%
Color	Pt-Co	32	55	22.6	20	120	41.3%
TN/TP Ratio	no unit	35	32.2	24.0	7.6	131.0	74.7%

Table 1.2 Summary Statistics of Water Quality Variables in Lake Trafford over the Period of 1998-2005.

Water Quality Variable	Units	Number of Observation	Mean	Standard Deviation	Minimum	Maximum	Coefficient Variation
Chlorophyll a	µg/L	91	56.2	51.1	4.8	244.4	90.9%
Total Nitrogen	mg/L	82	2.69	0.99	1.19	6.81	37.0%
Total Phosphorus	mg/L	90	0.221	0.122	0.035	0.603	54.9%
DO	mg/L	93	8.5	2.8	0.8	20.0	33.3%
BOD	mg/L	69	5.2	3.0	2.0	17.0	57.4%
Color	Pt-Co	69	130	77.1	15	500	59.5%
TN/TP Ratio	no unit	79	15.5	9.3	4.2	51.1	59.6%

1.4 Lake Trafford Background Information

Lake Trafford was formed during a Pleistocene high sea level stage (Flaig, 2000). When the ancient sea stood 42 feet above present sea level, the Talbot terrace was formed (Florida Geological Survey, 1962). The Talbot terrace is now in the northern part of Collier County which is a major portion of the Lake Trafford Watershed. Deposits of the Talbot terrace are characterized by very fine to coarse sand and some silt and clay (Florida Geological Survey, 1962), providing fairly rapid infiltration of rainwater in the lake watershed. Recent deposits are composed chiefly of organic materials, derived from decayed vegetation, mixed with the terrace deposits.

The piezometric surface of the Floridian aquifer is an imaginary surface representing the pressure head of the confined water. It is the height to which water will rise in a tightly cased well that penetrates the aquifer. The piezometric surface in the northern part of Collier County, north of Immokalee, is about 58 feet above mean sea level and slopes in a southwesterly direction to the Gulf of Mexico (Florida Geological Survey, 1962). Therefore, the flow of the ground water in the Florida aquifer in Collier County is generally to the southwest. Such ground water flow patterns are similar to the topographic elevation patterns and support the position that the lake drains to the south when at its' higher stages.

The lake was historically sand bottomed and supported a healthy population of native macrophytes before *Hydrilla verticillata* was introduced in 1969 (Everham, 2007). From the 1970s to the 1980s, herbicides were used to kill the *Hydrilla* and chemical treatments continued into the 1990s (Lake Trafford and You, 2000). As a result, the lake bed received pulses of decaying plant matter and the early stages of sediment diagenesis subsequently released the nutrients back into the lake water column. Human modifications to the landscape have changed the size and nature of the watershed. Modifications within the watershed have included road building to support increased agriculture and urbanization, these activities can increase nutrient loading (Henderson-Sellers and Markland, 1987), along with septic tank leakage (Rutter, 1996). Additionally, the Immokalee Water and Sewer District has a permit (FLA014132) for 2.36 mgd of land application to spray fields (with 4.867 mgd of deep well capacity as a backup) within the watershed. In the 1990s, the lake experienced several incidents of depleted oxygen and fish die-offs, including a massive event in April 1996, killing an estimated 50,000 fish (Flaig, 2000).

A Lake Trafford Restoration Feasibility Task Force was established by Collier County in 1996. The Big Cypress Basin has implemented a restoration project for the lake that involves hydraulic dredging of sediment from the lake. Phase I dredging began removing muck from the center of the lake in November 2005 and ended in May 2006. During the first phase, three million cubic yards of sediments were removed from the deeper portions of the lake. Phase II dredging efforts continued in 2007, removing additional sediments from the shallow littoral zone (In Your Region, 2007). Currently, the dredging project is on hold waiting for rain to bring the water level in the lake up to a stage where dredging can resume. This restoration effort will help improve the lake water quality by reducing internal loads of bioavailable nutrients, particularly phosphorus from the lake, and prevent the recurrence of algae blooms and fish kills (Flaig, 2000). In addition, a lake nutrient simulation model by Florida Gulf Coast University to investigate post-dredging management scenarios suggested that nutrient inputs from the landscape need to be controlled to increase the duration of the effect from dredging on the lake restoration (Everham, 2007).

1.5 TMDL Background Information

The TMDL Report for Lake Trafford is part of the implementation 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. The watershed approach, which is implemented using a cyclical management process that rotates through the state's fifty-two river basins over a five-year cycle, provides a framework for implementing the requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (Chapter 99-223, Laws of Florida). A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet the waterbody's designated uses. A waterbody that does not meet its designated uses is defined as impaired. TMDLs must be developed and implemented for each of the state's impaired waters, unless the impairment is documented to be a naturally occurring condition that cannot be abated by a TMDL or unless a management plan already in place is expected to correct the problem.

The development and implementation of a Basin Management Action Plan, or BMAP, to reduce the amount of pollutants that caused the impairment will follow this TMDL Report. These activities will depend heavily on the active participation of Collier County, the water management district, local governments, local businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for the impaired lake.

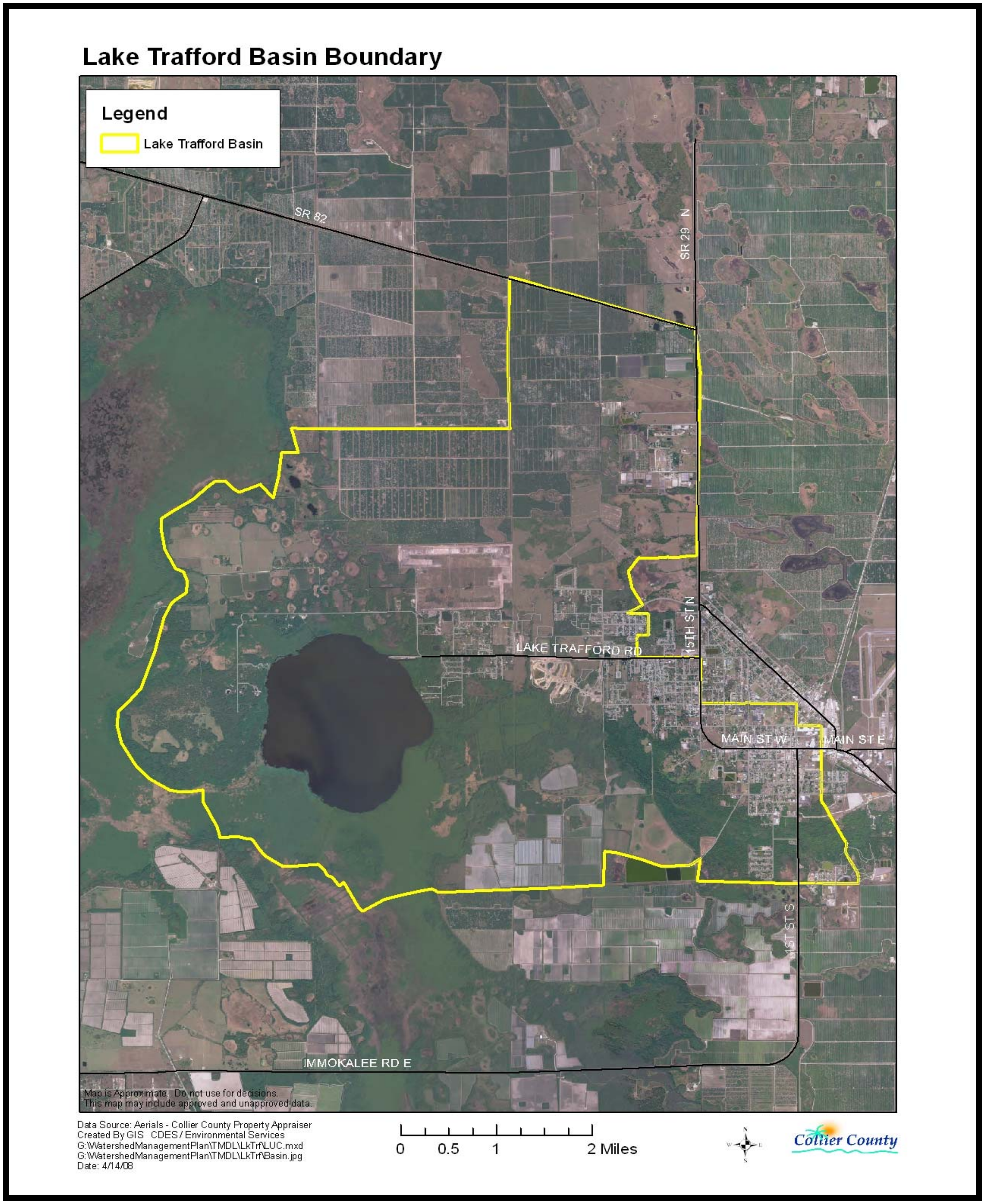

Figure 1.9 Lake Trafford Watershed Boundary and the Surrounding Areas.

Chapter 2: STATEMENT OF WATER QUALITY PROBLEM

2.1 Legislative and Rulemaking History

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

Lake Trafford is on Florida's 1998 303(d) list. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. The Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (FAC) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001 and amended in 2006 and January 2007.

2.2 Information on Verified Impairments

Nutrients

The Department used the IWR to assess for water quality impairments in Lake Trafford. The lake was verified as impaired for nutrients based on an elevated annual average Trophic State Index (TSI) value over the verification period (the Planning Period for the Group 1 basins is from January 1, 1995 – June 30, 2004 and the Verified Period is from January 1, 2000 – June 30, 2007). The IWR methodology uses the water quality variables; total nitrogen (TN), total phosphorus (TP), and Chla (a measure of algal mass, corrected and uncorrected) in calculating annual TSI values and in interpreting Florida's narrative nutrient threshold. According to the IWR 62-303.352, FAC, exceeding a TSI of 60 in any one year of the verified period is sufficient in determining nutrient impairment for a lake with color greater than 40. For Lake Trafford, water quality data obtained by the IWR Run31_1 and summarized in **Table 2.1** indicated that the mean color for the period was 130 Pt-Co (n = 69), resulting in a TSI of 60 for the threshold of lake nutrient impairment.

To calculate the TSI for a given year under the IWR, there must be at least one sample of TN, TP, and Chla taken within the same quarter (each season) of the year. The absence of data for at least one of the four seasons for a year will cause the elimination of the year from the analysis of TSI. As can be seen in **Figure 2.1**, the TSIs in Lake Trafford exceeded the threshold of 60 in each year of the verified period for which a TSI could be calculated [2000 (78.6), 2001 (75.5), 2002 (75.8), 2003 (71.7), 2004 (70.3), 2005 (73.8)].

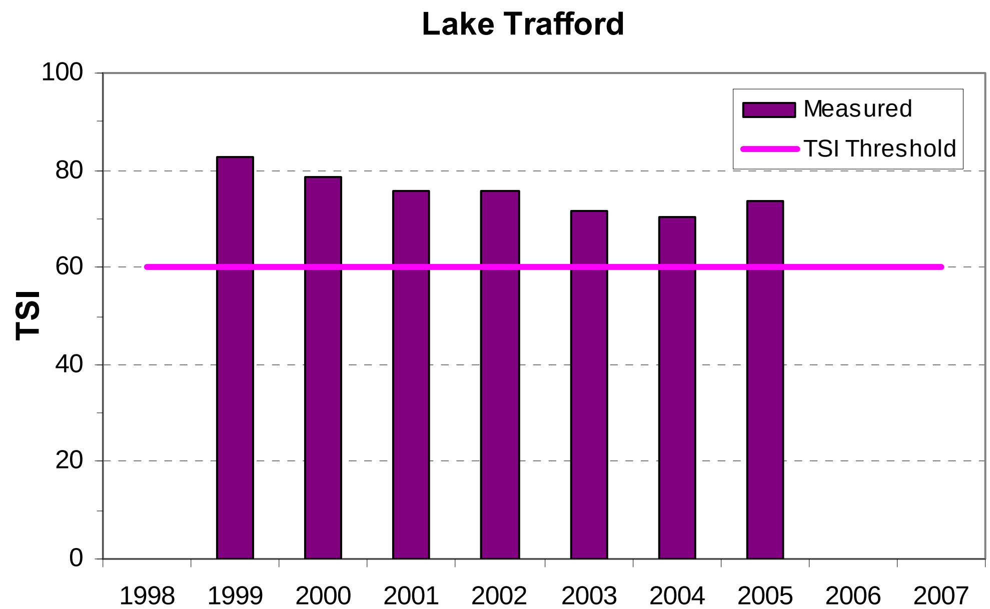

Figure 2.1 TSI threshold and Annual Mean Trophic State Indices (TSIs) for Lake Trafford Calculated from Annual Average Concentrations of TP, TN, and Chlorophyll *a* from 1998 to 2007 (insufficient data 1998, 2006, & 2007).

Un-ionized Ammonia

Lake Trafford was assessed as impaired for un-ionized ammonia based on samples collected during the Cycle 2 verified period. The lake, during this period, exceeded the criterion of 0.02 mg/L for fresh water lakes at a rate of greater than 10 percent (at a 90 percent confidence level assuming a binomial distribution). Of the 332 Lake Trafford un-ionized ammonia samples analyzed between January 2000 and June 2007, there were 44 exceedances. This resulted in an impaired status because, based on 332 samples, 41 or more exceedances results in impairment.

Dissolved Oxygen

The Department used the IWR to assess water quality impairments in Lake Trafford (WBID 3259W) and verified the impairment for low DO, with nutrients as the causative pollutant. The summary of DO and potential causative pollutant concentrations for sampling during the first and second verified periods are shown in **Tables 2.1** and **2.2**, respectively. After the first verified period (between 2000 and 2004), Lake Trafford was not verified as impaired for DO in part, because there was not at least 90 percent confidence that the exceedance rate was greater than or equal to 10 percent. But, during the second Verified Period (based on the Basin Rotation Schedule, WBID Groups are assessed with Verified Lists developed every 5 years), sample results (**Table 2.2**) revealed that WBID 3259W did meet the criteria for DO impairment and was thus listed as impaired.

Table 2.1. Summary of DO, BOD, TP, and TN Data from Verified Period (Cycle 1) Sampling (1994–2002) of Lake Trafford.

Parameter of Concern	Number of Samples	IWR Required Exceedances (for impairment)	Actual Number of Exceedances	Median
DO (IWR Run 18)	367	45	34	*
BOD	638	*	*	5.05
TP	300	*	*	.18
TN	535	*	*	2.51

* = Not Applicable

Table 2.2. Summary of DO, BOD, TP, and TN Data from Verified Period (Cycle 2) Sampling (2000–2007) of Lake Trafford.

Parameter of Concern	Number of Samples	IWR Required Exceedances (for impairment)	Actual Number of Exceedances	Median
DO (IWR Run 32)	357	44	52	*
BOD	493	*	*	4.1
TP	296	*	*	0.103
TN	409	*	*	2.43

* = Not Applicable

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface water is protected for five designated use classifications, as follows:

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

Lake Trafford is classified as a Class III freshwater waterbody, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the observed impairments [nutrients, un-ionized ammonia, and dissolved oxygen] for Lake Trafford is the state of Florida's narrative nutrient criterion [Rule 62-302.530(48) (b), FAC], the un-ionized ammonia criterion [Rule 62-302.530(3), FAC], and the dissolved oxygen criterion [Rule 62-302.530(30), FAC].

3.2 Interpretation of the Narrative Nutrient Criterion for Lakes

To place a waterbody segment on the Verified List for nutrients, the Department must identify the limiting nutrient or nutrients causing impairment as required by the IWR. The following method is used to identify the limiting nutrient(s) in streams and lakes.

The individual ratios over the entire verified period (i.e., January 1, 2000 to June 30, 2007 are evaluated to determine the limiting nutrient(s). If all the sampling event ratios are less than 10, nitrogen is identified as the limiting nutrient, and if all the ratios are greater than 30, phosphorus is identified as the limiting nutrient. Both nitrogen and phosphorus are identified as limiting nutrients if the ratios are between 10 and 30. For Lake Trafford, the median TN/TP ratio was 12.9 for the verified period, indicating co-limitation of TP and TN for the lake.

Florida's nutrient criterion is narrative only, i.e., nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. While the IWR provides a threshold for nutrient impairment for lakes based on annual average TSI levels, these thresholds are not standards and are not required to be used as the nutrient-related water quality target for TMDLs. In recognition that the IWR thresholds were developed using statewide average conditions, the IWR (Subsection 62-303.450, FAC) specifically allows the use of alternative, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in the waterbody.

The TSI originally developed by R. E. Carlson (1977) was calculated based on Secchi depth, chlorophyll concentration, and total phosphorus concentration and was used to describe a lake's trophic state. Carlson's TSI was developed based on the assumption that the lakes were all phosphorus limited. In Florida, because the local geology produced a phosphorus rich soil, nitrogen can be the sole or co-limiting factor for phytoplankton population in some lakes. In addition, because of the existence of higher color lakes in the state, using Secchi depth as an index to represent lake trophic state can produce misleading results.

Therefore, the TSI was revised to be based on total nitrogen, total phosphorus, and Chla concentrations. This revised calculation for TSI now contains a TN -TSI, TP -TSI, and Chla-TSI. As a result, there are three different ways of calculating a final in-lake TSI. If the TN to TP ratio is equal to or greater than 30, the lake is considered phosphorus limited and the final TSI is the average of the TP -TSI and the Chla-TSI. If the TN to TP ratio is 10 or less, the lake is considered nitrogen limited and the final TSI is the average of the TN -TSI and the Chla-TSI. If the TN to TP ratio is between 10 and 30, the lake is considered co-limited and the final TSI is the result of averaging the Chla-TSI with the average of the TN and TP TSI's.

The Florida-specific TSI was determined based on the analysis of data from 313 Florida lakes. The index was adjusted so that a Chla concentration of 20 μg/L was equal to a Chla-TSI value of 60. The final TSI for any lake may be higher or lower than 60 depending on the TN -TSI and the TP -TSI values. A TSI of 60 was then set as the threshold for nutrient impairment for most lakes (for those with a color higher than 40 platinum cobalt units) because, generally, the phytoplankton may switch to communities dominated by blue-green algae at Chla levels above 20 μg/L. These blue-green algae are often an unfavorable food source to zooplankton and many other aquatic animals. Some blue-green algae may even produce toxins, which could be harmful to fish and other animals. In addition, excessive growth of phytoplankton and the subsequent death of these algae may consume large quantities of dissolved oxygen and result in anaerobic conditions in lakes, which makes conditions in the impacted lake unfavorable for fish and other wildlife. All of these processes may negatively impact the health and balance of native fauna and flora.

Because of the amazing diversity and productivity of Florida lakes, some lakes have a natural background TSI that is different from 60. In recognition of this natural variation, the IWR allows for the use of a lower TSI (40) in very clear lakes, a higher TSI if paleolimnological data indicate the lake was naturally above 60, and the development of site-specific thresholds that better represent the levels at which nutrient impairment occurs.

For the Lake Trafford TMDL, the Department applied the Hydrologic Simulation Program Fortran (HSPF) to simulate water quality discharges to the lake and eutrophication processes in the lake to determine the appropriate nutrient target. The HSPF model was used to estimate existing conditions (before lake dredging) in the Lake Trafford watershed and the background TSI by setting land uses to natural or forested land, and then compare the resulting TSI to the IWR thresholds. If the background TSI can be reliably determined and represents an appropriate target for TMDL development, then an increase of 5 TSI units above background will be used as the water quality target for the TMDL. Otherwise, the IWR threshold TSI of 60 will be established as the target for TMDL development.

The HSPF estimated long-term average background TSI for Lake Trafford is 51.0. This estimate is based on averaging the TN (1.07 mg/L), TP (0.018 mg/L), and Chla (17.1 mg/L) concentrations for model years 1999-2007. The model indicated that in its background condition, the lake was almost always TP limited (8 of 9 years) with an average TN/TP ratio of 59.4. This is results in a restoration target TSI of 56.0 and a lake that is TP limited (instead of the co-limited lake as it exists today).

3.3 Narrative Nutrient Criteria Definitions

Chlorophyll *a*

Chlorophyll is a green pigment found in plants and is an essential component in the process of converting light energy into chemical energy. Chlorophyll is capable of channeling the energy of sunlight into chemical energy through the process of photosynthesis. In photosynthesis, the energy absorbed by chlorophyll transforms carbon dioxide and water into carbohydrates and oxygen. The chemical energy stored by photosynthesis in carbohydrates drives biochemical reactions in nearly all living organisms. Thus, chlorophyll is at the center of the photosynthetic oxidation-reduction reaction between carbon dioxide and water.

There are several types of chlorophyll; however, the predominant form is chlorophyll *a* (Chla). The measurement of Chla in a water sample is a useful indicator of phytoplankton biomass, especially when used in conjunction with analysis concerning algal growth potential and species abundance. The greater the abundance of Chla, typically the greater the abundance of algae. Algae are the primary producers in the aquatic food web, and thus are very important in characterizing the productivity of lakes and streams. As noted earlier, Chla measurements are also used to estimate the trophic conditions of lakes and lentic waters.

Nitrogen Total as N (TN)

Total nitrogen is the combined measurement of nitrate (NO_3), nitrite (NO_2), ammonia, and organic nitrogen found in water. Nitrogen compounds function as important nutrients to many aquatic organisms and are essential to the chemical processes that exist between land, air, and water. The most readily bio-available forms of nitrogen are ammonia and nitrate. These compounds, in conjunction with other nutrients, serve as an important base for primary productivity.

The major source of excessive amounts of nitrogen in surface water are the effluent from municipal treatment plants and runoff from urban and agricultural sites. When nutrient concentrations consistently exceed natural levels, the resulting nutrient imbalance can cause undesirable changes in a waterbody's biological community and drive an aquatic system into an accelerated rate of eutrophication. Usually, the eutrophication process is observed as a change in the structure of the algal community and includes severe algal blooms that may cover large areas for extended periods. Large algal blooms are generally followed by a depletion in dissolved oxygen concentrations as a result of algal decomposition.

Phosphorus Total as P (TP)

Phosphorus is one of the primary nutrients that regulates algal and macrophyte growth in natural waters, particularly in fresh water. Phosphate, the form in which almost all phosphorus is found in the water column, can enter the aquatic environment in a number of ways. Natural processes transport phosphate to water through atmospheric deposition, ground water percolation, and terrestrial runoff. Municipal treatment plants, industries, agriculture, and domestic activities also contribute to phosphate loading through direct discharge and natural transport mechanisms. The very high levels of phosphorus in some of Florida's streams and estuaries are usually caused by phosphate mining and fertilizer processing activities.

High phosphorus concentrations are frequently responsible for accelerating the process of eutrophication, or accelerated aging, of a waterbody. Once phosphorus and other important nutrients enter the ecosystem, they are extremely difficult to remove. They become tied up in biomass or deposited in sediments. Nutrients, particularly phosphates, deposited in sediments generally are redistributed to the water column. This type of cycling compounds the difficulty of halting the eutrophication process.

3.4 Un-ionized Ammonia

Florida's un-ionized ammonia criterion for Class III freshwater bodies states that the un-ionized ammonia shall be less than or equal to 0.02 mg/L as ammonia. This criterion, has been adopted by the State to protect aquatic life from the toxic effects of un-ionized ammonia and is not a nutrient related criterion.

3.5 Dissolved Oxygen

Florida's DO criterion for Class I and III freshwater bodies states that DO "shall not be less than 5.0 mg/L, and the normal daily and seasonal fluctuations above this levels shall be maintained." However, DO concentrations in ambient waters can be controlled by many factors, including the DO solubility, which is controlled by temperature and salinity; DO enrichment processes influenced by reaeration, which is controlled by flow velocity; photosynthesis of phytoplankton, periphyton, and other aquatic plants; DO consumption from the decomposition of organic materials in the water column and sediment and oxidation of some reductants such as ammonia and metals; and respiration by aquatic organisms.

