CENTRAL DISTRICT • KISSIMMEE RIVER BASIN •
UPPER KISSIMMEE PLANNING UNIT

FINAL TMDL Report

Nutrient TMDL for Lake Marian (WBID 3184)

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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Load for nutrients for Lake Marian, located in the Kissimmee River Basin. The TMDL will constitute the site-specific numeric interpretation of the narrative nutrient criterion pursuant to 62-302.531(2)(a), Florida Administrative Code (F.A.C.). Lake Marian was initially verified as impaired during Cycle 1 (verified period January 1, 1998, to June 30, 2005) due to excessive nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR) (Rule 62-303, F.A.C.), and was included on the Cycle 1 Verified List of impaired waters for the Kissimmee River Basin that was adopted by Secretarial Order on May 12, 2006.

Subsequently, during the Cycle 2 assessment (verified period January 1, 2003, to June 30, 2010), the impairment for nutrients was documented as continuing, as the Trophic State Index (TSI) threshold of 60 was exceeded during both 2003 and 2007. The TMDL establishes the allowable loadings to the lake that would restore the waterbody so that it meets its applicable water quality narrative criterion for nutrients.

1.2 Identification of Waterbody

Lake Marian is located in Osceola County, Florida. The estimated average surface area of the lake is 6,553 acres, with a normal pool volume of 46,819 acre-feet (ac-ft) and an average depth of 13 feet. Lake Marian is an open hydrologic system that receives drainage from a directly connected area of approximately 35,437 acres (**Figure 1.1**). The Lake Marian watershed's land use designations are primarily agriculture (43%), wetland (21.2%), pastureland (23.2%), and rangeland/upland forest (10.9%). Lake Marian receives runoff from the local basin and discharges to Lake Jackson, which discharges to Lake Kissimmee. Lake Kissimmee discharges to the Kissimmee River.

For assessment purposes, the Florida Department of Environmental Protection has divided the Kissimmee River Basin into water assessment polygons with a unique **w**ater**b**ody i**d**entification (WBID) number for each watershed or stream reach. Lake Marian is WBID 3184.

Figure 1.2 shows the location of the Lake Marian WBID and its sampling/monitoring stations.

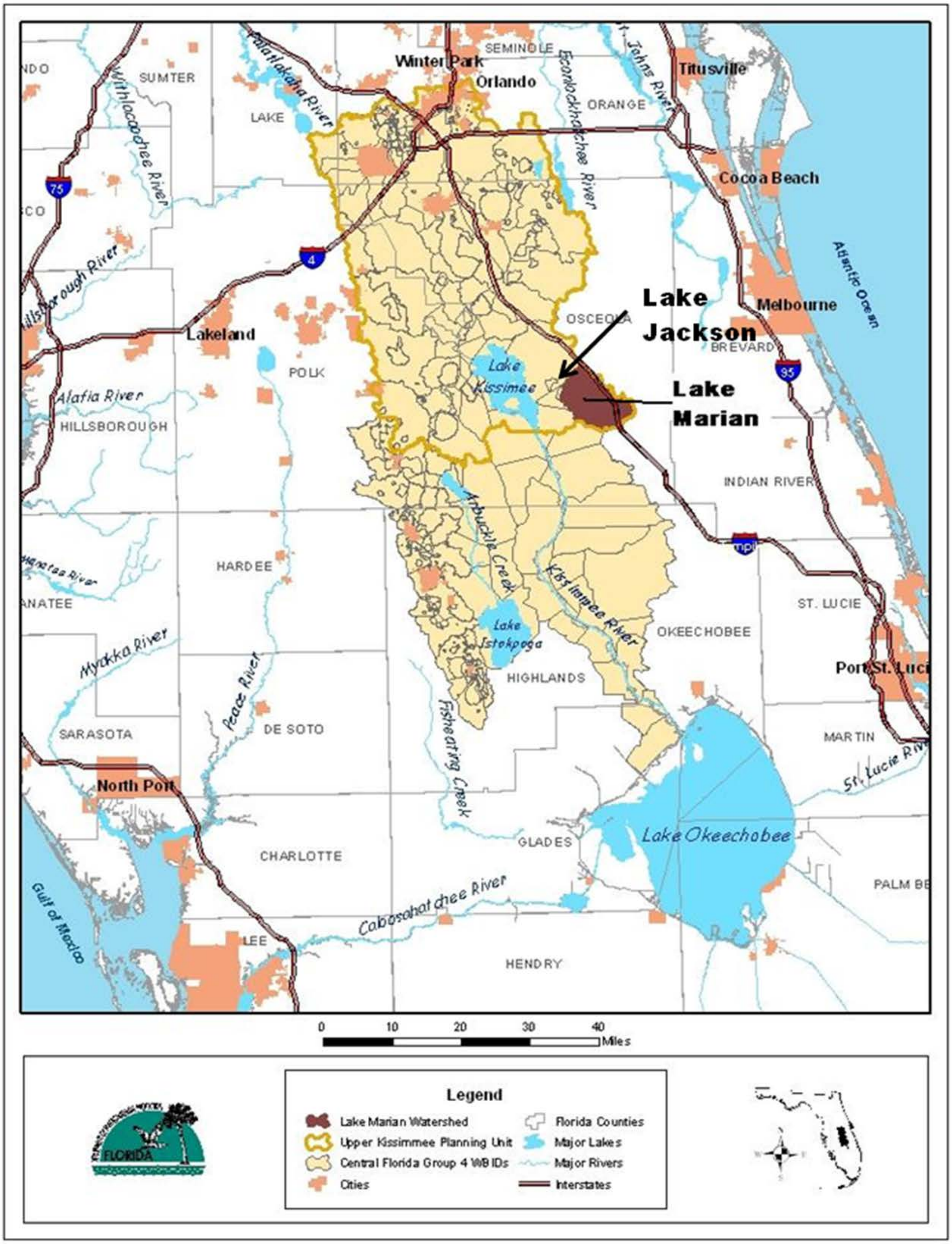

Figure 1.1. Upper Kissimmee Planning Unit and Lake Marian Watershed

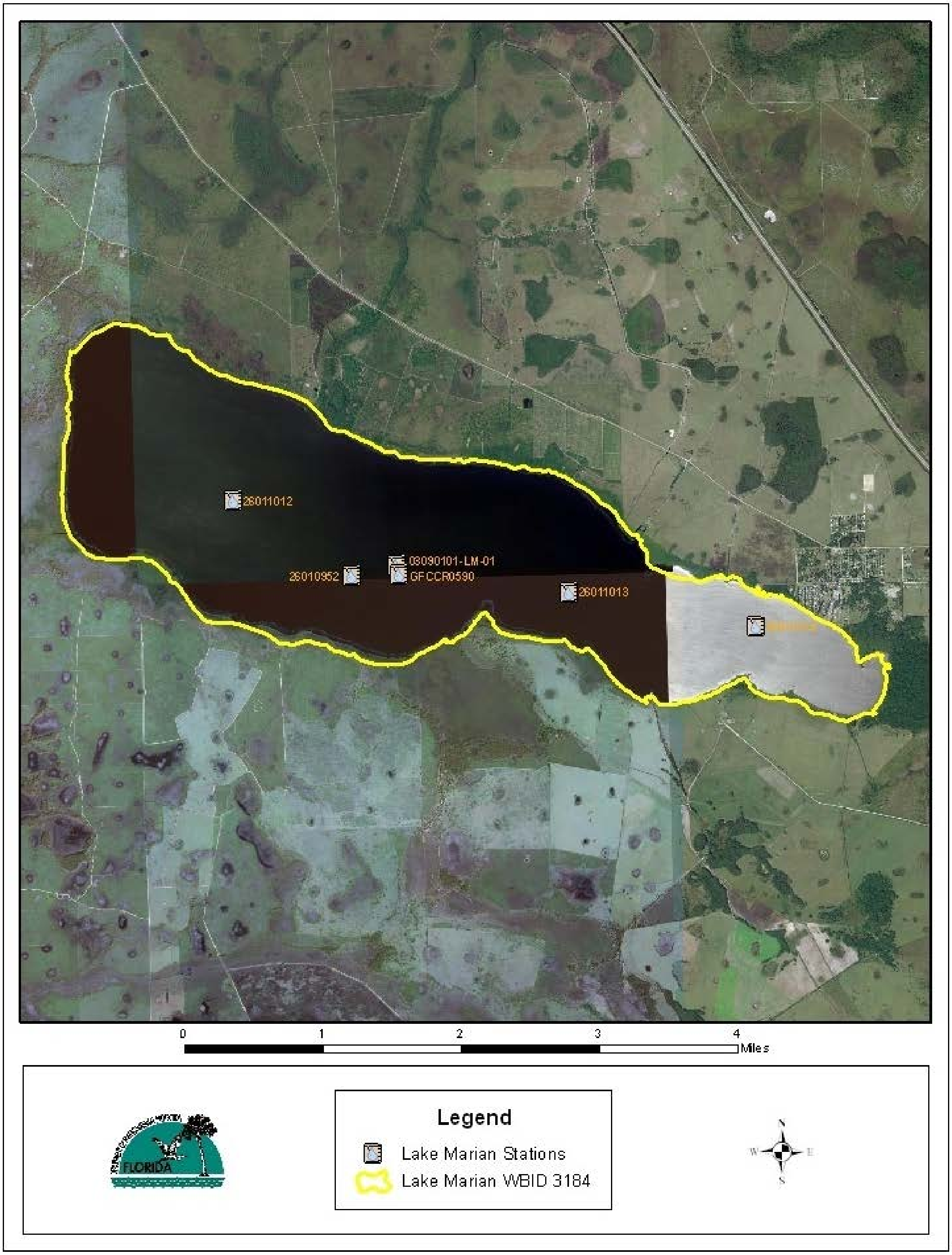

Figure 1.2. Lake Marian (WBID 3184) and Monitoring Stations

1.3 Background Information

As depicted in **Figure 1.1**, the Lake Marian watershed has a total surface water drainage area of approximately 35,437 acres. The water in Lake Marian discharges to Lake Jackson, which flows into Lake Kissimmee. Thus, water quality and quantity in Lake Marian directly influence the water quality and quantity of these downstream receiving waterbodies, and ultimately the Kissimmee River (**Figure 1.1**).

The TMDL report for Lake Marian is part of the implementation of the Department's watershed management approach for restoring and protecting water resources and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (FWRA) (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.

This TMDL Report will be followed by the development and implementation of a restoration plan to reduce the amount of pollutants that caused the verified impairment. These activities will depend heavily on the active participation of Osceola County, the South Florida Water Management District (SFWMD), 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.

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 U.S. Environmental Protection Agency (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 FWRA (Subsection 403.067[4], Florida Statutes [F.S.]), and the state's 303(d) list is amended annually to include basin updates.

Lake Marian was 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 Rule 62-303, F.A.C. (Identification of Impaired Surface Waters Rule, or IWR), in April 2001; the rule was amended in 2006 and January 2007.

2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in Lake Marian. All data presented in this report are from IWR Run 41. Data reduction followed the procedures in Rule 62-303, F.A.C. Data were further reduced by calculating daily averages. These are the data from which graphs and summary statistics were prepared. The annual averages were calculated from these data by averaging for each calendar quarter and then averaging the four quarters to determine the annual average. The lake was verified as impaired for nutrients based on an elevated annual average Trophic State Index (TSI) value over the Cycle 1 verified period for the Group 4 basins, which was January 1, 1998, to June 30, 2005). The impaired condition was documented as still present during the Cycle 2 verified period from January 1, 2003, to June 30, 2010.

The IWR methodology uses the water quality variables total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* (chl*a*) (a measure of algal mass, corrected and uncorrected) in calculating annual TSI values and in interpreting Florida's narrative nutrient threshold. For Lake Marian, data were available for the three water quality variables for all four seasons in 1998, 1999, 2000, 2002, 2003, and 2007 of the Cycle 1 and Cycle 2 verified periods. The resulting annual average TSI values for these years are

71.9, 76.2, 76.4, 72.2, 66.5, and 72.9, respectively. Under the IWR methodology, exceeding a TSI of 60 in lakes with color over 40 platinum cobalt units (PCU) in any one year of the verified period is sufficient for a determination of nutrient impairment. Only limited color data were available for Lake Marian. Annual average color values for the verified period (for years with color values in all 4 quarters) for the lake were 110 PCU (1998), 80 PCU (1999), and 110 PCU (2007). The daily average (**Figure 2.1**) and annual average (**Figure 2.2**) color values for the period of record (1966 to 2009) have increased slightly over time, as has the alkalinity (**Figure 2.3**) and pH (**Figure 2.4**), while the Secchi disk depth has remained almost constant over the same period (**Figure 2.5**).

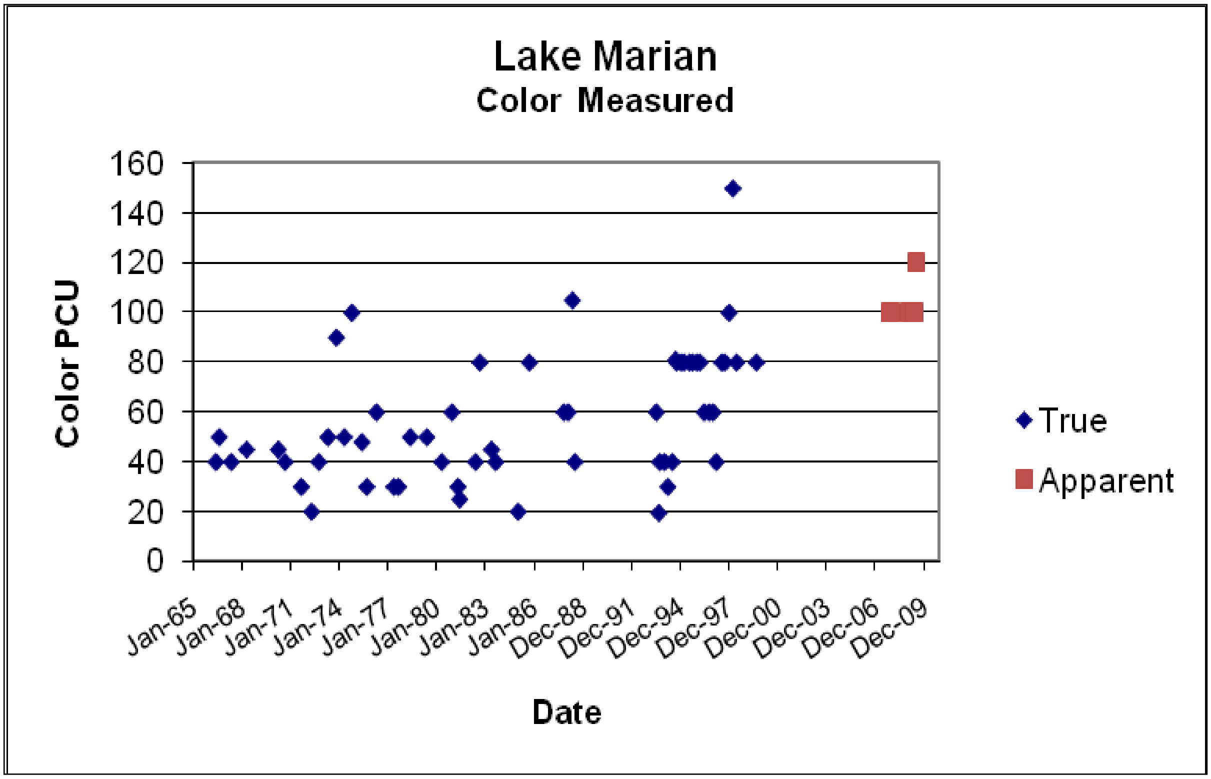

Figure 2.1. Daily Average Color (PCU) for the Period of Record, 1966–2009

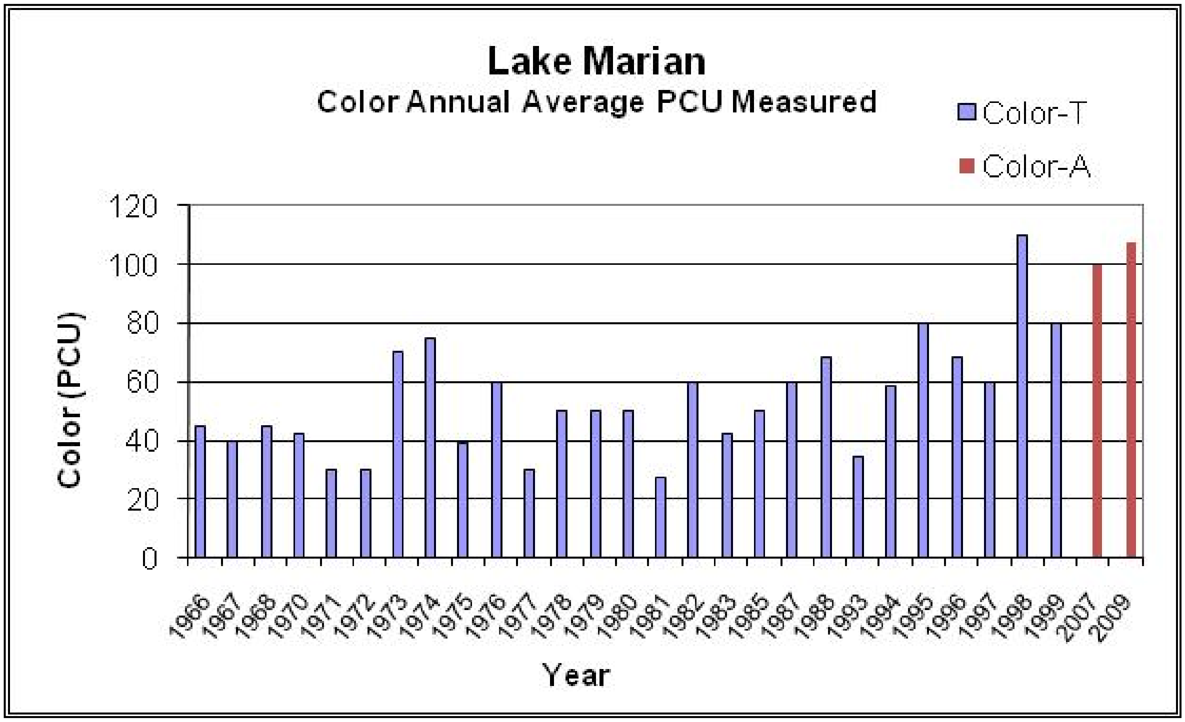

Figure 2.2. Annual Average Color (PCU) for the Period of Record, 1966–2009

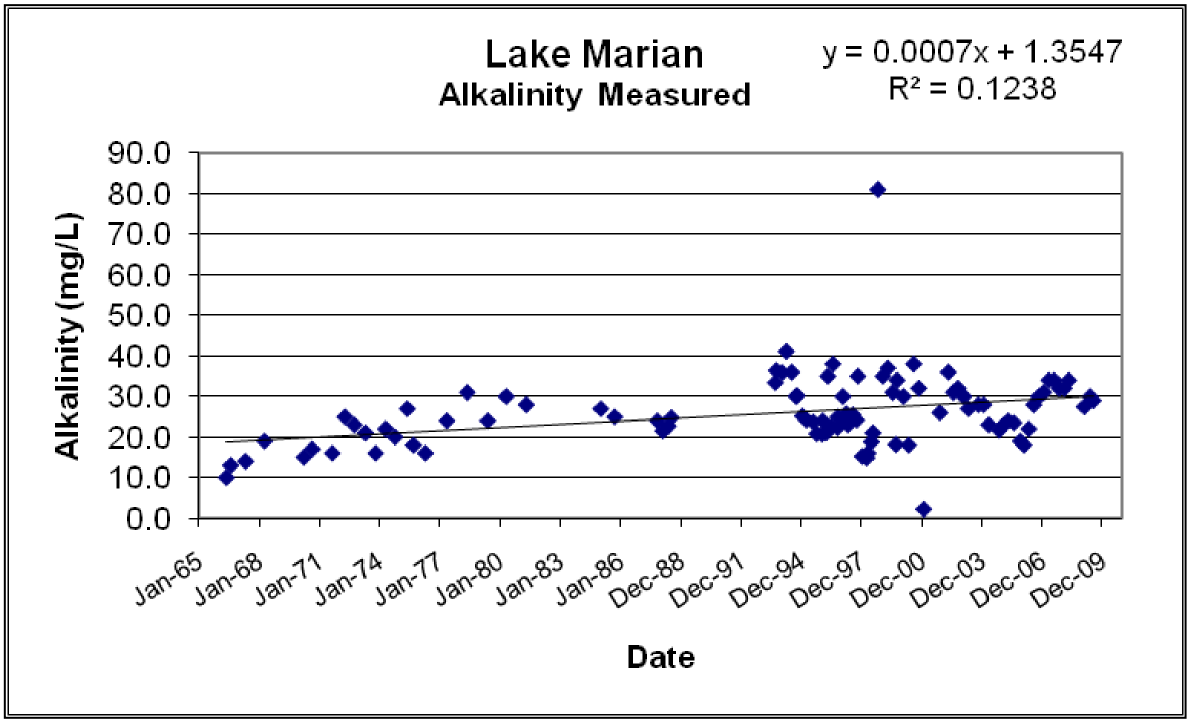

Figure 2.3. Daily Average Alkalinity (milligrams per liter [mg/L]) for the Period of Record, 1966–2009

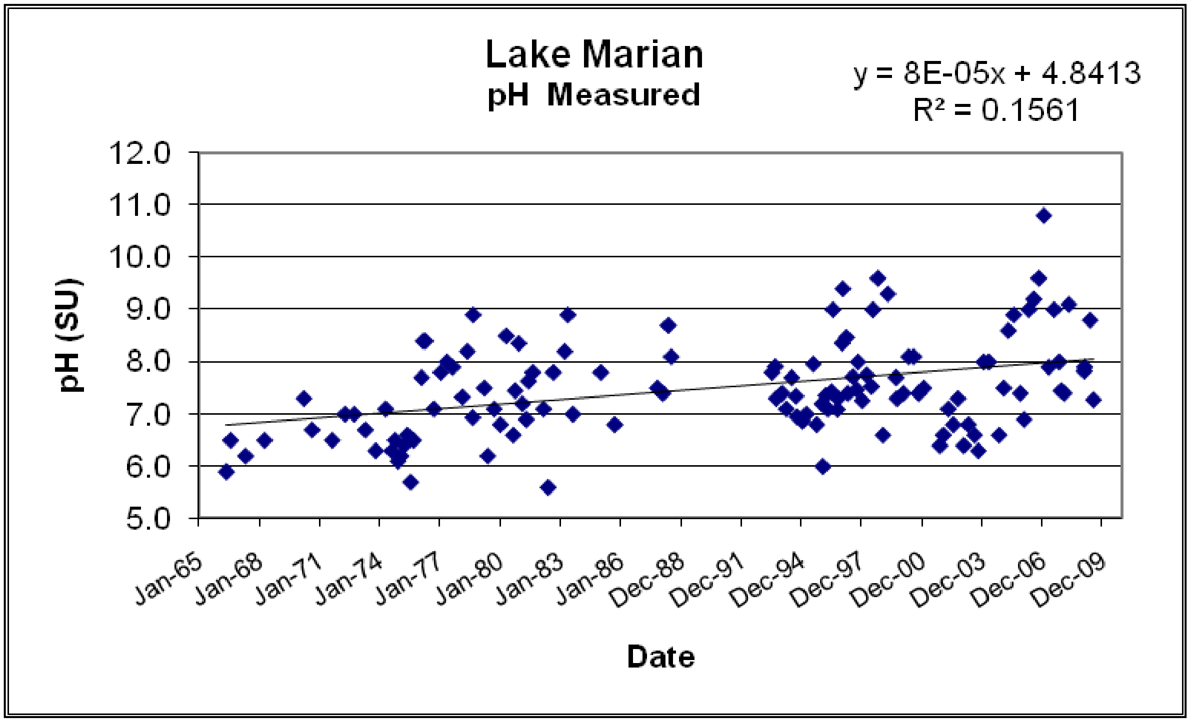

Figure 2.4. Daily Average pH (Standard Units [SU]) for the Period of Record, 1966–2009

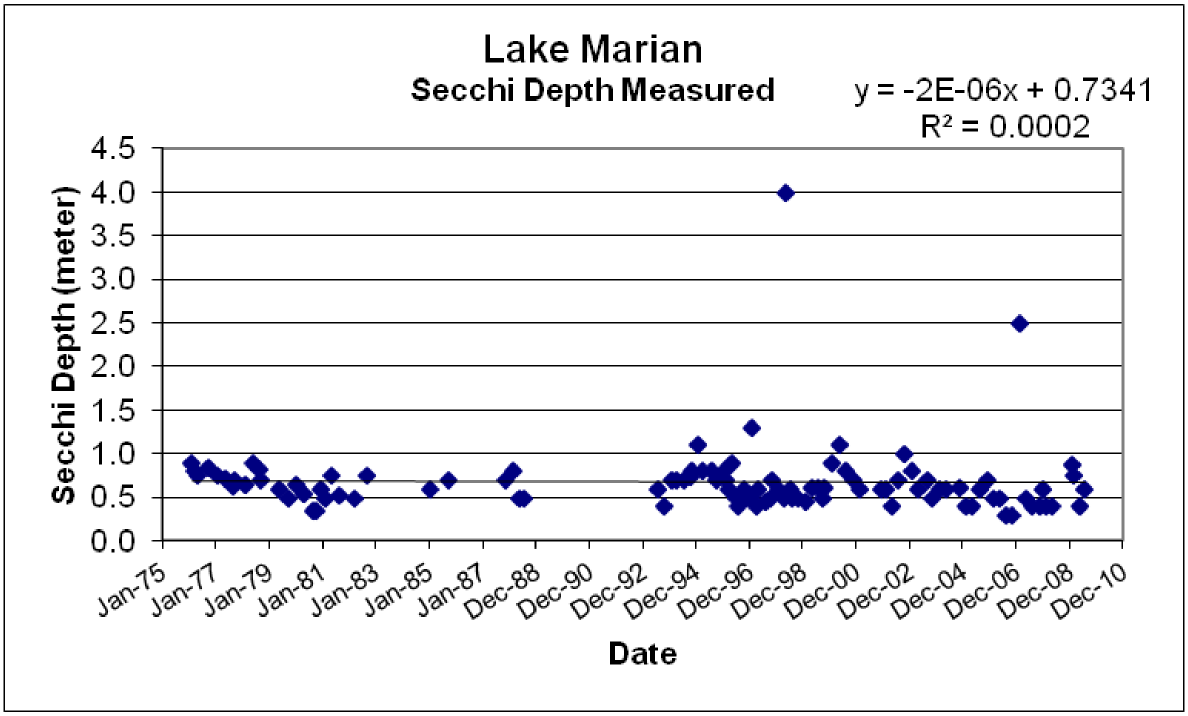

Figure 2.5. Daily Average Secchi Depth (meters), 1975–2010

The TSI is calculated based on concentrations of TP, TN, and corrected chl*a* (cchl*a*), as follows:

CHLATSI = 16.8 + 14.4 * LN(Chla)   Chlorophyll a in µg/L
TNTSI = 56 + 19.8 * LN(N)   Nitrogen in mg/L
TN2TSI = 10 * [5.96 + 2.15 * LN(N + 0.0001)]   Phosphorus in mg/L
TPTSI = 18.6 * LN(P * 1000) – 18.4
TP2TSI = 10 * [2.36 * LN(P * 1000) – 2.38]

If N/P > 30, then NUTRTSI = TP2TSI
If N/P < 10, then NUTRTSI = TN2TSI
if 10< N/P < 30, then NUTRTSI = (TPTSI + TNTSI)/2

TSI = (CHLATSI + NUTRTSI)/2   Note: TSI has no units

The Hydrologic Simulation Program Fortran (HSPF) model was run for 2000 to 2006. For modeling purposes, the analysis of the eutrophication-related data presented in this report for Lake Marian used "all" of the available data from 2000 to 2006 for which records of TP, TN, and chl*a* were sufficient to calculate seasonal and annual average conditions. To calculate the TSI for a given year under the IWR, there must be at least one sample of TN, TP, and chl*a* taken within the same quarter (each season) of the year. Because data were absent for at least one of the four seasons, 2001, 2004, 2005, and 2006 were eliminated from the TSI analysis for Lake Marian.

Figure 2.6 displays annual average TSI values for all data from 1980 to 2009 (including LakeWatch data). Annual averages labeled "M<" do not contain data from all 4 quarters and were not used in the determination of impairment. The Cycle 1 verified period (January 1998 to June 2006) annual average TSI values exceeded the IWR threshold level of 60 in 1998, 1999, 2000, 2002, and 2003, with an overall mean TSI result of 73.3. The TSI exceeded the threshold in Cycle 2 for 2003 (66.5) and 2007 (72.9).

Key to Figure 2.6 Legend for Calculation of Annual Averages

M< = results for measured data, does not include data from all four quarters
M4 = results for measured data, at least one set of data from all four quarters

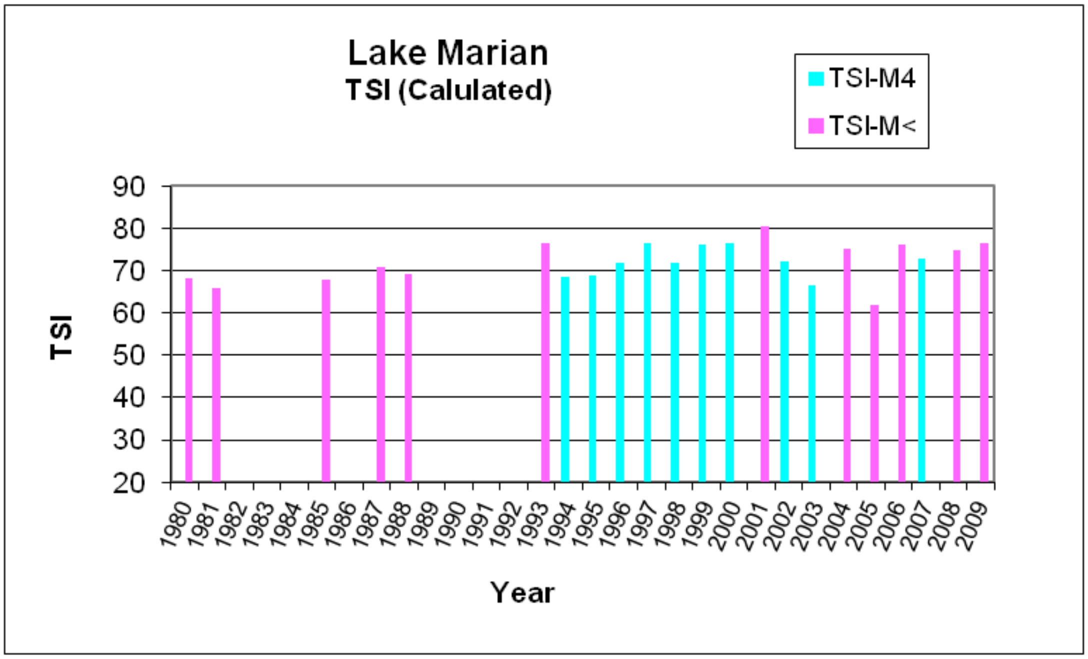

Figure 2.6. TSI Results for Lake Marian Calculated from Annual Average Concentrations of TP, TN, and CChl*a*, 1980–2009

Figures 2.7, **2.8**, and **2.9** display daily, annual, and monthly average TN results, respectively, for Lake Marian from 1971 to 2009. **Figures 2.10**, **2.11**, and **2.12** display daily, annual, and monthly average TP results, respectively, from 1970 to 2009. **Figures 2.13**, **2.14**, and **2.15** show daily, annual, and monthly average cchl*a* results, respectively, from 1980 to 2009. The daily and annual average values from all stations for TN indicated very little change, if any, over the period of record. TN monthly results were typically higher from November through February and lowest in late summer and early fall. The daily and annual average values from all stations for TP indicated a slight increase over the period of record. TP monthly results typically rose during early fall and were lowest in spring and midsummer. The daily and annual average values from all stations for cchl*a* indicated a slight increase over the period of record. Cchl*a* monthly results were typically highest in spring and summer and lowest in late fall and winter.

Table 2.1 lists summary statistics for the lake for TN, TP, and cchl*a* from 1966 to 2006. **Appendix D** provides individual water quality measurements (raw data) for TN, TP, and cchl*a* used in the assessment.

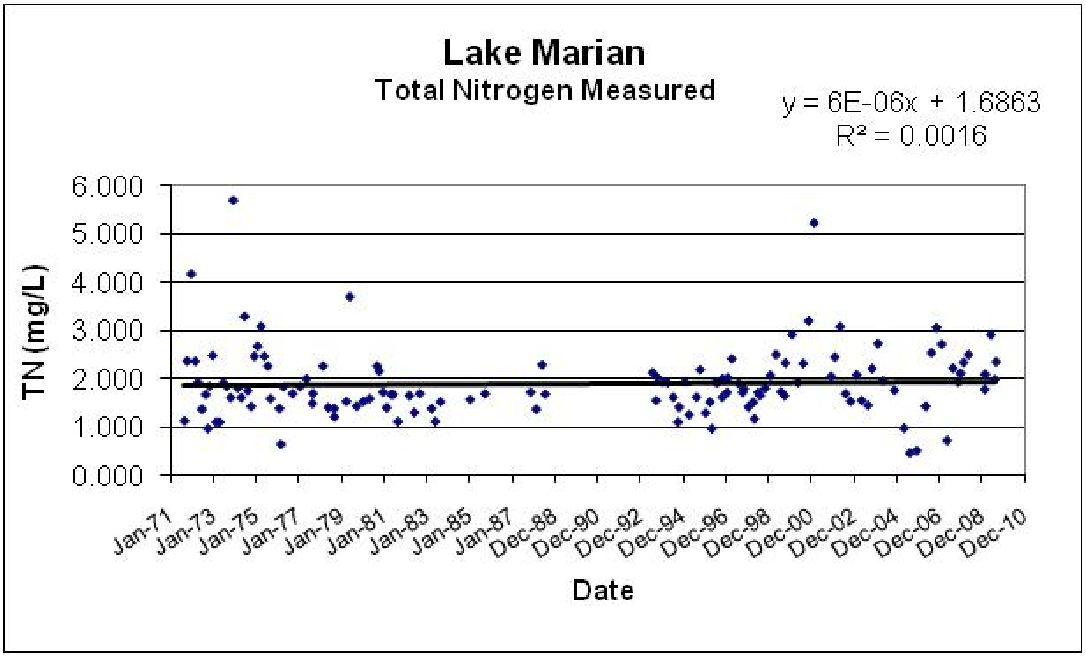

Figure 2.7. TN Daily Average Results for Lake Marian, 1971–2009

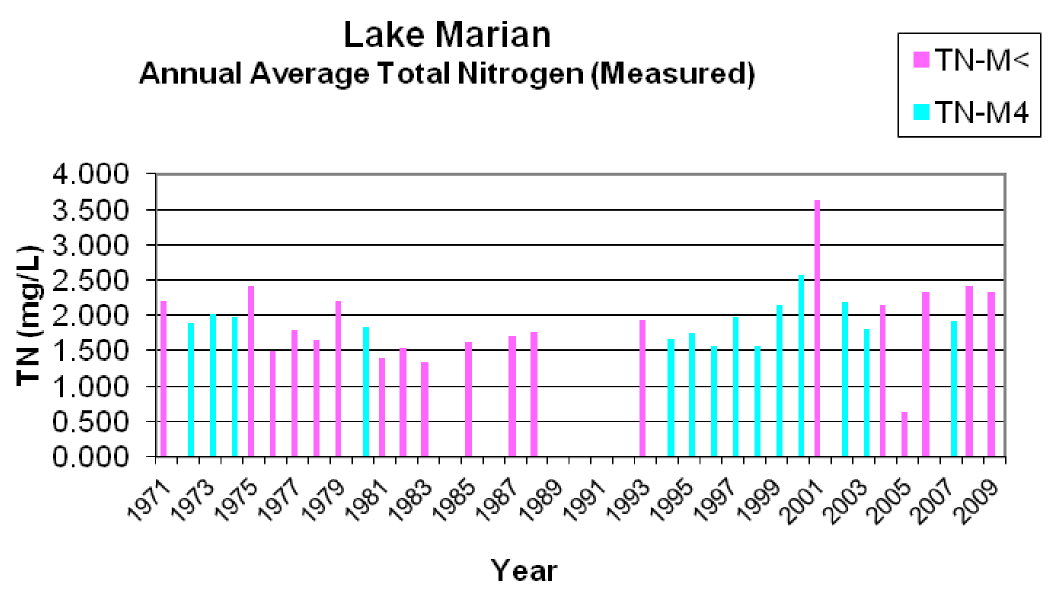

Figure 2.8. TN Annual Average Results for Lake Marian, 1971–2009

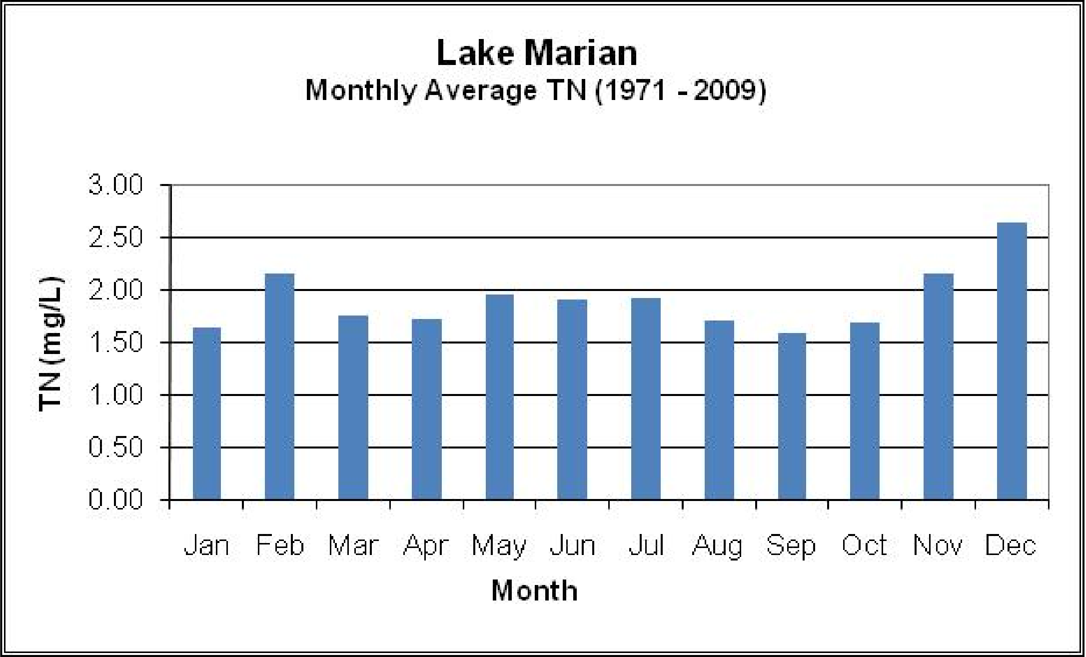

Figure 2.9. TN Monthly Average Results for Lake Marian, 1971–2009

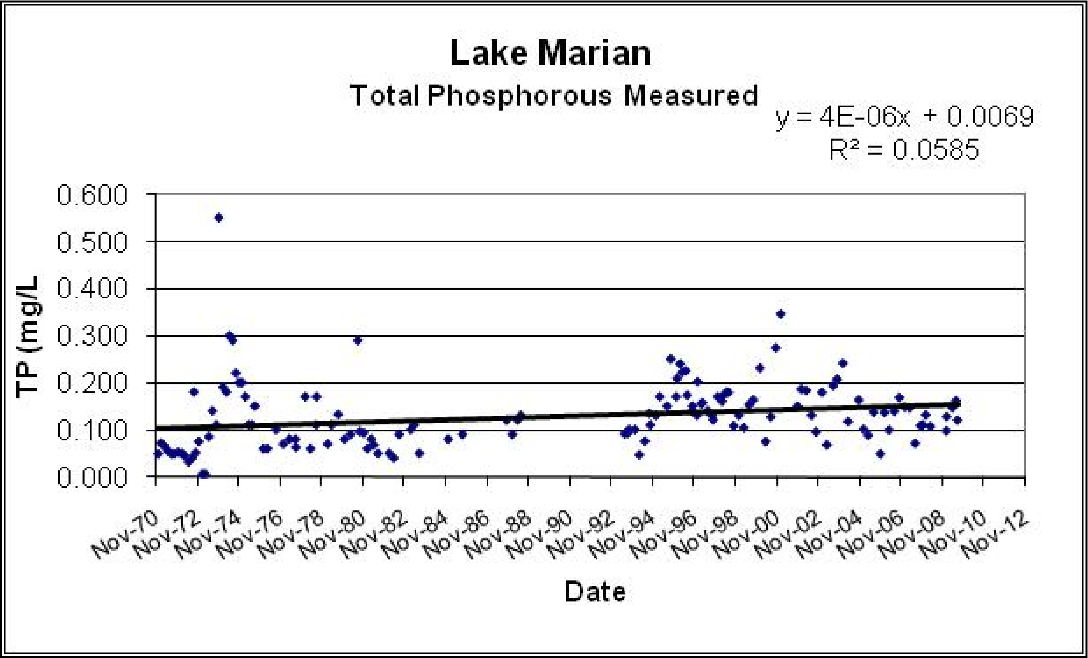

Figure 2.10. TP Daily Average Results for Lake Marian, 1970–2009

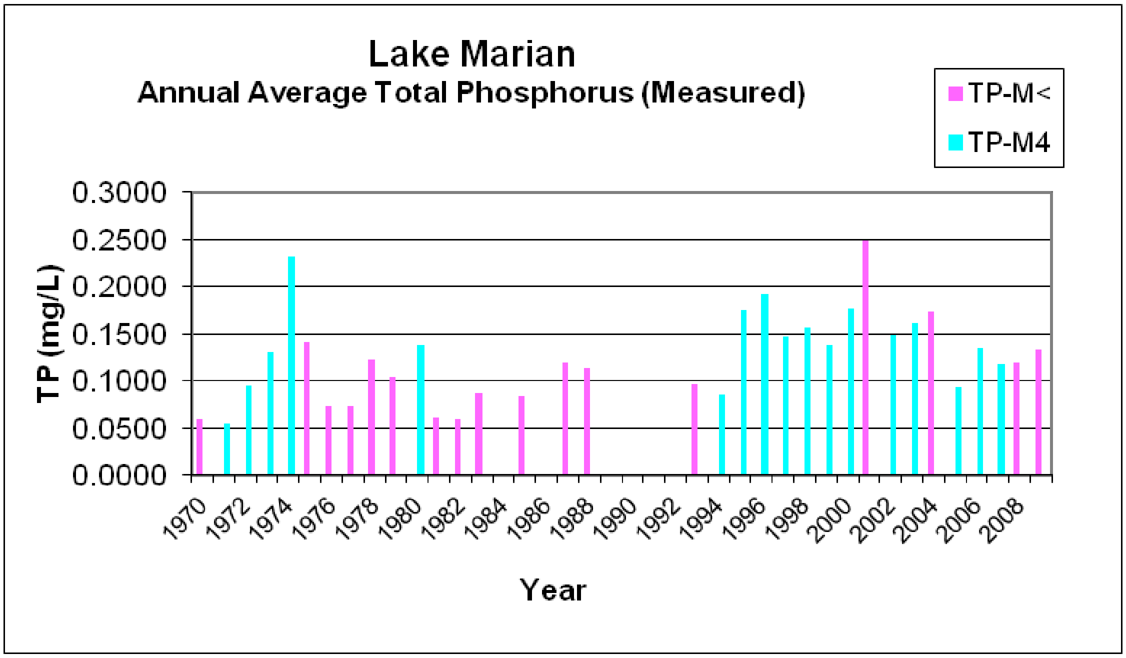

Figure 2.11. TP Annual Average Results for Lake Marian, 1970–2009

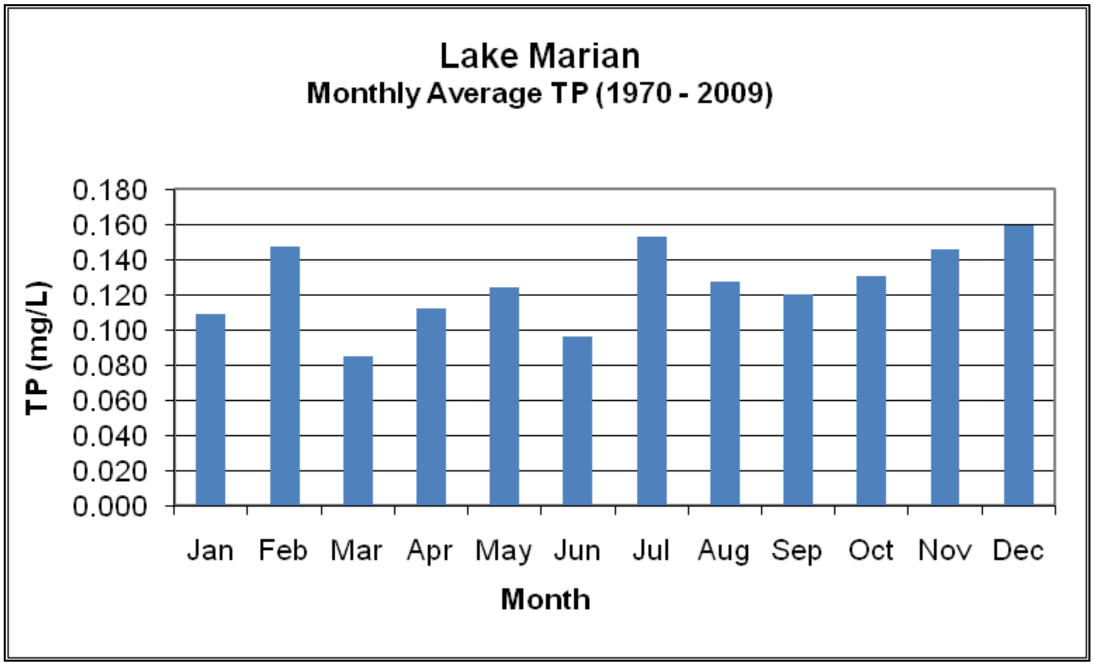

Figure 2.12. TP Monthly Average Results for Lake Marian, 1970–2009

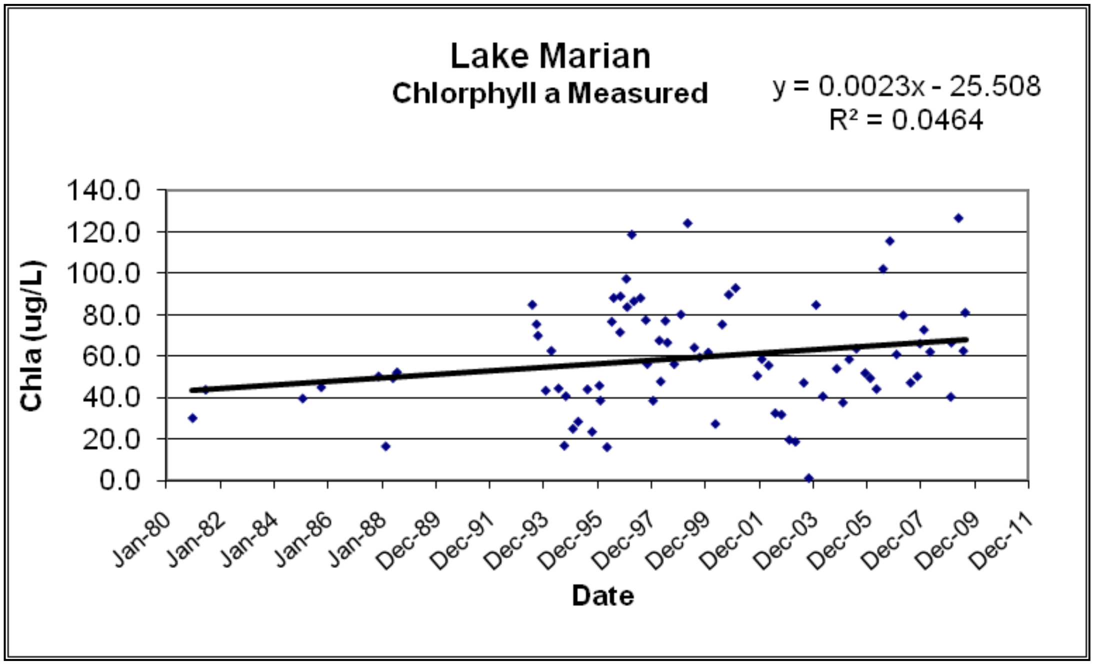

Figure 2.13. Chl*a* Daily Average Results for Lake Marian, 1980–2009

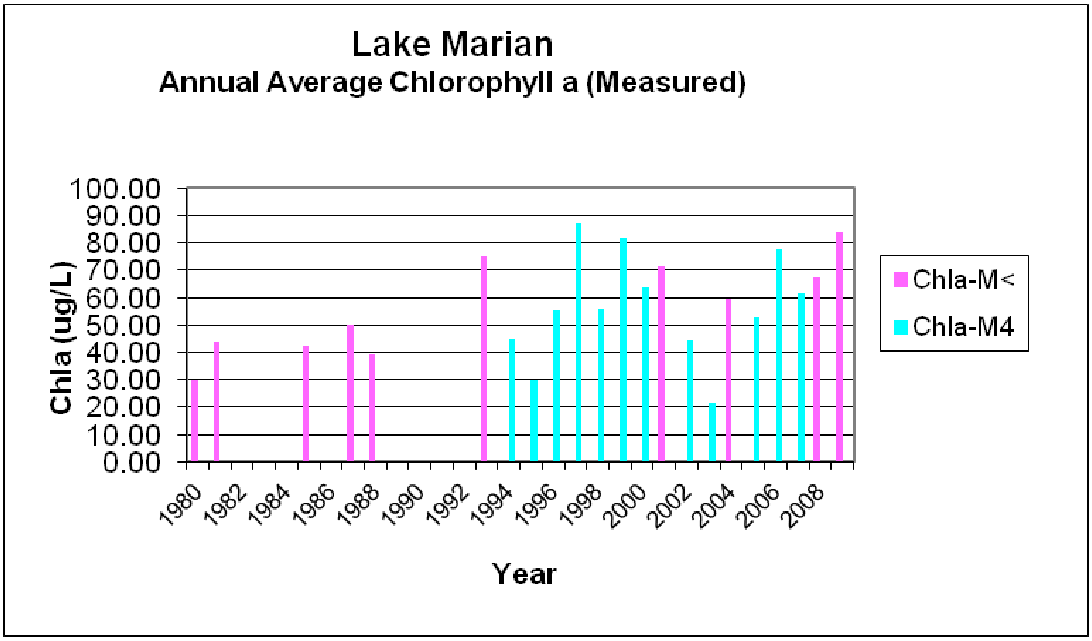

Figure 2.14. Chl*a* Annual Average Results for Lake Marian, 1980–2009

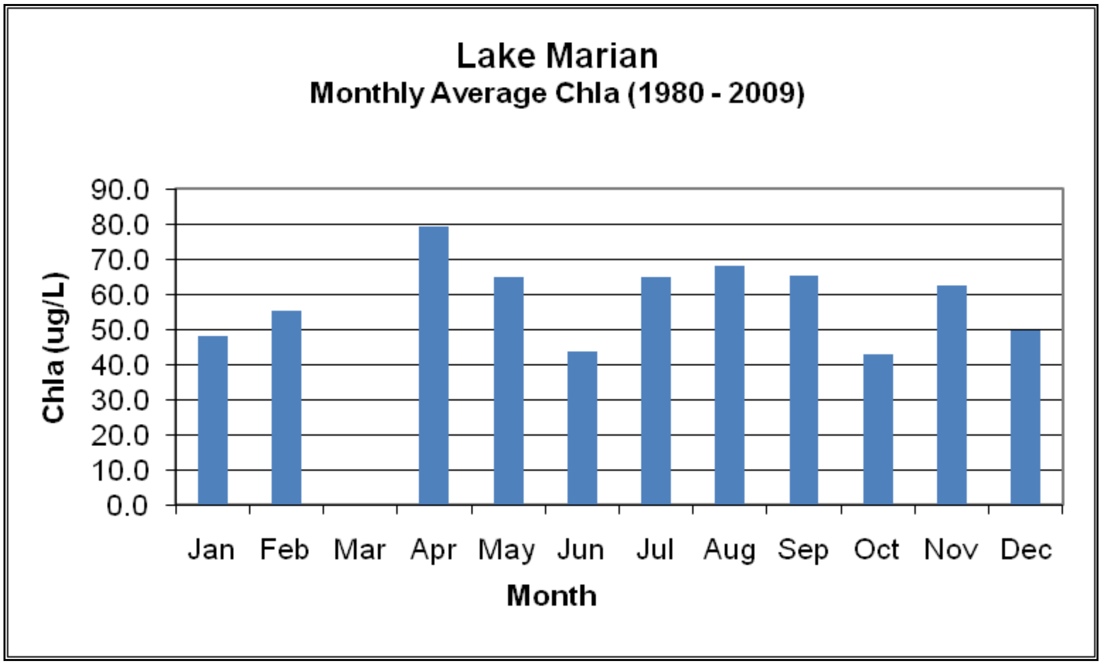

Figure 2.15. Chl*a* Monthly Average Results for Lake Marian, 1980–2009

Table 2.1. Water Quality Summary Statistics for TN, TP, Chl*a*, Color, Alkalinity, pH, and Secchi Depth for Lake Marian, 1966–2009