Lake Trafford is a highly colored lake with color ranging between 15 platinum cobalt units (PCU) and 500 PCU (1995-2004) with an average value of 120. The value of 15 PCU was reported from August 1999, the value reported for July was 100 and for September 75. If the value of 15 is removed, the range for color is 50 – 500 PCUs, with an average value of 121. The DO concentration in some seasons could be naturally low because of the high bacteria respiration supported by a large and constant supply of dissolved organic carbon (DOC) originating from the wetland areas that discharge into the lake. Although the major portion of the DOC pool is usually recalcitrant to most bacteria species, some bacteria species adapted to living in blackwater systems can readily use this DOC pool to support their growth. Bacteria activities can be significantly stimulated if nitrogen and phosphorus are added into the system because they provide bacteria with nutrients. Further stimulation of bacteria activities can be observed if DOCs of human origin (usually represented with the biochemical oxygen demand – BOD) are added to the system. Human DOCs are usually easy to decompose and can be readily used by bacteria. These DOCs not only can enhance the metabolic activities of bacteria species that use recalcitrant DOCs, but also provide the carbon source to those bacteria species that can not use recalcitrant DOCs. Therefore, input of human sources of DOC into a blackwater system should be properly controlled to improve the DO condition in these waters.

Another source of DO consumption may originate from the organic materials accumulated in the lake over time. Due to the limited amount of time available to this study, factors that control DO concentration in the lake were not examined by measuring the actual DO consumption rate from each source. Instead, TN, TP, and Chla concentrations were treated as the focus of this study. Possible impacts of these nutrients and phytoplankton on the DO level of the lake were evaluated by comparing the results from various HSPF scenarios discussed later.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Overview of Modeling Process

A watershed is the land area which catches rainfall and eventually drains or seeps into a receiving waterbody such as a stream, lake, or ground water (EPA, 1997). Land use pollution loading models have been often used to assess watershed impacts on water quality of a receiving waterbody. A detailed watershed model would be beneficial to estimate time series nutrients loads from potential sources of the watershed to predict algal responses in the receiving waterbody where the time scale of actual biological responses to nutrient loading from the watershed is at least equal to or less than that of the model prediction (EPA 1997).

The external load assessment from the watershed and the resulting in-lake water quality were evaluated using the Windows version of the Hydrologic Simulation Program Fortran (WinHSPF version 2.3). Assessing the external load entailed assessing land use patterns, soils, topography, hydrography, point sources, service area coverages, climate, and rainfall to determine the volume, concentration, timing, location, and underlying nature of the point, nonpoint, and atmospheric sources of nutrients to the lake.

HSPF is a tool that has been shown to be useful in the assessment of watershed-related properties. HSPF was developed to allow engineers and planners to assess the water quantity and quality of both surface water and ground water (interflow and baseflow). The model simulates the primary physical processes important for watershed hydrologic and pollutant transport. HSPF (Duda, 2001 and Brickell *et al.,* 2001) is a comprehensive package that can be used to develop a combined watershed and receiving water model. The model has the capability of modeling various species of nitrogen and phosphorus, Chla, coliform bacteria, and metals in receiving waters (bacteria and metals can be simulated as a “general” pollutant with potential instream processes including first-order decay and adsorption/desorption with suspended and bed solids). HSPF has been developed and maintained by Aqua Terra and the EPA. The PERLND (pervious land) module performs detailed analysis of surface and subsurface flow for pervious land areas based on the Stanford Watershed Model. Water quality calculations for sediment in pervious land runoff can include sediment detachment during rainfall events and reattachment during dry periods with potential for washoff during runoff events. For other water quality constituents, runoff water quality can be determined using buildup-washoff algorithms (like SWMM), “potency factors” (*e.g.,* factors relating constituent washoff to sediment washoff), or a combination of both. The IMPLND (impervious land) module performs analysis of surface processes only and uses buildup-washoff algorithms to determine runoff quality. The RCHRES module is used to simulate flow routing and water quality in the receiving waters, which are assumed to be one-dimensional. Receiving water constituents can interact with suspended and bed sediments through soil-water partitioning. HSPF can incorporate “special actions” that utilize user-specified algorithms to account for occurrences such as opening/closing of water control structures to maintain seasonal water stages or other processes beyond the normal scope of the model code.

More information on HSPF / BASINS can be found at ww.epa.gov/waterscience/basins/.

4.2 Potential Sources of Nutrients in the Lake Trafford Watershed

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

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination System (NPDES). These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs). To be consistent with Clean Water Act definitions, the term "point source" will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL. However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2.1 Point Sources

There are no NPDES permitted wastewater treatment facilities or industrial wastewater facilities that discharge directly to Lake Trafford. The facility listed in **Table 4.1** is within the Lake Trafford watershed, but was not included in the model as it is not a surface water discharger.

Table 4.1 NPDES Facilities in Lake Trafford Watershed

NPDES Permit ID	Facility Name	Receiving Water	Permitted Capacity (mgd)	Downstream Impaired WBID	Comments
FLA014132	Immokalee Wastewater Treat Plant	Spray Field/Deep Well	Land Application 2.36 Deep Well 4.867	Lake Trafford	not a NPDES surface water discharge. Reuse first, then deep well.

Municipal Separate Storm Sewer System Permittees

Municipal separate storm sewer systems (MS4s) may discharge nutrients to waterbodies in response to storm events. To address stormwater discharges, the EPA developed the National Pollutant Discharge Elimination System (NPDES) stormwater permitting program in two phases. Phase I, promulgated in 1990, addresses large and medium MS4s located in incorporated places and counties with populations of 100,000 or more. Phase II permitting began in 2003. Regulated Phase II MS4s, which are defined in Section 62-624.800, FAC, typically cover urbanized areas serving jurisdictions with a population of at least 10,000 or discharge into Class I or Class II waters, or Outstanding Florida Waters.

The stormwater collection systems in the Lake Trafford watershed, which are owned and operated by Collier County in conjunction with the Florida Department of Transportation (FDOT) District 1 permit number FLR04E048, are covered by a NPDES Phase I MS4 permit (FLR04E037).

4.2.2 Nonpoint Sources and Land Uses

Unlike traditional point source effluent loads, nonpoint source loads enter at so many locations and exhibit such large temporal variation that a direct monitoring approach is often infeasible. For the Lake Trafford TMDL, all nonpoint sources were evaluated by use of a watershed and lake modeling approach. Land use coverage's for the watershed were aggregated using the Florida Land Use, Cover and Forms Classification System (FLUCCS, 1999) into nine different land use categories. These categories are cropland/improved pasture/tree crops (agriculture), unimproved pasture/woodland pasture (pasture), rangeland/upland forests, commercial/industrial, high density residential (HDR), low density residential (LDR), medium density residential (MDR), water, and wetlands. The spatial distribution and acreage of different land use categories for HSPF were identified using the 2004 land use coverage (scale 1:24,000) provided by the South Florida Water Management District (SFWMD).

Table 4.2 shows the existing area of the various land use categories in the Lake Trafford watershed. **Figure 4.1** shows the drainage area of Lake Trafford and the spatial distribution of the land uses shown in **Table 4.2**.

As shown in **Figure 4.2**, the predominant land coverages for the Lake Trafford watershed include agriculture (35.5%), wetland (33.6%), forest/rangeland (8.4%), and pastureland (9.8%). Other uses include: commercial/industrial (2.7%), HDR (3.1%), MDR (3.0%), LDR (3.4%), and water (not Lake Trafford, 0.5%).

- Agriculture (Cropland/improved pasture/tree crops),
- Pasture (Unimproved pasture/woodland pasture),
- Forest (Undeveloped rangeland/upland forests),
- Commercial/industrial,
- High density residential (HDR),
- Medium density residential (MDR),
- Low density residential (LDR),
- Water, and
- Wetlands.

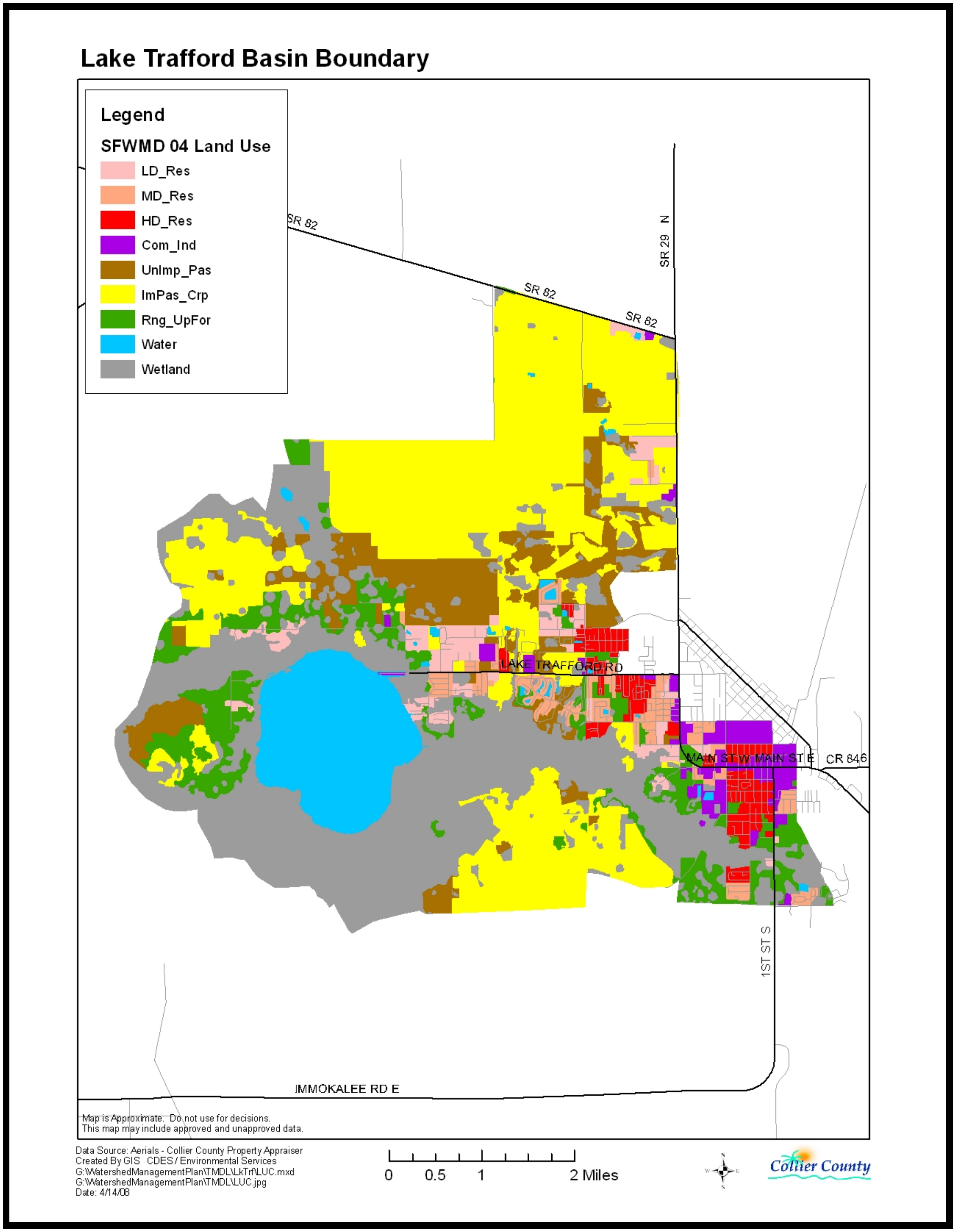

Figure 4.1 Lake Trafford Watershed and Existing Land Use Coverage

Table 4.2 Total and Percent of Existing Land Use Categories in the Lake Trafford Watershed Provided by Collier County

FLUCC[1)]	Land Use Category	Acreage (acre)	Percent Acreage (%)
110	Low density residential	624.5	3.4
120	Medium density residential	555.7	3.0
130	High density residential	564.2	3.1
140	Commercial and Industrial	502.6	2.7
210/220	Cropland/improved pasture/tree crops	6526.3	35.5
212/213	Unimproved pasture/woodland pasture	1800.0	9.8
300/400	Undeveloped rangeland/upland forests	1538.7	8.4
500	Water	92.0	0.5
600	Wetlands	6189.1	33.6
	Total	18393.1	100.0

[1)]FLUCC indicates Florida land use, cover and forms classification system (FLUCCS, 1999)

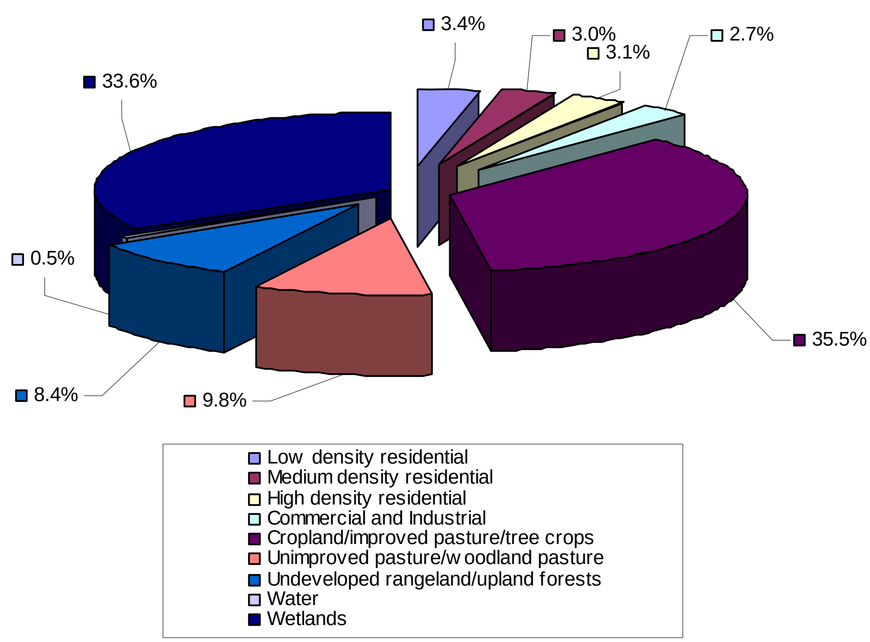

Figure 4.2 Percent Acreage of the Various Land Use Categories in the Lake Trafford Watershed.

Collier County Population

According to the U.S Census Bureau, the county occupies an area of approximately 2,025.34 square miles (sq mi). The total 2000 population estimated for Collier County, which includes (but is not exclusive to) the Lake Trafford watershed, was 251,377. The population density in Collier County, in the year 2000, was at or less than 124.1 people per sq mi. The estimated population for 2006 is 314,649, a 25% increase from 2000. For all of Collier County (2006), the Bureau reported a housing density of 93 houses per sq mi. Collier County is well below the average housing density for Florida counties of 158 housing units per sq mi (U. S. Census Bureau Web site, 2008).

Septic Tanks

Onsite sewage treatment and disposal systems (OSTDSs), including septic tanks, are commonly used where providing central sewer is not cost-effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDSs are a safe means of disposing of domestic waste. The effluent from a well-functioning OSTDS is comparable to secondarily treated wastewater from a sewage treatment plant. When not functioning properly, however, OSTDSs can be a source of nutrients (nitrogen and phosphorus), pathogens, and other pollutants to both ground water and surface water.

Septic tank effluent (STE) characteristics and loading rates have been reported in several studies (CHEC, 2003; CDM, 1991; IFAS, 1984). STE contains varied concentrations of nitrogen, phosphorus, chloride, sulfate, sodium, detergent surfactants, and pathogenic bacteria and viruses. OSTDS use soil adsorption capabilities to remove nutrients and bacteria from the treated effluent. Removal of TN in soils could vary from 40 to 60 percent (CHEC, 2003; IFAS, 1984) before reaching the water table. Once the nitrogen has reached the form of nitrate (NO_3) in the water table, it remains stable as it is transported to a water body. Phosphorus is removed from the STE at a higher rate, 50 to 98 percent (CHEC, 2003; CDM, 1991; IFAS, 1984), and from the ground water by sorption and precipitation. Phosphorus-contaminated water bodies from OSTDS are indicative of proximity of these systems, usually less than 150 ft (CHEC, 2003; IFAS, 1984). When at least two feet of unsaturated soil exist between the infiltration system and the water table, BOD_5 removals of > 90%, TSS removals of > 95% and fecal coliform reductions of > 99% (CDM, 2008) can be expected for a functional and properly maintained septic tank. Bacteria and viruses are effectively removed by adsorption and sorption processes in the ground water and are not transported far from the STE source.

IFAS estimated 11 to 18 lb/yr/capita of TN loading factor to the water table (1984); whereas, Anderson *et al.* (1994), as reported by CHEC (2003) and EPA (2002), estimated a 9.2 lb/yr/capita. Likewise for TP, the estimated per capita loading factors were 0.4 to 1.6 and 1.2 lb/yr, respectively. The difference relies on the decreasing loading rate of nutrients present in the current composition of detergent supplies that were implemented in recent years.

HSPF does not directly account for the impacts of failing septic tanks. This project established baseflow concentrations for inflows into Lake Trafford from human land uses based on data from Collier County Well C-01078. This is a surficial well (17-22 feet depth of samples) located on Lake Trafford Road, just east of Fish Creek. This well is located approximately 1.3 miles from the lake. The ground water in this area is down gradient from agricultural, commercial/industrial, and residential land uses and expected to move towards the lake. The impact of any contributions from septic tanks is factored into the model by using these site specific data to establish baseflow concentrations from human land uses.

Collier County Septic Tanks

As of 2007, Collier County had a cumulative registry of 43,833 septic systems. Data for septic tanks are based on 1971 – 2007 census results, with year-by-year additions based on new septic tank construction. The data do not reflect septic tanks that have been removed going back to 1970. From fiscal years 1994–2007, an average of 254 permits/year for repairs was issued in Collier County (Florida Department of Health, 2008). Based on the number of permitted septic tanks estimated for 2006 (43,833) and housing units (187,606) located in the county, approximately 77 percent of the housing units are connected to a central sewer line (i.e., wastewater treatment facility), with the remaining 23 percent utilizing septic tank systems.

4.3 Estimating Point and Nonpoint Source Loadings

4.3.1 Model Approach

The HSPF Model was utilized to estimate the nutrient loads within and discharged from the Lake Trafford Basin. The HSPF model allows the Department to interactively simulate and assess the environmental effects of various land use changes and associated land use practices. The data analysis and evaluation were focused on the 10-year model simulation period of 1998 through 2007 to represent recent and existing conditions. Although the lake was disturbed by sediment dredging (November 2005 through May 2006), it was decided that model calibration would be performed for the 5-year period from 1998 to 2002 and model validation was performed for another 5-year period from 2003 through 2007. Although not representative of a full year of data, water quality data for years 2006 and 2007 are also shown for informational purposes. The year 1998 was included in the calibration timeframe, but less weight was given to the model results for this first year of the model run, as it was used to establish antecedent conditions (model spin-up).

The Hydrological Simulation Program-FORTRAN (HSPF) model was developed under the joint sponsorship of the U.S. Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS). The model is capable of simulating both hydrologic and water quality processes in the watershed and receiving water bodies. This dynamic HSPF model allows input of rainfall, temperature, evaporation, evapotranspiration, point source flows and loads, upstream or tributary inflows and constituent loads, sediment mass and associated constituent loads, and other time series data. The model also allows input of parameters related to physical characteristics of subwatersheds (topography, roughness, etc.), land uses, soil characteristics, and agricultural practices to conduct watershed simulations. Within each subwatershed, HSPF conducts dynamic simulations of water quantity and quality in several layers including the land surface, several soil zones, and the ground water table. The watershed simulations can generate storm water runoff flows and concentrations or loads of sediments, BOD, nutrients, bacteria, pesticides, metals, toxic chemicals, and other quality constituent. The flows and loadings from the watershed can then be used together with channel and boundary information to conduct in stream simulations, which then yield dynamic results of flow, constituent concentrations and loads at the user-selected output locations. HSPF can also simulate the transport of flow, sediment, and their associated water quality constituents in stream channels and mixed reservoirs. These simulations include hydraulics, constituent advection, transport of conservative constituents, inorganic sediment, and generalized quality constituents, water temperature, nutrient cycles, DO related processes, first-order decay, sediment sorption and desorption, and other WQ processes. To conduct hydrology simulations in HSPF, the user must provide a rating relationship that relates flow, water depth, water surface area, and water volume at each model reach. While being a dynamic model, HSPF does not accept a dynamic downstream boundary condition and cannot simulate backwater effects.

Datasets of land use, soils and rainfall are used to calculate the combined impact of the watershed characteristics for a given modeled area on a waterbody represented in the model as a reach. GIS and model data set used to derive the inputs for HSPF included land use, soils, topography and depressions, hydrography, USGS gage and flow data, septic tanks, water use pumpage, point sources, rainfall, ground water, atmospheric deposition, solar radiation, control structures, and stream reaches.

IMPLND Module for Impervious Tributary Area

The IMPLND module of HSPF accounts for surface runoff from impervious land areas (*e.g.,* parking lots and highways). For the purposes of this model, each land use was assigned a typical percentage of directly connected impervious area (DCIA) as shown in **Table 4.3** based on published values (CDM, 2002). Four of the nine land uses contain fractions of impervious lands.

Table 4.3 Percentage of Impervious Area.

Land Use Category	% DCIA
1. Commercial / Industrial	80
2. Cropland / Improved pasture / Tree crops	0
3. High density residential	50
4. Low density residential	10
5. Medium density residential	25
6. Rangeland / Upland Forests	0
7. Unimproved pasture / Woodland pasture	0
8. Wetlands	0
9. Water	0

Note: Most of the water and wetland land uses in the system are modeled as a “reach” in HSPF.

PERLND Module for Pervious Tributary Area

The PERLND module of HSPF accounts for surface runoff, interflow, and ground water flow (baseflow) from pervious land areas. For the purposes of modeling, the total amount of pervious tributary area was estimated as the total tributary area minus the impervious area.

HSPF uses the Stanford Watershed Model methodology as the basis for hydrologic calculations. This methodology calculates soil moisture and flow of water between a number of different storages, including surface storage, interflow storage, upper soil storage zone, a lower soil storage zone, an active ground water zone, and deep storage. Rain that is not converted to surface runoff or interflow infiltrates into the soil storage zones. The infiltrated water is lost by evapotranspiration, discharged as baseflow, or lost to deep percolation (*e.g.,* deep aquifer recharge). In the HSPF model, water and wetlands land uses were generally modeled as pervious land (PERLND) elements. Since these land use types are expected to generate more flow as surface runoff than other pervious lands, the PERLND elements representing water and wetlands were assigned lower values for infiltration rate (INFILT), upper zone nominal storage (UZSN), and lower zone nominal storage (LZSN).

Hydrology for large water bodies *(e.g.,* Lakes) and rivers and streams should be modeled in the RCHRES module of HSPF (described below) rather than the PERLND module. For each subbasin containing a main stem reach, a number of acres should be removed from the water land use in PERLND, which are then modeled explicitly in RCHRES. The acres removed from these subbasins correspond to the areas of the lakes and the streams. In the reaches representing these waterbodies, HSPF accounts for direct rainfall on the water surface and direct evaporation from the water surface.

Several of the key parameters adjusted in the analysis include the following:

- LZSN (lower zone nominal storage) - LZSN is the key parameter in establishing an annual water balance. Increasing the value of LZSN increases the amount of infiltrated water that is lost by evapotranspiration and, therefore, decreases the annual streamflow volume.