Water Quality Parameter	Period of Record	Number of Samples	Minimum	Maximum	Mean	Median	Standard Deviation
TN (mg/L)	1971–2009	134	0.450	5.690	1.896	1.746	0.737
TP (mg/L)	1970–2009	143	0.006	0.550	0.128	0.117	0.072
Chl*a* (µg/L)	1980–2009	81	1.0	126.7	59.0	56.1	25.9
Color (PCU)	1966–2009	58	19.5	150.0	57.3	50.0	25.5
Alkalinity (mg/L)	1966–2009	96	2.20	81.00	26.07	25.00	9.04
pH (SU)	1966–2009	127	5.60	10.80	7.49	7.40	0.92
Secchi Depth (meters [m])	1976–2009	103	0.30	4.00	0.68	0.60	0.42

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 Marian 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 criterion applicable to the observed impairment for Lake Marian is the state of Florida's narrative nutrient criterion (Paragraph 62-302.530[48][b], F.A.C.). This TMDL will constitute the site-specific numeric interpretation of the narrative nutrient criterion pursuant to 62-302.531(2)(a), F.A.C., which states:

> *(2) The narrative water quality criterion for nutrients in paragraph 62-302.530(47)(b), F.A.C., shall be numerically interpreted for both nutrients and nutrient response variables in a hierarchical manner as follows:*
>
> *(a) Where a site specific numeric interpretation of the criterion in paragraph 62-302.530(47)(b), F.A.C., has been established by the Department, this numeric interpretation shall be the primary interpretation. If there are multiple interpretations of the narrative criterion for a waterbody, the most recent interpretation established by the Department shall apply. A list of the site specific numeric interpretations of paragraph 62-302.530(47)(b), F.A.C., may be obtained from the Department's internet site at http://www.dep.state.fl.us/water/wqssp/swq-docs.htm or by writing to the Florida Department of Environmental Protection, Standards and Assessment Section, 2600 Blair Stone Road, MS 6511, Tallahassee, FL 32399-2400.*
>
> *1. The primary site specific interpretations are as follows:*
>
> *a. Total Maximum Daily Loads (TMDLs) adopted under Chapter 62-304, F.A.C., that interpret the narrative water quality criterion for nutrients in paragraph 62-302.530(47)(b), F.A.C., for one or more nutrients or nutrient response variables;*
>
> *b. Site specific alternative criteria (SSAC) for one or more nutrients or nutrient response variables as established under Rule 62-302.800, F.A.C.;*

> *c. Estuary-specific numeric interpretations of the narrative nutrient criterion established in Rule 62-302.532, F.A.C.; or*
>
> *d. Other site specific interpretations for one or more nutrients or nutrient response variables that are formally established by rule or final order by the Department, such as a Reasonable Assurance Demonstration pursuant to Rule 62-303.600, F.A.C., or Level II Water Quality Based Effluent Limitations (WQBEL) established pursuant to Rule 62-650.500, F.A.C. To be recognized as the applicable site specific numeric interpretation of the narrative nutrient criterion, the interpretation must establish the total allowable load or ambient concentration for at least one nutrient that results in attainment of the applicable nutrient response variable that represents achievement of the narrative nutrient criterion for the waterbody. A site specific interpretation is also allowable where there are documented adverse biological effects using one or more Biological Health Assessments, if information on chlorophyll a levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicate there are no imbalances in flora and a stressor identification study demonstrates that the adverse biological effects are not due to nutrients.*

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 was used to identify the limiting nutrient(s) in streams and lakes:

> *The individual ratios over the entire verified periods for Cycle 1 (i.e., January 1, 1998, to June 30, 2005) and Cycle 2 (i.e., January 1, 2003, to June 30, 2010) were evaluated to determine the limiting nutrient(s). If all the sampling event ratios were less than 10, nitrogen was identified as the limiting nutrient, and if all the ratios were greater than 30, phosphorus was identified as the limiting nutrient. Both nitrogen and phosphorus were identified as limiting nutrients if the ratios were between 10 and 30. Although for 1998 and 2005, the lake was nitrogen limited; the mean TN/TP ratio was 14.2 for the Cycle 1 and Cycle 2 periods, 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 (Section 62-303.450, F.A.C.) 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 TP concentration, and was used to describe a lake's trophic state. It assumed that the lakes were all phosphorus limited. In Florida, because the local geology has 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 dark-water 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 TN, TP, and chl*a* concentrations. This revised calculation for TSI now contains options for determining a TN-TSI, TP-TSI, and chl*a*-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 chl*a*-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 chl*a*-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 chl*a*-TSI with the average of the TN- and TP-TSIs.

The Florida-specific TSI was determined based on the analysis of data from 313 Florida lakes. The index was adjusted so that a chl*a* concentration of 20 μg/L was equal to a chl*a*-TSI value of 60. The final TSI for any lake may be higher or lower than 60, depending on the TN- and TP-TSI values. A TSI of 60 was then set as the threshold for nutrient impairment for most lakes (for those with color higher than 40 PCU) because, generally, phytoplankton communities may become dominated by blue-green algae at chl*a* levels above 20 µg/L. These blue-green algae are often an undesirable food source for 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 phytoplankton growth and the subsequent death of these algae may consume large quantities of dissolved oxygen (DO) and result in anaerobic conditions in a lake, making conditions 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, almost all 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 Marian TMDL, the Department applied the HSPF model to simulate water quality discharges and eutrophication (or accelerated aging) processes, in order to determine the appropriate nutrient target. The model was used to estimate existing conditions in the Lake Marian watershed and the background TSI by setting land uses to natural or forested land, and then comparing the resulting TSI with the IWR thresholds. If the background TSI could be reliably determined and represented an appropriate target for TMDL development, then an increase of 5 TSI units above background would be used as the water quality target for the TMDL. Otherwise, the IWR threshold TSI of 60 would be established as the target for TMDL development.

3.3 Narrative Nutrient Criterion Definitions

3.3.1 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 chl*a*. The measurement of chl*a* in a water sample is a useful indicator of phytoplankton biomass, especially when used in conjunction with the analysis of algal growth potential and species abundance. Typically, the greater the abundance of chl*a* in a waterbody, 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, chl*a* measurements are also used to estimate the trophic conditions of lakes and lentic waters.

3.3.2 Nitrogen Total as N (TN)

TN 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 take place between land, air, and water. The most readily bioavailable forms of nitrogen are ammonia and nitrate. These compounds, in conjunction with other nutrients, serve as an important base for primary productivity.

The major sources 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 accelerate the eutrophication rate in an aquatic system. 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 depletion in DO concentrations as a result of algal decomposition.

3.3.3 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 Florida streams and estuaries are sometimes linked to phosphate mining and fertilizer processing activities.

High phosphorus concentrations are frequently responsible for accelerating the eutrophication process in 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.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Overview of Modeling Process

The Lake Marian watershed is a part of a larger network of lakes and streams that drain to the Kissimmee River, and ultimately, Lake Okeechobee. As there are several other lakes/streams in the Kissimmee River Basin for which TMDLs are being developed, the Department contracted with CDM to gather all available information and to set up, calibrate, and validate HSPF model projects for these waters (see **Appendix B** for modeling details).

HSPF (EPA 2001; Bicknell *et al.* 2001) is a comprehensive package that can be used to develop a combined watershed and receiving water model. The external load assessment conducted using HSPF was intended to determine the loading characteristics of the various sources of pollutants to Lake Marian. 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.

The model has the capability of modeling various species of nitrogen and phosphorus, chl*a*, coliform bacteria, and metals in receiving waters (bacteria and metals can be simulated as a "general" pollutant with potential in-stream 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 and is available as part of the EPA-supported software package BASINS (Better Assessment Science Integrating Point and Nonpoint Sources).

The PERLND (pervious land) module performs detailed analyses 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 wash off during runoff events. For other water quality constituents, runoff water quality can be determined using buildup-wash off algorithms, "potency factors" (*e.g.*, factors relating constituent wash off to sediment wash off), or a combination of both.

The IMPLND (impervious land) module performs analysis of surface processes only and uses buildup-wash off algorithms to determine runoff quality. The RCHRES (free-flowing reach or mixed reservoir) 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 is available at www.epa.gov/waterscience/basins/.

4.2 Potential Sources of Nutrients in the Lake Marian 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 has meant discharges to surface waters that typically have a continuous flow via a discernible, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges, such as those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs). To be consistent with 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 permitted WWTFs or industrial wastewater facilities that discharge directly to Lake Marian. The facility listed in **Table 4.1** is within the Lake Marian watershed but was not included in the model, as it is not a surface water discharger.

Table 4.1. NPDES Facilities in the Lake Marian Watershed

MGD = Million gallons per day

NPDES Permit ID	Facility Name	Receiving Water	Permitted Capacity (MGD)	Downstream Impaired WBID	Comments
FLA010989	Lake Marian Paradise WWTF	None	0.02	Not Applicable	No surface water discharge

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 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, F.A.C., 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 (OFWs).

The stormwater collection systems in the Lake Marian watershed, which are owned and operated by Osceola County, are covered by NPDES Phase II MS4 Permit Number FLR04E012. The collection system for the Florida Department of Transportation (FDOT) District 5 is covered by NPDES Permit Number FLR04E024. The collections systems for the Florida Turnpike are covered by NPDES Permit Number FLR04E049.

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 variations that a direct monitoring approach is often infeasible. For the Lake Marian TMDL, all nonpoint sources were evaluated by the use of a watershed and lake modeling approach. Land use coverages in the watershed and subbasin were aggregated using the 1999 Florida Land Use, Cover and Forms Classification System (FLUCCS) into nine different land use categories: 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 2000 land use coverage (scale 1:24,000) provided by the SFWMD.

The predominant land uses in the Lake Marian watershed are cropland/improved pasture (43%), wetland (21.2%), forest/rangeland (10.9%), unimproved pastureland (23.2%), commercial/industrial (0.6%), and residential housing (1.1%). **Table 4.2** shows the existing area of the various land use categories in the Lake Marian watershed (not including the surface area of water). **Figure 4.1** shows the drainage area of Lake Marian and the spatial distribution of the land uses listed in **Table 4.2**.

Table 4.2. Lake Marian Watershed Existing Land Use Coverage in 2000

Lake Marion Watershed Existing Land Use Coverage	Watershed (Acres)	Watershed (%)
Cropland/improved pasture	15,254.00	43.05%
Wetland	7,502.10	21.17%
Forest/rangeland	3,857.00	10.88%
Pastureland	8,211.40	23.17%
Commercial/industrial	225.90	0.64%
High-density residential	3.40	0.01%
Medium-density residential	138.80	0.39%
Low-density residential	244.30	0.69%
Sum	**35,436.90**	**100.00%**

Osceola County Population

According to the U.S. Census Bureau (U.S. Census Bureau website 2008), the county occupies an area of approximately 1,321.9 square miles. The total population in 2000 for Osceola County, including (but not exclusive to) the Lake Marian watershed, was 172,493. The population density in Osceola County in 2000 was at or less than 130.5 people per square mile. The Census Bureau estimates the 2006 Osceola County population at 244,045 (185 people/square mile). For all of Osceola County (in 2006), the Bureau reported a housing density of 83 houses per square mile. Osceola County is well below the average housing density for Florida counties of 158 housing units per square mile.

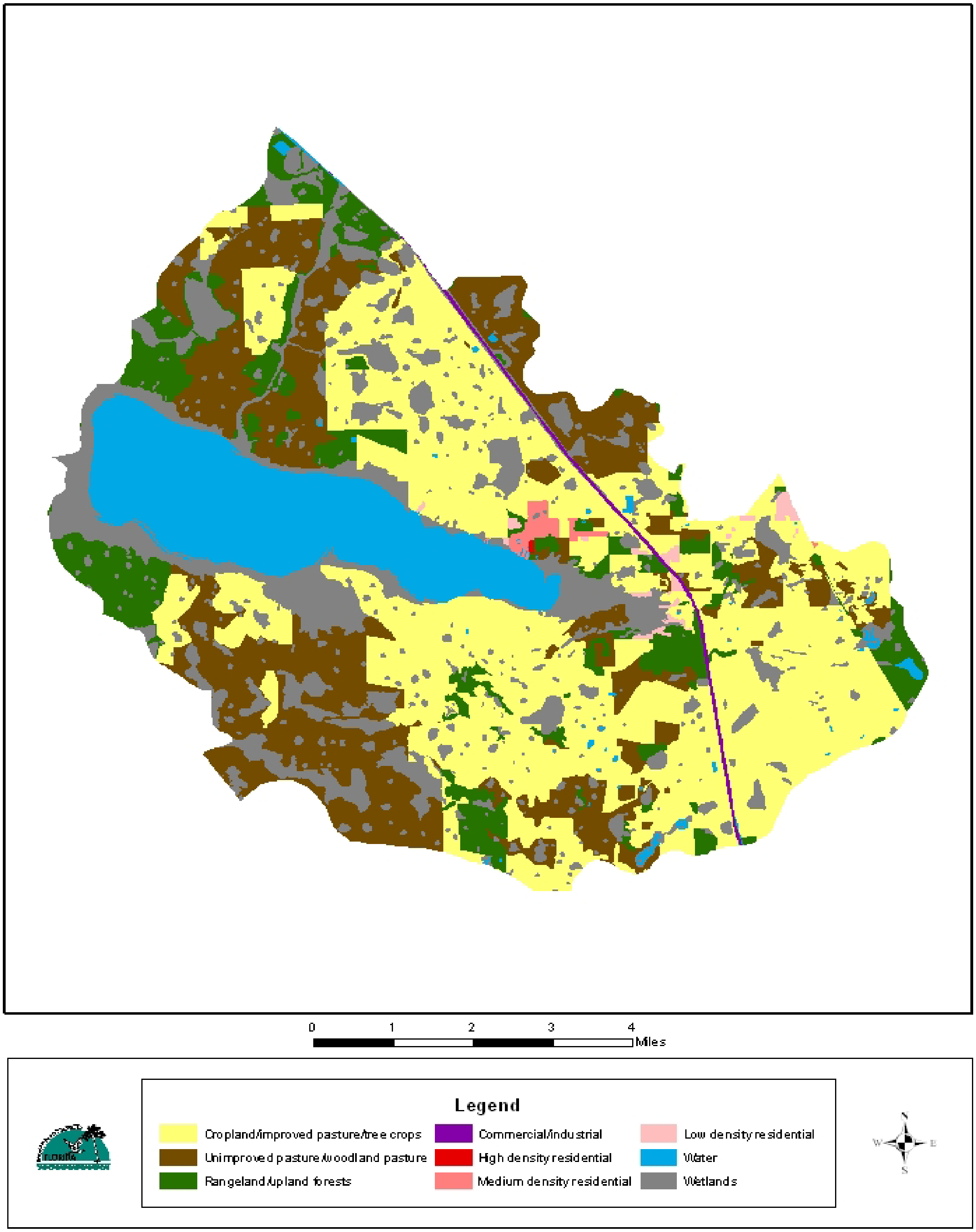

Figure 4.1. Lake Marian Watershed Existing Land Use Coverage in 2000

Septic Tanks

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

The 2008 CDM report, *Section 2.5.2.1, Septic Tanks*, describes in detail how septic tanks were included in the HSPF model. In general, the model does not directly account for the impacts of failing septic tanks. CDM concluded that failing septic tanks were not thought to have significant impacts on Lake Marian and therefore were not explicitly included in the model, because (1) there is a limited amount of urban land in the study area, (2) failure rates are typically low (10% failing or less), and (3) the amount of urban land believed to be served by septic tanks is also low in the study area.

Osceola County Septic Tanks

As of 2006, Osceola County had a cumulative registry of 24,148 septic systems. Data for septic tanks are based on 1971 to 2006 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 to 2006, an average of 157.4 permits per year for repairs was issued in Osceola County (Florida Department of Health [FDOH] 2008). Based on the number of permitted septic tanks estimated for 2006 (24,148) and housing units (109,892) located in the county, approximately 78% of the housing units are connected to a central sewer line (*i.e.*, wastewater treatment facility), with the remaining 22% utilizing septic tank systems. As depicted in **Table 4.3**, there are 142 OSTDS within the Lake Marian watershed, all associated with residential properties.

Table 4.3. Septic Tank Coverage for Urban Land Uses in the Lake Marian Watershed

Note: Septic tank coverage estimated based on available septic tank and sewer service area information.

Receiving Water	HSPF Model Reach	Number of Commercial OSTDS	Number of High-Density Residential OSTDS	Number of Low-Density Residential OSTDS	Number of Medium-Density Residential OSTDS
Lake Marian	450	0	99	21	22

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 Marian watershed. The model allows the Department to interactively simulate and assess the environmental effects of various land use changes and associated land use practices. The water quality parameters (impact parameters) simulated within the model for Lake Marian include water quantity (surface runoff, interflow, and baseflow), and water quality (TN, organic nitrogen, ammonia nitrogen, nitrogen oxides [NO_X], TP, organic phosphorus, ortho phosphorus, phytoplankton as biologically active chl*a* [corrected], temperature, total suspended solids [TSS], DO, and ultimate carbonaceous biological oxygen demand [CBOD]). Datasets of land use, soils, topography and depressions, hydrography, U.S. Geological Survey (USGS) gauge and flow data, septic tanks, water use pumpage, point sources, ground water, atmospheric deposition, solar radiation, control structures, and rainfall (CDM 2008) 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.

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 4.4,** based on published values (CDM 2002). Four of the nine land uses contain some impervious areas.

Table 4.4. Percentage of DCIA

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

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%

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, lower soil storage zone, 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 waterbodies *(e.g.,* lakes) and rivers and streams that connect numerous lakes throughout the project area were modeled in RCHRES rather than PERLND (see *Section 4.3.1.3* of the 2008 CDM report). For each subbasin containing a main stem reach, a number of acres were removed from the water land use in PERLND that were 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 accounted 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 stream flow 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 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 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, accounts for direct water surface inflow (rainfall) and direct water surface outflow (evaporation), and routes flows based on a rating curve supplied by the modeler. Within each subbasin of each planning unit model, a RCHRES element was developed that defines the depth-area-volume relationship for the modeled waterbody.

The depth-area-volume relationships for Lakes Alligator, Myrtle, Hart, Gentry, East Tohopekaliga, Tohopekaliga, Cypress, Hatchineha, and Kissimmee in the Upper Kissimmee Planning Unit were obtained from the *Upper Kissimmee Chain of Lakes Routing Model, Appendix B* (Post Buckley Schuh and Jernigan [PBSJ] *et al.* 2001). For all other major lakes and the impaired WBIDs in the project area, the stage-area-volume relationships were developed based on the lake's bathymetry data. *Section 4.2.10* of the 2008 CDM report provides more detailed information on how the lake bathymetry data were used to develop the depth-area-volume relationships.

For the lakes with hydraulic control structures, the design discharge rates were used in the depth-area-volume-discharge relationships once the lake stages were 1 foot or more than the target levels. When the lake stages were between 0 and 1 foot above the targets, the flows were assumed to vary linearly between 0 (0 feet above target) and the design flows (1 foot above target).

As discussed in the 2008 CDM report, *Section 4.2.11*, the depth-area-volume relationships for the reaches in the Upper Kissimmee Planning Unit were developed based on the cross-section data extracted from the other models.

An initial Manning's roughness coefficient value of 0.035, typical for natural rivers and streams, was used in flow calculations. In some instances, the roughness coefficient value was adjusted during the model calibrations to reflect local conditions, such as smaller values for well-maintained canals and larger values for meandering, highly vegetated, and not well-defined streams. The slopes of water surface (S) were approximated with the reach bottom slopes, which were estimated based on the Digital Elevation Model data.

Implementation of Hydraulic Control Structure Regulation Schedules

To simulate the hydraulic control structure regulation schedules in the HSPF model, the stages were approximated with step functions, as described in detail in *Section 4* of the 2008 CDM report. Variable step functions were used to approximate different regulation schedules. In each approximation, a step function was defined such that stage variations generally equaled 1 foot. In several instances, however, stage variations were less than 1 foot or less than 1.5 feet due to the stage variations in the original regulation schedules. For each hydraulic control structure, a sequential dataset was created to mimic the regulation schedules. Sequential datasets in this HSPF modeling application define the discharge column to evaluate from the FTABLE.

An FTABLE is a table in the HSPF model input file that summarizes the geometric and hydraulic properties of a reach. Normally, an FTABLE has at least three columns: depth, surface area, and volume. For the FTABLE associated with a reach with a control structure, Columns 4 through 8 can be used to define control structure operation flow rates for different operation zones. For example, the approximated operation schedule for a given lake may have four operation zones (1 through 4). For each year from January 1 to April 5 (Zone 1), the sequential dataset instructs the HSPF model to use the discharge rate in Column 4 in the FTABLE. Similarly, Columns 5, 6, and 7 in the FTABLE are used as the operation schedule progresses into Zones 2, 3, and 4, respectively.

Lake Marian Existing Land Use Loadings

The HSPF simulation of pervious lands (PERLNDs) and impervious lands (IMPLNDs) calculates hourly values of runoff from pervious and impervious land areas, and interflow and baseflow from pervious lands, plus loads of water quality constituents associated with these flows. For PERLNDs, TSS (sediment) was simulated in HSPF by accounting for sediment detachment caused by rainfall, and the subsequent wash off of detached sediment when surface runoff occurs. Loads of other constituents in PERLND runoff were calculated in the GQUAL (general quality constituent) model of HSPF, using a "potency factor" approach (*i.e.*, defining how many pounds of constituent are washed off per ton of sediment washed off).

One exception occurs for DO, which HSPF evaluates at the saturation DO concentration in surface runoff. For PERLNDs, concentrations of constituents in baseflow were assigned based on typical values observed in several tributaries in the study area such as Boggy Creek and Reedy Creek, and interflow concentrations were set at values between the estimated runoff and baseflow concentrations. For IMPLNDs, TSS (sediment) is simulated by a "buildup-wash off" approach (buildup during dry periods, wash off with runoff during storm events), and again the "potency factor" approach was used in the IQUAL module for other constituents except DO, which again was analyzed at saturation.

The "general" water quality constituents that were modeled in HSPF include the following:

- *Ammonia nitrogen.*
- *Nitrate nitrogen.*
- *CBOD (ultimate).*
- *Orthophosphate.*
- *Refractory organic nitrogen.*

One feature of HSPF is that the CBOD concentration 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.

The total loadings of nitrogen and phosphorus for Lake Marian were estimated using the HSPF model. Modeling frameworks were designed to simulate the period from 2000 to 2006.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Determination of Loading Capacity

Nutrient enrichment and the resulting problems related to eutrophication are generally widespread and 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 hydrometeorological 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 Marian will meet the narrative nutrient criterion and thus maintain its function and designated use as a Class III water. To achieve this goal and address public comments, the Department decided to update the model developed by CDM (2008) by focusing on the water budgets and nutrient loads of the lakes with nutrient impairments. The model inputs were reconstructed by utilizing hourly input data, and the hydrology and water quality calibrations were significantly improved by adding additional stations for calibration. The HSPF model input data (meteorological data) were compiled from December 1997 to August 2009 at different weather stations, and the model was run from 2000 to 2006 on an hourly time step. The model results obtained from the revised HSPF were compared with the observed data and the independent model results simulated by the Watershed Assessment Model (WAM) that was recently updated by Soil and Water Engineering Technology, Inc. (SWET) for the South Florida Nutrient Budget Analysis for the Lake Okeechobee watershed.

The entire watershed area in the Kissimmee Chain of Lakes (KCOL) HSPF TMDL model covers more than 900,000 acres and consists of 41 subbasins in the model domain. Given this large model domain and the use of the model to develop long-term average TMDL conditions for the impaired lakes, it is impossible at this time to address many of the issues for smaller pieces of land embedded within the 41 larger subbasins. This is because the model is set up with large subbasins, and all the area for each land use within each subbasin is aggregated into one total area for each land use type, and then the subbasin-scale nutrient loads to the impaired waterbodies are estimated for TMDL development.

5.1.1 Meteorological Data

The meteorological data for the revised model were obtained from the stations of the Florida Automatic Weather Network (FAWN), an observation platform owned by the University of Florida. The following hourly meteorological data in the period from December 1997 to August 2009 obtained from this station were included: solar radiation, wind speed, dew point temperature, and air temperature (**Table 5.1**). Pan evaporation and evapotranspiration (ET) rates are also an important factor in hydrologic balances and modeling, since they provide estimates of hydrologic losses from land surfaces and waterbodies within the watershed.

Table 5.1. General Information on Weather Stations for the KCOL HSPF Modeling

Location Name	Start Date	End Date	Frequency	Facility	County	Comment
Avalon	12/15/1997	Present	Hourly	FAWN	Orange	Meteorological data
Lake Alfred	12/31/1997	Present	Hourly	FAWN	Polk	Meteorological data

To estimate lake evaporation, 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). Treommer *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, a pan coefficient of 0.75 was used for the KCOL TMDL modeling. Hourly meteorological data as inputs for HSPF were created using the water management district utility program that provides operational capabilities for the input time-series data necessary for HSPF. **Figures 5.1** and **5.2** show selected time-series input data for hourly air temperature and wind speed. Meteorological data gaps in the period from 2000 to 2006 from the stations were found to be minimal. However, if data during the period of record at a given station were missing for a month or longer, the data from the closest station were used to complete the dataset. If data were missing for only a short period (*i.e.,* days), the average of the values from the day before and the day after was used to represent the data for the missing days.

Rainfall is the predominant factor contributing to the hydrologic balance of a watershed. It is the primary source of surface runoff and baseflow from the watershed to the receiving waters, as well as a direct contributor to the surface of receiving waters. The Department maintains a rainfall dataset that combines radar observations from the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service Weather Surveillance Radar 88 Doppler (WSR-88Ds) and hourly rainfall observations from an operational *in situ* rain gauge network. The rainfall data were extracted for the project area for use in the model.

The Department's multisensor rainfall dataset was checked against (and supplemented by) the hourly rainfall data obtained from the SFWMD for 51 rainfall stations located within Glades, Highlands, Okeechobee, Osceola, Orange, and Polk Counties. The data from these stations were collected between January 1991 and December 2006. For the revised calibration, the same hourly rainfall data were used as in the previous model. The 2008 CDM report contains additional information and describes how the rainfall data were used in the model.