- LZETP (lower zone evapotranspiration parameter) – LZETP affects the amount of potential evapotranspiration that can be satisfied by lower zone storage and is another key factor in the annual water balance.

- INFILT (infiltration) - INFILT can also affect the annual water balance. Increasing the value of INFILT decreases surface runoff and interflow, increases the flow of water to the lower soil storage and ground water, and results in greater evapotranspiration.

- UZSN (upper zone nominal storage) - Reducing the value of UZSN increases the percentage of flow that is associated with surface runoff as opposed to ground water flow. This would be appropriate for areas where receiving water inflows are highly responsive to rainfall events. Increasing UZSN can also affect the annual water balance by resulting in greater overall evapotranspiration.

RCHRES Module for Stream/Lake Routing

The RCHRES module of HSPF conveys flows input from the PERLND and IMPLND modules, together with rainfall directly on the water surface and balances this with outflows from evaporation, and outflows based on a rating curve supplied by the modeler. This project consists of a single set of PERLND and IMPLND land uses representing the watershed, draining to a single RCHRES, representing Lake Trafford. The RCHRES element defines the depth-area-volume relationship for the modeled waterbody. HSPF input parameters and values used for model calibration are shown in **Table 4.4**.

Table 4.4 HSPF Input Parameters and Values for Model Calibration

HSPF Variable	Description	Units	Value	Source
HTRCH Module				
CFSAEX	Correction factor for solar radiation	none	0.90	Calibration
KATRAD	Longwave radiation coefficient	none	13.07	Calibration
KCOND	Conductive-convection heat transport coefficient	none	10.12	Calibration
KEVAP	Evaporation coefficient	none	2.24	Default
SEDTRN Module				
KSAND	Coefficient in sandload formula	complex	6	Previous studies
EXPSND	Exponent in sandload formula	complex	1.5	Previous studies
W	Fall velocity in still water - silt	in/s	1.00E-05	Previous studies
TAUCD	Critical shear stress for deposition - silt	lb/ft^2	0.09	Calibration
TAUCS	Critical shear stress for scour - silt	lb/ft^2	0.32	Previous studies
M	Erodibility coefficient of sediment - silt	$lb/ft^2/day$	3.2	Calibration
W	Fall velocity in still water - clay	in/s	1.60E-06	Previous studies
TAUCD	Critical shear stress for deposition - clay	lb/ft^2	0.09	Calibration
TAUCS	Critical shear stress for scour - clay	lb/ft^2	0.46	Previous studies
M	Erodibility coefficient of sediment - clay	$lb/ft^2/day$	3.2	Calibration
OXRX Module				
KBOD20	Unit BOD decay rate at 20 deg C	hr^{-1}	0.0104	Calibration
TCBOD	Temperature correction coefficient for BOD decay	none	1.067	Calibration
KODSET	Rate of BOD settling	ft/hr	0.010	Calibration
BENOD	Benthal oxygen demand at 20 deg C (assuming sufficient water column DO)	$mg/m^2/hr$	31.4	Calibration
TCBEN	Temperature correction coefficient for benthal oxygen demand	none	1.037	Calibration
NUTRX Module				
KTAM20	Nitrification rate of ammonia at 20 deg C	hr^{-1}	0.002	Previous studies
TCNIT	Temperature correction coefficient for nitrification	None	1.07	Default

Table 4.4 HSPF Input Parameters and Values for Model Calibration (Cont.)

HSPF Variable	Description	Units	Value	Source
PLANK Module				
RATCLP	Ratio of chlorophyll a content of biomass to phosphorus content	none	3.0	Calibration
NONREF	Nonrefractory fraction of algae and zooplankton biomass	none	0.95	Calibration
ALNPR	Fraction of nitrogen requirements for phytoplankton growth that is satisfied by nitrate	none	0.75	Calibration
EXTB	Base extinction coefficient for light	ft^{-1}	0.43	Calibration
MALGR	maximum unit algal growth rate	hr^{-1}	0.112	Calibration
CMMLT	Michaelis-Menton constant for light-limited growth	ly/min	0.033	Default
CMMN	Nitrate Michaelis-Menton constant for nitrogen limited growth	mg/l	0.045	Default
CMMNP	Nitrate Michaelis-Menton constant for phosphorus limited growth	mg/l	0.028	Default
CMMP	Phosphate Michaelis-Menton constant for phosphorus limited growth	mg/l	0.015	Default
TALGRH	Temperature above which algal growth ceases	deg F	92.0	Calibration
TALGRL	Temperature below which algal growth ceases	deg F	43.0	Calibration
TALGRM	Temperature below which algal growth is retarded	deg F	83.0	Calibration
ALR20	Algal unit respiration rate at 20 deg C	hr^{-1}	0.006	Calibration
ALDH	High algal unit death rate	hr^{-1}	0.003	Calibration
ALDL	Low algal unit death rate	hr^{-1}	0.0015	Calibration
CLALDH	Chlorophyll a concentration above which high algal death rate occurs	ug/l	90	Default
PHYSET	Rate of phytoplankton settling	ft/hr	0.008	Calibration
REFSET	Rate of settling for dead refractory organics	ft/hr	0.00045	Calibration
CVBO	Conversion from mg biomass to mg oxygen	mg/mg	1.31	Previous studies
CVBPC	Conversion from biomass expressed as phosphorus to carbon	mols/mol	106	Previous studies
CVBPN	Conversion from biomass expressed as phosphorus to nitrogen	mols/mol	10	Previous studies
BPCNTC	Percentage of biomass which is carbon (by weight)	none	49	Previous studies

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Determination of Loading Capacity

Nutrient enrichment and the resulting problems related to eutrophication tend to be widespread and are frequently manifested far (in both time and space) from their source. Addressing eutrophication involves relating water quality and biological effects (such as photosynthesis, decomposition, and nutrient recycling), as acted upon by hydrodynamic factors (including flow, wind, tide, and salinity) to the timing and magnitude of constituent loads supplied from various categories of pollution sources. The assimilative capacity should be related to some specific hydro-meteorological condition such as an 'average' during a selected time span or to cover some range of expected variation in these conditions.

The goal of this TMDL development is to identify the maximum allowable TN and TP loadings from the watershed, so that Lake Trafford will meet the narrative nutrient water quality, un-ionized ammonia, and dissolved oxygen criteria and thereby maintain its function and designated use as a Class III water. In order to achieve the goal, the Department selected the HSPF model as the watershed and waterbody model. It was run dynamically through the ten-year period on an hourly time step to simulate Chla responses in the lake to watershed nutrient loading and to ultimately estimate the assimilative capacity of the lake.

5.1.1 Meteorological and Stage Data

Hourly meteorological data for Lake Trafford were obtained from the Immokalee station of the Florida Automatic Weather Network (FAWN) where the 10-yr hourly meteorological data from 1998 to 2007 were recorded. FAWN is an observation platform owned by the University of Florida. The weather station is located at Immokalee, Collier County about 2 miles northeast Lake Trafford as shown in **Figure 5.1**. The hourly meteorological data were included as follows: rainfall, solar radiation, wind speed, dewpoint temperature, and air temperature. Daily potential evapotranspiration was available from this weather station and was converted to hourly values for the model using the WDMUtil included with the EPA BASINS tool kit (Better Assessment Science Integrating point and Nonpoint Sources).

Pan-evaporation is also an important parameter for simulating direct evaporation from the surface of the lake. Free water-surface evaporation is different from pan-evaporation, which can be computed by using methods to correct for the difference in heat storage capabilities of water in a pan versus in a lake (Lee and Swancar, 1997). Free water-surface evaporation is a function of many factors including barometric pressure, wind speed, the amount of solar radiation, and temperature. The energy-budget method is known to be the most accurate way to measure lake evaporation (Winter 1981) and requires a large amount of data collection. Lee and Swancar (1997) derived pan coefficients for lakes in central Florida, ranging from 0.70 to 0.77 for Lake Lucerne and 0.71 to 0.75 for Lake Alfred. On an annual basis, the long-term annual average coefficient of 0.74 was derived by Farnsworth et al (1982). Trommer et al

(1999) also used a coefficient of 0.75 applied to pan evaporation data from the Bradenton 5 ESE weather station to estimate evaporation for Ward Lake in Manatee County, Florida. Given the range in Florida values of 0.70 to 0.77, and that Ward Lake was closest to Lake Trafford, a pan coefficient of 0.75 was used for this TMDL project.

Weather station name, periods of data availability and data collection frequency are shown in **Table 5.1**. **Figure 5.1** shows the location map for the weather stations, including the USGS lake stage station. Daily pan evaporation data were available from S65_E operated by the South Florida Water Management District. The pan evaporation data from the same location were utilized by CDM for the Kissimmee River Basin lake TMDLs (CDM 2008). Several data gaps were identified within the available period of record for the meteorological data. If the period of record at a given station was missing data for a month or longer, the data from the closest station were used to complete the dataset. However, if data were missing for only a short period of time (i.e., days), the average, of the values from the day before and the day after were used to represent the data for the missing days.

Table 5.1 General Information on Weather Station and USGS Gauge Station

Location Name	Start Date	End Date	Frequency	Facility	County	Comment
Immokalee	12/30/1997	Present	Hourly/Daily	FAWN	Collier	Meteorological data
S65_E	10/01/1983	09/30/2007	Daily	WMD	Osceola	Pan evaporation
USGS 02291200	04/01/1941	12/30/2007	Daily	USGS	Collier	Stage elevation above NGVD 1929, feet

Stage-area-volume relationships were computed using a bathymetric map available for use in the model development. The bathymetric map with a 0.5 feet-interval contour for the lake prior to dredging was provided by ArtEneering, Inc. DesignCad Pro2000 was used to obtain the area of each contour and the surface area of the lake was estimated to be about 1522 acres when the lake stage is 20.28 ft above sea level. The FTABLE in HSPF was also created using a stage-volume-area relation. The obtained quadratic equation allowed lake levels obtained from the stage gauge to be directly related to changes in lake volume and surface areas. A similar approach was also used by Environmental Consulting & Technology, Inc. (1989) for Lake Apopka. Based on the relationship between stage and lake volume, the lake volume varied dramatically as a function of changing lake levels during the period of 1989-2007, ranging from 3012 ac-ft in September 2007 to 12446 ac-ft in October 1995, with an average of 7244 ± 1808 ac-ft. In particular, lake volumes lower than the 19-year average volume were observed, especially in 2006 and 2007.

The time step selected for the model was hourly. Therefore, obtaining hourly rainfall as a model input was important, as it drives the hydrology, hydraulics, and transport within the system. On an annual basis, total annual rainfall varied from 22.93 to 65.85 inches during the modeling period of 1998-2007, with an average annual rainfall of 46.28 ± 13.34 inches (**Figure 5.2**). The 10-yr average rainfall at the Immokalee station during this period is slightly lower than the long-term average rainfall (51.99 inches per year) based on the 71-yr record from the Mountain Lake National Weather Service station located in Polk County (Swancar et al., 2000). The deficiency in annual rainfall from the long term average was significant in 2006 and 2007, when the annual rainfall recorded was 33.9 inches and 22.9 inches, respectively. As a result, lake stage levels in 2007 were the lowest during the modeling period as shown in the following sections.

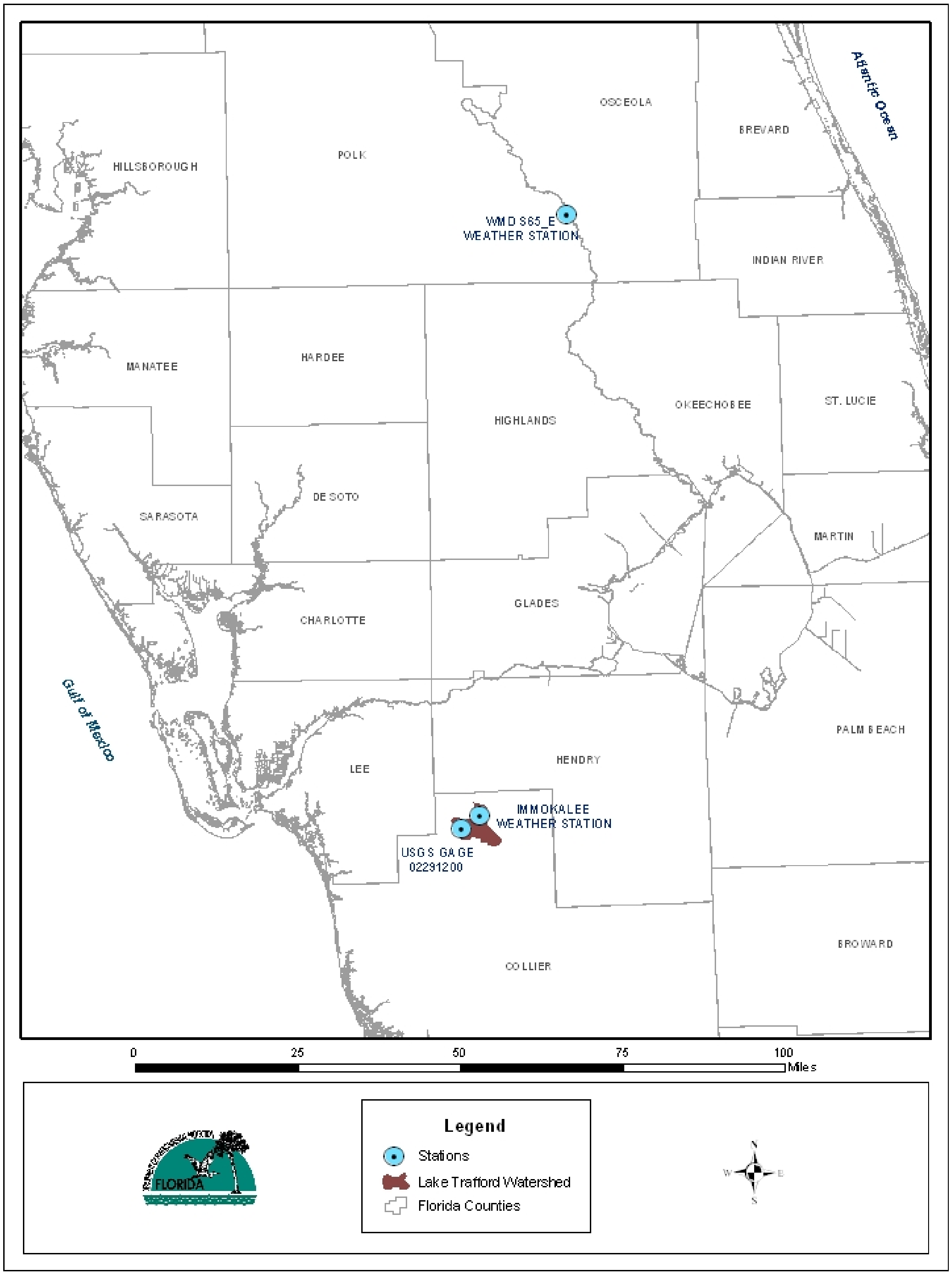

Figure 5.1 Location Map for Immokalee and SFWMD Weather Stations and USGS Gauge Station.

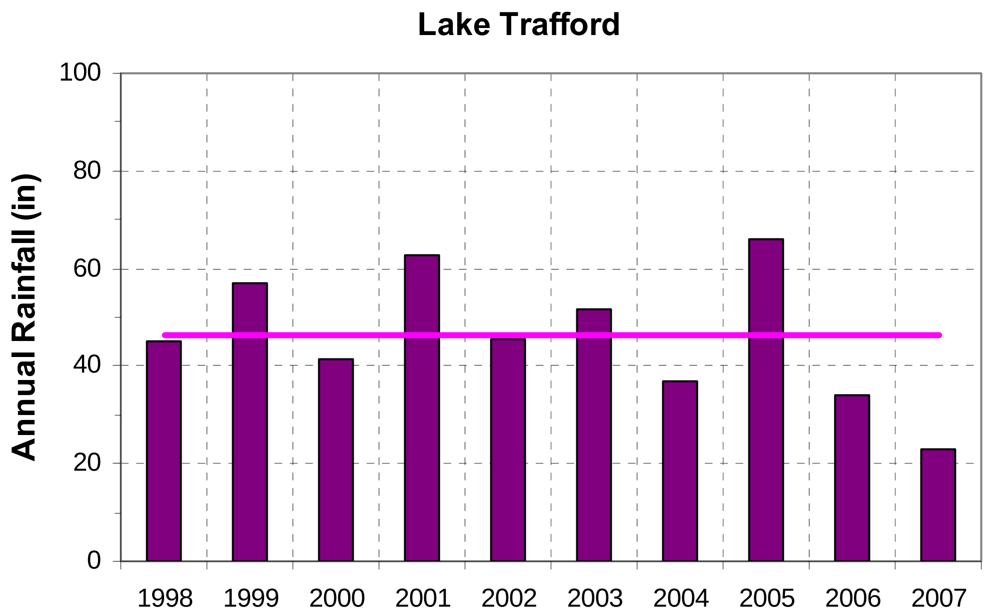

Figure 5.2 Total Annual Rainfall (Inches) Observed from the Immokalee Station during the Calibration and Validation Period of 1998-2007.

5.1.2 Model Calibration

Temperature Calibration for Lake Trafford

Lake temperature is a critical habitat characteristic for fish and other organisms, and affects rates of water quality processes, especially DO. Although lake temperature itself is considered as a conservative parameter, model calibration and validation for the lake was determined to include water temperature since the lake is impaired for DO. Key parameters controlling the energy balance for water temperature are as follows: short and long wave radiation, conduction, convection, evaporation, and ground conduction (HSPF manual,2001). For Lake Trafford, parameters PSTEMP, IWTGAS and RCHRES (KATRAD, KCOND, KEVAP) were adjusted as shown in **Table 4.4** for calibration. The observed and model predicted time-series of daily average water temperature is shown in **Figure 5.3**. **Figure 5.4** depicts the temperature calibration for the year 2003, indicating that the model performed well enough to simulate temperature-associated parameters such as DO.

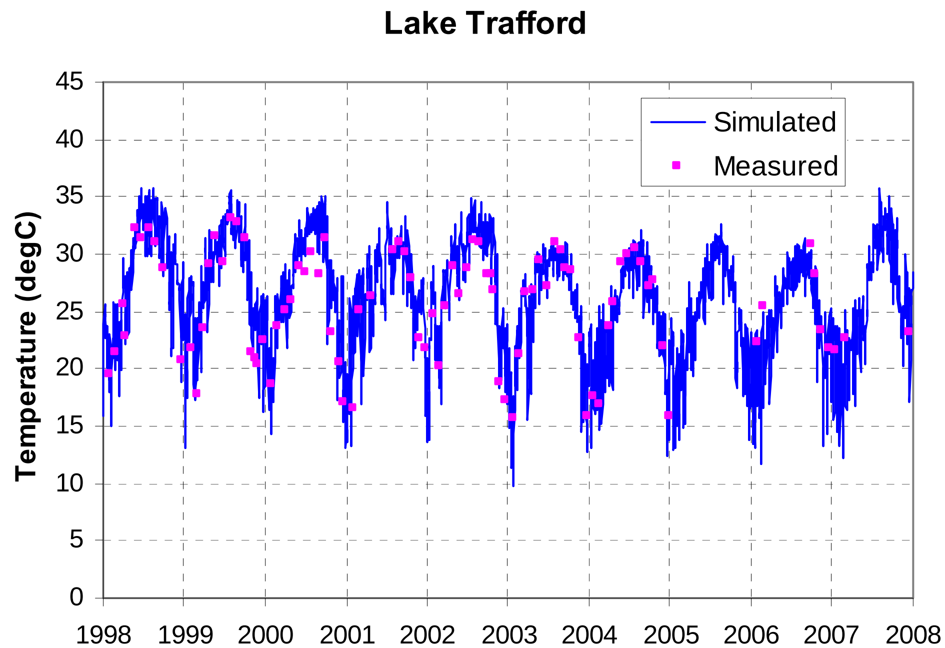

Figure 5.3 Observed versus Simulated Daily Temperature (deg C) during the Simulation Period of 1998-2007.

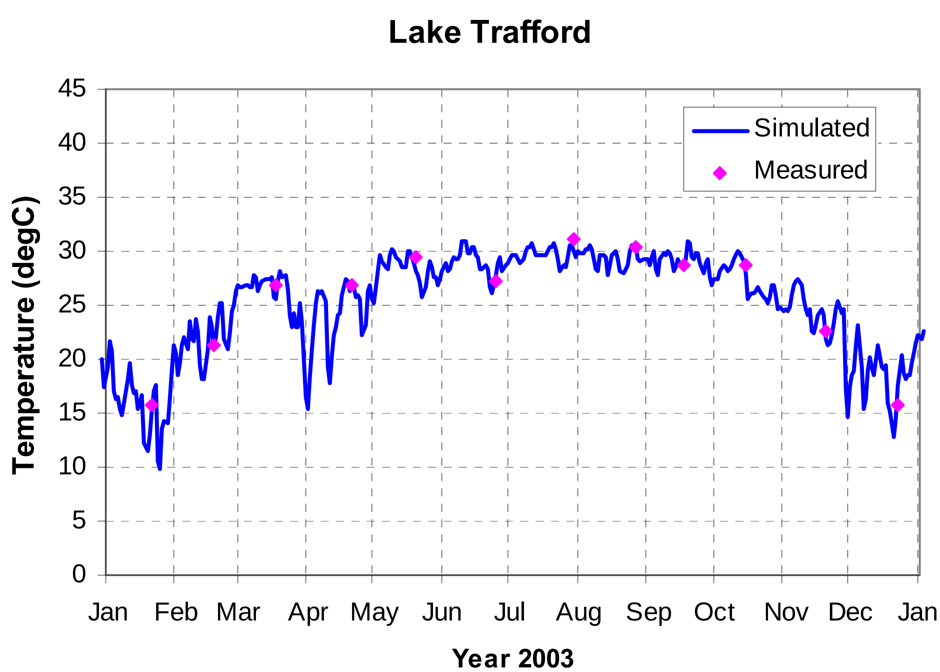

Figure 5.4 Observed versus Simulated Daily Temperature (deg C) in the Selected Year of 2003.

Hydrology Calibration for Lake Trafford

The HSPF model, based on the aggregated land use categories, simulated the watershed hydraulic and hydrology as well as in-lake water quality. The predicted lake level was a result of the balance between water input from the watershed and losses from the lake. Therefore, it is important to evaluate the lake levels over time in order to obtain reasonable water budgets. The simulated lake levels were calibrated and validated using the USGS gauge data obtained from January 1, 1998 to December 31, 2007 (**Figure 5.5** and **Table 5.2**). The model fit to the overall patterns and levels throughout the modeling period was excellent. Although there was noticeable discrepancy between the observed and simulated lake levels in 2000 and 2001 (**Figure 5.5**). In general, simulated lake levels varied from 17.36 ft to 22.59 ft, with an average of 19.8 ft (n = 3652) over the period of the simulation. Similarly, the observed data showed that lake levels ranged from 17.08 ft to 21.86 ft and averaged about 19.7 ft (n = 3424), indicating that the model simulation well represents the long term average stage for Lake Trafford. Noteworthy, is that both simulated and observed lake levels were lowest in 2007. This is attributed to the dry conditions that occurred in 2007, with an annual rainfall of only 22.9 inches.