Figure 5.3 shows hourly rainfall assigned in the model to the Lake Marian subbasin. During the period of model simulation from 2000 to 2006, the total annual average rainfall varied from 24.9 to 61.5 inches, with an average annual rainfall of 42.9 ± 11.6 inches (**Figure 5.4**). The 7-year average rainfall during this period was lower than the 100-year state average rainfall (54 inches) (Southeast Regional Climate Center [SERCC] 2010). The noticeable deficiency in annual rainfall from the long-term (100-year) average was identified in 2000 and 2006, when the annual rainfall recorded was 24.9 and 35.2 inches, respectively. The comparison between the local 7-year rainfall data and the state's long-term average rainfall data indicated that 2000 and 2006 were dry years, while 2005 was considered a wet year during the simulation period.

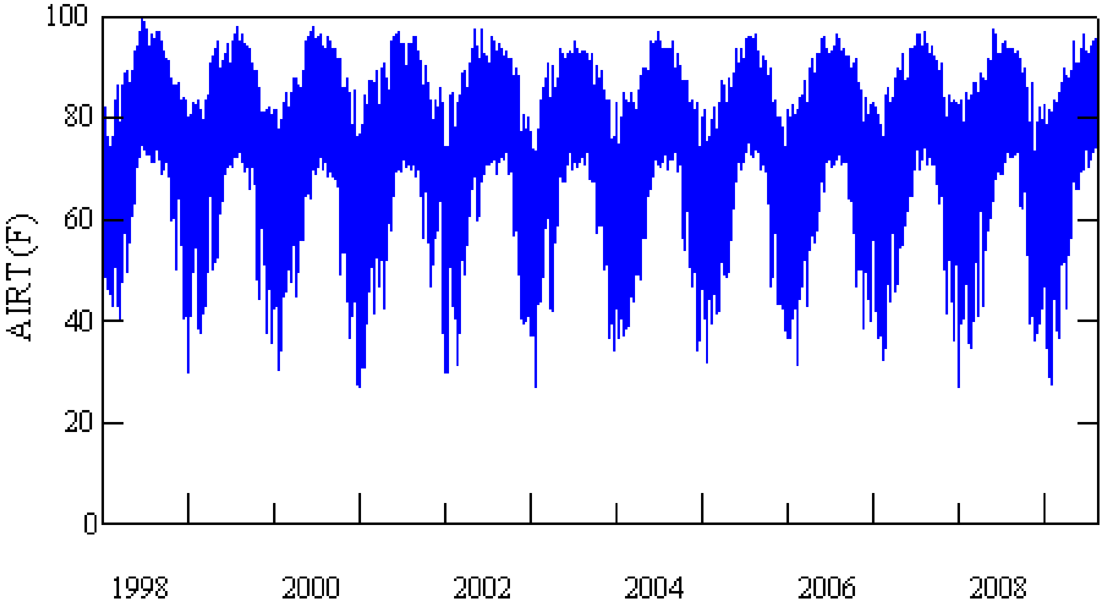

Figure 5.1. Hourly Observed Air Temperature (°F.) Observed from the FAWN Station, 1998–2009

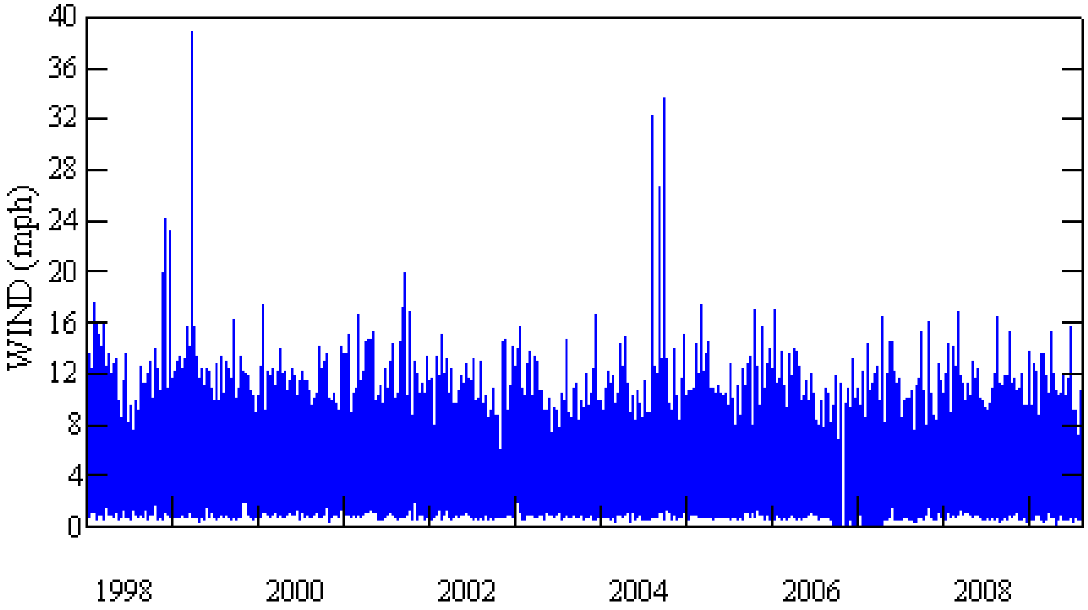

Figure 5.2. Hourly Observed Wind Speed (mph) Observed from the FAWN Station, 1998–2009

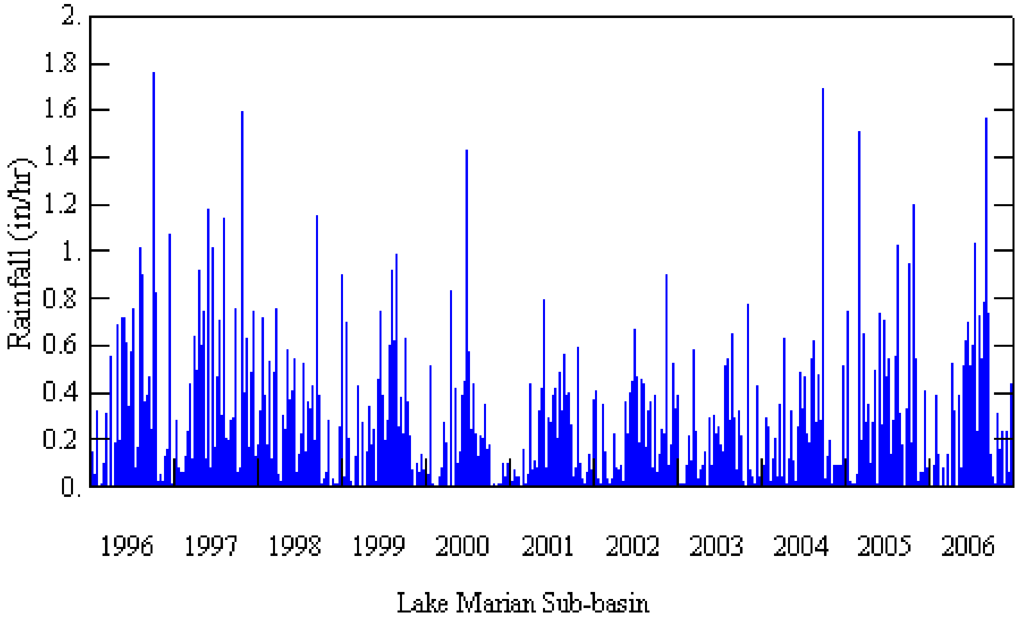

Figure 5.3. Hourly Rainfall (inches/hour) for the Lake Marian Subbasin, 1996–2006

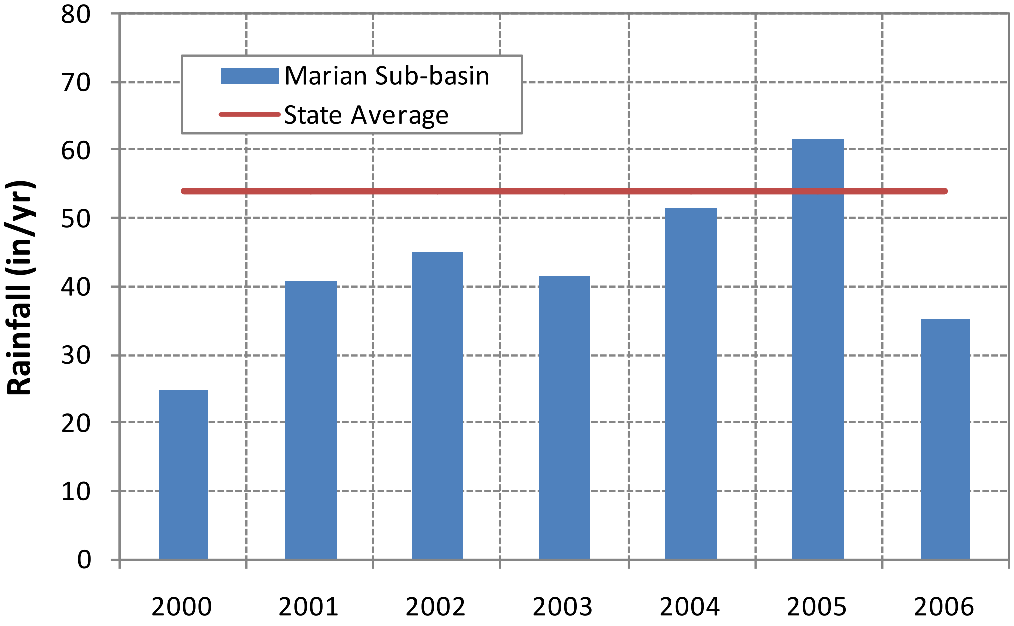

Figure 5.4. Annual Rainfall (inches/year) for the Lake Marian Subbasin During the Simulation Period and Long-Term (1909–2009) State Average Annual Rainfall (54 inches/year)

5.2 Model Calibration

5.2.1 Temperature Calibration for Lake Marian

Water temperature itself is considered as a conservative parameter that does not undergo chemical reactions in the system. Water temperature is a critical habitat characteristic for fish and other organisms, and affects the rates of biogeochemical processes of functional importance to the environment. For example, the saturation level of DO varies inversely with temperature. The decay of reduced organic matter, and hence oxygen demand caused by the decay, increases with increasing temperature. Some form of temperature dependence is present in nearly all processes. The prevalence of individual phytoplankton and zooplankton species is often temperature dependent. It should be also noted that the water temperature in a stream is a result of the heat balance along with the water movement in the air-land-stream system. The following key parameters control the energy balance for water temperature: short- and long-wave radiation, conduction, convection, evaporation, and ground conduction (HSPF manual 2001).

For Lake Marian, parameters PSTEMP, IWTGAS, and RCHRES (KATRAD, KCOND, KEVAP) were adjusted for temperature calibration. As a result, the simulated daily average lake temperature was in good agreement with the observed daily average temperature (**Figures 5.5** and **5.6**). The box and whisker plot showed that the 7-year mean (24.0 °C.) of the observed lake temperature was similar to that of the simulated lake temperature (23.1 °C.) (**Figure 5.7**). Overall, it was decided that the model calibration for temperature was acceptable.

5.2.2 Hydrology Calibration for Lake Marian

The HSPF model, based on the aggregated land use categories, was used to simulate watershed hydraulic and hydrology. Because the study area is largely pervious land, the calibration process focused on the development of appropriate pervious area hydrologic parameters. Initial parameter values were determined based on previous modeling efforts (CDM 2003). Values were then adjusted to improve the match between measured and modeled stream flows. Parameter values were largely maintained within a range of possible values based on CDM's previous experience with the HSPF hydrologic model and on BASINS Technical Note 6 (Hartigan 1983; Hartigan *et al.* 1983a; Hartigan *et al.* 1983b; Wagner 1986; CDM 2002; EPA 2000).

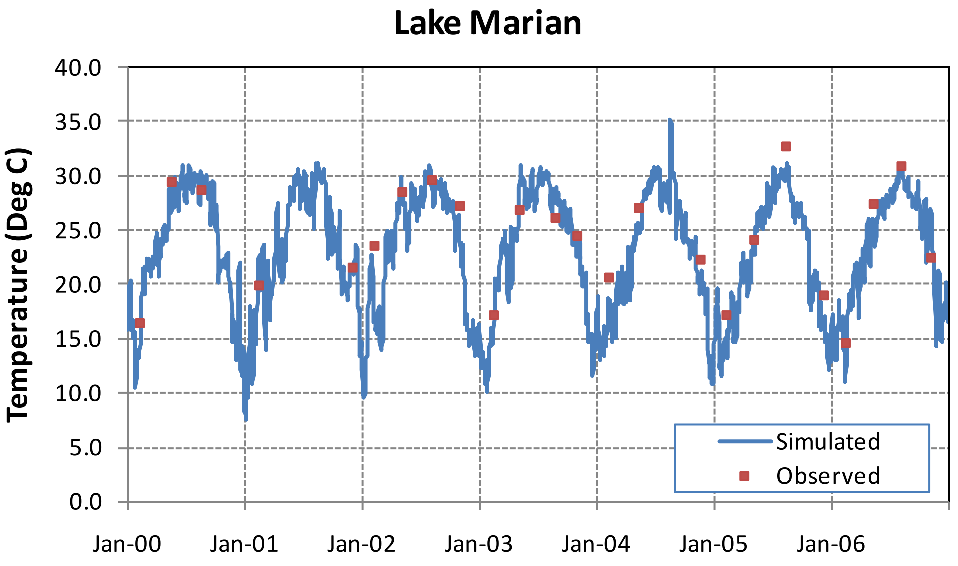

Figure 5.5. Observed Versus Simulated Daily Lake Temperature (°C.) in Lake Marian During the Simulation Period, 2000–06

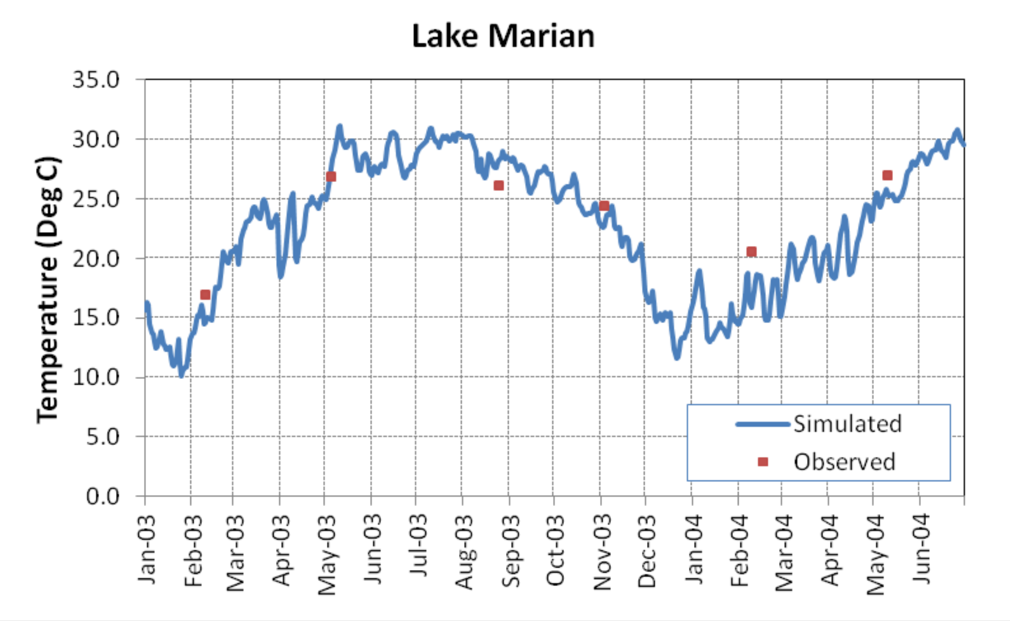

Figure 5.6. Monthly Variation of Observed Versus Simulated Daily Lake Temperature (°C.) in Lake Marian During the Selected Simulation Period, January 2003-June 2004

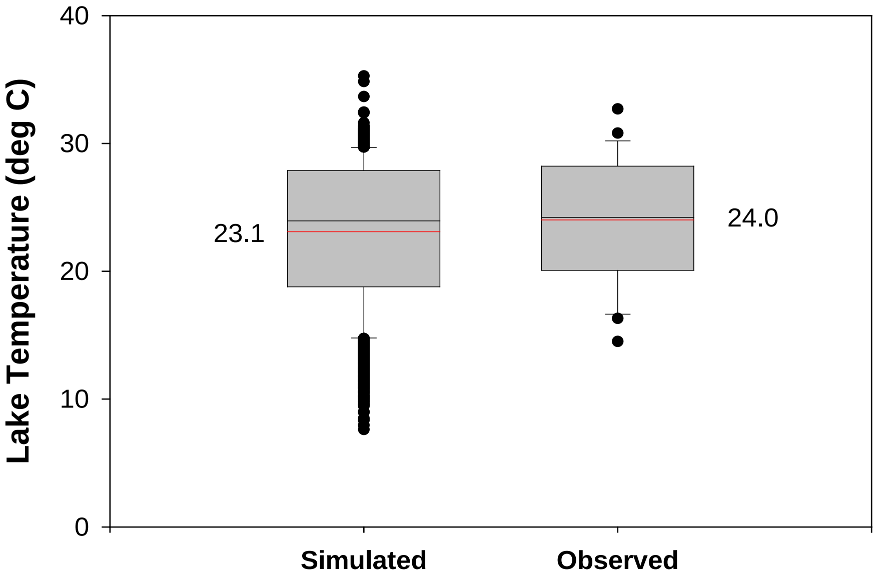

Figure 5.7. Daily Measured Versus Simulated Lake Temperature for Lake Marian During the Selected Period, January 2003–June 2004.

Besides the 16 major hydraulic control structures discussed in *Section 4.2.5* of the 2008 CDM report, many local small hydraulic control structures throughout the Reedy Creek and Boggy Creek watersheds in the Upper Kissimmee Planning Unit were identified by other studies (URS Greiner 1998; USGS 2002). It appears that measurements made at the flow stations with the most flow measurements in the project area were somewhat affected by the hydraulic control structures. Ideally, flow stations that are not affected by any hydraulic control structures should be selected for hydrologic model calibrations.

To minimize the effects from hydraulic control structures, the initial calibration focused on three gauged subbasins in the northern part of the study area in the Upper Kissimmee Planning Unit (Reedy Creek, Shingle Creek, and Boggy Creek), which are not largely influenced by hydraulic control structures. Parameters were established for these subbasins that provided a reasonable match to measured data. These parameter values and relationships to land use were then uniformly applied to all the subbasins in the planning units. Furthermore, subbasin-specific parameters such as LZSN, UZSN, and INFILT were developed based on local hydrologic soil group information. Further flow calibrations at the control structures were completed by adjusting control structure flow rates and lake volumes, when appropriate. A detailed discussion of this method is included in *Section 4.5* of the 2008 CDM report.

Table 5.2 shows model calibration stations for flow and lake levels of Lake Marian. The HSPF model outputs at these stations were calibrated using the observed data and independent model outputs simulated by WAM. The independent simulated results from WAM would especially help at locations where there are no measured data available for the HSPF hydrology calibration.

Table 5.2. General Information on Key Stations for Model Calibration

NA = Not available

Station	Station Name	Agency	County	Type
LMARIAN	Lake Marian	Water management district	Osceola	Stage
LMARIAN	Lake Marian outflow	NA	Osceola	Flow

The predicted lake level was a result of the water balance between simulated water inputs from the watershed and losses from the lake. The simulated lake levels in Lake Marian were calibrated with the observed lake levels obtained from January 2000 to December 2006. **Figure 5.8** shows a good agreement between daily time series of observed versus simulated lake levels, and **Figure 5.9** indicates a good relationship between the observed lake level and the simulated lake elevation, with a correlation coefficient of 0.774 (n = 2526). In general, simulated daily lake levels varied from 55.0 to 62.5 feet, with a 7-year average of 58.0 feet (n = 2560) over the simulation period.

Similarly, the observed data showed that daily lake levels ranged from 54.9 to 61.0 feet and averaged about 57.9 feet (n = 2526). Simulated annual mean lake levels also agreed well with observed annual mean lake levels, within one-sigma standard errors (**Table 5.3**). Overall, daily and annual lake levels indicated that the model simulation well represents the short- and long-term average stage for Lake Marian.

Flow comparisons of observed daily flow and simulated daily flow were also performed at several calibration stations where the incoming and outgoing flows of the impaired lakes primarily occur. For Lake Marian, there is only an outlet at the northwest side of the lake discharging flow to Lake Jackson (**Table 5.2**). The outgoing flow from Lake Marian was calibrated with the WAM-generated outflow from Lake Marian because no measured flow data were available for flow calibration.

Figure 5.10 shows the simulated cumulative daily flows from both HSPF and WAM at the Lake Marian outlet from 2000 to 2006. The cumulative flow by HSPF was 83,322 cubic feet per second (cfs) over the 7-year period, similar to 84,803 cfs simulated by WAM (**Table 5.4**). The lowest annual cumulative flow by HSPF was observed in 2000 and 2001 during the dry years. The second lowest annual flow was simulated for 2006, showing the annual flow at 6,324 cfs when rainfall was at 35.2 inches. The peak annual flow of 31,671 cfs was observed in 2005 when rainfall was the highest during the period of simulation.

The WAM-generated annual flow indicates a similar annual flow pattern, showing the peak annual flow in 2005 and the lowest flow in 2000. The similarities in the long-term and annual cumulative flow between HSPF and WAM show that both results present similar flow patterns representative of dry and wet years throughout the modeling period. Although no outgoing flow leaving Lake Marian was measured, the simulated outgoing flow estimated by HSPF was validated by the results from WAM.

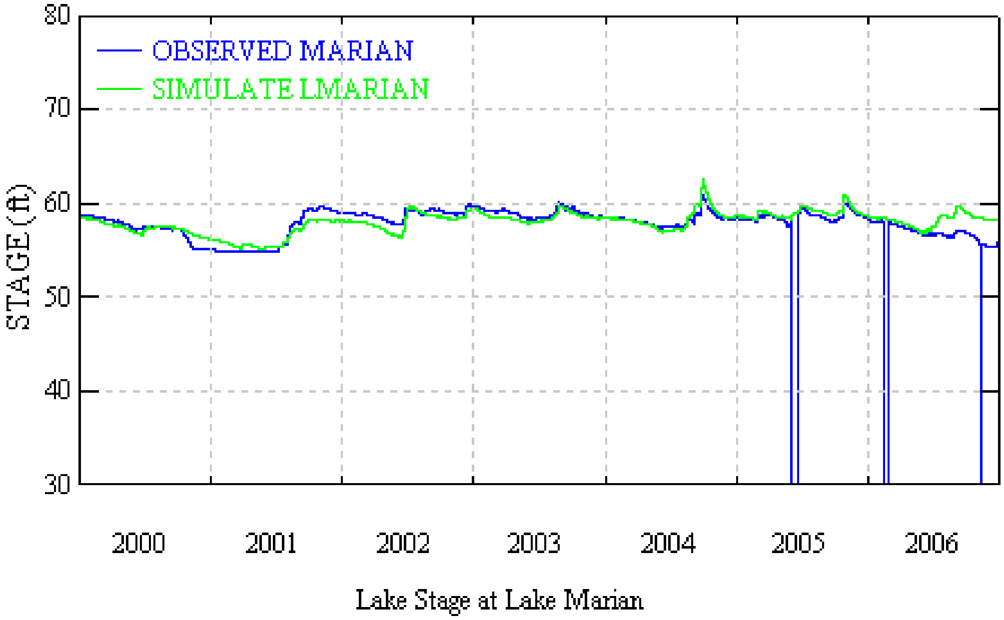

Figure 5.8. Time-Series Observed Versus Simulated Lake Stage (feet, National Geodetic Vertical Datum [NGVD]) in Lake Marian During the Simulation Period, 2000–06

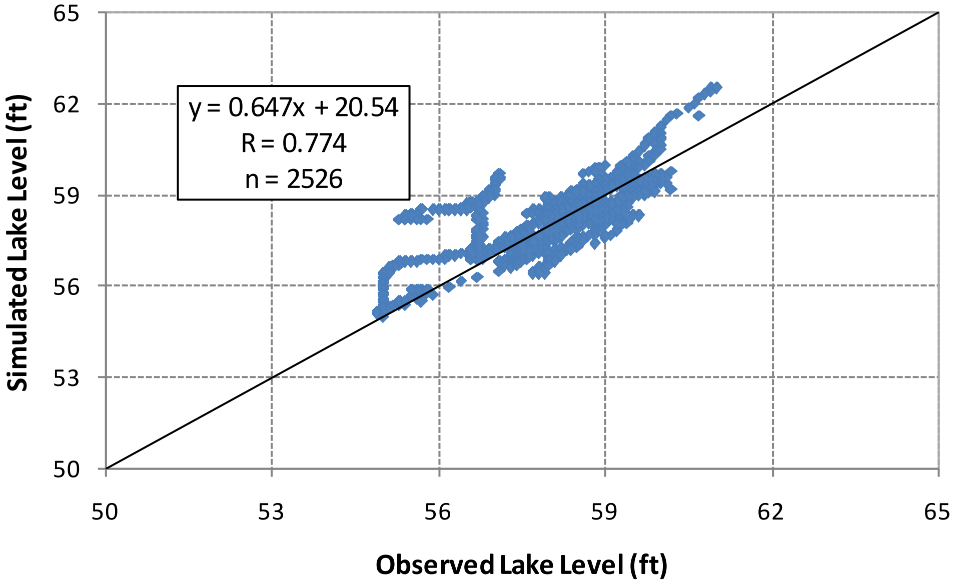

Figure 5.9. Daily Point-to-Point Paired Calibration of Lake Level (feet) During the Simulation Period, 2000–06 (solid line indicates the ideal 1-to-1 line, R represents a correlation coefficient of the best fit between observed and simulated lake levels, and n indicates the number of observations)

Table 5.3. Observed and Simulated Annual Mean Lake Level (feet, NGVD) and Standard Deviation for Lake Marian

Year	Observed Stage (feet)	Standard Deviation (+/-)	Simulated Stage (feet)	Standard Deviation (+/-)
2000	57.3	1.1	57.4	0.6
2001	56.6	1.9	56.5	1.2
2002	58.9	0.5	58.2	0.8
2003	59.0	0.5	58.6	0.4
2004	58.3	0.7	58.4	1.1
2005	58.6	0.5	59.0	0.5
2006	56.9	0.8	58.2	0.6
Average	**57.9**	**1.3**	**58.0**	**1.1**

Based on the simulated results, the Department was able to construct the water budget for Lake Marian (**Table 5.5**). The results indicate that incoming and outgoing waters are reasonably balanced. The estimated total inflow to Lake Marian varied from 19,143 ac-ft/yr in 2000 to 96,111 ac-ft/yr in 2005, with a 7-year average of 54,838 ac-ft/yr. As shown in **Table 5.5**, during the wet year in 2005, the simulated total annual inflows via surface runoff, interflow, and baseflow were estimated to be three times as high as those in the dry years of 2000 and 2006. As a result, the lake discharged more in 2005, peaking at 62,808 ac-ft/yr.