A series of statistical analyses were conducted to find out how well the model predicted lake elevations at the daily and annual basis. For a daily comparison (i.e., point-to-point comparison), a relationship between daily observed lake levels and simulated lake levels is shown in **Figure 5.6**. These data indicate a positive correlation, with a correlation coefficient (r) of 0.79. With the exception of the year 2000, the model responded to both high and low stage levels of the observed data. Moreover, annual variations in the simulated stage showed only small differences from the observed stage (**Table 5.2**). In **Table 5.2**, observed annual average lake levels varied from 17.88 to 20.54 ft over the 10 yr period, similar to the simulated annual mean elevation in the range of 18.33 to 20.41 ft. The difference between the annual observed stage and the annual simulated stage, as calculated by the observed annual stage minus the simulated annual stage for each year, varied between -0.57 ft and +0.44 ft over the years, indicating only a 3% difference. Moreover, the correlation coefficient (r) for the annual average elevation between observation versus simulation was estimated to be 0.9401 (y = 0.6981x + 6.0724, n = 10). Based on the point-to-point calibration and annual patterns of lake elevation, it was decided that the model hydrology simulation was acceptable for estimating watershed loads to Lake Trafford.

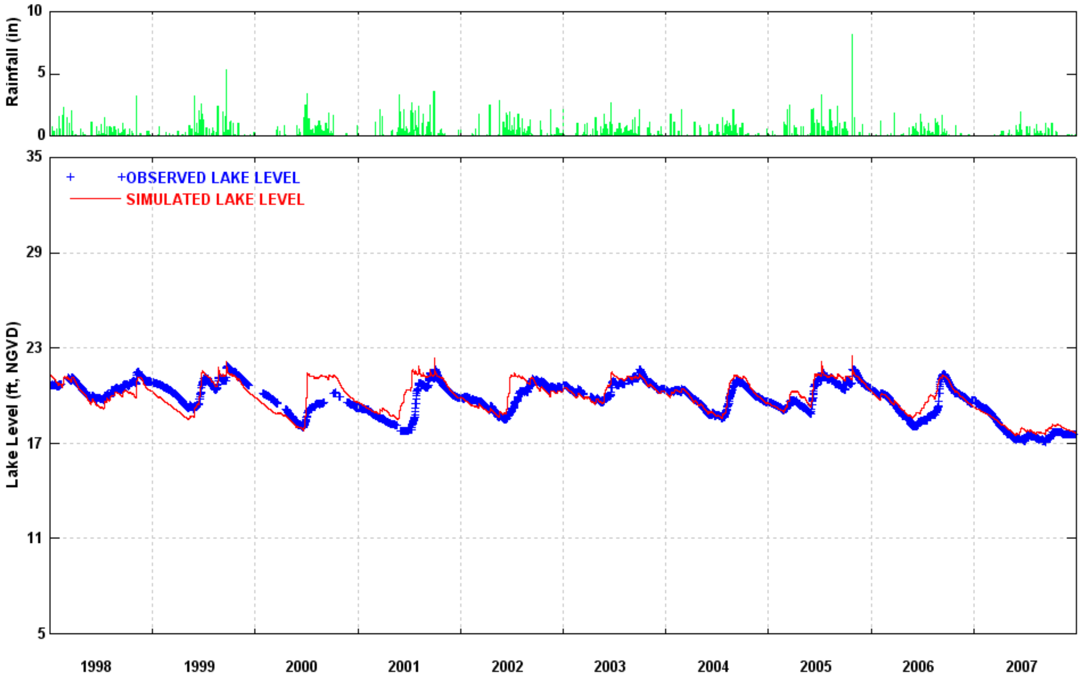

Figure 5.5 Observed Rainfall (inches) and Stage Level (ft, NGVD) versus Simulated Lake Level during the Calibration and Validation Period of 1998-2007.

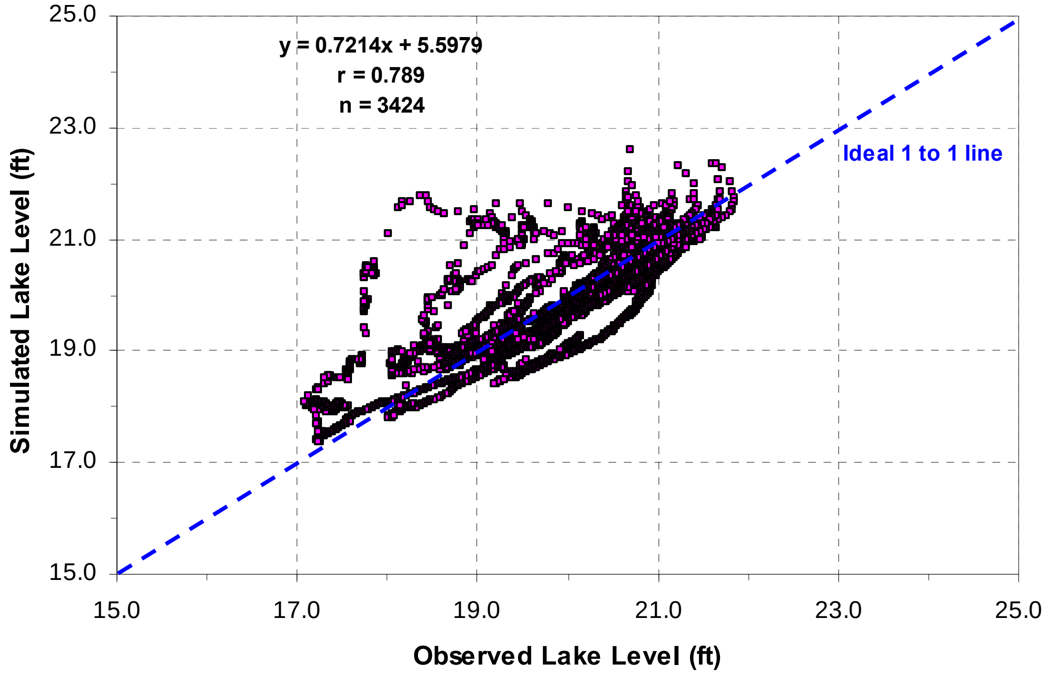

Figure 5.6 **Daily Point-to-Point Paired Calibration of Stage Elevation (ft) during the Simulation Period of 1998-2007. R and n Indicated a Correlation Coefficient and the Number of Observations over the Period, Respectively. Blue Dotted Line Indicated the Ideal 1 to 1 Line.**

Table 5.2 **Summary of Statistics of Observed Versus Simulated Annual Mean Lake Level for Lake Trafford during the Simulation Period.**

Year	Observed Lake Level (ft)	Standard Deviation (+/-)	Number of Observation	Simulated Lake Level (ft)	Standard Deviation (+/-)	Number of Simulation
1998	20.54	0.45	343	20.38	0.64	365
1999	20.52	0.71	342	20.08	1.00	365
2000	19.23	0.61	236	19.67	1.13	366
2001	19.46	1.16	351	20.03	1.03	365
2002	19.87	0.73	365	19.91	0.79	365
2003	20.50	0.49	327	20.32	0.54	365
2004	19.84	0.66	366	19.83	0.71	366
2005	20.24	0.82	365	20.41	0.84	365
2006	19.51	0.89	365	19.70	0.66	365
2007	17.88	0.73	364	18.33	0.45	365

Water Budget for Lake Trafford

Lake water budgets can be an important tool for understanding the relative importance of water inflow to and outflow from a lake. HSPF simulations were conducted for the watershed considering both pervious and impervious surfaces. The modeled watershed has separate parameter values to assess runoff hydrographs and include adjustments for infiltrations, base flow, ground water storage, seasonal variations, hydrograph shape factors, wetland and water table interactions, and other parameters.

Water pathways (i.e., surface runoff, interflow, baseflow and direct precipitation) through each land use category that carry nutrients from non- and point sources were identified in HSPF and nutrient loads from different types of land use were then quantified. For this estimate, new Schematic and Mass-Link blocks in HSPF were created to separate monthly flow components (i.e., surface runoff, interflow, baseflow) coming to the receiving waterbody. Outflow such as discharges (or seepage out) from the lake were also estimated.

Monthly total inflows to the lake over the calibration and validation period were represented as shown in **Figures 5.7** and **5.8**. Based on total monthly inflows, a couple of the patterns were found for the incoming waters to Lake Trafford:

1) In normal rainfall years, a greater volume of water flowed into the lake during the wet season from May to October relative to the dry season,
2) Direct rainfall was an important component recharging the lake during dry seasons while interflow and baseflow were the major contributors during the summer months of each year, and
3) In most months, the quantity of interflow and baseflow was proportionally associated with the amounts of precipitation.

Total annual inflows and outflows were estimated to construct the water budget of Lake Trafford during the simulation period. **Table 5.3** shows the total annual inflow and outflow (ac-ft) to and from the lake and changes in lake volume. In 2005, when annual rainfall was highest (65.85 inches), the simulated total annual inflows via surface runoff, interflow, and baseflow were estimated to be increased by two to four times, compared to those in the previous year. As a result, the lake volume increased in the same year (about 872 ac-ft) even though the discharge from the lake was at its greatest (about 38,634 ac-ft). In 2007, when the annual rainfall (22.9 inches) was lowest, inflows via interflow and baseflow were limited and changes (decreases) in lake volume were significant. These findings are well coincident to the current conditions of the lake, with exposure of the littoral zone and the occurrence of little to no discharge from the lake.

The relative importance of incoming flows to the lake, for each year, is shown in **Figure 5.9**. Surface runoff seems constant over the 10-yr period except for year 2007, comprising about 20-25% of the total incoming flows. However, in 2007 under very dry conditions, surface runoff and direct precipitation are the major pathways carrying nutrients and other pollutants, accounting for approximately 80% of the incoming flow. The percent contribution of each pathway to the lake over the 10-yr period is shown in **Figure 5.10**. As can be seen in **Table 5.3**, on average baseflow is the largest contributor of water at 32%, followed by interflow (24%), direct rainfall

(23%), and surface runoff (21%). However, each individual component is critical to maintaining the lake water level over the 10-yr period of simulation.

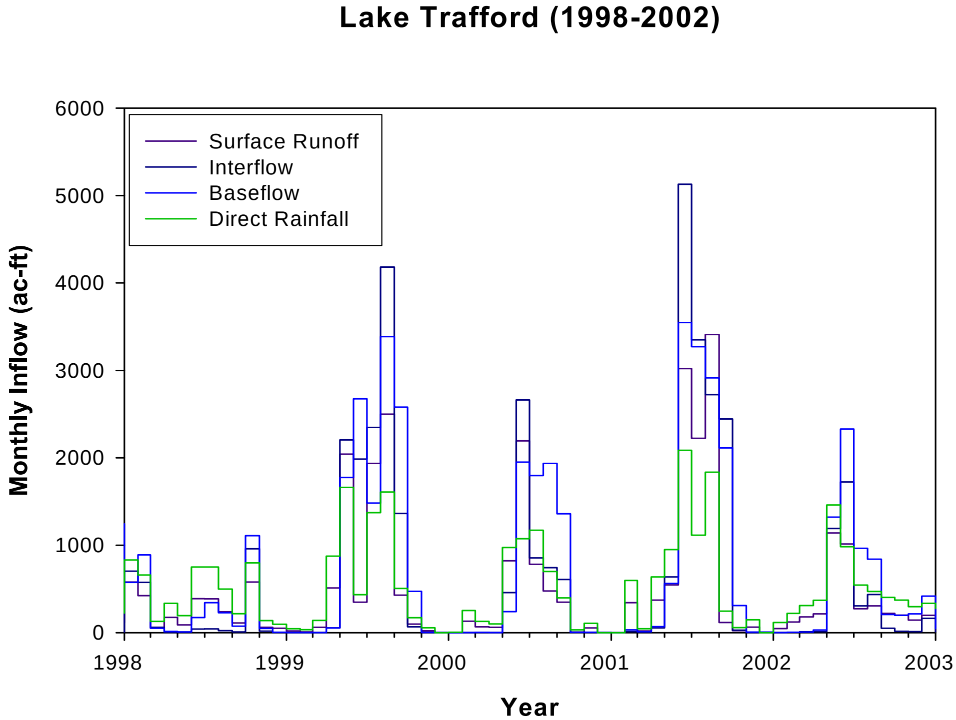

Figure 5.7. Simulated Total Monthly Inflows to Lake Trafford during the Calibration Period of 1998-2002.

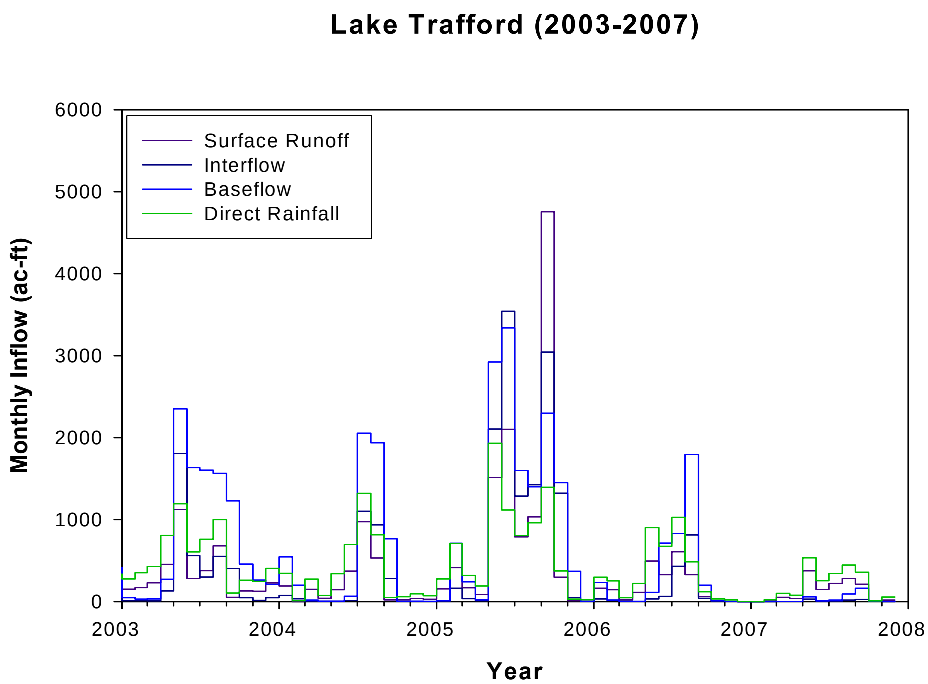

Figure 5.8. Simulated Total Monthly Inflows to Lake Trafford during the Validation Period of 2003-2007.

Table 5.3. Simulated Total Annual Inflows and Outflows (ac-ft) to and from Lake Trafford during the Calibration and Validation Period of 1998-2007.

Year	Surface Runoff (ac-ft)	Interflow (ac-ft)	Baseflow (ac-ft)	Direct Precipitation (ac-ft)	Evaporation (ac-ft)	Outflow (ac-ft)	Change in Lake Volume (ac-ft)
1998	3203	2452	4769	5527	-6884	-12505	-3,438
1999	8031	12209	12433	7003	-6671	-33370	-365
2000	4943	5335	7294	4948	-7204	-15603	-288
2001	10145	14395	12844	7718	-7295	-37503	304
2002	3866	3766	6132	5553	-7067	-11957	292
2003	3975	4007	9902	6376	-6863	-17359	39
2004	2715	2503	5820	4494	-7205	-9063	-736
2005	11355	12985	14372	8180	-7385	-38634	872
2006	2287	1444	3921	4110	-7345	-5555	-1,138
2007	1357	92	345	2204	-6140	-3	-2,144
Average	5,188	5,919	7,783	5,611	-7,006	-18,155	-660

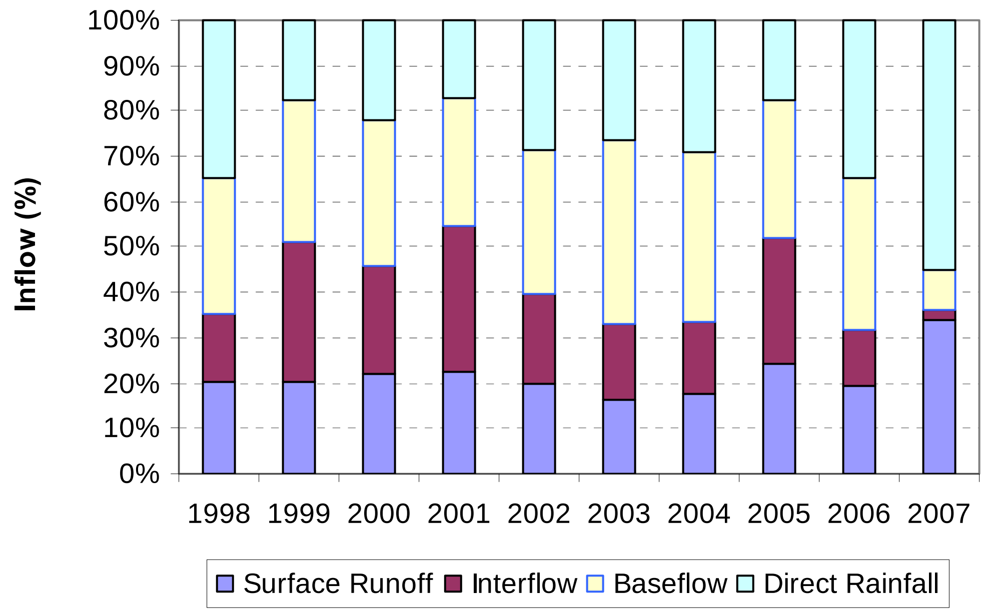

Figure 5.9. **Relative Importance of Total Annual Inflows of Surface Runoff, Interflow, Baseflow and Direct Rainfall to Lake Trafford during 1998-2007.**

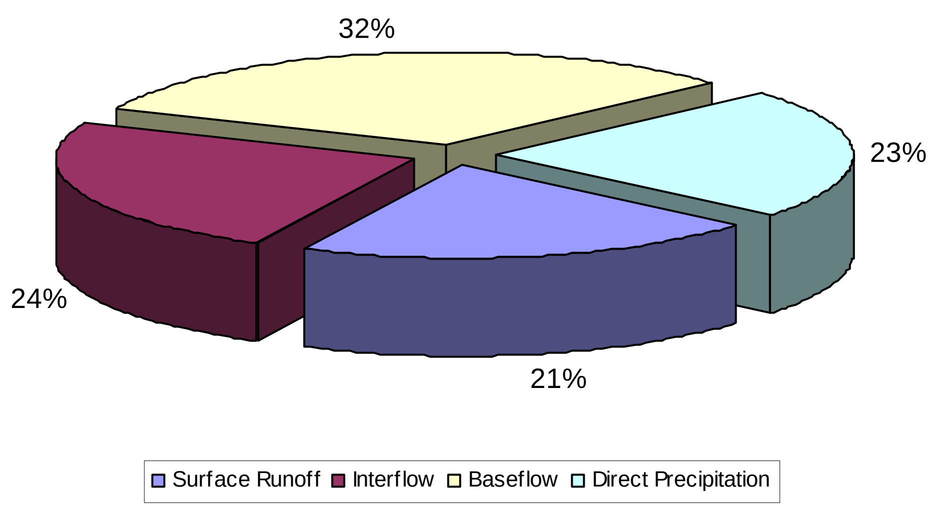

Figure 5.10. **Percent Inflows of Surface Runoff, Interflow, Baseflow and Direct Rainfall to Lake Trafford over the 10-yr period.**

Lake Trafford Existing Land Use Loadings

The total existing land use loadings of nitrogen and phosphorus to Lake Trafford were estimated using the HSPF model. The watershed loads were calculated from the HSPF PERLND and IMPLND flows and the corresponding concentrations of each land use category. Interflow and baseflow concentration data of the water quality parameters of interest for this study are limited for the period of simulation. The two sample collections (October 9, 2006 and March 19, 2007) obtained from the station Well C -01078, located in a residential area, were available for nutrient analyses. These well nutrient data provided by Collier County were incorporated into the model simulation for interflow and baseflow nutrient loads. **Table 5.4** presents input parameters that include assigned potency factors, interflow concentrations, and baseflow concentrations for model calibration. For values showing ranges, the lower end of the ranges are applicable for undeveloped areas (e.g., forest, wetland), whereas the higher end of the ranges are applicable for developed areas (agricultural, residential, and commercial/industrial). To the extent possible, average concentrations calculated from available data were used. However, given the uncertainty, ground water concentrations were estimated during the model calibration process to help match measured data and predicted model results. Dissolved oxygen concentrations associated with the pollutant loads were estimated using saturation concentrations calculated from daily average air temperatures.

Table 5.4. HSPF Input Parameters for Potency Factor and Concentrations of Water Quality Constituent in Interflow and Baseflow

HSPF Input Parameter	Water Quality Constituent				
	Ortho P	Ammonia N	Nitrate N	CBOD	Refractory Organic N
Interflow Concentration (mg/l)	0.03 - 0.45	0.03 - 0.48	0.01 - 0.23	1.5 - 19	0.7 - 1.87
Baseflow Concentration (mg/l)	0.02 - 0.24	0.02 - 0.05	0.01 - 0.12	1.5 - 3.0	0.6 - 1.5
Potency Factor (lb/ton sediment)	3.4	0.1	0.2	130	14

Nonpoint source loads of TN and TP were simulated for the existing conditions of the Lake Trafford Watershed, as shown in **Figures 5.11** through **5.16,** and in **Tables 5.5** and **5.6**. TN and TP loading coefficients for different land use types were estimated to make sure that calibrated loading rates of TN and TP from each land use are reasonable. **Figure 5.11** and **Figure 5.13** show the estimated average loading rates of TN and TP from the nine land use categories over the calibration and validation period. As expected, greatest export coefficients of TN and TP were found for commercial, with 41.7 lbs/ac/yr for TN and 1.99 lbs/ac/yr for TP. For forest, loading coefficients of TN and TP were estimated to be 2.0 lbs/ac/yr and 0.10 lbs/ac/yr, respectively. For cropland and tree crops, the TN and TP coefficients were 8.1 lbs/ac/yr and 1.41 lbs/ac/yr. These estimated coefficients are comparable to those used for another study (Frink, 1991) with the TN load coefficients of 2.1 ± 0.4 lbs/ac/yr for forest, 6.8 ± 2.0 lbs/ac/yr for agricultural, indicating the values used here are comparable.

Figure 5.12 and **Figure 5.14** show the annual average TN and TP loads from the existing land use to Lake Trafford, indicating cropland and tree corps are the major contributors supplying annual TN loads of 53,027 lbs/yr and annual TP loads of 9,184 lbs/yr. These TN and TP loads account for about 37% of the total TN loads and about 63% of the total TP loads to the lake during the simulation period. Under the existing conditions, simulated long term daily loads of TN and TP to Lake Trafford were estimated to be 420.1 lb/day and 40.9 lb/day, respectively (**Table 5.5** and **Table 5.6**). Based on the model results, there is an annual pattern showing that existing TN and TP loads are strongly associated with annual rainfall. For example, greater nutrient loads were found during wet years especially in 2001 and 2005. Overall, rainfall-driven runoff such as surface runoff and interflow are the most important means to deliver TN and TP to the lake, accounting for about 70% of the total loads while TN and TP loads via baseflow comprise of 22% and 28%, respectively (**Figure 5.15** and **Figure 16**).

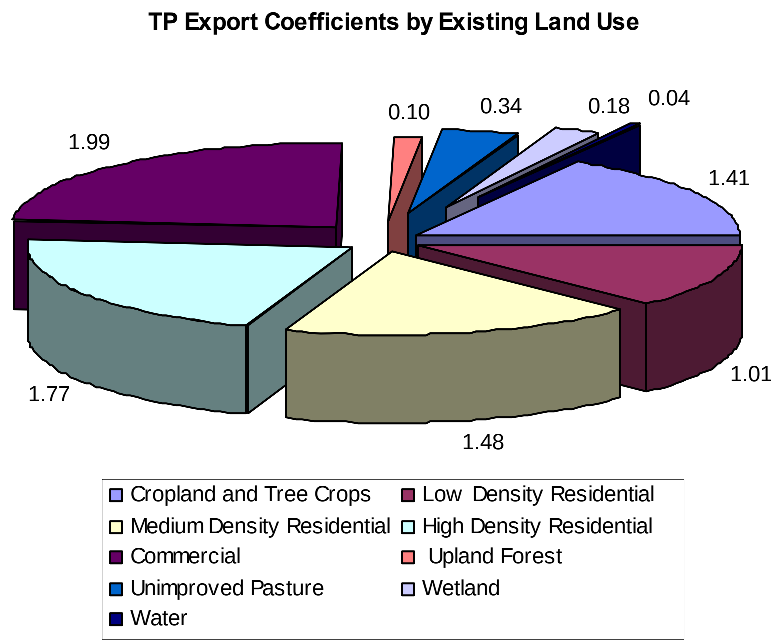

Figure 5.11. Average TP Export Coefficients (lb/ac/yr) of Different Land Use Types to Lake Trafford over the 10-yr period.

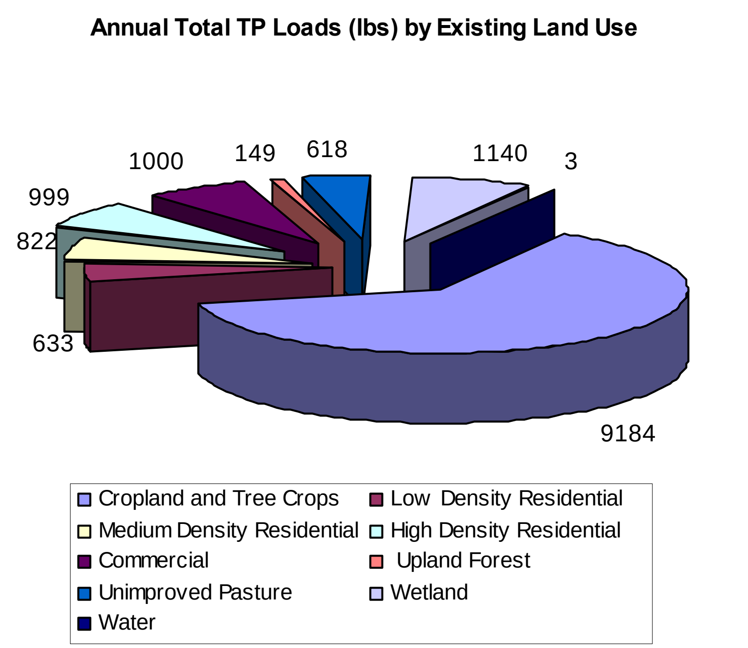

Figure 5.12. Annual Average TP Loads (lbs/yr) from Different Land Use Types to Lake Trafford over the 10-yr period.

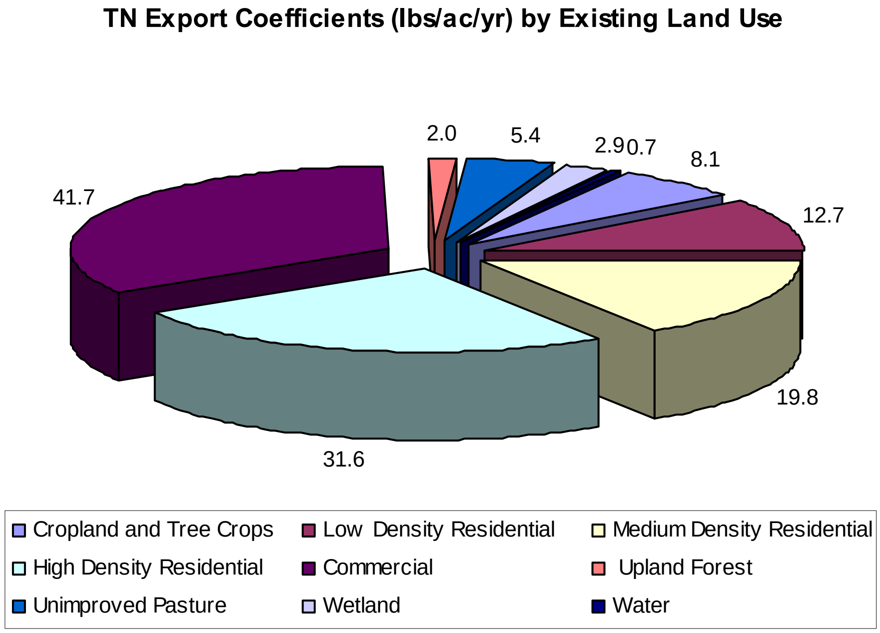

Figure 5.13. Average TN Export Coefficients of Different Land Use Types to Lake Trafford over the 10-yr Period.

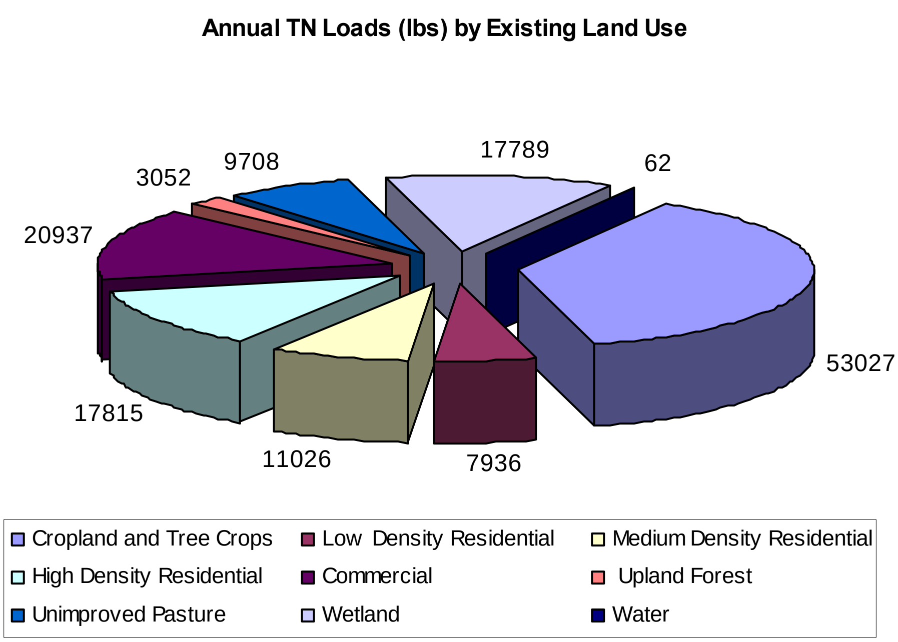

Figure 5.14. Annual Average TN Loads from Different Land Use Types to Lake Trafford over the 10-yr Period.

Table 5.5. Simulated Average Daily Loads of TN to Lake Trafford from the Existing Land Use during the Calibration and Validation Period of 1998-2007.

Year	Total N				
	Surface Runoff	Interflow	Baseflow	Direct Precipitation	Total
	(lb/day)	(lb/day)	(lb/day)	(lb/day)	(lb/day)
1998	135.3	42.3	57.2	31.7	266.5
1999	225.8	193.8	146.1	40.3	606.0
2000	213.0	82.9	83.7	28.6	408.2
2001	312.8	232.5	150.8	44.5	740.4
2002	161.7	59.1	71.9	32.0	324.6
2003	159.1	52.2	117.1	36.6	365.1
2004	143.7	36.6	67.5	25.8	273.6
2005	443.3	209.4	165.8	47.3	865.8
2006	124.7	20.8	46.9	23.6	216.1
2007	116.5	1.0	4.5	12.8	134.9
Average	203.6	93.1	91.1	32.3	420.1

Table 5.6. Simulated Average Daily Loads of TP to Lake Trafford from the Existing Land Use during the Calibration and Validation Period of 1998-2007.

Year	Total P				
	Surface Runoff	Interflow	Baseflow	Direct Precipitation	Total
	(lb/day)	(lb/day)	(lb/day)	(lb/day)	(lb/day)
1998	7.2	7.3	7.4	0.9	22.8
1999	14.7	32.3	18.4	1.2	66.5
2000	15.8	13.9	10.5	0.9	41.0
2001	24.9	38.7	18.9	1.3	83.9
2002	7.7	9.9	9.1	1.0	27.6
2003	7.2	8.5	14.9	1.1	31.6
2004	5.9	6.1	8.5	0.8	21.3
2005	36.1	34.8	20.7	1.4	93.0
2006	5.0	3.5	6.0	0.7	15.2
2007	4.5	0.1	0.6	0.4	5.6
Average	12.9	15.5	11.5	1.0	40.9

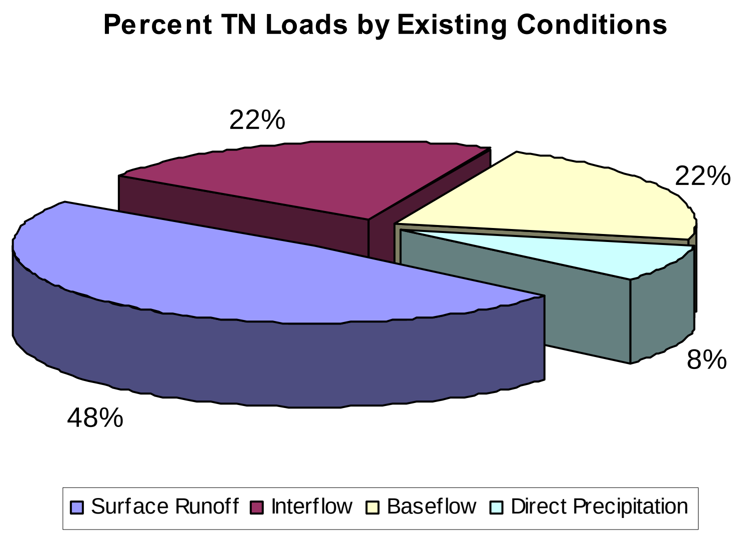

Figure 5.15. Percent Average Daily TN Loads via Surface Runoff, Interflow, Baseflow and Direct Rainfall to Lake Trafford over the 10-yr Period under the Existing Condition.

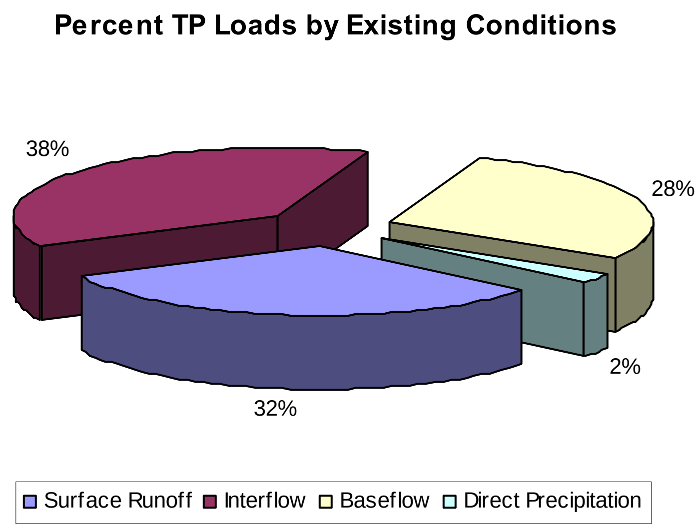

Figure 5.16. Percent Daily TP Loads via Surface Runoff, Interflow, Baseflow and Direct Rainfall to Lake Trafford over the 10-yr Period under the Existing Condition.

Water Quality Calibration for Lake Trafford

Water quality monitoring stations in Lake Trafford were used for calibration purposes. A total of 50 water quality stations are listed in FL STORET. However, monthly water quality data were collected from only 9 stations (as shown in **Table 5.7)** for all parameters of interest over the calibration and validation period (January 1, 1998 through December 31, 2007).

Table 5.7. General Information on Water Quality Stations during the Calibration and Validation Period of 1998-2007.

Station	Latitude	Longitude	Number of Observation	Start Date	End Date
21FLCOLLLKTRAF1	26.4329	-81.4863	2097	1996	2007
21FLCOLLLKTRAF2	26.4355	-81.4951	2094	1996	2007
21FLCOLLLKTRAF3	26.4281	-81.4949	2088	1996	2007
21FLCOLLLKTRAF4	26.4152	-81.4990	2146	1996	2007
21FLCOLLLKTRAF5	26.4095	-81.4934	2099	1996	2007
21FLCOLLLKTRAF6	26.4292	-81.4829	1107	1999	2007
21FLCOLLLKTRAF7	26.4266	-81.4810	1108	1999	2007
21FLCOLLLKTRAF8	26.4216	-81.4783	943	1999	2007
21FLGW 3496	26.4231	-81.4934	2309	1998	2004

The model calibration is used to compare simulated water quality parameters to the observed data obtained from these water quality stations. Prior to calibrating water quality parameters of interest, it is appropriate to make sure that sediment loads simulated by the model for the lake are properly calibrated against the observed TSS. This is because the water quality parameters of interest are often associated with fine suspended sediments and sediment delivered from the land surface is considered as one of the most common constituents washed off from different types of land use. In order to properly estimate the budgets of pollutants (e.g., phosphorus or trace metals) that are associated with sediment, it is reasonable to calibrate sediment particle loads prior to calibration for the pollutants of interest, so that their budgets can be properly estimated. A daily simulation for TSS was conducted for Lake Trafford to help calibrate water quality parameters of concern. **Figure 5.17** shows the time-series of simulated versus observed TSS for Lake Trafford. The 10-yr mean concentration of the observed TSS is 18.4 ± 15.7 mg/L (n = 102) similar to the simulation with the average of 14.0 ± 6.9 mg/L (n = 3652). Overall, the predicted TSS for the lake showed reasonable agreement with the observed pattern and quantity.

As the waterbody was impaired for nutrients, un-ionized ammonia, and dissolved oxygen, the model calibration for water quality focused on nutrients (un-ionized ammonia is part of the nutrient calibration) and DO. Time series plots, annual mean concentrations, and box and whisker plots of simulated and observed constituents were shown in **Figures 5.18** through **5.30**.

The time series of simulated Chla for Lake Trafford, plotted against the observed Chla, generally showed a reasonable agreement over the period of calibration and validation (**Figure 5.18**). The model reasonably predicted both the peak concentrations of observed Chla (greater than 200 µg/L) that occurred during the growing season in1999 and 2005 and the lower concentrations of observed Chla that occurred at levels less than 10 µg/L. Although seasonal fluctuations in the observed concentrations, as shown in **Figure 5.19**, were significant, with a coefficient variance of about 91%, the model followed the seasonal pattern of observed Chla. Accordingly, predicted annual mean concentrations for each year agreed with the observed annual mean concentration within one standard error. It should be noted, that the annual mean concentrations for each year were calculated based on the four quarterly means for the same year. The years 2006 and 2007 did not have data from each calendar quarter, so annual means could not be calculated. The box and whisker plots also indicate that the mean, median, and distribution percentiles of simulated Chla over the period of simulation were very similar to those of the observed Chla (**Figure 5.20**). There were excellent agreements in mean, median, 10^{th} and 90^{th} percentiles of simulated versus observed Chla. For example, the mean and median for the observed Chla were 53.0 µg/L and 39.4 µg/L, similar to 44.8 µg/L and 31.7 µg/L for the simulated Chla. The 10^{th} and 90^{th} percentiles of the observed Chla values were 7.8 µg/L and 112.5 µg/L, respectively whereas the 10^{th} and 90^{th} percentiles of the simulated values in the range were 11.2 µg/L and 94.9 µg/L, respectively. Overall, the results of statistical analyses between simulated versus observed Chla indicated that the model prediction of existing conditions was acceptable.

There is an acceptable agreement between the observed TN and the simulated TN as shown in **Figure 5.21** through **Figure 5.23**. The time series of simulated TN over the calibration and validation period reasonably predicted peak and base concentrations of the observed TN concentrations, although, there are only limited observed water quality data available in 2006 and 2007. In **Figure 5.22**, annual averages for years 1998, 2006, and 2007 could not be determined due to insufficient data to calculate quarterly means for each quarter of those years. Based on the box and whisker plot, mean, median, and distribution percentiles of simulated TN matched to those of observed TN (**Figure 5.23**). The 10-yr mean and median for the observed TN were 2.60 mg/L and 2.34 mg/L, similar to the 2.38 mg/L and 2.14 mg/L for the simulated TN. The 10^{th} and 90^{th} percentiles of the observed TN were 1.7 mg/L and 3.8 mg/L, respectively. Similarly, the 10^{th} and 90^{th} percentiles of the simulated TN values were 1.7 mg/L and 3.3 mg/L, respectively. Following the same procedures, the time series of simulated TP was calibrated against the observed TP (**Figure 5.24**). Compared to the simulated time series of TP, the observed TP showed a wide range of variation in concentration over the period. For example, a mean concentration of the observed TP in 2002 was 0.223 mg/L with the coefficient of variance of about 70%. Whereas the annual mean of 0.180 mg/L was simulated by the model, with a coefficient of variance of about 35%. The box and whisker plot for TP also indicated that the mean and median between simulation and observation are in good agreement, in contrast to the values for the 10^{th} and 90^{th} percentiles (**Figure 5.26**). Peak concentrations of TN and TP in 2007 are possibly associated with the lowest simulated water volume and the lowest Chla production in that year.

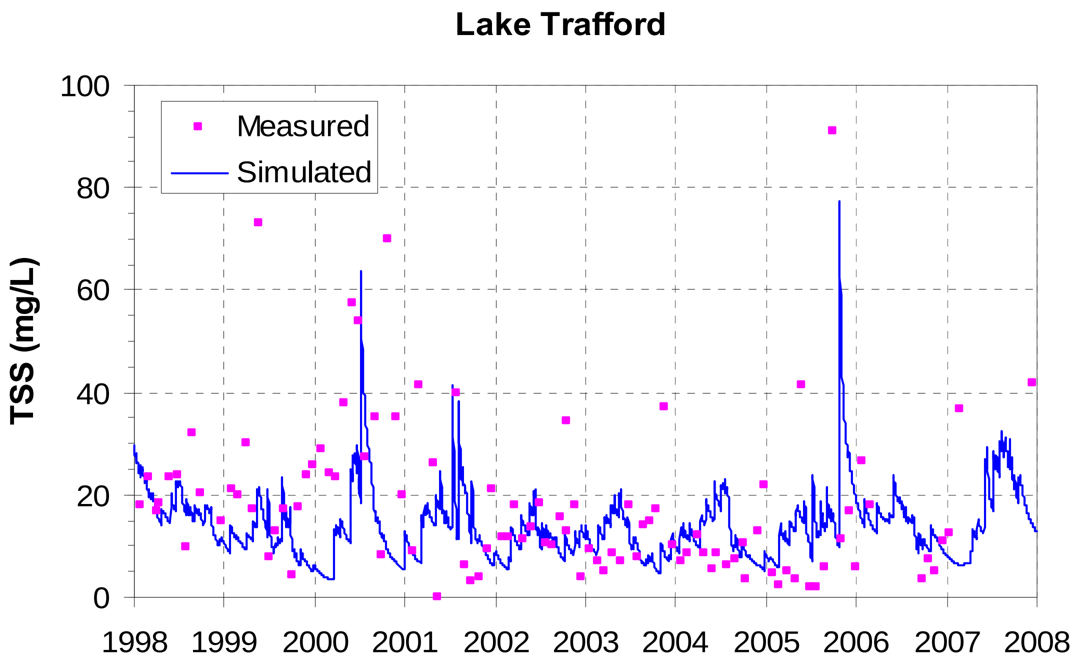

Figure 5.17 Time Series of Simulated versus Observed Total Suspended Solid (TSS) Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007

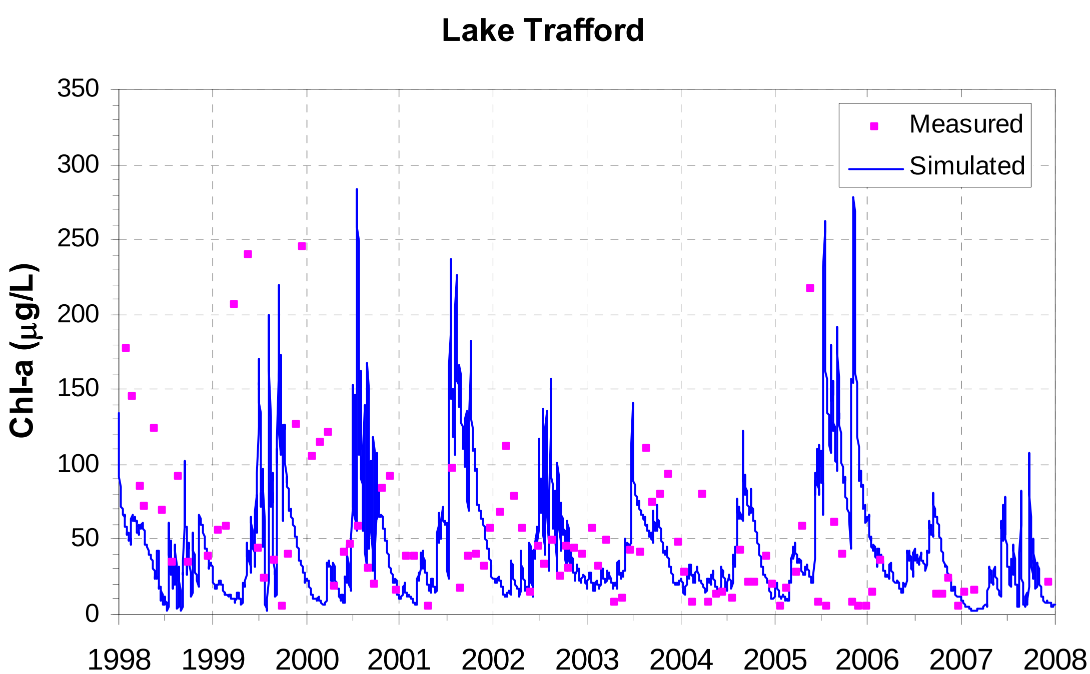

Figure 5.18 Time Series of Simulated versus Observed Chla Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007

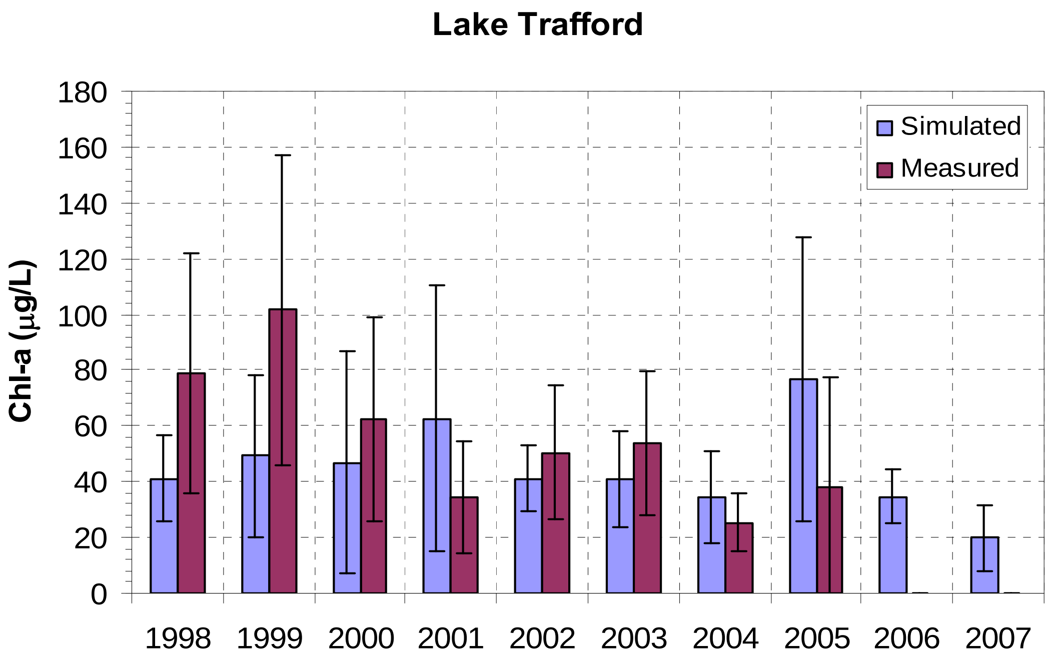

Figure 5.19 Annual Averages of Simulated versus Observed Chla Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007. Error Bars represent 1-sigma standard deviation.