Figure 5.11 shows the relative importance of incoming flows to the lake. Total annual inflows and outflows were estimated to construct the water budget of Lake Marian during the simulation period. On average, direct rainfall is the largest contributor of water at 42.1%, followed by subbasin interflow (30.5%), subbasin baseflow (16.2%), and subbasin runoff (11.2%). Therefore, interflow may be the major pathway carrying water and its constituents, including nutrients and other pollutants, to the lake and maintaining the lake water level.

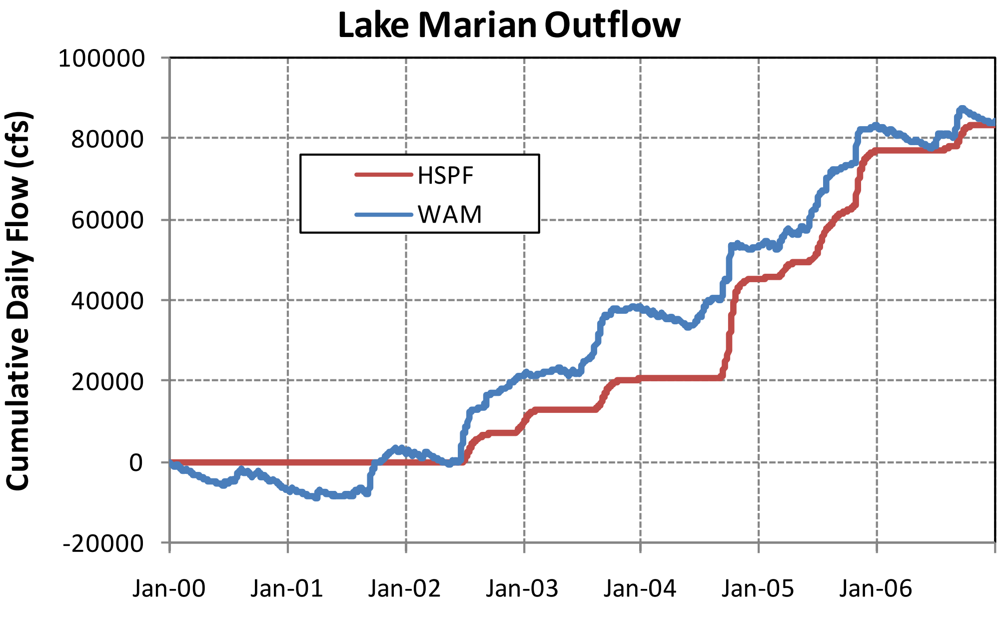

Figure 5.10. Cumulative Daily Flows Obtained by HSPF and WAM at Lake Marian Outflow, 2000–06

Table 5.4. Simulated Annual Total Flows Obtained by HSPF and WAM at Lake Marian Outflow, 2000–06

Year	HSPF Annual Total Flow (cfs)	WAM Annual Total Flow (cfs)
2000	0	-6,922
2001	0	9,020
2002	9,715	19,275
2003	10,863	16,859
2004	24,750	15,428
2005	31,671	29,957
2006	6,324	1,186
Grand Total	**83,322**	**84,803**

Table 5.5. Simulated Annual Total Inflow and Outflow (ac-ft/yr) for Lake Marian During the Simulation Period, 2000–06

Year	Subbasin Runoff (ac-ft/yr)	Subbasin Interflow (ac-ft/yr)	Subbasin Baseflow (ac-ft/yr)	Direct Precipitation (ac-ft/yr)	Evaporation (ac-ft/yr)	Outflow (ac-ft/yr)
2000	554	3,529	2,341	12,720	-31,241	0
2001	1,158	11,032	7,198	20,246	-29,853	0
2002	2,823	21,418	9,410	24,233	-31,024	-19,268
2003	1,602	11,738	10,448	22,689	-30,327	-21,547
2004	18,087	24,520	11,056	28,363	-31,846	-49,082
2005	14,964	30,719	15,774	34,655	-33,549	-62,808
2006	3,745	14,124	5,867	18,853	-32,427	-12,541
Average	**6,133**	**16,726**	**8,871**	**23,108**	**-31,467**	**-23,607**

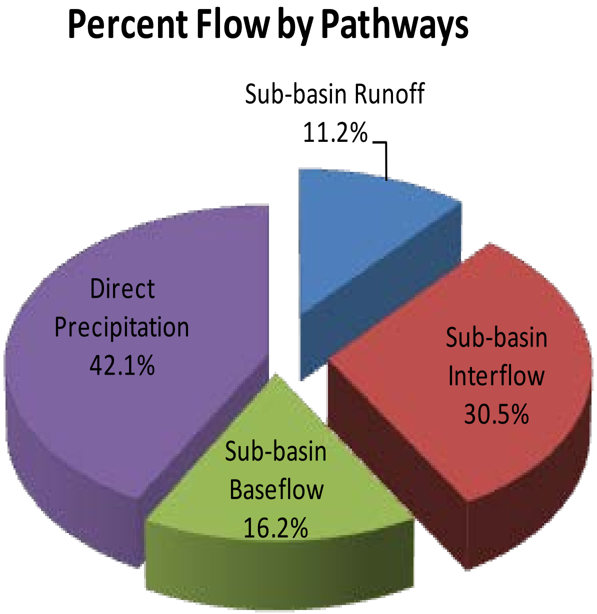

Figure 5.11. Long-Term (7-year) Averaged Annual Percent Inflows to Lake Marian During the Simulation Period, 2000–06

5.2.3 Lake Marian Nonpoint Source Loadings

Nonpoint source loads of TN and TP from different types of land use were estimated for the existing conditions in the Lake Marian watershed based on the HSPF PERLND and IMPLND flows and the corresponding concentrations of each land use category. The estimated TN and TP loading coefficients for land use types were compared with literature values to make sure that the calibrated loading rates of TN and TP from each land use were reasonable.

Tables 5.6 and **5.7** show the estimated average loading rates of TN and TP from the nine land use categories over the simulation period. Loading coefficients of TN and TP for rangeland/upland forest were estimated to be 2.2 and 0.06 lbs/ac/yr, respectively. These estimated coefficients are comparable to the literature values for forest with the load coefficients of 2.1 ± 0.4 lbs/ac/yr for TN and 0.1 ± 0.03 lbs/ac/yr for TP (Frink 1991), and the export rates of 2.4 lbs/ac/yr for TN and 0.04 lbs/ac/yr for TP (Donigian 2002). The agreements between the simulated loading rates and the literature values indicate that the estimated TN and TP loadings from the natural types of land uses for Lake Marian are acceptable. For cropland/improved pasture/tree crops, export coefficients of TN and TP were estimated to be about 8.0 and 0.63 lbs/ac/yr, respectively. For unimproved pastureland/woodland pastureland, estimated TN and TP loading rates were about 5.6 and 0.29 lbs/ac/yr, respectively. These estimated rates for anthropogenic land uses are comparable to the literature values (5.9 lbs/ac/yr for TN, 0.3 lbs/ac/yr for TP) categorized as agriculture (Frink 1991; Donigian 2002).

Tables 5.8 and **5.9** show the annual average TN and TP loads from various transport pathways to Lake Marian, indicating that subbasin interflow is the major contributor supplying a 7-yr averaged annual TN load of 244,300 lbs/yr and TP load of 14,241 lbs/yr. These TN and TP loads via subbasin interflow account for about 37.8% of the total TN loads and about 75.5% of the total TP loads to the lake during the simulation period (**Figures 5.12** and **5.13**). The second largest TN and TP contributions to Lake Marian are subbasin runoff and direct precipitation, respectively, accounting for 33.6% for TN and 10.2% for TP.

Based on the model results, existing TN and TP loads appear to be strongly associated with annual rainfall (**Figures 5.14** and **5.15**). For example, greater nutrient loads were found during wet years, especially in 2004 and 2005, while lower TN and TP loads were estimated during dry years in 2000 and 2006. Overall, rainfall-driven runoff such as surface runoff and interflow are the most important means to deliver TN and TP to the lake. Under the existing conditions, the simulated total watershed loads of TN and TP to Lake Marian, on a long-term average, were estimated to be 195,827 and 12,793 lbs/yr, respectively (**Tables 5.8** and **5.9**).

5.2.4 In-Lake Water Quality Calibration

As discussed in **Chapter 4**, in the evaluation of nutrients and phytoplanktonic algae (as chl*a*), the HSPF model accounts for the following water quality constituents:

- *Organic nitrogen (organic N).*
- *Ammonia nitrogen (ammonia N).*
- *Nitrite + nitrate nitrogen (nitrate N).*
- *Organic phosphorus (organic P).*
- *Inorganic phosphorus (inorganic P).*
- *Phytoplanktonic algae (chla).*

Table 5.6. Comparison Between Simulated TN Loading Rates for the Lake Marian Subbasin and Nonpoint TN Loading Rates with the Expected Ranges from the Literature

Land Use Type	Simulated TN Loading Rate for the Lake Marian Subbasin (lbs/ac/yr)	TN Loading Rate (lbs/ac/yr) by Donigian (2002)
High-density residential	5.1	8.5 (5.6-15.7) for Urban
Low-density residential	6.9	8.5 (5.6-15.7) for Urban
Medium-density residential	6.3	8.5 (5.6-15.7) for Urban
Commercial/industrial	3.7	8.5 (5.6-15.7) for Urban
Unimproved pastureland/ woodland pasture	5.6	5.9 (3.4-11.6) for Agriculture
Cropland/improved pasture/ tree crops	8.0	5.9 (3.4-11.6) for Agriculture
Wetlands	2.1	2.2 (1.4-3.5)
Rangeland/upland forest	2.2	2.4 (1.4-4.3)

Table 5.7. Comparison between Simulated TP Loading Rates for the Lake Marian Subbasin and Nonpoint TP Loading Rates with the Expected Ranges from the Literature

Land Use Type	Simulated TP Loading Rate for the Lake Marian Subbasin (lbs/ac/yr)	TP Loading Rate (lbs/ac/yr) by Donigian (2002)
High-density residential	0.47	0.26 (0.20-0.41) for Urban
Low-density residential	0.41	0.26 (0.20-0.41) for Urban
Medium-density residential	0.43	0.26 (0.20-0.41) for Urban
Commercial/industrial	0.47	0.26 (0.20-0.41) for Urban
Unimproved pastureland/ woodland pasture	0.29	0.30 (0.23-0.44) for Agriculture
Cropland/improved pasture/ tree crops	0.63	0.30 (0.23-0.44) for Agriculture
Wetlands	0.05	0.03 (0.02-0.05)
Rangeland/upland forest	0.06	0.04 (0.03-0.08)

Table 5.8. Simulated Annual TN Loads (lbs/yr) to Lake Marian via Various Transport Pathways under the Current Condition

Year	TN Load by Subbasin Runoff (lbs/yr)	TN Load by Subbasin Interflow (lbs/yr)	TN Load by Subbasin Baseflow (lbs/yr)	TN Load by Direct Precipitation (lbs/yr)	Total Incoming TN Load (lbs/yr)
2000	13,048	21,113	5,735	26,663	66,559
2001	34,336	62,743	17,527	42,425	157,031
2002	89,229	116813	22,836	50,797	279,675
2003	45,304	63,922	25,554	47,552	182,333
2004	104,782	133,451	26,976	59,530	324,738
2005	188,957	168,635	37,994	72,772	468,358
2006	98,738	79,074	14,019	39,578	231,409
Average	**82,056**	**92,250**	**21,520**	**48,474**	**244,300**

Table 5.9. Simulated Annual TP Loads (lbs/yr) to Lake Marian via Various Transport Pathways under the Current Condition

Year	TP Load by Subbasin Runoff (lbs/yr)	TP Load by Subbasin Interflow (lbs/yr)	TP Load by Subbasin Baseflow (lbs/yr)	TP Load by Direct Precipitation (lbs/yr)	Total Incoming TP Load (lbs/yr)
2000	168	2,526	347	796	3,838
2001	335	7,389	1,060	1,267	10,051
2002	716	13,565	1,380	1,517	17,178
2003	424	7,416	1,546	1,420	10,806
2004	1,081	15,488	1,631	1,778	19,979
2005	1,621	19,622	2,292	2,174	25,709
2006	834	9,267	844	1,182	12,127
Average	**740**	**10,753**	**1,300**	**1,448**	**14,241**

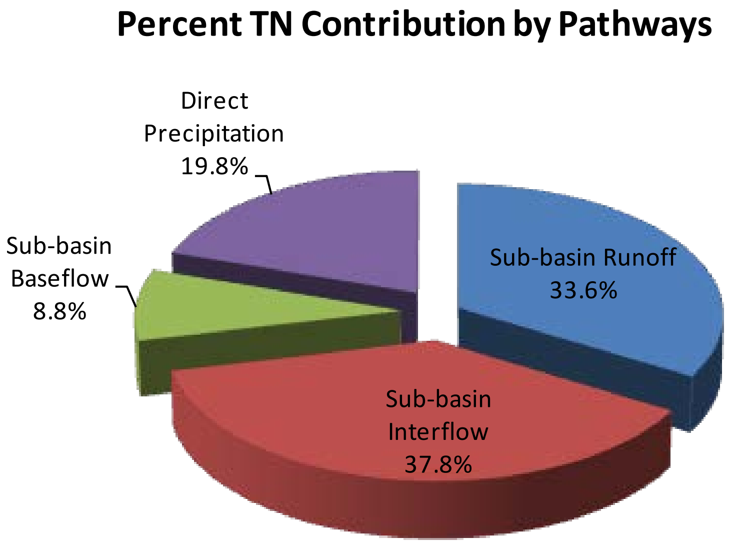

Figure 5.12. Percent TN Contribution to Lake Marian under the Existing Condition During the Simulation Period, 2000–06

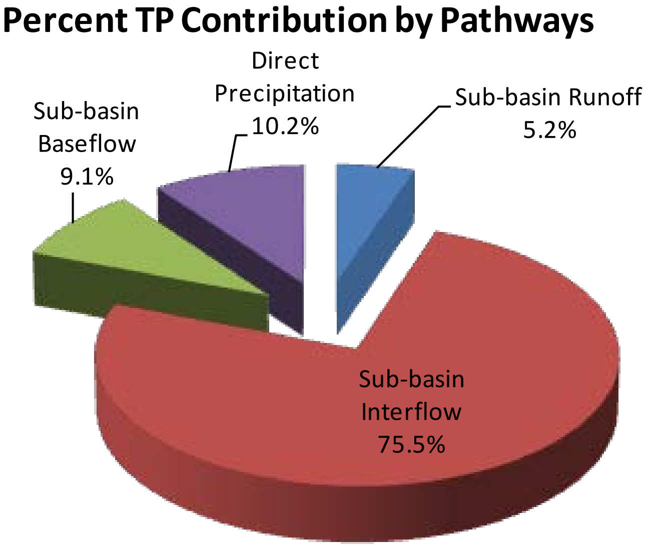

Figure 5.13. Percent TP Contribution to Lake Marian under the Existing Condition During the Simulation Period, 2000–06

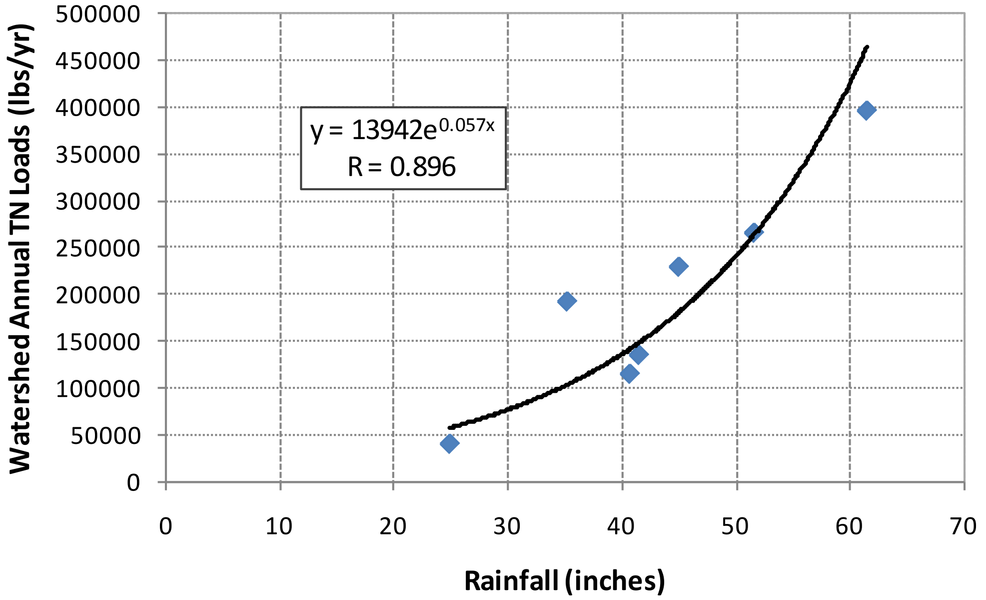

Figure 5.14. Relationship Between Rainfall Versus Watershed Annual TN Loads to Lake Marian under the Existing Condition During the Simulation Period, 2000–06

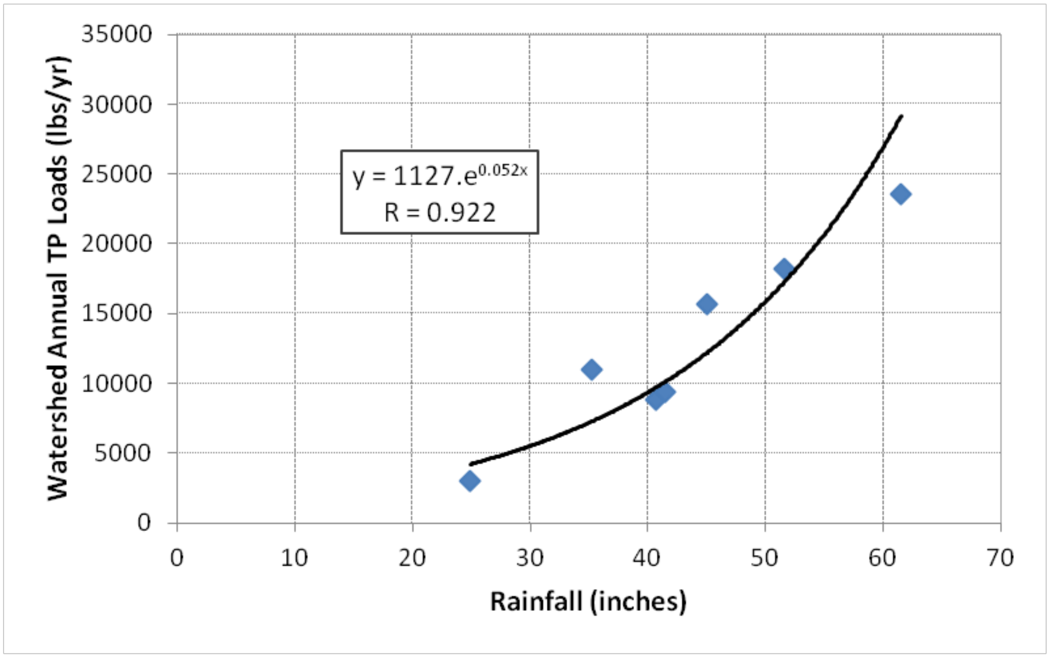

Figure 5.15. Relationship Between Rainfall Versus Watershed Annual TP Loads to Lake Marian under the Existing Condition During the Simulation Period, 2000–06

Organic N and organic P in the model are associated with several water quality constituents, including ultimate CBOD, phytoplankton, and refractory organics that result from the death of algae. The following key processes affect the model simulation of phytoplankton concentration in receiving waters: phytoplankton growth, phytoplankton respiration, phytoplankton death, and phytoplankton settling. Phytoplankton growth is modeled based on a specified maximum growth rate, which is adjusted by the model based on water temperature, and is limited by the model based on available light and inorganic N and P. Similarly, death and respiration are modeled based on specified rates that are adjusted for water temperature. A higher death rate may be applied by the model under certain conditions (*e.g.*, high water temperature, high chl*a* concentration). Settling is modeled based on a constant settling rate. Growth increases the concentration of phytoplankton, while the other processes reduce the concentration of phytoplankton.

The key processes affecting the model simulation of nitrogen concentrations in receiving waters include the following:

- *First-order decay of biochemical oxygen demand (BOD) (organic N associated with BOD is converted to ammonia N in this process).*
- *BOD settling (organic N associated with BOD is lost to lake sediments).*
- *Phytoplankton growth (inorganic N is converted to phytoplankton N).*
- *Phytoplankton respiration (phytoplankton N is converted to ammonia N).*
- *Phytoplankton death (phytoplankton N is converted to BOD and/or refractory organic N).*
- *Phytoplankton settling (phytoplankton N is lost to lake sediments).*
- *Refractory organic N settling to lake sediments.*
- *Nitrification (conversion of ammonia N to nitrate N).*
- *Sediment flux (ammonia N is released from sediment to overlying water).*

Ultimately, the rate at which nitrogen is removed from the receiving water depends on the rate at which inorganic N is converted to organic N (by phytoplankton growth) and the rate at which the organic N forms (as BOD, as refractory organic N, and as phytoplankton N) settle to the lake sediments.

The key processes affecting the model simulation of phosphorus concentrations in the lake include the following:

- *First-order decay of BOD (organic P associated with BOD is converted to inorganic P in this process).*
- *BOD settling (organic P associated with BOD is lost to lake sediments).*
- *Phytoplankton growth (inorganic P is converted to phytoplankton P).*
- *Phytoplankton respiration (phytoplankton P is converted to inorganic P).*
- *Phytoplankton death (phytoplankton P is converted to BOD and/or refractory organic P).*
- *Phytoplankton settling (phytoplankton P is lost to lake sediments).*
- *Refractory organic P settling to lake sediments.*
- *Sediment flux (inorganic P is released from sediment to overlying water).*

Ultimately, the rate at which phosphorus is removed from the lake water depends on the rate at which inorganic P is converted to organic P (by phytoplankton growth) and the rate at which the organic P forms (as BOD, as refractory organic P, and as phytoplankton P) settle to the lake sediments.

Waterbodies with long mean residence times (months or years) allow substantial time and relatively quiescent conditions for phytoplankton growth. In contrast, these processes are expected to have little impact in free-flowing stream reaches with short residence times (a day or less) and relatively turbulent conditions. However, it is possible to see high phytoplankton levels in streams during dry weather periods, if the stream has some areas of standing water.

Reaeration is a process of exchange between the water and the overlying atmosphere that typically brings oxygen into the receiving water (unless the receiving water DO concentration is above saturation levels). In the long term, phytoplankton growth and respiration typically provide a net DO benefit (*i.e.,* more DO is introduced through growth than is depleted through respiration). The other three processes take oxygen from the receiving water. The results of the modeling suggest that reaeration and sediment oxygen demand (SOD) are often the key processes in the overall DO mass balance, though the other processes may be important in lakes with relatively high loadings.

The model simulated flows and associated loads from the tributary area into the Lake Marian reach (RCHRES 450) to perform HSPF water quality calculations. Simulations included concentrations of water quality constituents such as phytoplankton and various forms of nitrogen and phosphorus. During HSPF calibration, water quality input parameters that represented the physical and biological processes in the lake were set so that the simulated concentrations were comparable to the available measured water quality data for Lake Marian.

The time series of simulated TN over the simulation period reasonably predicted the seasonal variation and annual trends (**Figures 5.16** through **5.18)**. Based on the box and whisker plot (**Figure 5.16**), the mean, median, and distribution percentiles of simulated TN matched those of observed TN. The 7-year mean and standard deviation for the observed TN were 2.13 ± 1.01 mg/L, similar to those of simulated TN (2.17 ± 0.26 mg/L). The 10th and 90th percentiles of the observed TN were 1.06 and 3.06 mg/L, respectively. Similarly, the 10th and 90th percentiles of the simulated TN values were 1.86 and 2.55 mg/L, respectively. On annual average, as calculated based on quarterly means for each year, a similar annual variation within one standard deviation was observed, ranging from 1.899 ± 0.100 to 2.506 ± 0.041 mg/L for the simulated TN and from 1.81 ± 0.378 to 2.58 ± 0.578 mg/L for the observed TN (**Figure 5.18**).

Following the same procedures, the time series of simulated TP was calibrated against the observed TP (**Figure 5.19**). Compared with the simulated time series of daily TP, the observed TP showed a wide range of variation in concentration over the period. Although the observed daily TP values fluctuated widely in most years, the box and whisker plot and the annual means for TP also indicated that the mean, median, and 10th and 90th percentiles between simulation and observation were in good agreement (**Figures 5.20** and **5.21**). The mean and median of the simulated TP over the simulation period predicted 0.133 ± 0.05 and 0.104 mg/L, respectively, similar to the mean (0.155 ± 0.07 mg/L) and median (0.139 mg/L) of the observed TP. Annual variations of the observed and simulated annual TP were also in reasonable agreement within 1-sigma standard deviations (**Figure 5.21**). For example, a mean concentration of the observed TP in 2000 was the highest, showing a concentration of 0.177 ±

0.019 mg/L, with a coefficient of variance (CV) of about 8%, while the highest annual mean of 0.232 ± 0.092 mg/L was simulated by the model for 2000, with a CV of about 40%.

The time series of simulated chl*a* for Lake Marian, plotted against the observed chl*a*, generally showed a reasonable agreement over the simulation period (**Figure 5.22**). The model reasonably predicted both the peak concentrations of observed chl*a* during the growing season and the lower concentrations of observed chl*a*. The box and whisker plots also indicated that the mean, median, and distribution percentiles of simulated chl*a* over the period of simulation were very similar to those of the observed chl*a* (**Figure 5.23**). There were good agreements in the mean, median, and 10th and 90th percentiles of simulated versus observed chl*a*. For example, the mean and median for the observed chl*a* were 54.5 ± 27.42 and 51.8 µg/L, similar to 39.4 ± 14.8 and 37.3 µg/L for the simulated chl*a*. The 10th and 90th percentiles of the observed chl*a* values were 22.6 and 91.6 µg/L, respectively, while the 10th and 90th percentiles of the simulated values in the range were 21.8 and 59.0 µg/L, respectively. Predicted annual mean concentrations for each year also agreed with the observed annual mean concentration within one standard error over the simulation period (**Figure 5.24**).