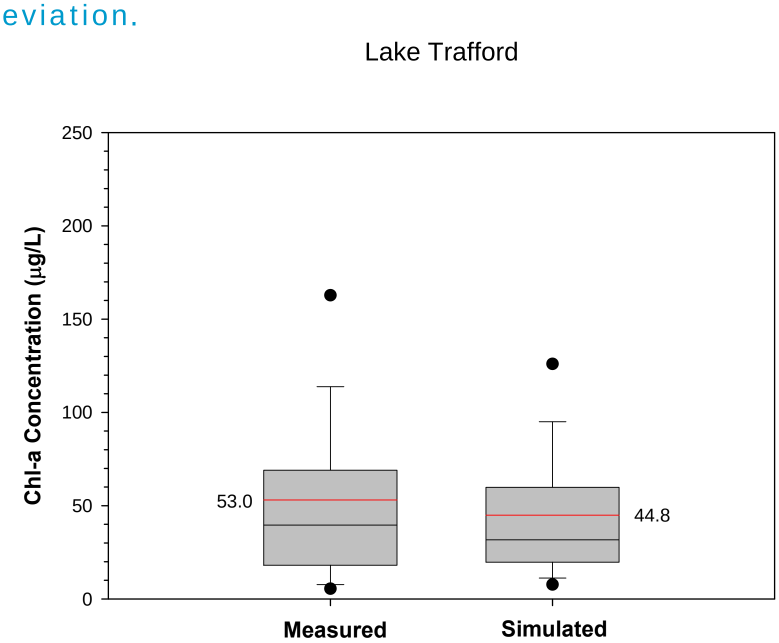

Figure 5.20 Box and Whisker Plot of Simulated versus Observed Chla Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007. Red Lines with Values Represent Mean Concentrations of Each Series.

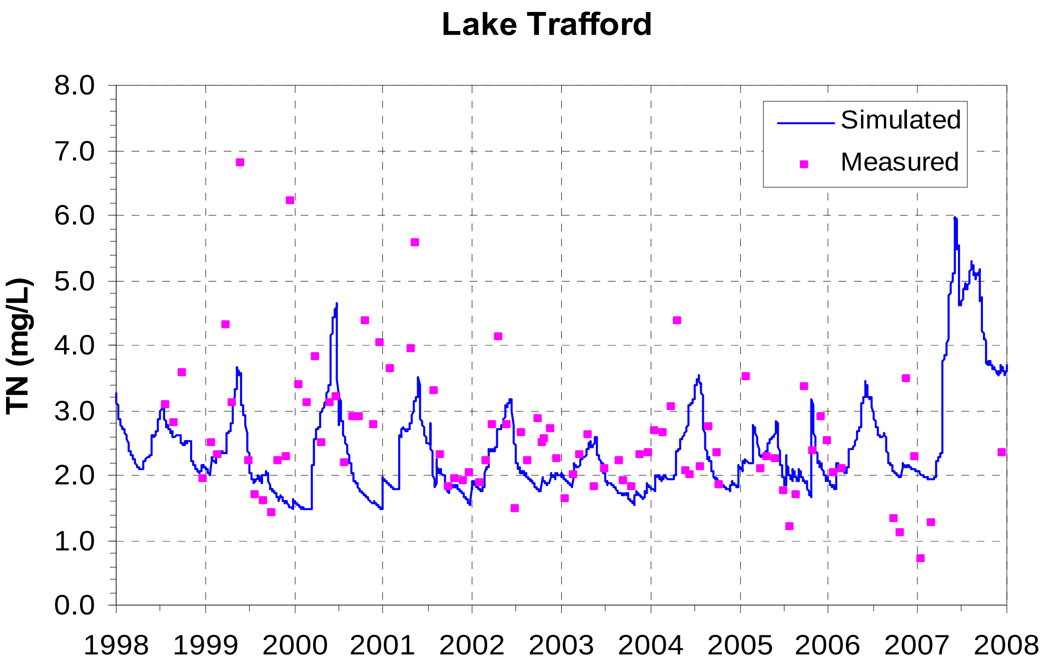

Figure 5.21 Time Series of Simulated versus Observed TN Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007

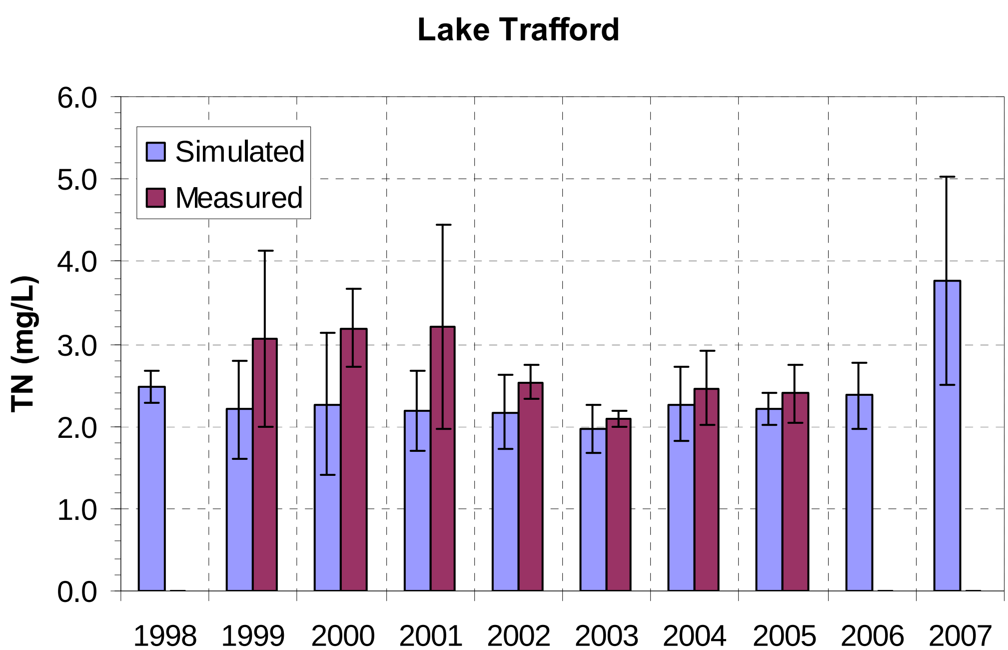

Figure 5.22 Annual Averages of Simulated versus Observed TN Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007. Error Bars represent 1-sigma standard deviation.

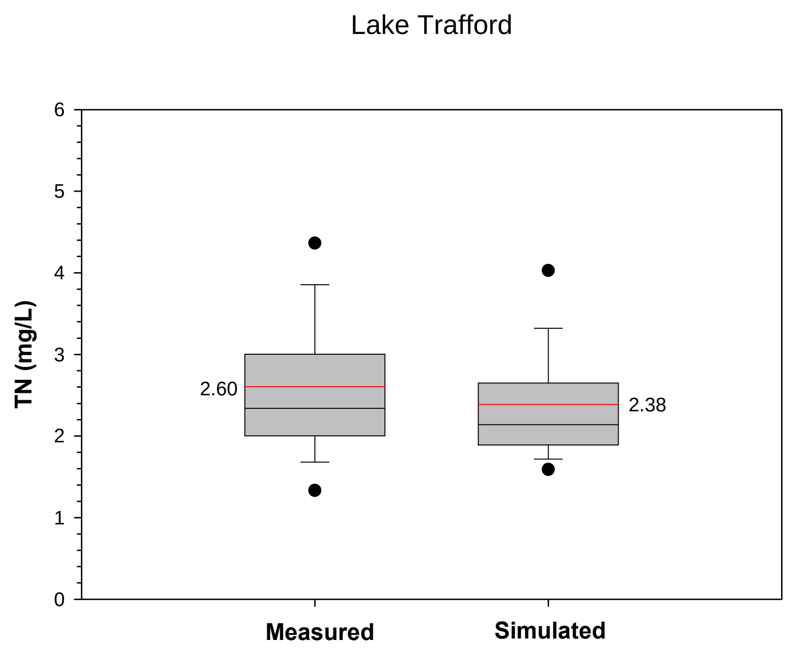

Figure 5.23 Box and Whisker Plot of Simulated versus Observed TN Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007. Red Lines with Values Represent Mean Concentrations of Each Series.

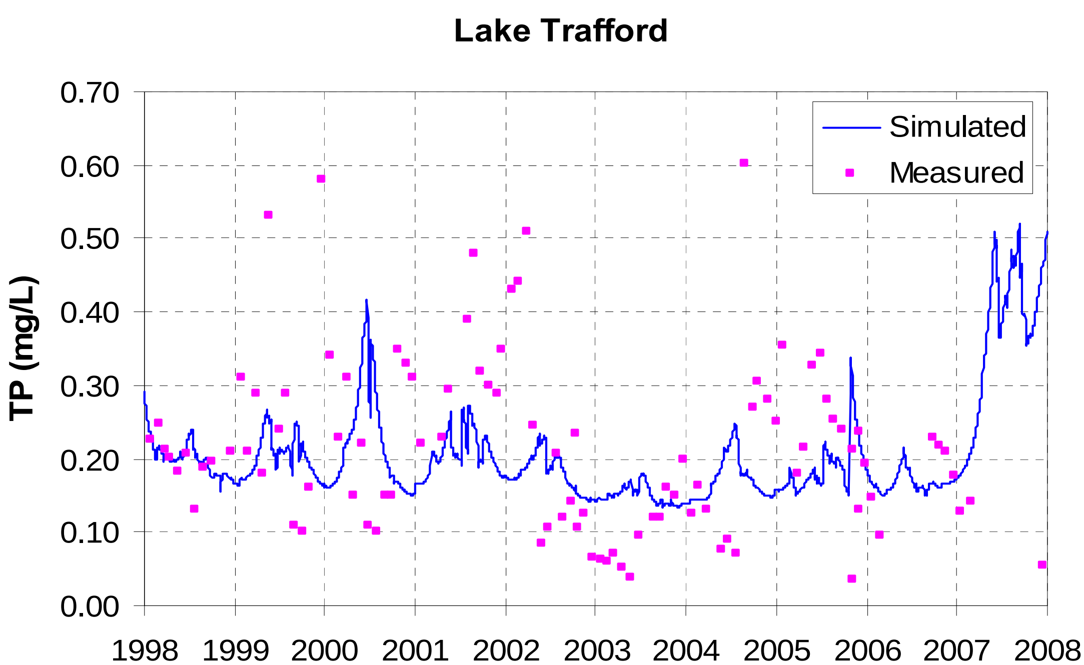

Figure 5.24 Time Series of Simulated versus Observed TP Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007

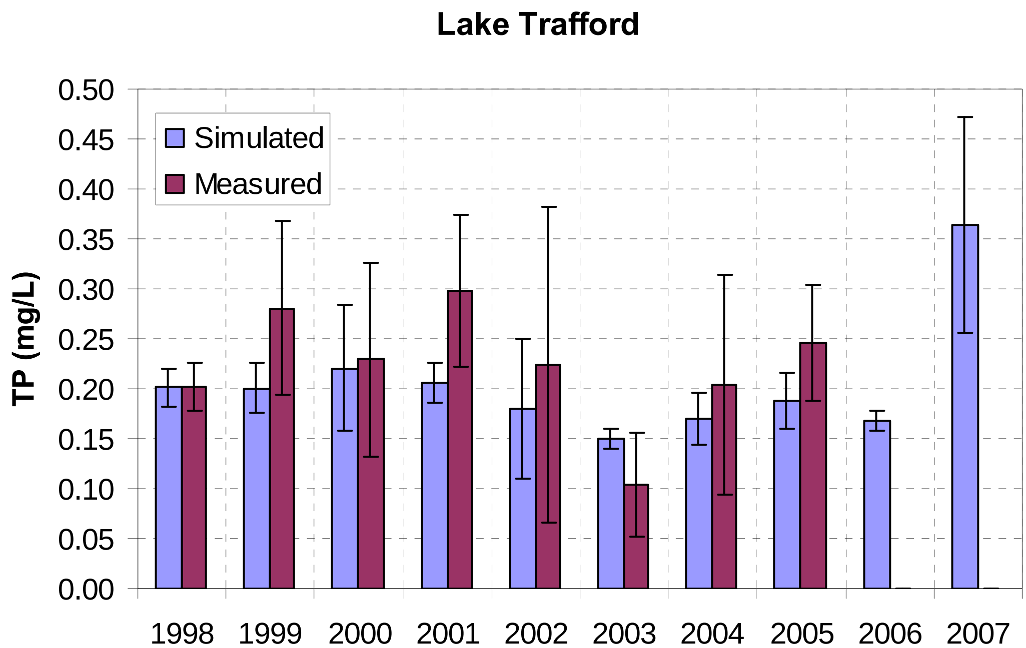

Figure 5.25 Annual Averages of Simulated versus Observed TP Concentrations. Error Bars represent 1-sigma standard deviation.

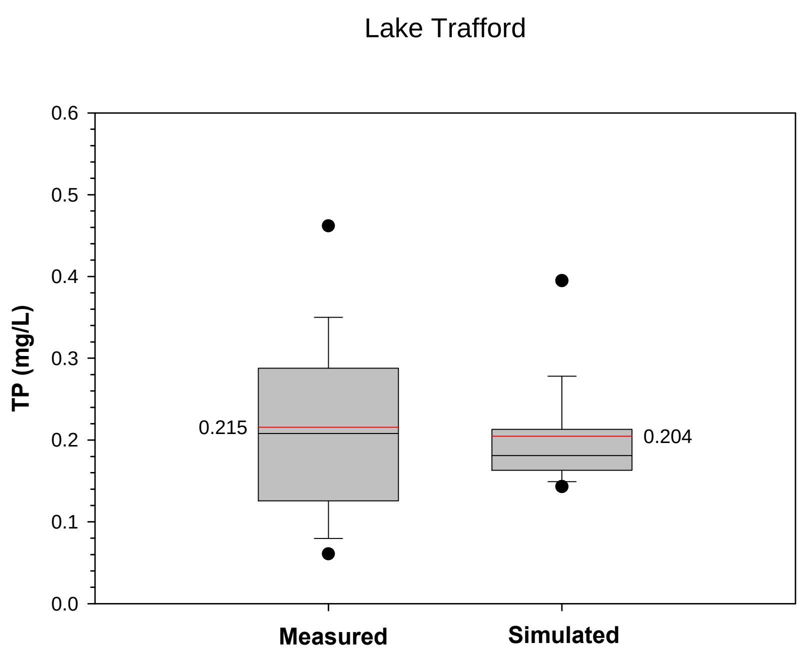

Figure 5.26 Box and Whisker Plot of Simulated versus Observed TP Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007. Red Lines with Values Represent Mean Concentrations of Each Series.

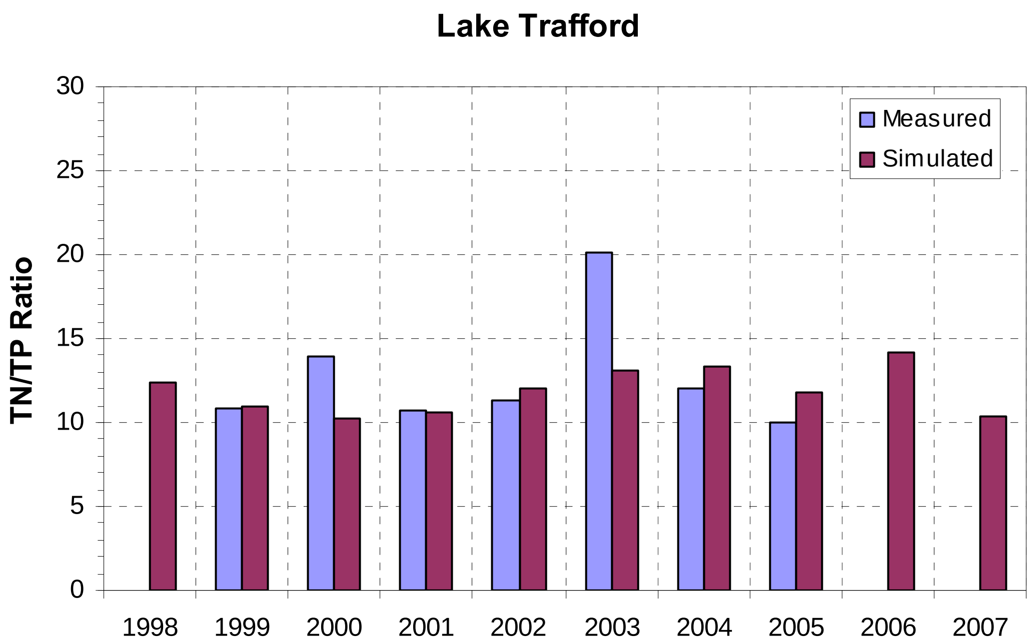

Figure 5.27 Annual Average of Simulated versus Observed TN/TP Ratios in Lake Trafford from January 1, 1998 to December 31, 2007

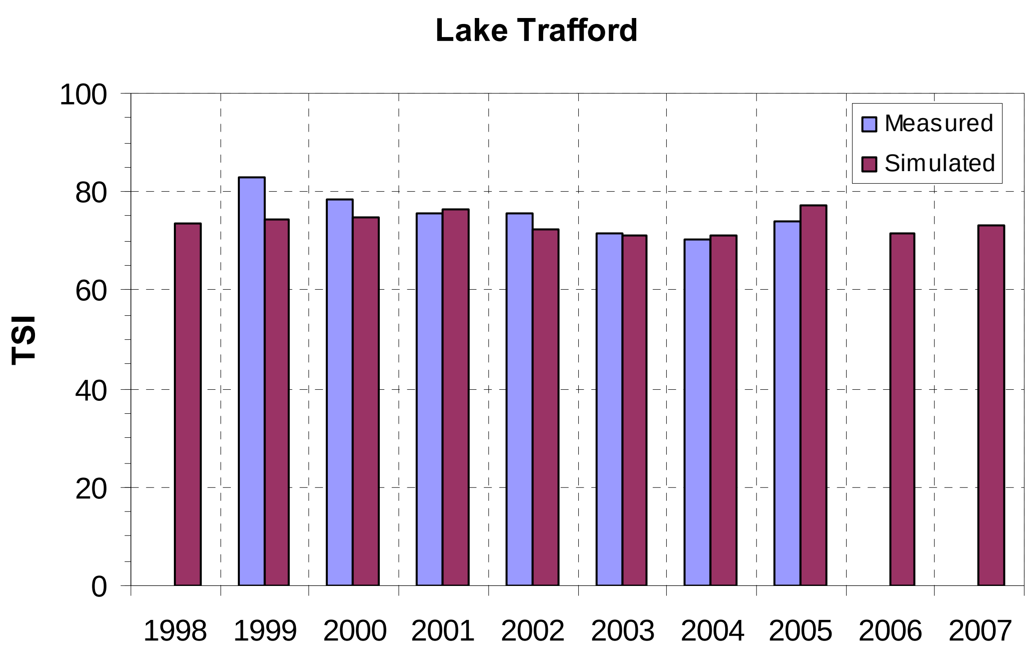

Figure 5.28 Simulated versus Observed Trophic State Index (TSI) in Lake Trafford from January 1, 1998 to December 31, 2007

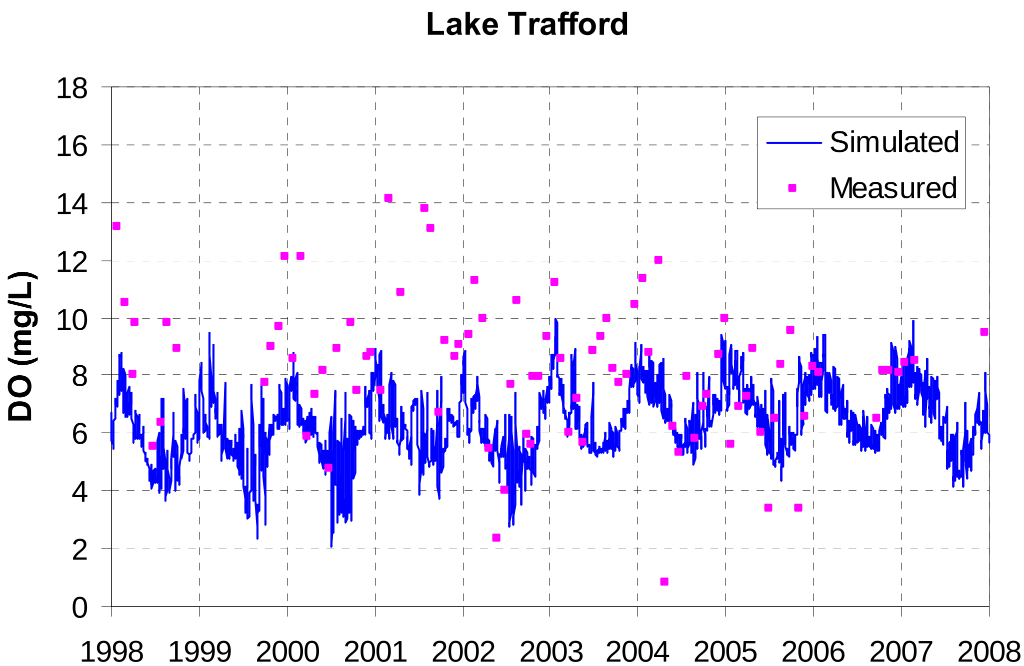

Figure 5.29 Time Series of Simulated versus Observed DO Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007

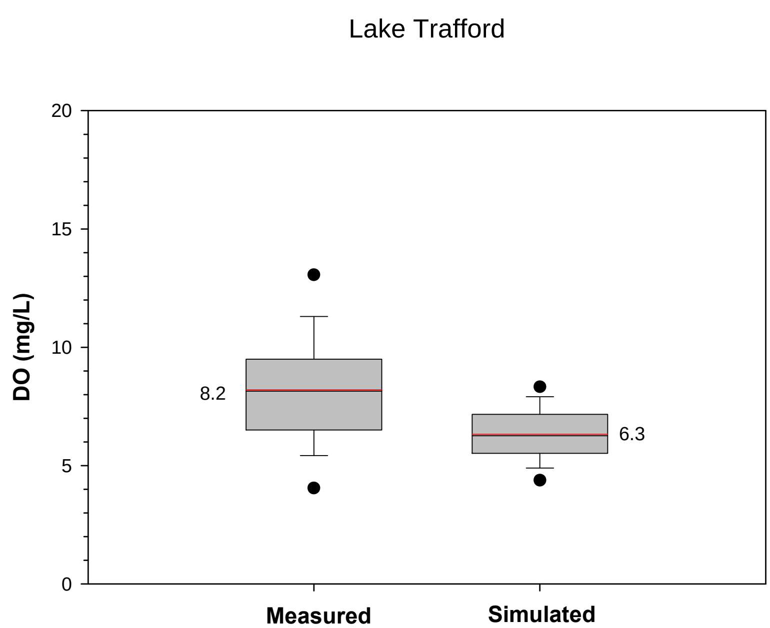

Figure 5.30 Box and Whisker Plot of Simulated versus Observed DO Concentrations in Lake Trafford from January 1, 1998 to December 31, 2007. Red Lines with Values Represent Mean Concentrations of Each Series.