Based on the simulated TN, TP, and chl*a* concentrations, simulated annual TSIs for Lake Cypress were calculated and compared with those calculated based on the observed TN, TP, and cchl*a* concentrations (**Figure 5.25**). The simulated TSI for the lake ranged from 67.1 to 75.5, with a 7-year average of 70.36 ± 2.7 (n = 7). This long-term predicted average TSI agreed with the average observed TSI of 71.7 ± 5.0 (n = 3), indicating that the model calibration was acceptable.

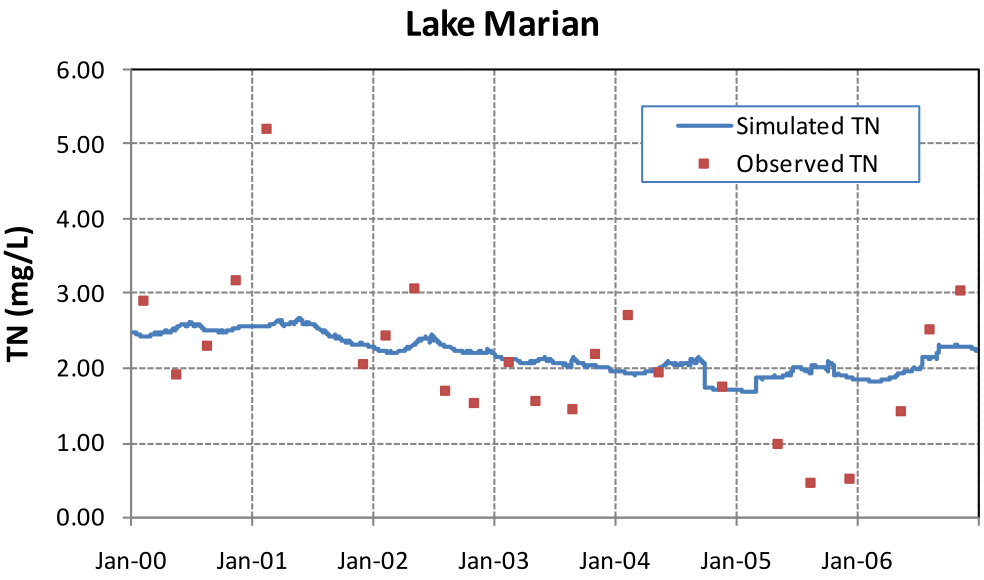

Figure 5.16. Time-Series of Observed Versus Simulated Daily TN Concentrations in Lake Marian During the Simulation Period, 2000–06

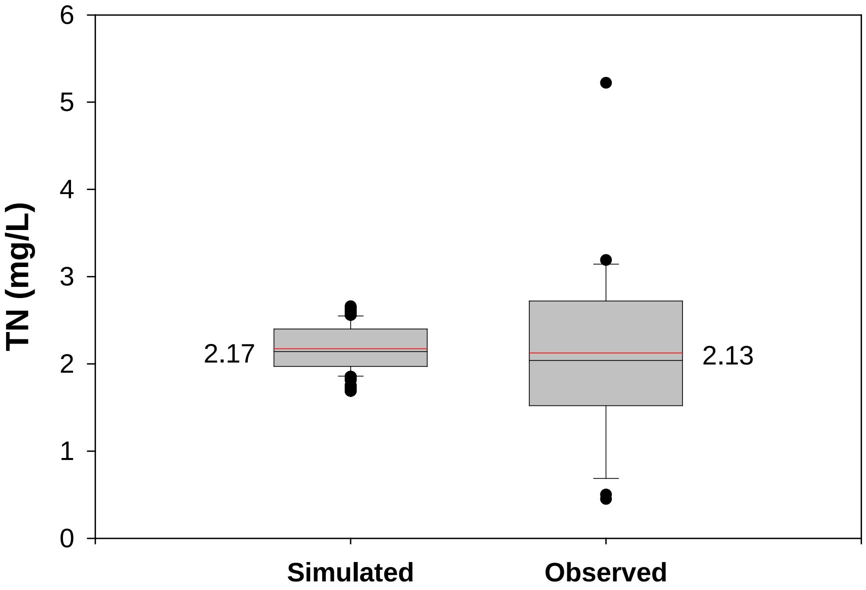

Figure 5.17. Box and Whisker Plot of Simulated Versus Observed TN in Lake Marian, 2000–06 (red line represents mean concentration of each series)

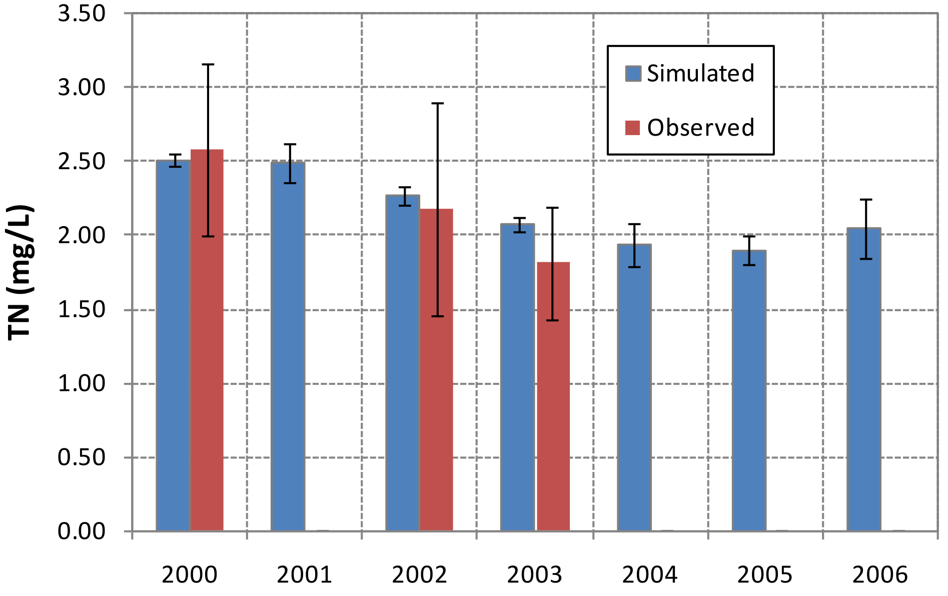

Figure 5.18. Annual Mean Concentrations of Observed Versus Simulated TN in Lake Marian During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviations)

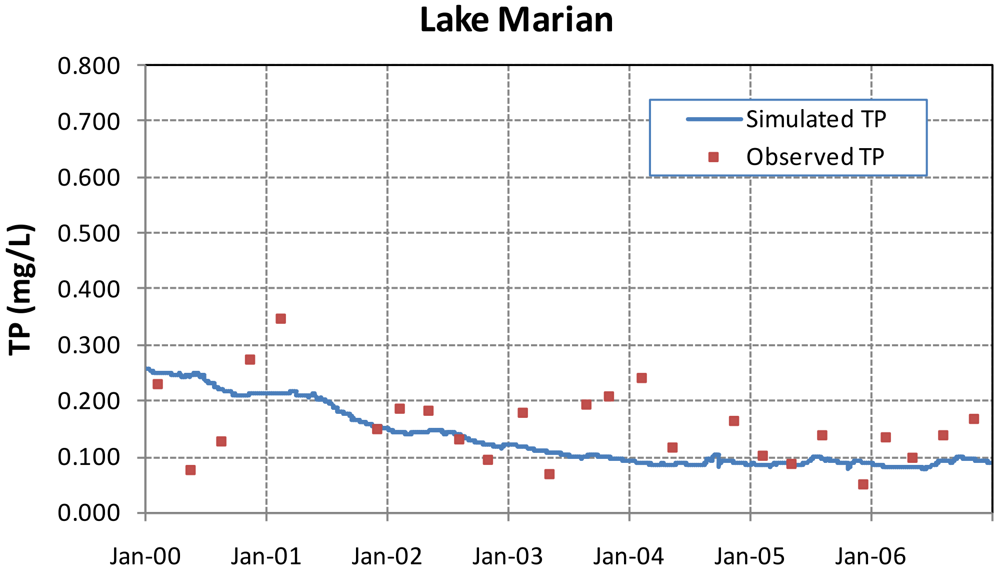

Figure 5.19. Time-Series of Observed Versus Simulated Daily TP Concentrations in Lake Marian During the Simulation Period, 2000–06

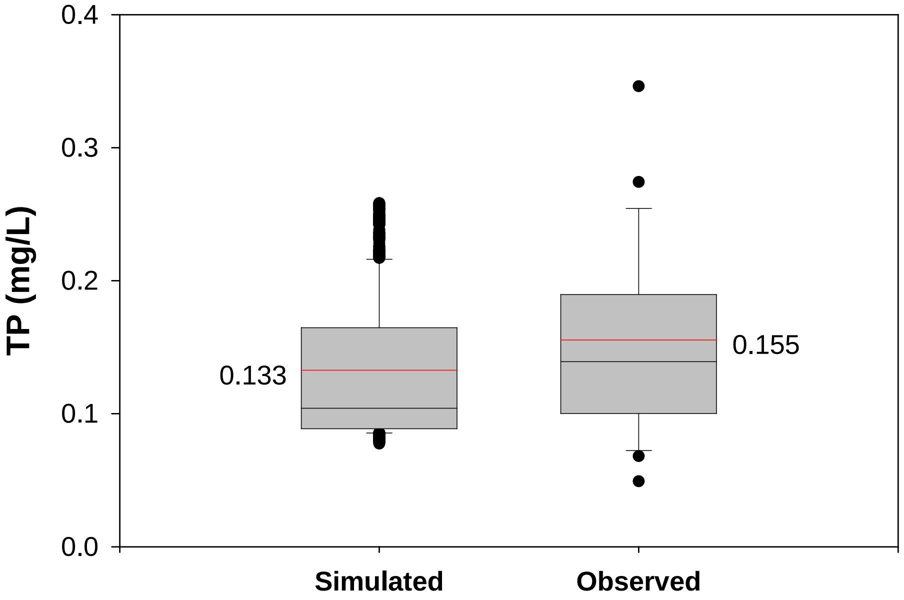

Figure 5.20. Box and Whisker Plot of Simulated Versus Observed TP in Lake Marian, 2000–06 (red line represents mean concentration of each series)

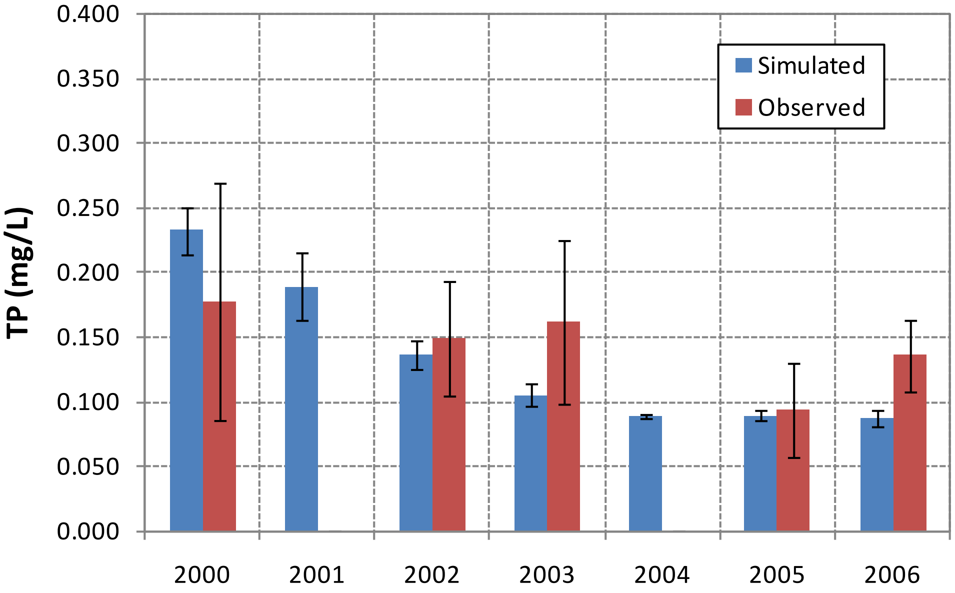

Figure 5.21. Annual Mean Concentrations of Observed Versus Simulated TP in Lake Marian during the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviations)

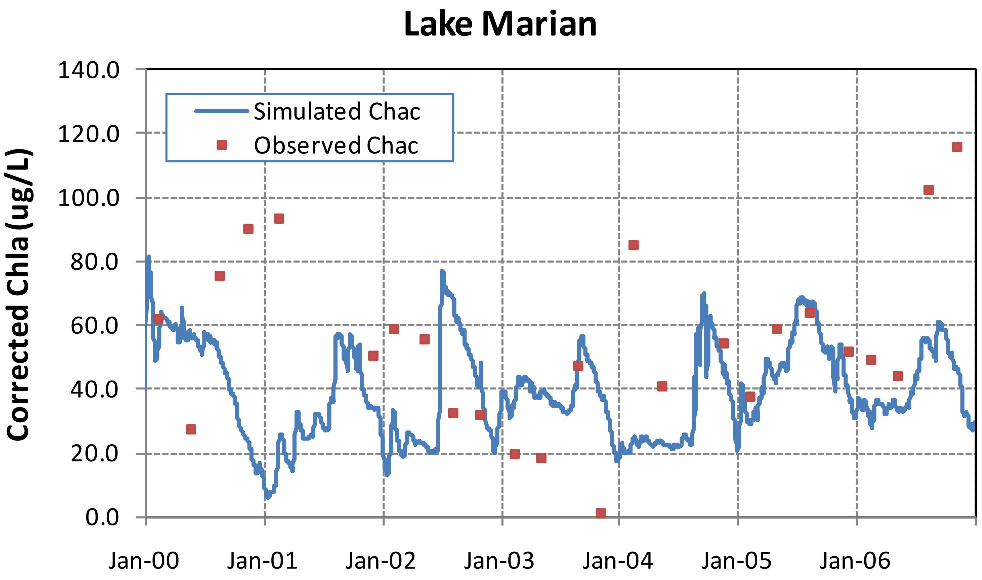

Figure 5.22. Time-Series of Observed Versus Simulated Daily CChl*a* Concentrations in Lake Marian During the Simulation Period, 2000–06

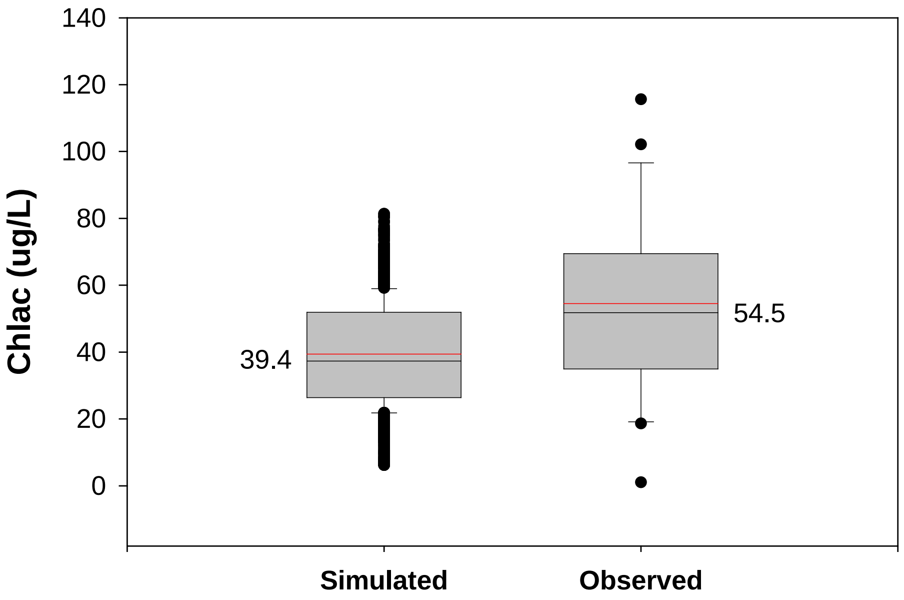

Figure 5.23. Box and Whisker Plot of Simulated Versus Observed CChl*a* in Lake Marian from 2000 to 2006 (red line represents mean concentration of each series)

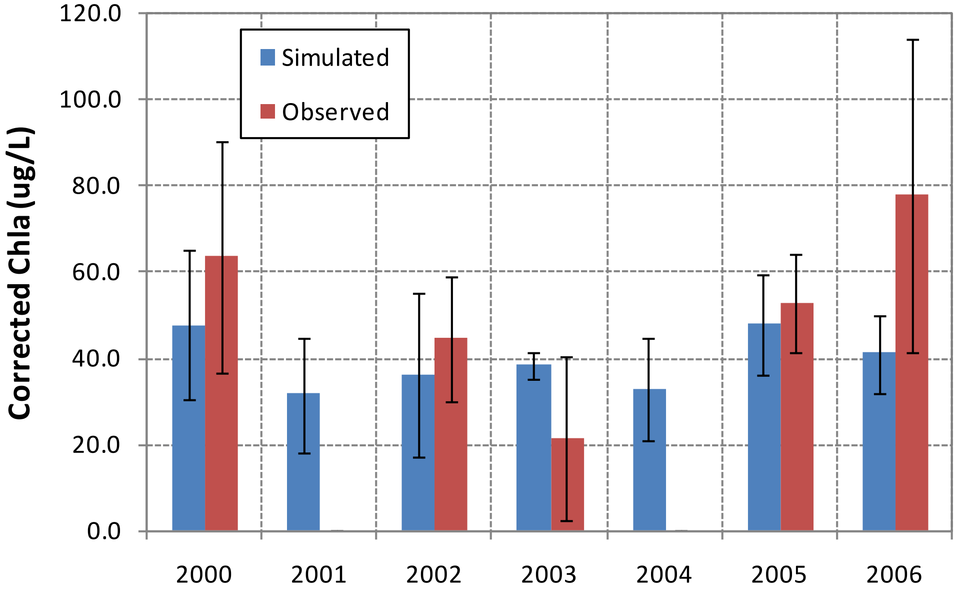

Figure 5.24. Annual Mean Concentrations of Observed Versus Simulated CChl*a* in Lake Marian During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviations)

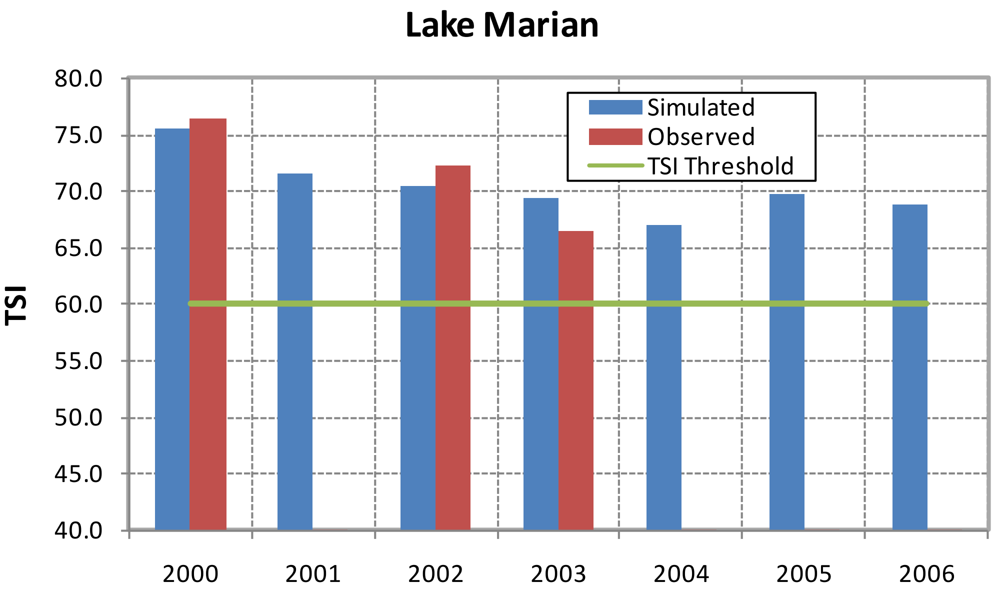

Figure 5.25. Observed Versus Simulated Annual TSIs in Lake Marian During the Simulation Period, 2000–06 (solid line indicates TSI threshold of 60)

5.3 Background Conditions

HSPF was used to evaluate the "natural land use background condition" for the Lake Marian watershed. For this simulation, all current land uses were "reassigned" to a mixture of forest and wetland. The current condition was maintained the same as in the calibrated model for all waterbody physical characteristics. From this point forward, the natural land use background is referred to as "background."

As discussed earlier, for existing conditions, the threshold TSI value of 60 was exceeded in all 7 years of the simulation (as well as the measured data), and the lake is considered co-limited by nitrogen and phosphorus (average ratio of 13.5). Based on the background model run results, the predeveloped lake should have had annual average TP concentrations ranging from 0.024 to 0.040 mg/L, with a long-term average of 0.030 mg/L. The predeveloped annual average TN concentrations ranged between 0.93 and 1.22 mg/L, with a long-term average of 1.13 mg/L. The predeveloped annual average chl*a* ranged from 9.8 to 13.9 µg/L, with an average of 11.2 µg/L. The resulting annual average TSI values ranged between 51.9 and 55.5, with a long-term average of 53.1.

5.4 Selection of the TMDL 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 the TSI from "historical" levels. This 10-unit increase is assumed to represent the transition of a lake from one trophic state (*e.g.*, 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 reserves 5 TSI units to allow for future changes in the basin and as part of the implicit margin of safety (MOS) in establishing the assimilative capacity. The final target developed for the restoration of Lake Marian includes achieving a long-term average TSI less than or equal to 58.1 (background of 53.1 plus 5). **Table 5.10** shows that the existing TSI for Lake Jackson may improve as Lake Marian meets the TSI target under the TMDL condition.

Table 5.10. Simulated TSIs for the Existing Condition, Natural Background Condition, and TMDL Condition with Percent Reductions in the KCOL System

= Empty cell/no data

TSI and % Reduction	Lake Kissimmee	Lake Jackson	Lake Marian
Background TSI (2000–06)	50.1	54.7	53.1
Target TSI (Background TSI+5)	55.1	59.7	58.1
Calibrated Existing TSI	60.0	67.1	70.4
Lake Marian TMDL % Reduction	59.83% (by Marian)	61.7% (by Marian)	58.1% (TN55/TP53)
Lake Jackson TMDL % Reduction	59.77% (by Jackson)	59.7% (TN20/TP25)	-
Lake Cypress TMDL % Reduction	58.0% (by Cypress)	-	-
Lake Kissimmee TMDL % Reduction	55.0% (TN15/TP17)	-	-

The serial reductions in loadings were repeated until the load reduction resulted in the lake meeting the requirements of the TSI target. **Figure 5.26** depicts the TSI results for the existing condition, natural background condition, and TMDL condition. **Table 5.11** shows summary statistics of the TSIs for different conditions. To meet the long-term TSI target of 58.1, the existing watershed TN and TP loads were reduced by 55% for TN and 53% for TP, resulting in the long-term average TSI of 58.1. Under these reduction conditions, the long-term average in-lake concentrations in Lake Marian are expected to be 1.14 mg/L for TN, 0.049 mg/L for TP, and 20.0 µg/L for cchl*a*. Therefore, it was decided that the watershed load reductions of 55% TN and 53% for TP, which met the TSI target, best represent the assimilative capacity for the waterbody, resulting in achieving aquatic life–based water quality criteria.

The 7-year averaged existing watershed loads, not including direct precipitation, were estimated to be 195,827 lbs/yr for TN and 12,793 lbs/yr for TP. A 55% watershed load reduction in TN resulted in an allowable load of 88,122 lbs/yr. A 53% watershed load reduction in TP resulted in an allowable load of 6,013 lbs/yr. The resulting percent reductions applied to the existing watershed load will be applied to both the load allocation (LA) and stormwater wasteload allocation (MS4) components of the TMDL.

5.5 Critical Conditions

The estimated assimilative capacity was based on annual average conditions (*i.e.*, values from all four seasons in each calendar year) rather than critical/seasonal conditions because (1) the methodology used to determine assimilative capacity does not lend itself very well to short-term assessments; (2) for lakes, the Department is generally more concerned with the net change in overall primary productivity, which is better addressed on an annual basis; and (3) the methodology used to determine impairment in lakes is based on an annual average and requires data from all four quarters of a calendar year.

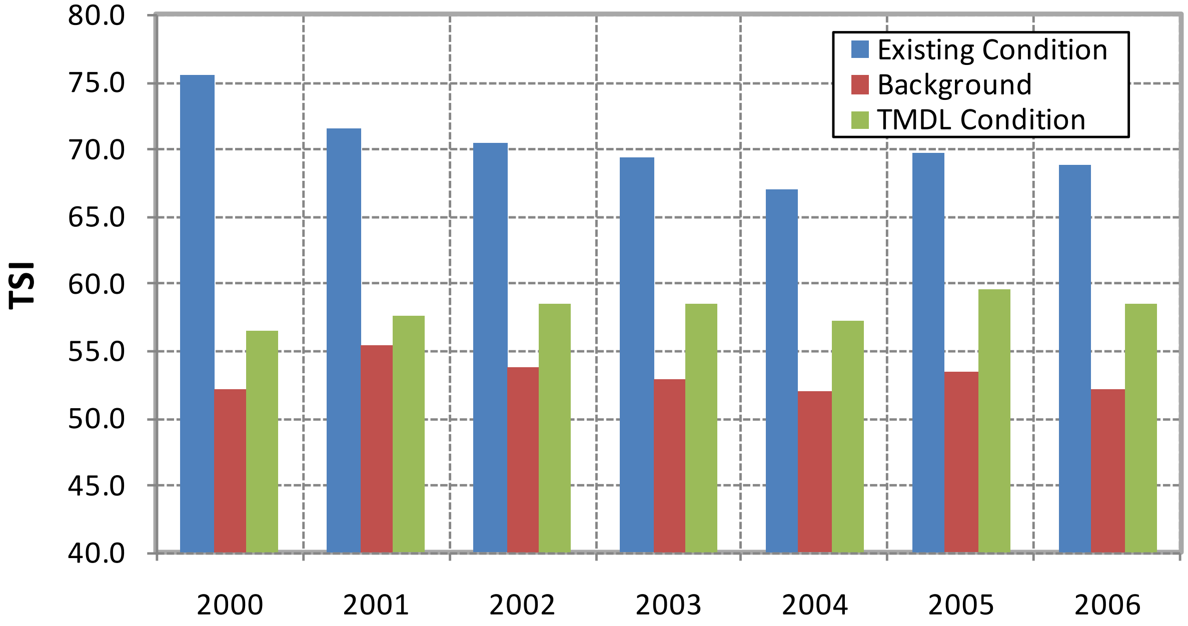

Figure 5.26. Simulated TSIs for the Existing Condition, Natural Background Condition, and TMDL Condition for Lake Marian during the Simulation Period, 2000–06

Table 5.11. Summary Statistics of Simulated TSIs for the Existing Condition, Natural Background Condition, and TMDL Condition for Lake Marian

Statistic	Existing TSI	Background TSI	TMDL TSI
Count	7.0	7.0	7.0
Median	69.7	52.9	58.5
Average	70.4	53.1	58.1
Standard	2.7	1.3	1.0
Minimum	67.1	51.9	56.5
Maximum	75.5	55.5	59.5
CV (%)	3.8%	2.4%	1.7%

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:

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

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

WLAs for stormwater discharges are typically expressed as a “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 nonpoint sources (given the nature of stormwater transport). The permitting of MS4 stormwater discharges is also different than the permitting of most wastewater point sources. Because MS4 stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of Best Management Practices (BMPs).

This approach is consistent with federal regulations (40 Code of Federal Regulations § 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 NPDES stormwater WLA is expressed as a percent reduction in the stormwater from MS4 areas. The TMDLs are the site-specific numeric interpretation of the narrative nutrient criterion pursuant to 62-302.531(2)(a), F.A.C. The TMDLs for Lake Marian are expressed as loads and percent reductions and represent the long-term annual average load of TN and TP from all watershed sources that the waterbody can assimilate and maintain the Class III narrative nutrient criterion (**Table 6.1**). The expression and allocation of the TMDL in this report is based on the loadings necessary to achieve the water quality criterion and designated uses of the surface waters.

Table 6.1. Lake Marian Load Allocations

NA = Not applicable

WBID	Parameter	WLA for Wastewater (lbs/yr)	WLA for Stormwater (% reduction)	LA (% reduction)	MOS	TMDL (lbs/yr)
3184	TN	NA	55%	55%	Implicit	88,122
3184	TP	NA	53%	53%	Implicit	6,013

The LA and TMDL daily load for TN is 241 lbs/day, and for TP, 16.5 lbs/day.

These reductions are based on long-term (7-year) averages of data from 2000 to 2006. Based on the TMDL modeling conducted for this report (reductions of watershed loadings), the long-term average lake concentration for TP is 0.049 mg/L, for TN 1.14 mg/L, and for cchl*a* 20.0 µg/L. As these reductions are provided as a percentage, they are applicable over any time frame, including daily. The Department acknowledges that there may be more than one way to achieve the cchl*a* restoration goal. For example, hydrologic restoration that includes restoring historical lake water levels and reconnecting the lake to historical wetlands could result in achieving the cchl*a* target with different in-lake concentrations of nutrients.

6.2 Load Allocation (LA)

Because the exact boundaries between those areas of the watershed covered by the WLA allocation for stormwater and the LA allocation are not known, both the LA and the WLA for stormwater will receive the same percent reduction. The LA is a 53% reduction in TP and a 55% reduction in TN of the total nonpoint source watershed loadings from the period from 2000 to 2006. As the TMDL is based on the percent reduction in total watershed loading and any natural land uses are held harmless, the percent reductions for the anthropogenic sources may be greater. 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)

6.3.1 NPDES Wastewater Discharges

As noted in **Chapter 4, Section 4.2.1,** there are no active NPDES-permitted facilities located within the Lake Marian watershed that discharge surface water within the watershed. Therefore, the WLA for wastewater for the Lake Marian TMDL is “not applicable” because there are no wastewater or industrial wastewater NPDES facilities that discharge directly to Lake Marian.

6.3.2 NPDES Stormwater Discharges

The stormwater collection systems in the Lake Marian watershed, which are owned and operated by Osceola County, are covered by NPDES Phase II MS4 Permit Number FLR04E012. The collection system for FDOT District 5 is covered by NPDES Permit Number FLR04E024. The collection systems for the Florida Turnpike are covered by NPDES Permit Number FLR04E049. The WLA for MS4 stormwater discharges is a 53% reduction in TP and a 55% reduction in TN of the total watershed loading for the period from 2000 to 2006; these are the required percent reductions in MS4 stormwater sources.

It should be noted that any MS4 permittee is only responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads within its jurisdiction. As the TMDL is based on the percent reduction in total watershed loading and any natural land uses are held harmless, the percent reduction for just the anthropogenic sources may be greater.

6.4 Margin of Safety (MOS)

TMDLs must address uncertainty issues by incorporating an 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, Paragraph 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 (Department 2001), an implicit MOS was used in the development of the Lake Marian TMDL because the TMDL was based on the conservative decisions associated with a number of the modeling assumptions and allows only a five-unit TSI increase above background conditions in determining the assimilative capacity (*i.e.*, loading and water quality response) for Lake Marian.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of the TMDL by rule, the Department will work cooperatively with stakeholders to development a plan to restore the waterbody. This will be accomplished by creating a Basin Management Action Plan. BMAPs are the primary mechanism through which TMDLs are implemented in Florida (see Subsection 403.067[7], F.S.). A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies. The BMAP will be designed to identify the actions needed to achieve the restoration goals, including steps to meet a long-term average cchl*a* concentration in the lake of no greater than 13.7 µg/L. These projects will depend heavily on the active participation of the SFWMD, local governments, businesses, and other stakeholders. While the required percent reduction for nutrients is specified in **Chapter 6**, no specific projects have been identified at this time. The Department will work with these organizations and individuals during BMAP development to identify specific projects directed towards achieving the established TMDL for the impaired waterbody.

The BMAP will be developed through a transparent, stakeholder-driven process intended to result in a plan that is cost-effective, technically feasible, and meets the restoration needs of the applicable waterbodies. **Section 7.2** (below) provides a framework of the issues and activities that need to be completed as part of the development of the BMAP.

Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and MS4 permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- *Water quality goals.*
- *Appropriate load reduction allocations for stakeholders (quantitative detailed allocations, if technically feasible).*
- *A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach.*

- *A description of further research, data collection, or source identification needed (if any) to achieve the TMDL.*
- *Timetables for implementation.*
- *Confirmed and potential funding mechanisms.*
- *An evaluation of future increases in pollutant loading due to population growth.*
- *Any applicable signed agreement(s).*
- *Local ordinances defining actions to be taken or prohibited.*
- *Any applicable local water quality standards, permits, or load limitation agreements.*
- *Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures.*
- *Stakeholder statements of commitment (typically a local government resolution).*

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

7.2 Next Steps for TMDL Implementation

The Department will establish the detailed allocation for the WLA for stormwater and the LA for nonpoint sources under Paragraph 403.067(6)(b), F.S.

As part of BMAP development, the Department will work with stakeholders to identify the water quality monitoring locations appropriate for assessing progress towards lake restoration. The BMAP will be developed over a period that is sufficient to allow for the collection and analysis of any necessary additional information. Development of the BMAP under Paragraph 403.067(6)(b), F.S., does allow time for further monitoring, data analysis, and modeling to develop a better understanding of the relationship between watershed loadings, impacts from permitted WWTFs, proposed hydrologic modifications, proposed reconnection to wetlands, and resulting algae (cchl*a*) concentration. As is the case when any modeling approach is used, some uncertainty always remains in the existing data and model predictions, and this may lead the Department to support gathering additional data or information.

For lakes within the Kissimmee Chain of Lakes, the refinement of water quality targets may be needed, and making this decision should be a high priority. This element should be investigated prior to any determination calling for new projects, to ensure that the outcome of such projects will provide the expected or implied water quality benefit and help achieve system restoration goals.

The future BMAP planning process may need to consider the issue of the related stresses of nutrient loading within the complexities of hydrologic alteration. For example, in some cases reductions in Florida lake elevations over the last several decades have likely led to reduced tannin levels and influenced assimilative capacities for nutrient loading (D. Tomasko, pers. comm., 2013), factors not addressed in these current TMDLs. Lakes Cypress and Marian, for example, have dropped approximately 2 to 3 feet in lake elevation since the 1940s and 1950s, respectively. In Lake Cypress, the TP-rich sediments are 55% more likely to be resuspended into the water column in their recent, lowered stages, than if lake levels had remained at historical levels. As such, nutrient load reduction targets based on water quality models that used TSI criteria could be problematic for lakes where hydrologic restoration might improve water quality by decreasing the frequency of bottom resuspension and increasing the amounts of tannins.

7.3 Restoration Goals

The impairments in Lakes Cypress, Jackson, Kissimmee, and Marian are linked to the Department's nutrient criterion and as stated in **Chapter 3**, Florida's nutrient criterion is narrative only. Accordingly, a nutrient-related target is 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. The IWR (Section 62-303.450, F.A.C.) specifically allows the use of alternative, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in a waterbody. The draft TMDLs are based on maintaining the current lake levels and color.

Stakeholders have requested that the Department include as a component of the BMAP the evaluation of alternative restoration goals that might result if lake levels and lake color were increased as a result of other restoration projects. They are seeking to restore to the extent practicable the historical lake levels, seasonal variations in stage, and connections to wetlands that have been isolated from the lakes due to current lake stage operational criteria. An adaptive management approach to restoration, in which the Department considers hydrologic restoration—and its effects on tannin levels—is a viable consideration to be evaluated in achieving the TMDL.

One of the major restoration efforts under way in the region is the Kissimmee River Restoration Project. Lakes Kissimmee, Hatchineha, and Cypress are part of the Central and Southern Florida (C&SF) Project operated by the SFWMD under regulations prescribed by the Secretary of the Army. Modifications to C&SF waterbody regulation schedules require evaluations of environmental effects that meet National Environmental Policy Act (NEPA) procedural requirements for a proposed federal action. The authorized headwaters component of the Kissimmee River Restoration Project increases the regulatory range of water levels on Lakes Kissimmee, Hatchineha, and Cypress by 1.5 feet and modifies the stage regulation schedule in a manner that increases the seasonal variations in stage and the connections to wetlands that have been isolated from the lakes as a result of current lake stage regulation. These changes may restore the lake stage and color to a more natural condition over time and may also have the potential to alter the relationship between watershed loading and the resulting in-lake concentrations of chl*a*. Plans to alter the hydrology of C&SF Project lakes must meet NEPA procedural requirements, which include input from stakeholders and evaluation of the effects of proposed actions on water quality, water supply, and flood protection.

Additionally, another way of determining if returning to a more natural lake stage and color level would alter the restoration goals would be to conduct paleolimnological studies on the lake sediments to identify historical water quality conditions. If such studies are agreed to as part of the BMAP process, the Department may take the lead and conduct studies in Lake Tohopekaliga (WBID 3173A), Lake Cypress (WBID 3180A), and/or Lake Kissimmee (WBID 3183B), and reevaluate restoration goals before making any final allocation of load reductions under the BMAP. Additionally, the Department will not move forward with setting final specific allocations of load reductions under the BMAP for Lakes Marian or Jackson without determining whether there is a need for further studies to identify historical water quality conditions in these lakes.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

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

The rule requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) 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 Kissimmee.

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 the 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 5 or more acres of land, and the master drainage systems of local governments with a population above 100,000, which are better known as MS4s. However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the FDOT throughout the 15 counties meeting the population criteria. The Department received authorization to implement the NPDES stormwater program in 2000.

An important difference between the NPDES and the state's stormwater/ERP 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 1 and 5 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, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that all MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Electronic Copies of Measured Data and 2008 CDM Report for the Lake Marian TMDL

All information gathered by CDM, and the HSPF model setup and calibration/validation, are contained in the document, *Kissimmee River Watershed TMDL Model Development Report* (CDM 2008), and is available upon request (~100 megabytes on disk). Lake Marian is included in the HSPF model project termed UKL_Open.UCI.

The 2008 CDM report and all data used in the Lake Marian TMDL report are available upon request. Please contact the following individual to obtain this information:

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Florida Department of Environmental Protection
Water Quality Evaluation and TMDL Program
Watershed Evaluation and TMDL Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
Email: douglas.gilbert@dep.state.fl.us
Phone: (850) 245–8450
Fax: (850) 245–8536

Appendix C: HSPF Water Quality Calibration Values for Lake Marian

HSPF Variables	Units	Value	Source
CFSAEX	none	0.65-0.88	Calibration
KATRAD	none	9.57	Calibration
KCOND	none	6.12	Calibration
KEVAP	none	2.24	Default
KSAND	complex	0.5	Previous studies
EXPSND	complex	2.0	Previous studies
W	in/s	0.02	Previous studies
TAUCD	lb/ft^2	0.05-0.09	Calibration
TAUCS	lb/ft^2	0.32-0.48	Calibration
M	$lb/ft^2/day$	0.02	Calibration
W	in/s	0.000003	Previous studies
TAUCD	lb/ft^2	0.05-0.09	Calibration
TAUCS	lb/ft^2	0.31-0.48	Previous studies
M	$lb/ft^2/day$	0.02	Calibration
KBOD20	hr^{-1}	0.012-0.025	Calibration
TCBOD	none	1.037	Calibration
KODSET	ft/hr	0.000	Calibration
BENOD	$mg/m^2/hr$	8.4-25.2	Calibration
TCBEN	none	1.037	Calibration
KTAM20	hr^{-1}	0.001-0.03	Previous studies
TCNIT	None	1.07	Default
RATCLP	none	1.0-3.0	Calibration
NONREF	none	0.70-1.00	Calibration
ALNPR	none	0.75	Calibration
EXTB	ft^{-1}	0.05-0.68	Calibration
MALGR	hr^{-1}	0.105-0.158	Calibration
CMMLT	ly/min	0.033	Default
CMMN	mg/l	0.045	Default
CMMNP	mg/l	0.028	Default
CMMP	mg/l	0.015	Default
TALGRH	deg F	93	Calibration
TALGRL	deg F	43	Calibration
TALGRM	deg F	83	Calibration
ALR20	hr^{-1}	0.003	Calibration
ALDH	hr^{-1}	0.002-0.009	Calibration
ALDL	hr^{-1}	0.0020-0.0028	Calibration
CLALDH	ug/l	60-90	Default
PHYSET	ft/hr	0.0005-0.0800	Calibration
REFSET	ft/hr	0.000-0.004	Calibration
CVBO	mg/mg	1.31	Previous studies
CVBPC	mols/mol	106	Previous studies
CVBPN	mols/mol	10	Previous studies
BPCNTC	none	49	Previous studies

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Appendix D: All Hydrologic Outputs and Model Calibrations for the Impaired Lake and Its Connected Lakes

Flow Calibration

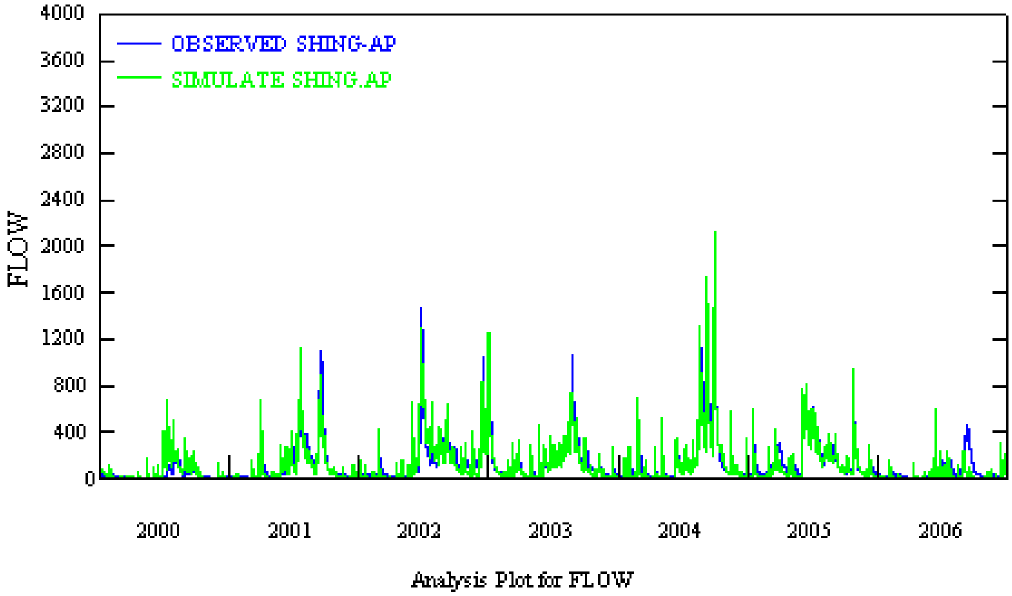

Figure D-1. Observed Versus Simulated Daily Flow (cfs) at Shingle Creek near Airport, 2000–06

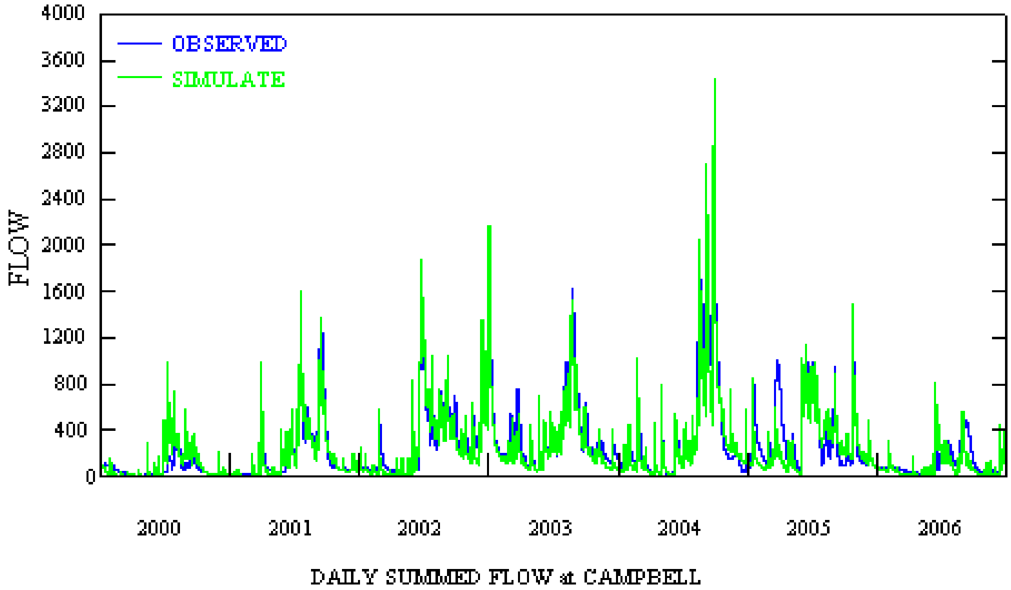

Figure D-2. Observed Versus Simulated Daily Flow (cfs) at Campbell Station in Shingle Creek, 2000–06

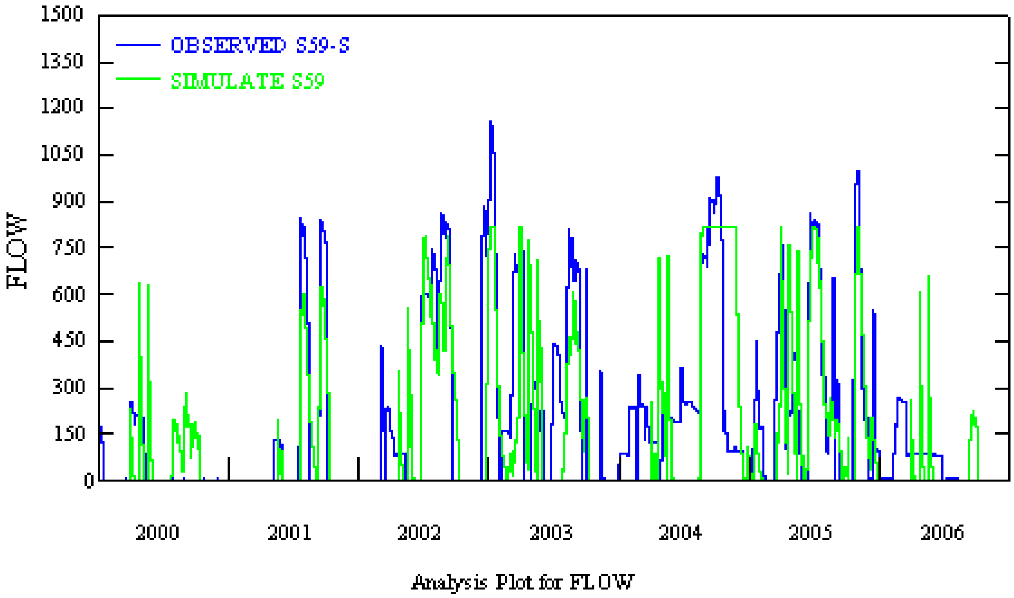

Figure D-3. Observed Versus Simulated Daily Flow (cfs) at S59 for East Lake Tohopekaliga Outflow, 2000–06

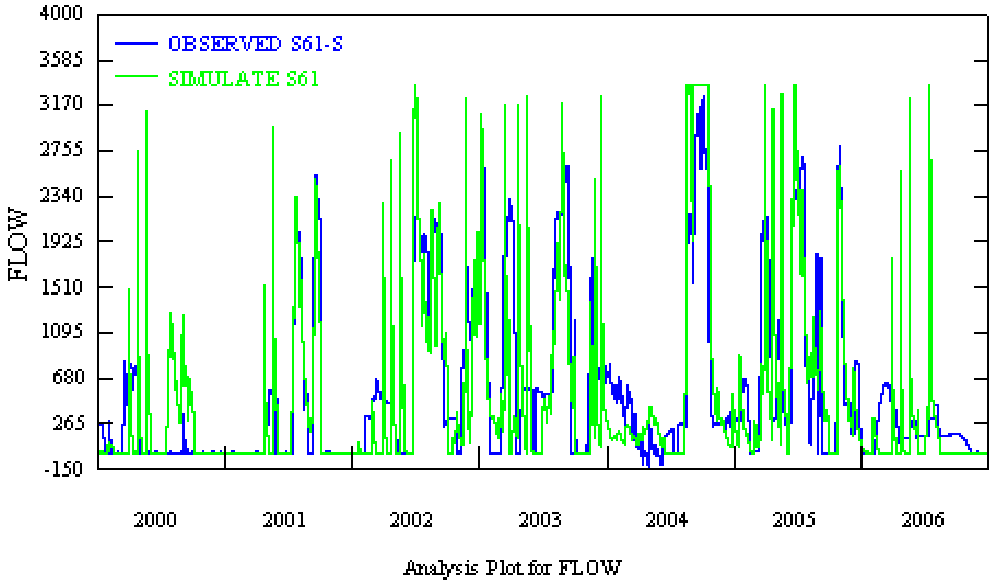

Figure D-4. Observed Versus Simulated Daily Flow (cfs) at S61 for Lake Toho Outflow, 2000–06

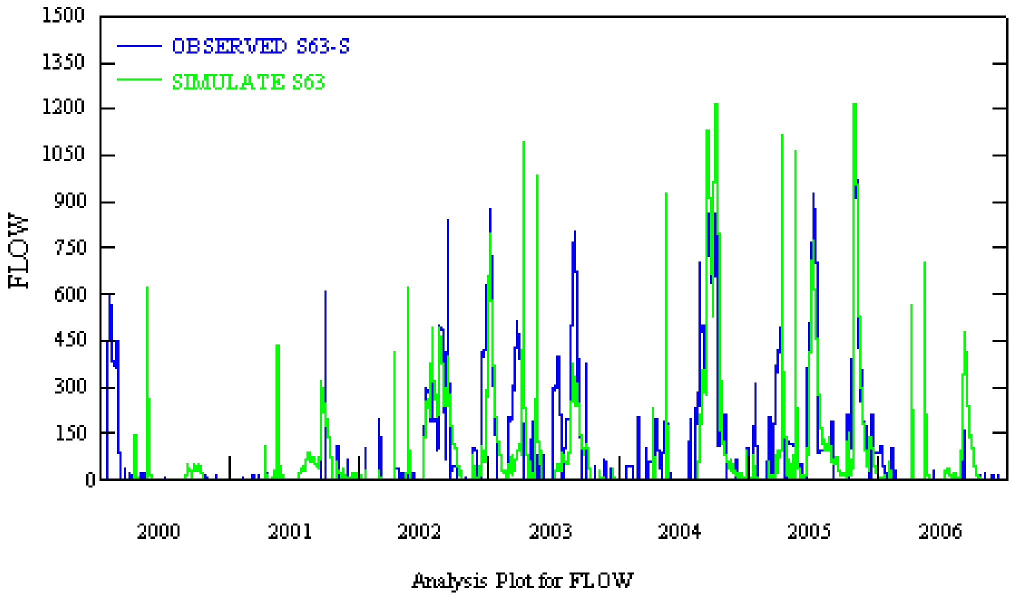

Figure D-5. Observed Versus Simulated Daily Flow (cfs) at S63 for Lake Gentry Outflow, 2000–06

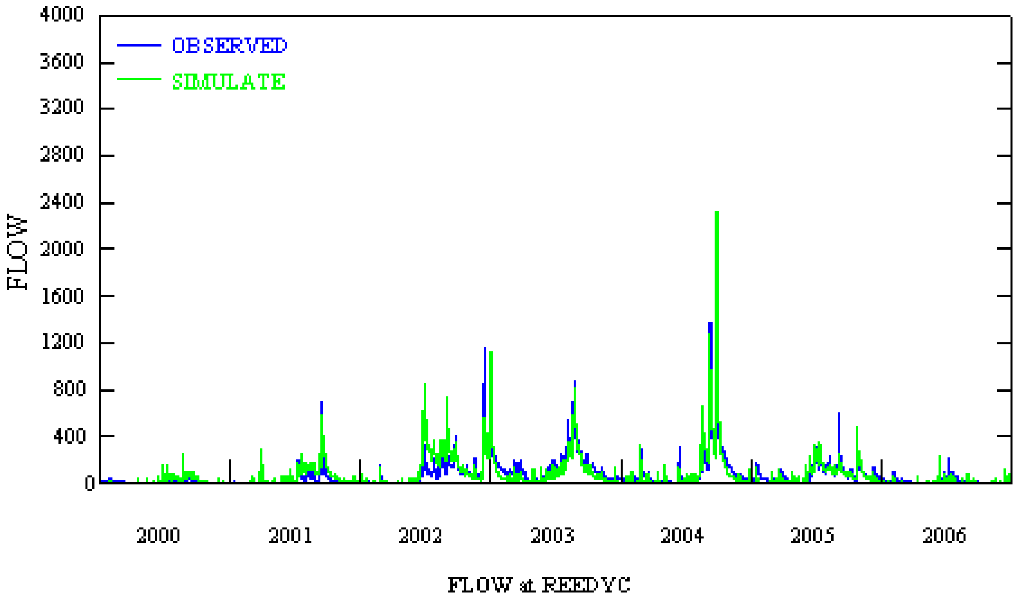

Figure D-6. Observed Versus Simulated Daily Flow (cfs) at Reedy Creek Station, 2000–06