An annual mean ratio of TN/TP in the water column also was estimated to calculate lake TSI (**Figure 5.27**). It is reasonable to make sure that the model predictions of the nutrition status of the lake match the ratios of the observed data. Both simulated and observed TN/TP ratios ranged from 10 to 20, indicating that the lake has been co-limited for the 10-yr period. Annual TSI's were calculated based on the annual TN/TP ratio for each year (**Figure 5.28**). The simulated TSI for the lake ranged from 71.1 to 76.3 with the 10-yr average of 73.6 ± 2.1 (n = 10). This long term predicted average TSI agreed with the 7-yr average observed TSI of 75.5 ± 4.1 (n = 7), indicating that the model calibration is acceptable.

For DO calibration, a time series plot and a box and whisker plot of the simulated and observed DO are shown in **Figure 5.29** and **Figure 5.30**. As discussed, there are monthly observed DO data available from nine water quality stations. In general, most of observed DO data were collected from surface water (<0.5 ft), while the model considers the lake water column as a single well-mixed layer. In many cases, the model did not predict the oversaturated DO levels measured at the surface of the lake (exceeding 8 mg/L). However, the seasonal pattern of simulated DO follows the observed DO. More importantly, the model reasonably predicted the lower portion of observed DO, as supported by the fact that the 10^{th} percentile (5.4 mg/L) of observed DO is similar to that (4.9 mg/L) of simulated DO. This means that the model reasonably responded to the DO consumption processes that created the DO impairment of the waterbody.

5.1.3 Background Conditions

HSPF Model

HSPF was used to describe and evaluate the “natural land use background condition” for the Lake Trafford watershed. For this simulation, all current land uses were ‘reassigned’ to a mixture of forest, wetland, and water. The GIS coverage titled SWFFS Pre-Development Vegetation was downloaded from the SFWMD web site. All of the various vegetation categories in the coverage were aggregated using the 1999 FLUCCS codes into the categories included in the model. Based on the FLUCCS codes, all vegetation communities were aggregated into forest, wetlands, and water as shown in **Table 5.8** (lake acreage not included). The current condition was maintained for all waterbody physical characteristics.

In order to evaluate the in-lake responses to the natural background load reductions, another important re-adjustment for natural land use conditions was to set up the background SOD rate and benthic nutrient flux which would result from the reduced inputs of organic matter to bottom sediments. A common approach for adjusting SOD rate is to use a linear relationship between SOD rate and organic carbon content of sediment related to water column productivity (Chapra, 1997), and has been previously used by the Army Corps of Engineers for the Inland Bays Model and by Hydroqual Inc. for the Appoquinimink Creek model. For Lake Trafford, the algorithm for the linear assumption that reductions in SOD rate and benthic nutrient flux are directly related to reductions in primary productivity is as follows:

$$(\mathbf{SOD})_{\mathbf{nlu}} = (\mathbf{SOD})_{\mathbf{cal}} - \left[\left\{1 - \frac{(\mathbf{Chla})_{\mathbf{nlu}}}{(\mathbf{Chla})_{\mathbf{cur}}}\right\} \times (\mathbf{SOD})_{\mathbf{cal}}\right]$$

where $(\mathbf{SOD})_{\mathbf{nlu}}$ is the rate of SOD (or benthic ammonia and phosphate flux) under the natural land use conditions,

$(\mathbf{Chla})_{\mathbf{nlu}}/(\mathbf{Chla})_{\mathbf{cur}}$ is the ratio of an average concentration of Chla under the natural land use conditions to an average concentration of Chla under the current conditions, and

$(\mathbf{SOD})_{\mathbf{cal}}$ is the rate of SOD (or benthic ammonia and phosphate flux) at which the model was calibrated for DO.

Initially, after the land use reassignments, the sediment oxygen demand and nutrient fluxes remain the same as in the calibrated model. After the model was run with the background land use, the SOD was reduced from 31.4 mg/m^2/hr in the calibrated model to 11.8 mg/m^2/hr based on the reductions in the algal biomass between the current condition and the background condition. From this point forward, the natural land use will be referred to as “background.” As discussed earlier, for existing conditions, the threshold TSI value of 60 is exceeded in all of the ten years of simulation, and the lake is considered co-limited by nitrogen and phosphorus in all years. As can be seen in **Table 5.9**, under background conditions, the lake is considered P-limited (mean TN/TP of 59) and the threshold TSI value of 60 was only exceeded in the first year (1998, spin-up year) of the 10-year simulation. As previously discussed, 2007 is the second of two very dry years. In the model, the lake is drying up, algal growth is severely limited by TP, and the nitrogen concentration increases. The year 1998 was not included in the development of the target TSI, as this year was used to establish antecedent conditions in the lake (spin-up). While atypical, the year 2007 was included in the development of the target TSI to capture the variance the lake would demonstrate under background conditions.

Table 5.8 Natural Land Use Category and Acreage.

FLUCC[1)]	Land Use Category	Acreage (acre)	Percent Acreage (%)
300/400	Undeveloped rangeland/upland forests	9,989.7	54.3
500	Water	92.0	0.5
600	Wetlands	8,311.3	45.2
	Total	18,393.0	100.0

[1)]FLUCC indicates Florida land use, cover and forms classification system (FDOT, 1985)

Table 5.9 Background Model Results for Nutrients

Year	TP (mg/l)	TN (mg/l)	Chla (ug/l)	TSI	TN/TP Ratio	Nutrient Limitation
1998	0.096	1.58	21.7	63.5	16.4	Colimit
1999	0.031	0.89	21.4	55.2	28.9	Colimt
2000	0.020	0.84	17.3	52.5	41.3	TP
2001	0.019	0.88	25.8	54.8	45.5	TP
2002	0.015	0.82	13.9	47.6	54.1	TP
2003	0.015	0.80	17.6	48.9	53.7	TP
2004	0.013	0.83	12.2	44.6	64.5	TP
2005	0.021	0.99	32.3	57.6	46.2	TP
2006	0.011	1.07	9.0	40.4	99.5	TP
2007	0.017	2.47	3.9	39.4	149.2	TP
Average (1999-2007)	0.018	1.07	17.1	51	59.2	TP

5.2 Selection of the TMDL TSI Target

It should be recognized that the direct application of background as the target TSI would not allow for any assimilative capacity. The IWR uses as one measure of impairment in lakes, a 10 unit change in TSI from "historical" levels. This 10 unit increase is assumed to represent the transition of a lake from one trophic state (say mesotrophic) to another nutrient enriched condition (eutrophic). The Department has assumed that allowing a 5 unit increase in TSI over the background condition would prevent a lake from becoming impaired (changing trophic states) and reserve 5 TSI units to allow for future changes in the basin and as part of the implicit margin of safety in establishing the assimilative capacity. Additionally, the TN/TP ratio of the current conditions in the impaired lake indicates co-limitation by both nitrogen and phosphorus in all years (1998-2007) while the TN/TP ratio for the background condition is strong TP limitation. The final nutrient target developed for restoration of Lake Trafford, included both achieving a long-term average TSI of Background plus 5 (**Figure 5.31**) and phosphorus limitation.

The background model run was assessed for the years 1999 – 2007. An annual TSI was calculated for each year. The long-term (1999-2007) average TSI was determined by using the long-term average TN, TP, and Chla to calculate a TSI of 51.0. As has been Department practice, when acceptable background conditions can be established, the target for TMDL development becomes the background TSI, plus 5 TSI units. This establishes the target TSI for Lake Trafford as 56.0 (51.0 + 5 TSI units).

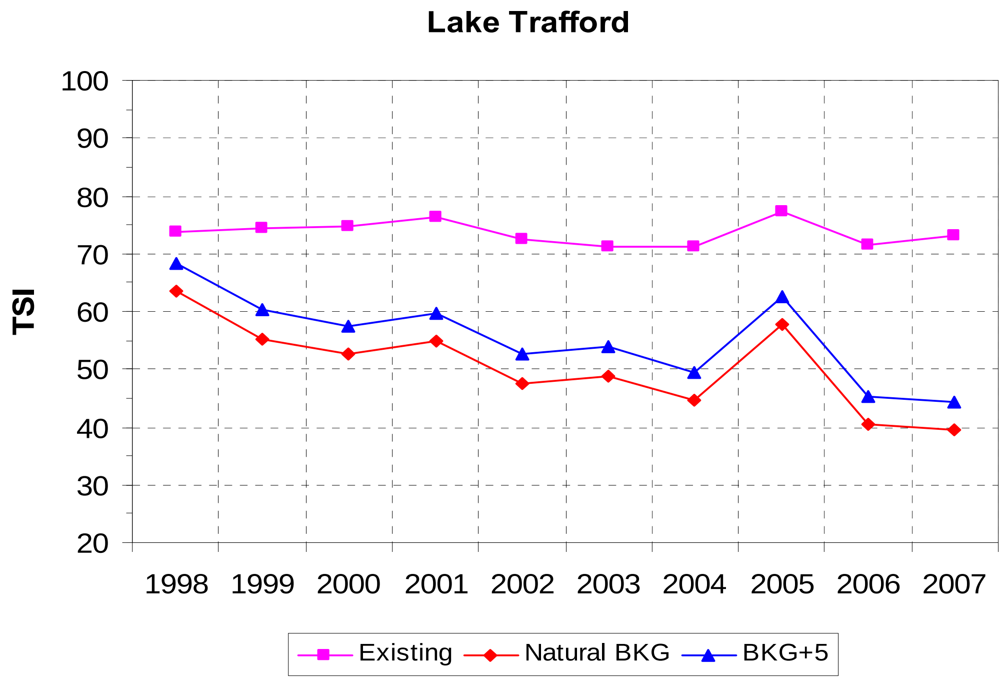

Figure 5.31 TSI for Existing, Background, and Background+5, from 1998 to 2007.

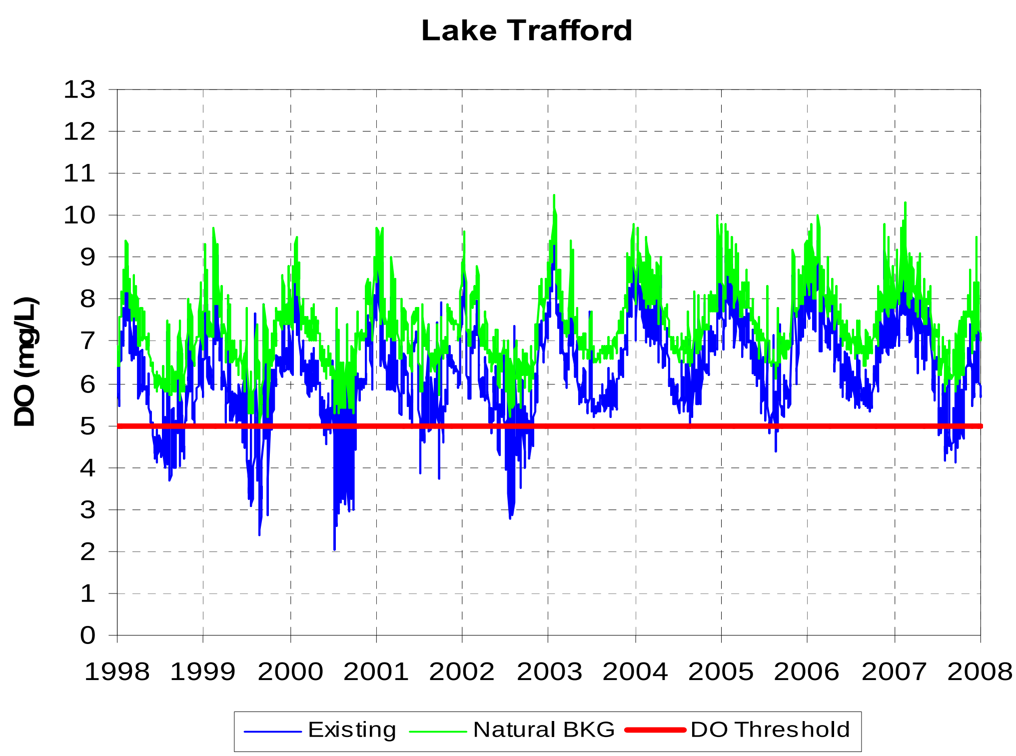

Figure 5.32 Existing (Calibrated) and Background DO.

Once the target TSI of 56.0 was established, HSPF was rerun for existing conditions (simulation run) with decreasing loads for runoff, interflow, and baseflow until the both the long-term average target TSI was met and phosphorus limitation was achieved. One feature of HSPF is that the CBOD has associated concentrations of organic N and organic P. Consequently, the TN concentration is equal to the sum of ammonia N, nitrate N, refractory organic N, and a fraction of the CBOD concentration. Similarly, the TP concentration is equal to the sum of ortho P and a fraction of the CBOD concentration. As a result, reductions in these fractions of nutrients associated with CBOD were also included in the model. Additionally, reductions were made to total suspended solids. The results from each series of reductions were compared to the TSI target, nutrient limitations, and background concentrations (to ensure that the load reduction did not result in water quality better than the background conditions).

Background Total Ammonia

The HSPF model was not set up to model pH. Therefore, un-ionized ammonia could not be calculated for the model results. Compliance with the un-ionized ammonia criterion will be discussed in Chapter 6.

Background Dissolved Oxygen

As can be seen on **Figure 5.32**, the model predicts that under the background land use, dissolved oxygen (DO) is above the criterion value of 5.0 mg/L. For current conditions (simulation), the range in DO is 2.1 – 11.1 mg/L, with an average of 6.7 mg/L. For background conditions, the range was 5.0 – 10.5 mg/L, with an average of 7.4 mg/L.

5.3 Simulations for TMDL Load Reductions

A series of scenario simulations was accomplished to develop the TMDL for Lake Trafford, by iteratively reducing nutrient loads from the watershed to the lake. In-lake conditions, such as SOD and benthic flux were also adjusted based on the previous equation so that the series of scenario load reductions from the watershed would reflect in-lake conditions accordingly.

Annual Chla, TN, and TP and the time series for DO depicting the response to the selected load reductions are presented and compared with those of current and background simulations in **Figures 5.33** through **5.36**. The serial reductions in loadings were repeated until the load reduction resulted in the lake meeting the requirements of the TSI target (56) and the DO threshold (5.0 mg/L). In addition, the load reduction strategy focused on making phosphorus the limiting nutrient, as shown by the desirable TN/TP ratio under the background condition. Results of the load reduction scenario with 60% for TN and 77% for TP not only met the long-term TSI target, but also met the DO threshold of 5.0 mg/L throughout the simulation period (as shown on **Figure 5.37**). The recommended load reductions to achieve the long-term TSI of 56 resulted in a long-term average Chla of 19.04 ug/L, TN of 1.09 mg/L, TP of 0.025 mg/L, and a TN/TP ratio of 44. Therefore, it was decided that the load reduction with 60% TN and 77% for TP, which met both DO and TSI targets, will best represent the assimilative capacity for the waterbody, resulting in achieving aquatic life-based water quality criteria.

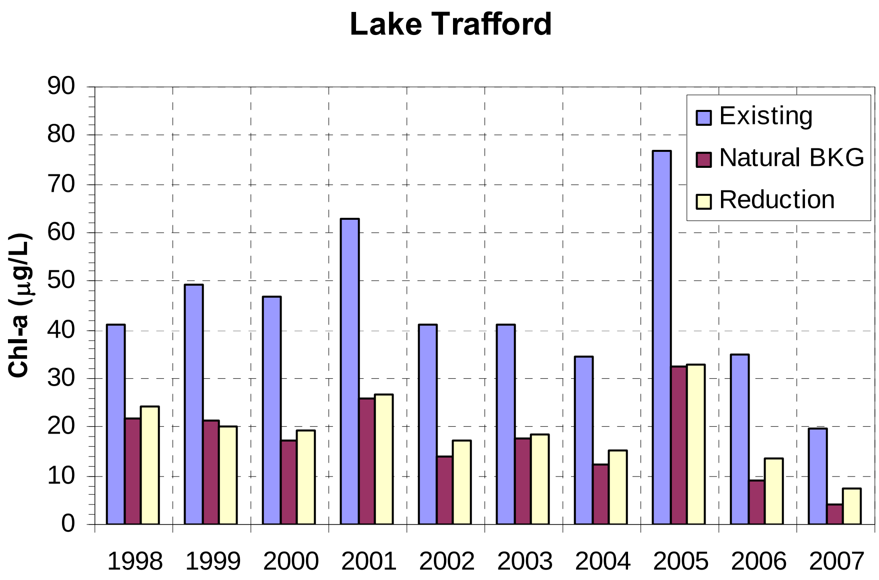

Figure 5.33 Annual Chla of Existing (Calibrated), Background and Load Reduction.

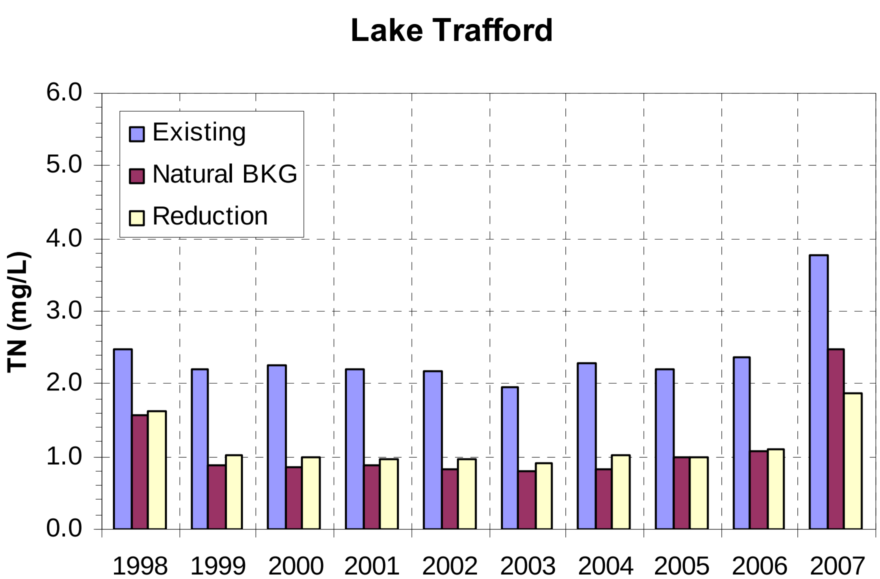

Figure 5.34 Annual TN of Existing (Calibrated), Background and Load Reduction.

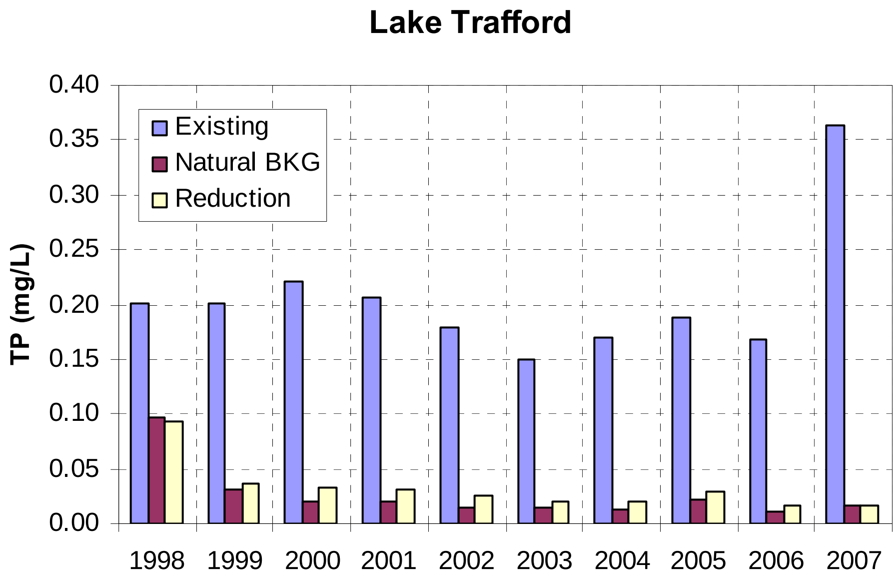

Figure 5.35 Annual TP of Existing (Calibrated), Background and Load Reduction.

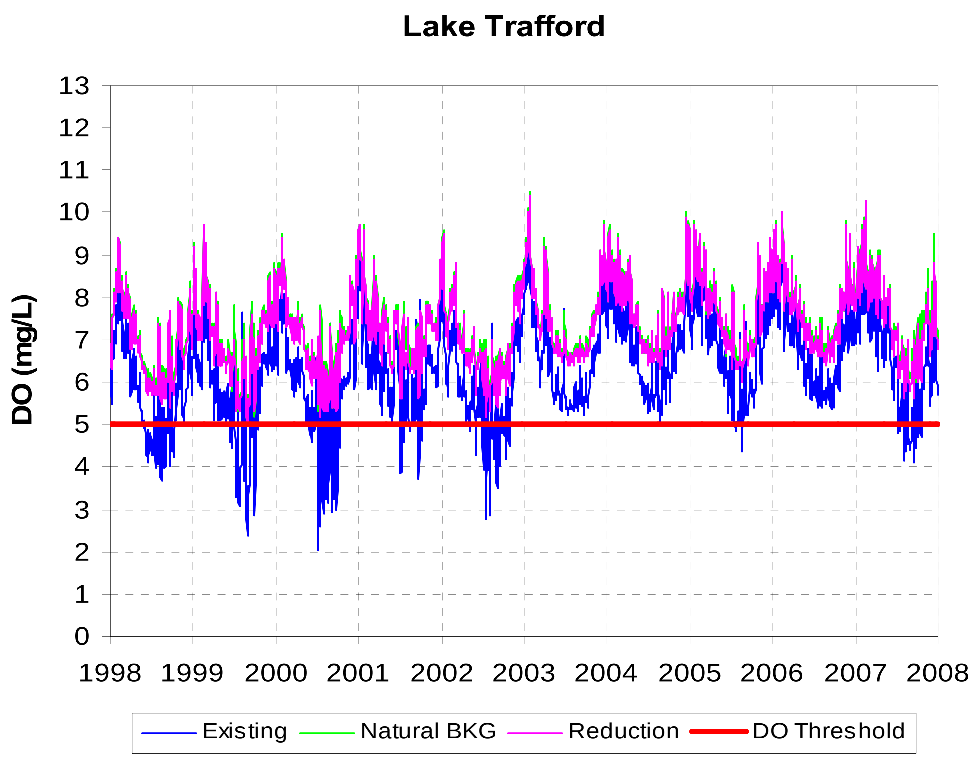

Figure 5.36 Daily DO of Existing (Calibrated), Background and Load Reduction.

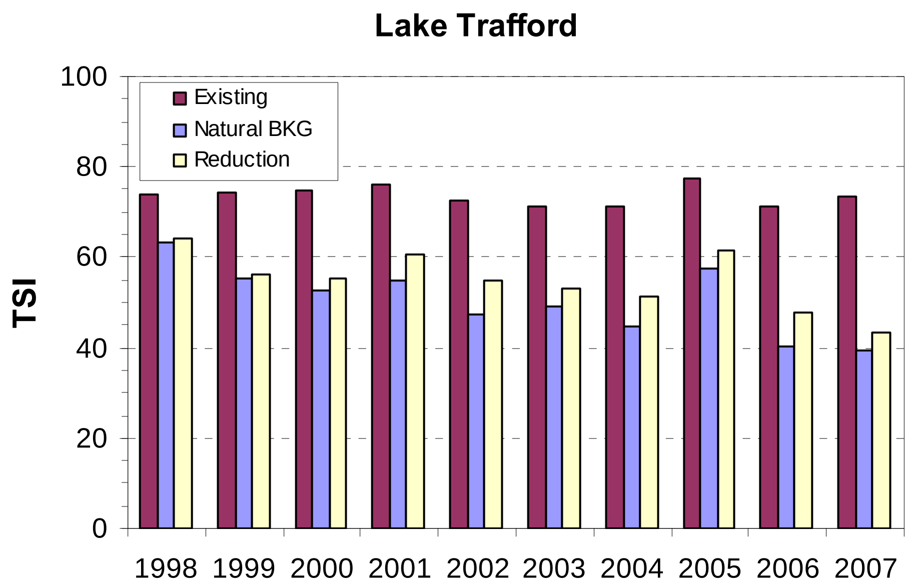

Figure 5.37 TSI of Existing (Calibrated), Background and Load Reduction.

Calculation of Allowable TMDL Load

The model predictions for current condition loads of TN are 141,543 lbs/yr and for TP 14,559 lbs/yr. A 60 percent reduction in TN results in an allowable loading of 56,617 lbs/yr. A 77 percent reduction in TP results in an allowable loading of 3,348 lbs/yr. To calculate a daily allowable loading, each annual average load was divided by 365. This results in a daily allowable load for TN of 155.1 lbs/day and for TP, 9.17 lbs/day.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

A TMDL can be expressed as the sum of all point source loads (wasteload allocations or WLAs), nonpoint source loads (load allocations or LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty about the relationship between effluent limitations and water quality:

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

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

It should be noted that the various components of the TMDL equation may not sum up to the value of the TMDL because a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and b) TMDL components can be expressed in different terms [for example, the WLA for stormwater is typically expressed as a percent reduction and the WLA for wastewater is typically expressed as a mass per day].

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

This approach is consistent with federal regulations [40 CFR § 130.2(I)], which state that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or **other appropriate measure**. The TMDL for Lake Trafford is expressed in terms of pounds per year (converted from kilograms per year as shown in Chapter 5) and percent reductions, and represent the long-term annual average load of TN and TP the waterbody can assimilate and maintain the Class III narrative nutrient criterion (**see Table 6.1).**

Table 6.1 Lake Trafford TMDL Load Allocations

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	Stormwater (% reduction)				
3259W	TN	N/A	60	56,617	Implicit	56,617	60
3259W	TP	N/A	77	3,348	Implicit	3,348	77

N/A – Not Applicable
*The load reductions of TN and TP will correct the impairments for nutrients, un-ionized ammonia, and dissolved oxygen. The allowable loads as pounds/day are for TN 155.1 lbs/day and for TP 9.17 lbs/day. Achieving a long-term TSI of 56 results in an average Chla of 19.04 ug/L, TN of 1.09 mg/L, TP of 0.025 mg/L, and a TN/TP ratio of 44.

6.2 Load Allocation (LA)

The allowable LA is 56,617 lbs/year for TN and 3,348 lbs/year for TP. This corresponds to reductions from the existing loadings of 60 percent for TN and 77 percent for TP. It should be noted that the LA may include loading from stormwater discharges regulated by the Department and the Water Management District that are not part of the NPDES Stormwater Program **(see Appendix A).**

6.3 Wasteload Allocation (WLA)

NPDES Wastewater Discharges

As noted in Chapter 4, Section 4.2.1, there are no active National Pollutant Discharge Elimination System (NPDES) permitted facilities that have a surface water discharge located within the Lake Trafford watershed.

NPDES Stormwater Discharges

The wasteload allocation for stormwater discharges is a 60 percent reduction in loading for TN and 77 percent reduction in loading for TP, which are the required percent reductions in nonpoint sources. It should be noted that any MS4 permittee will only be responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control, and is not responsible for reducing other nonpoint source loads within its jurisdiction.

6.4 Margin of Safety (MOS)

TMDLs must address uncertainty issues by incorporating a MOS into the analysis. The MOS is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody [Clean Water Act, Section 303(d)(1)(c)]. Considerable uncertainty is usually inherent in estimating nutrient loading from nonpoint sources, as well as predicting water quality response. The effectiveness of management activities (e.g., stormwater management plans) in reducing loading is also subject to uncertainty.

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings. Consistent with the recommendations of the Allocation Technical Advisory Committee (Florida Department of Environmental Protection, February 2001), an implicit margin of safety (MOS) was used in the development of the Lake Trafford TMDL. An implicit MOS was used because the TMDL was based on the conservative decisions associated with a number of the modeling assumptions and allowing for a 10 TSI unit increase (5 TSI units above natural background conditions and an additional 5 TSI units to allow for future changes) in determining the assimilative capacity (i.e., loading and water quality response) for Lake Trafford.

6.5 Evaluation of TMDL on Un-ionized Ammonia

Lake Trafford was placed on the Verified List for unionized ammonia following the procedures established in Rule 62-303, FAC. While un-ionized ammonia is not a modeled parameter, the impact on un-ionized ammonia of reducing TN as a part of the nutrient TMDL was examined. The mean TN concentration for the verified period is 2.84 mg/L. The annual average concentration of TN in the lake, once the TMDL is achieved, has been calculated as 1.09 mg/L. The current ratio between total ammonia and TN is 0.05 (based on the quarterly means from 2000 – 2007). Based on this ratio, the annual average total ammonia concentration in the Lake after the TMDL is achieved was calculated as [(1.09*0.05) =0.054 mg/L]. The model predicted average total ammonia is 0.04. The current ratio of un-ionized ammonia to TN is 0.006 (based on the quarterly means from 2000 – 2007). Based on this ratio, the annual average un-ionized ammonia concentration in the Lake after the TMDL is achieved was calculated as [(1.09*0.006) =0.006 mg/L]. This value is below the un-ionized ammonia criterion of 0.02 mg/L specified in Rule 62-302.530, FAC. As the model predicted total ammonia concentration is less than the concentration calculated by the ratios, the predicted concentration of un-ionized ammonia after achieving the TMDL should be even less than that predicted from the ratios derived from the current condition. Taken together, this indicates that under the TMDL for TN, the average un-ionized ammonia concentration in the lake will meet water quality standards. Therefore, the un-ionized ammonia TMDL is the same as the TMDL for nutrients, a 60 percent reduction in nitrogen and a 77 percent reduction in phosphorus. The phosphorus reduction is included in this TMDL to account for the reductions in Chla that would result in a lower pH, less recycling of ammonia, and reduced un-ionized ammonia concentrations.

6.6 Evaluation of TMDL on Dissolved Oxygen

As described in Chapter 5, reductions in TN of 60 percent and TP of 77 percent results in a daily minimum DO for 1998-2007 of 5.0 mg/L. This indicates that once the long-term average TSI of 56 is achieved, the DO in the lake will meet the Class III criterion.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

Following adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, which will be a component of the Basin Management Action Plan for the Lake Trafford watershed. This document will be developed in cooperation with local stakeholders and will attempt to reach consensus on more detailed allocations and on how load reductions will be accomplished.

The Basin Management Action Plan (BMAP) will include:

- Appropriate allocations among the affected parties.
- A description of the load reduction activities to be undertaken.
- Timetables for project implementation and completion.
- Funding mechanisms that may be utilized.
- Any applicable signed agreements.
- Local ordinances defining actions to be taken or prohibited.
- Local water quality standards, permits, or load limitation agreements.
- Monitoring and follow-up measures.

It should be noted that TMDL development and implementation is an iterative process, and this TMDL will be re-evaluated during the BMAP development process and subsequent Watershed Management cycles. The Department acknowledges the uncertainty associated with TMDL development and allocation, particularly in estimates of nonpoint source loads and allocations for NPDES stormwater discharges, and fully expects that it may be further refined or revised over time. If any changes in the estimate of the assimilative capacity AND/OR allocation between point and nonpoint sources are required, the rule adopting this TMDL will be revised, thereby providing a point of entry for interested parties.

References

Anderson, D.L, *et al.,*1994. *In-Situ Lysimeter Investigation of Pollutant Attenuation in the Vadose Zone of a Fine Sand.* Onsite Wastewater Treatment: Proceedings of the Seventh International Symposium on Individual and Small Community Sewage Systems. American Society of Agricultural Engineers, St. Joseph, MI.

ART Engineering. 2007. Lake Bottom Sediment using Ground Penetrating Radar (GPR) at Lake Trafford, Florida. Available at http://www.art-engineering.com

Ashley, J. 2004. Lake Trafford Restoration. Central and Southern Florida Ecosystem Restoration Critical Project Letter Report. US Army Corps of Engineers. Jacksonville District. Available at http://www.saj.usace.army.mil/projects/laketraf.htm

Bicknell, B. R., Imhoff, J. C., Kittle, J. L., Donigian, A. S., Jr. and Johanson, R. C. 2001. Hydrologic Simulation Program-Fortran, User's manual for Release 12. U.S. Environmental Protection Agency, EPA/600/R-97/080, Environmental Research Laboratory, Athens, GA.

Carlson, Robert E. 1977. *A Trophic State Index for Lakes.* Limnology and Oceanography. 22: 361-369.

Chapra, S. 1997. *Surface Water-Quality Modeling*. The McGraw-Hill Companies, INC. p844.

CDM, 1991. *Sarasota Bay National Estuary Program. Point / Nonpoint Source Pollution Loading Assessment. Phase 1*. January 1991.

CDM, 2002. *Northern Coastal Basin Watersheds Hydrology Model Development : Pellicer Creek Planning Unit 9B*. Prepared for the St. Johns River Water Management District, Palatka, FL.

CDM. 2008. Kissimmee River Watershed TMDL Model Development Report. A Report to Florida Department of Environmental Protection, Tallahassee, Florida.

CHEC, 2003. *Assessing the Densities and Potential Water Quality Impacts of Septic Tank Systems in the Peace and Myakka River Basins*. Prepared by the Charlotte Harbor Environmental Center, Inc. for Charlotte Harbor National Estuary Program.

Duda, P., Kittle, J., Gray, M. Jr., Hummel, P., Dusenbury, R. 2001. WinHSPF Version 2.0: An Interactive Windows Interface to HSPF (WinHSPF), User's Manual. Washington, D.C.: U.S. Environmental Protection Agency, 2001.

Everham, E. 2007. Lake Trafford Watershed Management Plan – Phase I Final Report. Florida Gulf Coast University, Florida, June 5, 2007.

Environmental Consulting & Technology, Inc. 1989. *Bathymetric Analysis of Lake Apopka.* A Report to St. Johns River Water Management District, Palatka, Florida. November, 1989.

Farnsworth, R.K., Thompson, E.S., and Peck, E.L., 1982, *Evaporation atlas for the contiguous 48 United States*: National Oceanic and Atmospheric Administration Technical Report NWS 33, 26 p., 4 sheets.

Flaig, E. 2000. Lake Trafford. Available at http://naples.net/presents/trafford/

Florida Department of Environmental Protection, February 2001. *A Report to the Governor and the Legislature on the Allocation of Total Maximum Daily Loads in Florida.* Florida Department of Environmental Protection, Allocation Technical Advisory Committee, Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, Florida.

—, April 2001. Chapter 62-302, *Surface Water Quality Standards,* Florida Administrative Code (*F.A.C.*), Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, Florida.

—, April 2001. *Chapter 62-303, Identification of Impaired Surface Waters Rule (IWR), Florida Administrative Code*. Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, Florida.

—, June 2004. Division of Water Resource Management, Bureau of Information Systems, Geographic Information Systems Section, Florida Department of Environmental Protection, Tallahassee, Florida. Available at http://www.dep.state.fl.us/gis/contact.htm

Florida Department of Health, July 2004. Florida Department of Health web site. Available at http://www.doh.state.fl.us/
; or http://www.doh.state.fl.us/environment/OSTDS/statistics/ostdsstatistics.htm.

Florida Department of Transportation, 1999. *Florida Land Use, Cover and Forms Classification System (FLUCCS)*. Florida Department of Transportation Thematic Mapping Section.

Florida Geological Survey. 1962. *Ground-Water Resources of Collier County, Florida*. U.S. Geological Survey, Tallahassee, Florida

Frink, 1991. *Estimating Nutrient Exports to Estuaries*. J. Environ. Qual. 20(4): 717-724.

FWRA, 1999. *Florida Watershed Restoration Act,* Chapter 99-223, Laws of Florida.

Henderson-Sellers, B. and Markland, H. 1987. *Decaying Lake: The Origins and Control of Cultural Eutrophication*. John Wiley & Sons.

IFAS, 1984. *Impact of On-Site Sewage Disposal Systems on Surface and Ground Water Quality*, November 1984. Prepared by the Institute of Food and Agricultural Sciences Soil Science Department, University of Florida, Gainesville, FL for Florida Department of Health and Rehabilitative Services (HRS).

In Your Region, 2007. The South Florida Water Management District Local Government News. Volume 2, Issue 1.

Lake Trafford and You: Community Opinion. 2000. ISS 4935 Senior Seminar in Social Science. Florida Gulf Coast University, Florida.

Lee and Swancar, 1997 *Influence of evaporation, ground water, and uncertainty in the hydrologic budget of Lake Lucerne, a seepage lake in Polk County, Florida*: U.S. Geological Survey Water-Supply Paper 2439, 61 p.

Rutter, R. 1996. A bioassessment of five lakes in Highlands County and on lake in Collier County, Florida, with emphasis on the macroinvertebrate fauna. Florida Department of Environmental Protection, Punta Gorda, FL.

Swancar, Amy, Lee, T.M., and O'Hare, T.M., 2000, Hydrogeologic setting, water budget, and preliminary analysis of ground-water exchange at Lake Starr, a seepage lake in Polk ... fl.water.usgs.gov/Abstracts/wri00_4030_swancar.htm

Treommer, J., DelCharco, M., Lewelling, B. 1999. *Water Budget and Water Quality of Ward Lake, Flow and Water-Quality Characteristics of the Braden River Estuary, and the Effects of Ward Lake on the Hydrologic System, West-Central Florida*. U.S. Geological Survey Water-Resources Investigations Report 98-4251, Tallahassee, Florida.

U. S. Environmental Protection Agency, 1997. *Compendium of Tools for Watershed Assessment and TMDL Development, USEPA, Office of Water, Washington, DC 20460, EPA841-B-97-006, May 1997.*

U.S. Environmental Protection Agency (EPA), 2001. *Better Assessment Science Integrating Point & Non-point Sources BASINS version 3.0 User Manual*, Electronic File, http://www.epa.gov/waterscience/basins/bsnsdocs.html, Accessed June 2007.

U.S. Environmental Protection Agency, 2002. *Onsite Wastewater Treatment Systems Manual*. EPA /625/R-00/008.
http://www.epa.gov/ordntrnt/ORD/NRMRL/Pubs/625R00008/625R00008.htm

U. S. Census Bureau Web Site. 2008. Available at http://www.census.gov/; or http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US12&-_box_head_nbr=GCT-PH1&-ds_name=DEC_2000_SF1_U&-_lang=en&-format=ST-2&-_sse=on.

Winter, T.C., 1981, *Uncertainties in estimating the water balance of lakes*: Water Resources Bulletin, v17, n1, p82-115.

Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Rule 62-40, F.A.C.

Rule 62-40, F.A.C., requires the state's water management districts (WMDs) to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a SWIM plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. To date, no PLRG has been developed for Lake Trafford.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementation of the Phase I NPDES stormwater program in 1990. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific Standard Industrial Classification (SIC) codes, construction sites disturbing five or more acres of land, and master drainage systems of local governments with a population above 100,000, which are better known as municipal separate storm sewer systems (MS4s). However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the Florida Department of Transportation throughout the fifteen counties meeting the population criteria. The Department received authorization to implement the NPDES Stormwater Program in 2000.

An important difference between the federal NPDES and the state's stormwater permitting programs is that the NPDES program covers both new and existing discharges, while the other state programs focus on new discharges. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between one and five acres, and to local governments with as few as 1,000 people. While these urban stormwater discharges are now technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility similar to other point sources of pollution, such as domestic and industrial wastewater discharges. It should be noted that all MS4 permits issued in Florida include a re-opener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: TN, TP, Chlorophyll *a* Raw Data, and HSPF input information used in the TMDL Analysis for Lake Trafford

All data, copies of the model and model input decks used to produce the Lake Trafford TMDL report are available upon request.

Please Contact:
Douglas Gilbert, Environmental Manager
Florida Department of Environmental Protection
Bureau of Watershed Management
Watershed Assessment Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
douglas.gilbert@dep.state.fl.us
Phone: (850) 245-8450; Suncom: 205-8450
Fax: (850) 245-8536

Appendix C: Public Comments and FDEP Responses.

Appendix C.1: Comments from Mac Hatcher, Collier County

The below comments were received by email from Mr. Mac Hatcher of the Collier County Environmental services Department July 8, 2008

Comment 1
On page 9 in the 2nd paragraph there is a discussion of the Floridian aquifer. Lake Trafford is separated from the Floridian aquifer by confining units. It intrudes into the surficial system which is not discussed in this section. Since ground water flow is such a large component of the water budget there should be some discussion of the surficial system here.

FDEP Response:
The piezometric surface of the Floridian aquifer was introduced in this introductory section, implying that the flow of ground water in the Floridian aquifer in Collier County is generally to southwest. This head direction is similar to that of the topographic elevation, indicating that the general directions of surface and ground water flows would be southwesterly. Such background information is helpful in a better understanding of general inflow and outflow directions in the watershed. Hydrodynamic or hydrogeochemical interactions between the Floridian aquifer and surficial system were not discussed here since the HSPF model simulates a portion of active ground water. Moreover, the interactions between the lake and the Floridian aquifer are unlikely since the Floridian aquifer is confined by relatively impermeable limestone layers in Collier County and the top of the aquifer is almost everywhere less than 400 feet below mean sea level. On page 39, the importance of baseflow (active ground water), however, was addressed in more detail and quantified to construct the lake water budget. Based on the water budget, baseflow is the largest contributor of inflows to the lake, comprising of 32% of the total annual inflow over the 10-yr period.

Comment 2.
In the 3rd paragraph you discuss the influence of the sediment nutrient flux yet this source of nutrients does not seem to be included in the Assessment of Sources or the Determination of Assimilative Capacity.
Since this source of nutrients has been identified and targeted for remedial actions it should be included.

FDEP Response:
Sediment nutrient flux is an important source of nutrients especially phosphorus. In general, sediment phosphorus undergoes early chemical diagenesis in organic rich sediment and subsequently releases bioavailable phosphorus to the overlying water column. However, it may be often complicated to quantify the regeneration of phosphorus via biogeochemical processes in the sediment because of phosphorus addition to sediment pore water via incoming ground water carrying more phosphorus. For Lake Trafford, however, these nutrient sources from both sediment and groundwater have been already taken into account in the model to determine the assimilative capacity of the lake. To better display this sediment nutrient flux issue in the report, the Department revised Chapter 5 in the report by adding the following paragraph on Page 50:

"Sediment nutrients (PO4 and NH4) fluxes were taken into account in the HSPF model as model input parameters to simulate water quality parameters. For the calibrated model, sediment fluxes of PO4 and NH4 from bottom sediment were set to 0.02 mg/m^2/day and 0.012 mg/m^2/day, respectively. These rates were adjusted accordingly for later simulations to represent natural background land use conditions and load reduction conditions, based on the equation described in the following section."

Comment 3.
Lake Trafford discharges at around 18 - 19 ft. Although there is a column for Outflow in Table 5.3 it is not clear that this loss is reflected in the model.

FDEP Response:
Total annual inflows and outflows (ac-ft/yr) were estimated as shown in Table 5.3. In the table, negative signs in the columns of Evaporation and Outflow indicate loss of water out of the lake. As described in

Chapter 4 and 5, these inflows and outflows were simulated by adjusting key parameters including soil moisture, lower and upper zone storage, infiltration, and ground water storage, etc. On page 39, the second paragraph explained how simulated inflows and outflows are related to annual rainfall. For example, when the rainfall was lowest in 2007, inflows to the lake via interflow and baseflow were minimal possibly due to lower water table. Similarly, outflow out of the lake was also the lowest over the 10-yr period as shown in Table 5.3. These findings are coincident to the current conditions of the lake such as exposure of the littoral zone and the occurrence of little discharge from the lake.

Appendix C.1: Comments from Nath Ananta, SFWMD.

The below comments were received by email from Dr. Ananta Nath of the South Florida Water Management District (SFWMD) on July 28, 2008

Comment 1: At high water levels Lake Trafford does NOT drain through Fakahatchee Strand; some outflow from the lake can occur at lake stages above 21ft NGVD, making its way through Camp Keais Strand, Florida Panther National wildlife Refuge, Merritt Canal in Picayune Strand Restoration Project area to the 10,000 Islands estuary.

FDEP Response: In a sentence cited in section 1.2 of Chapter 1 there was a reference in the statement of Work, SFWMD) which indicated "…at high water level during the wet season it drains south through Fakahatchee strand to Southern Golden Gate Estates Critical project area." If this is not the case, please provide reference which counters this assumption.

Comment 2: Good background information in Section 1.4

FDEP Response: Thank you.

Comment 3: The 80%DCIA of commercial/industrial land use incorporated in the simulation of IMPLND module is exorbitantly high. Upland forests/unimproved pasture/woodland pasture also can share some DCIA.

FDEP Response: Good Question, please provide a reference(s) to support your statement of why the 80% DCIA for the land use is exorbitantly high. We used the same percent DCIA values that CDM used for Kissimmee River Basin lakes. These values are all published values by CDM (2002).

Comment 4: The RCHRES simulation with the lake outflow occurring at 18ft stage is not representative of the real inflow-outflow situation of Lake Trafford.

FDEP Response: Throughout the TMDL report, it was not mentioned that the lake outflow occurs at 18 ft. The outflows can be the losses of water from the lake via surface, subsurface, ground water, aquatic plants, withdrawal etc. Specific details about the outflow is beyond the scope of what we are doing. However, in conversations with Collier County representatives it was indicated that "Lake Trafford discharges at around 18 - 19 ft". But, in any case, please elaborate on why the 18 ft. stage is unrealistic.

Comment 5: The highly convective nature of the south Florida thunderstorm activities make meteorological data from just one station unrepresentative of the rainfall input for the watershed. SFWMD has several weather stations in the watershed with long term records (Corkscrew/Immokalee Landfill/Bonita Springs/North Naples etc. We had earlier evaluated the FAWN data of the Immokalee IFAS Station, and observed it to be inconsistent with neighboring stations in several occasions. Evaluation of the data from these neighboring stations would have been more useful than comparing with Mountain Lake Station in Polk County, over 100 miles away from Lake Trafford.

FDEP Response: The FAWN (Florida Automated Meteorological Network) data was also referred to before deciding on which data to use. The Immokalee station takes a measurement every 15 min and so creates 4 readings per an hour. The hourly meteorological data used for the Lake Trafford model were basically obtained from the 4 measurements, providing the data greatly accurate. In other word, we can say we've got the data from 4 independent measurements (or 4 locations). Only pan evaporation data were obtained from the station in Polk County because the data were not readily available. I had checked several locations maintained by SFWMD but locations closed to coastal areas were excluded because vapor pressure seems different from inland. And also I made sure that the pan evaporation rate we used was comparable to that by other study for Immokalee Master Plan. As long as a station is in similar latitude, there should be no problem in general…

Comment 6: It appears there are rooms for improvements in overall simulation for TN and TP. With the present analysis, there are considerable uncertainty in the assessment of load allocation and determination of TMDL for Lake Trafford.

FDEP Response: Certainly, there is an uncertainty in the modeling; however, we have demonstrated calibration plots with statistical analyses to make sense out of it. Please provide more evidence to support the statement of "considerable uncertainty". Please refer to the below Lake Trafford water level calibration graph, which appears to show good comparison between model results and actual observed data.