Statistics for Hydrologic Calibration/Validation

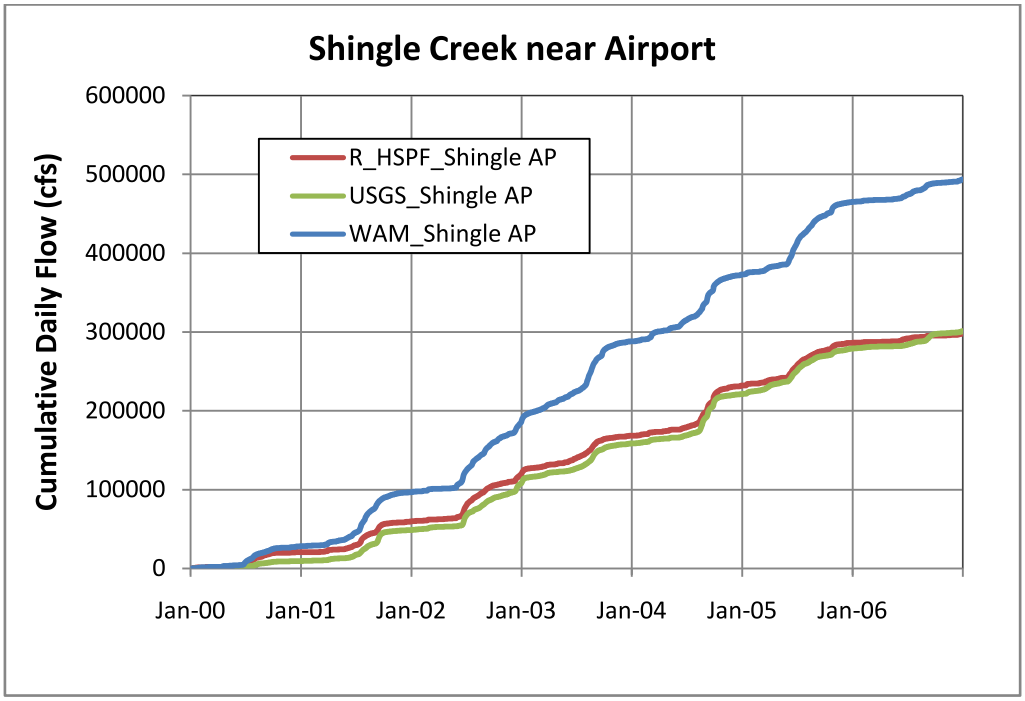

Figure D-7. Observed Versus Simulated Cumulative Daily Flows for Shingle Creek near Airport, 2000–06

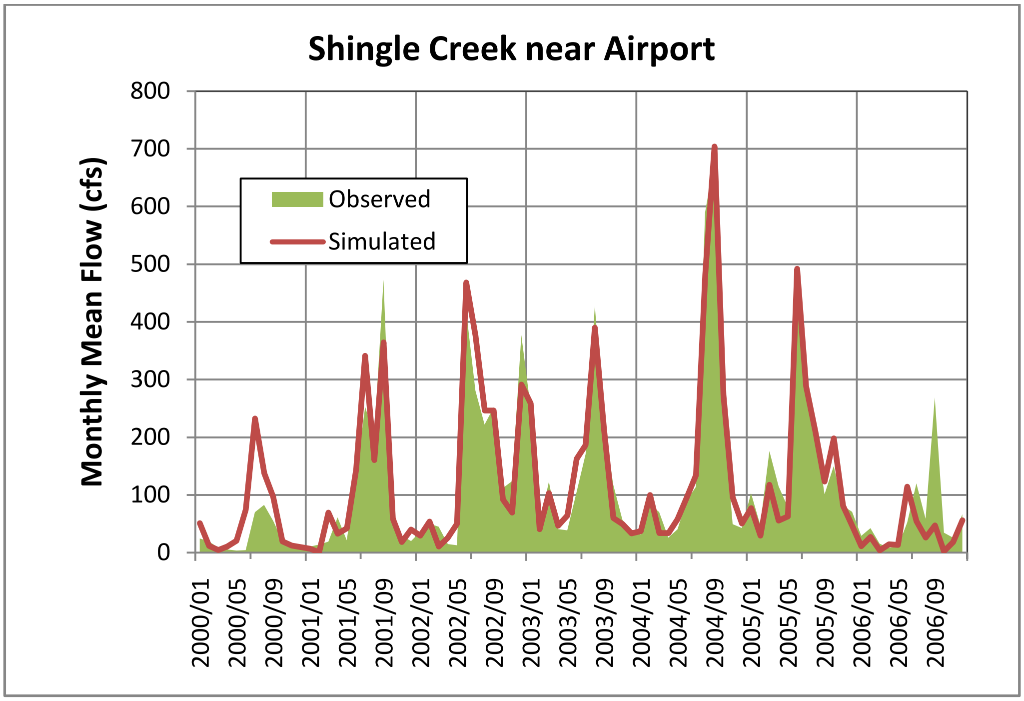

Figure D-8. Observed Versus Simulated Monthly Flows for Shingle Creek near Airport, 2000–06

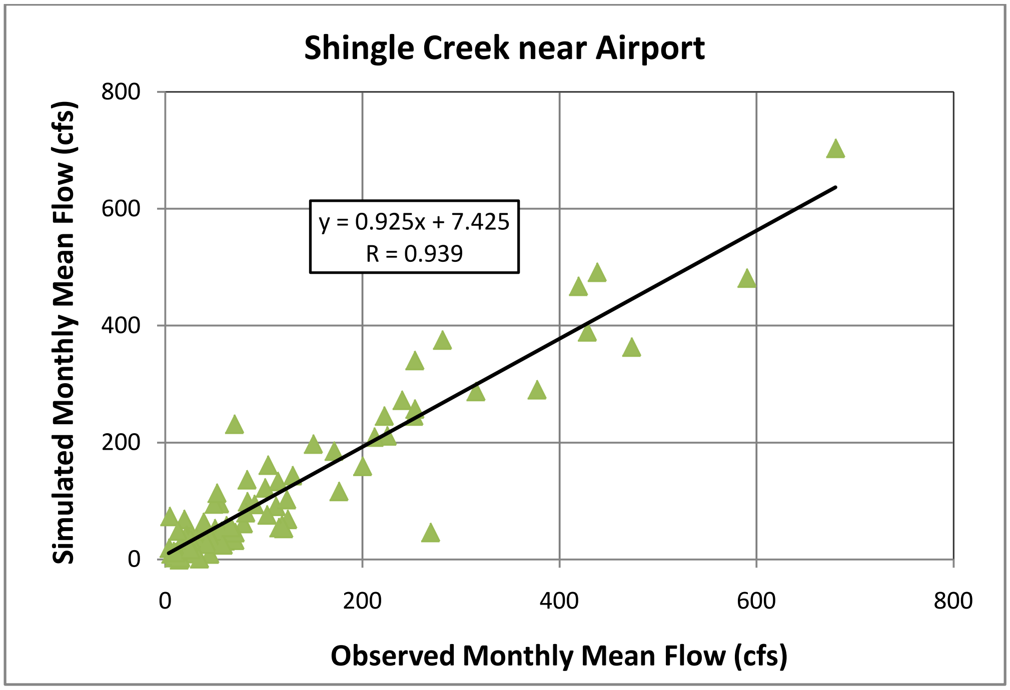

Figure D-9. Relationship Between Observed and Simulated Monthly Flows for Shingle Creek near Airport, 2000–06

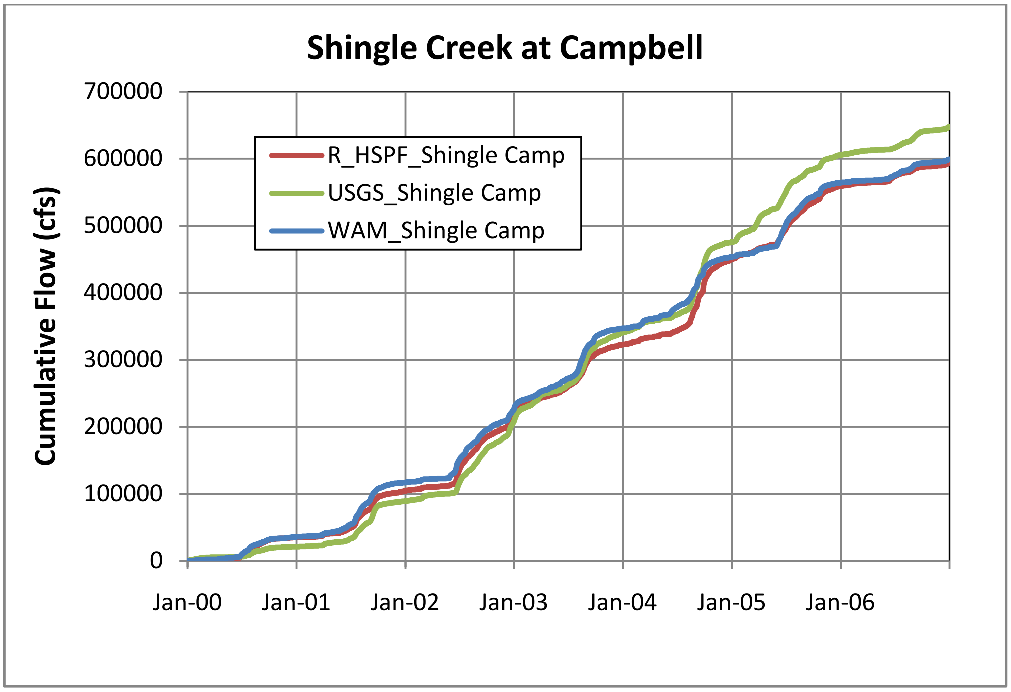

Figure D-10. Observed Versus Simulated Cumulative Daily Flows for Shingle Creek at Campbell, 2000–06

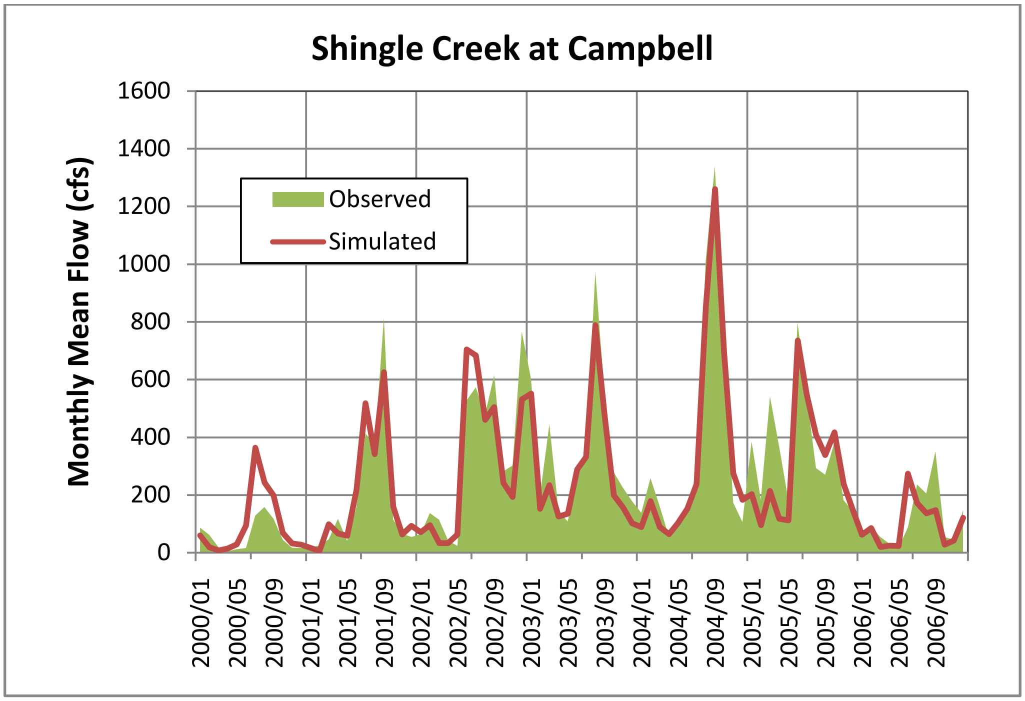

Figure D-11. Observed Versus Simulated Monthly Flows for Shingle Creek at Campbell, 2000–06

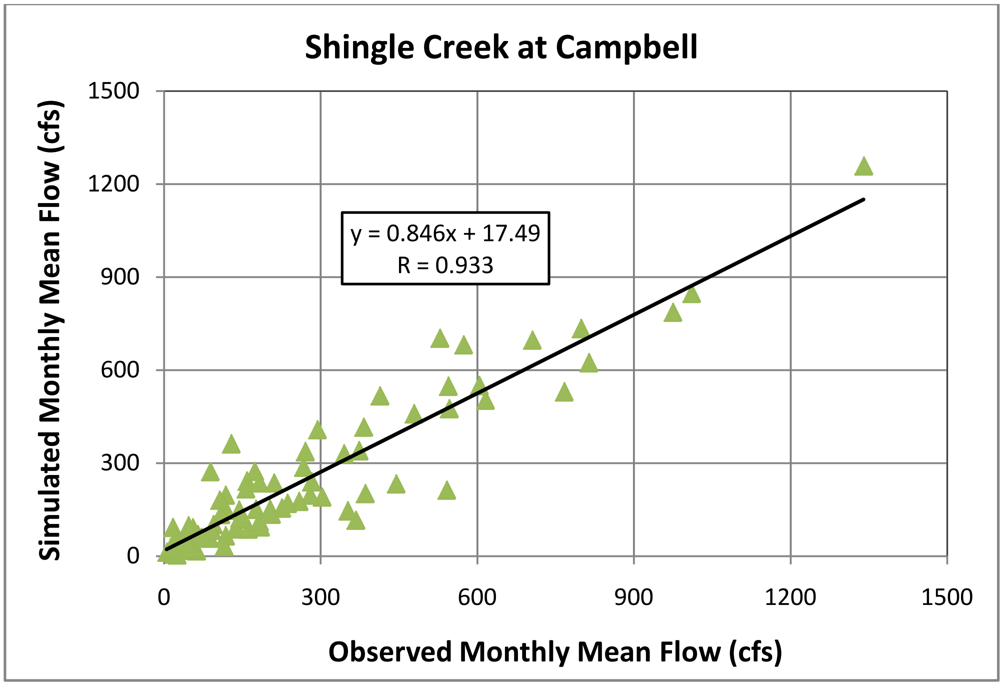

Figure D-12. Relationship Between Observed and Simulated Monthly Flows for Shingle Creek at Campbell, 2000–06

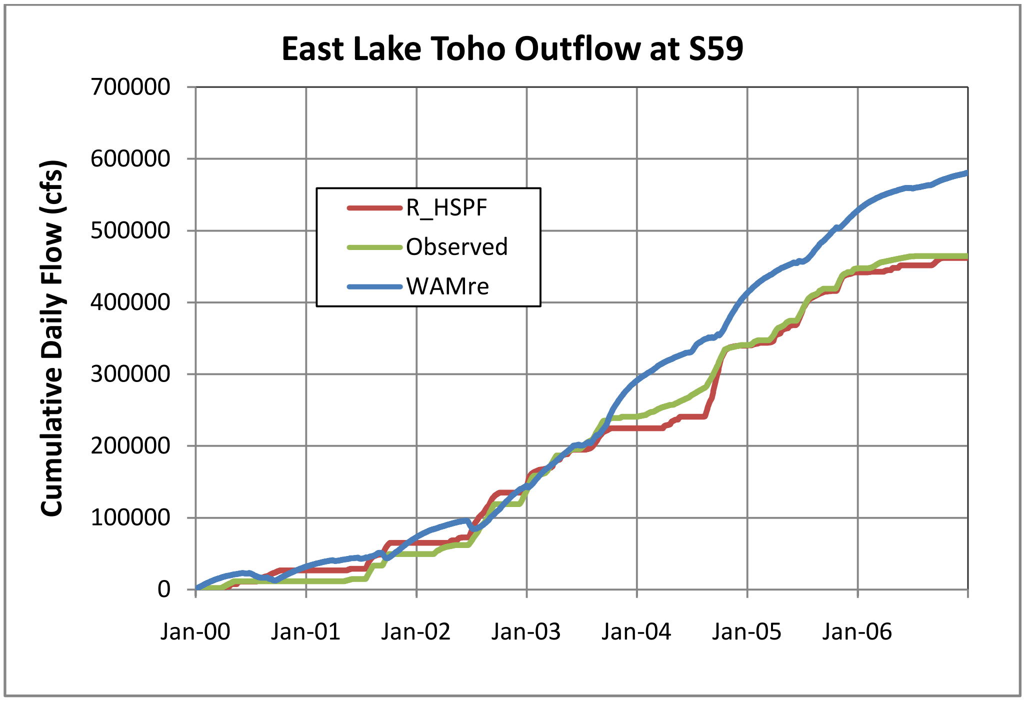

Figure D-13. Observed Versus Simulated Cumulative Daily Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

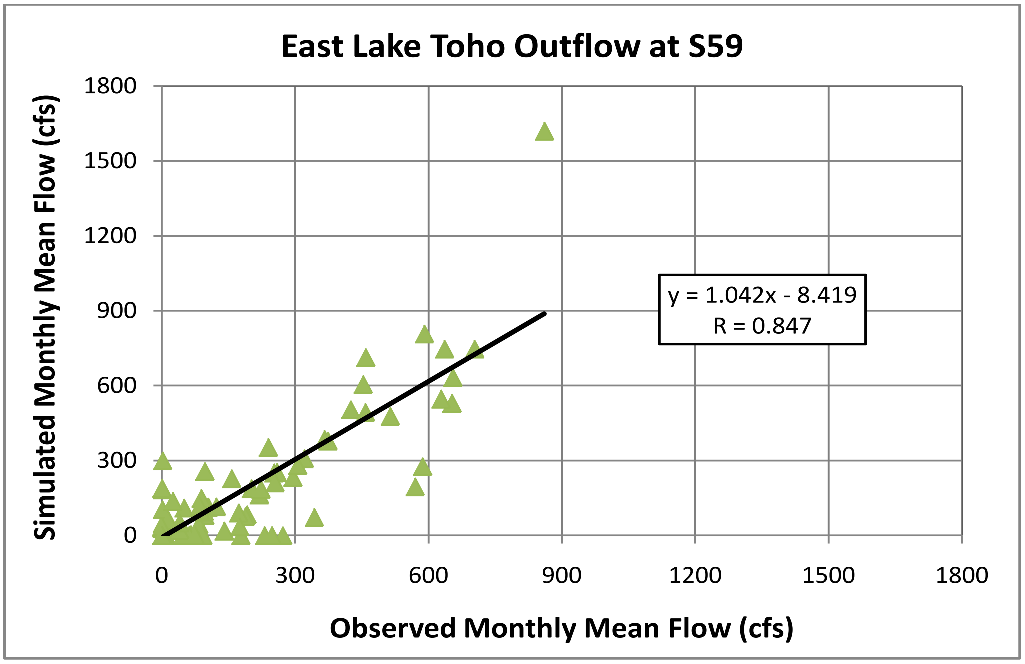

Figure D-14. Relationship Between Observed and Simulated Monthly Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

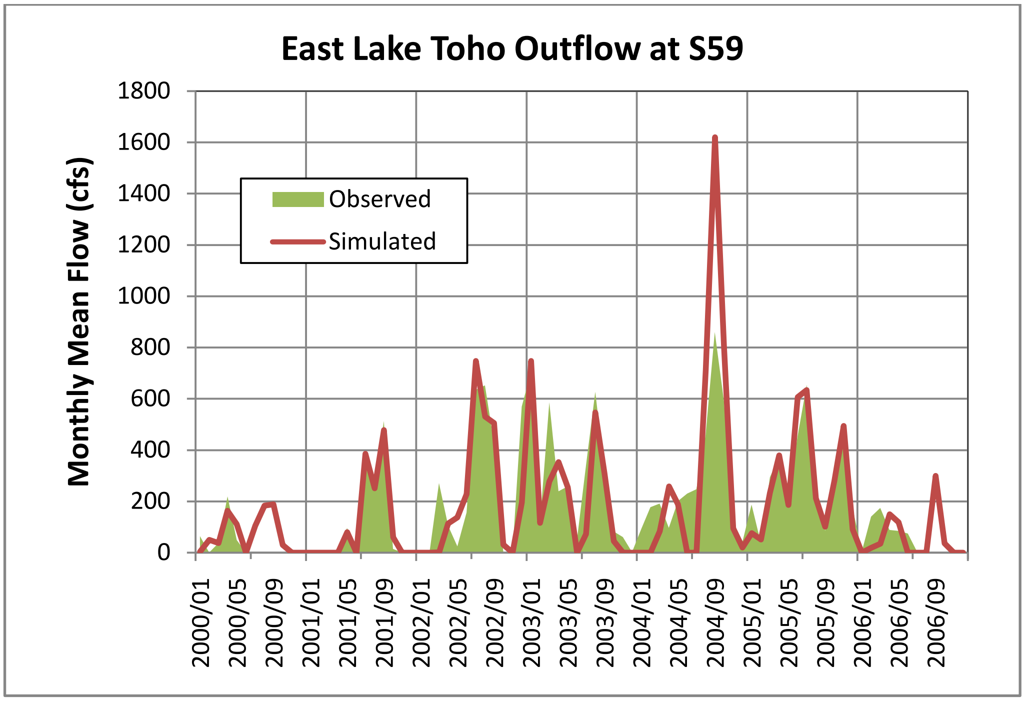

Figure D-15. Observed Versus Simulated Monthly Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

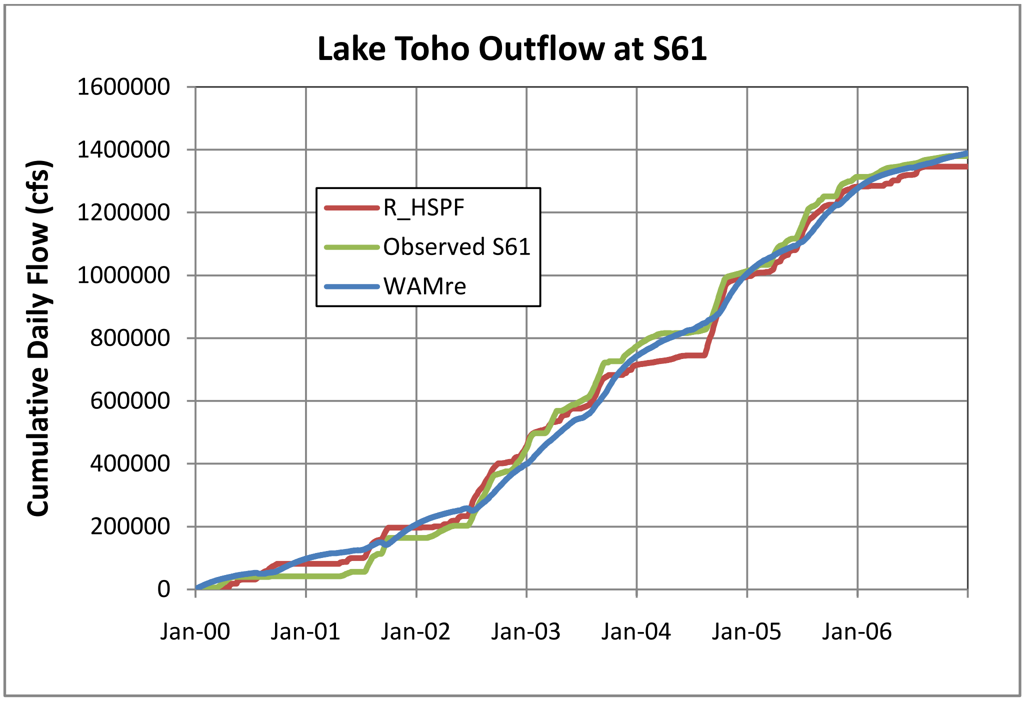

Figure D-16. Observed Versus Simulated Cumulative Daily Flows for Lake Tohopekaliga Outflow at S61, 2000–06

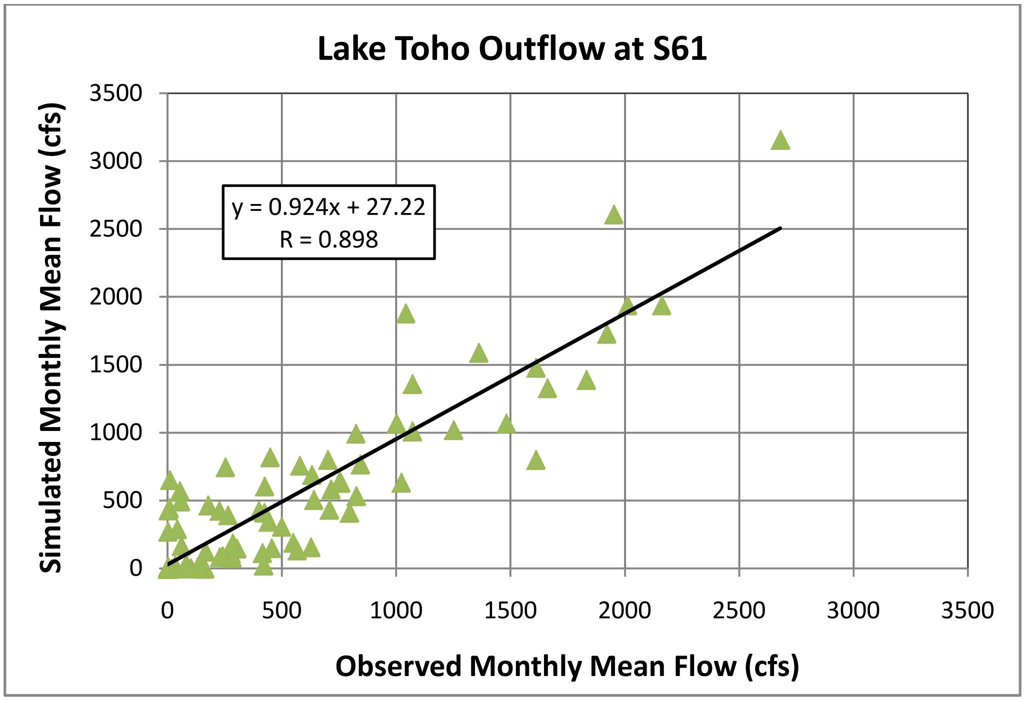

Figure D-17. Relationship Between Observed and Simulated Monthly Flows for Lake Tohopekaliga Outflow at S61, 2000–06

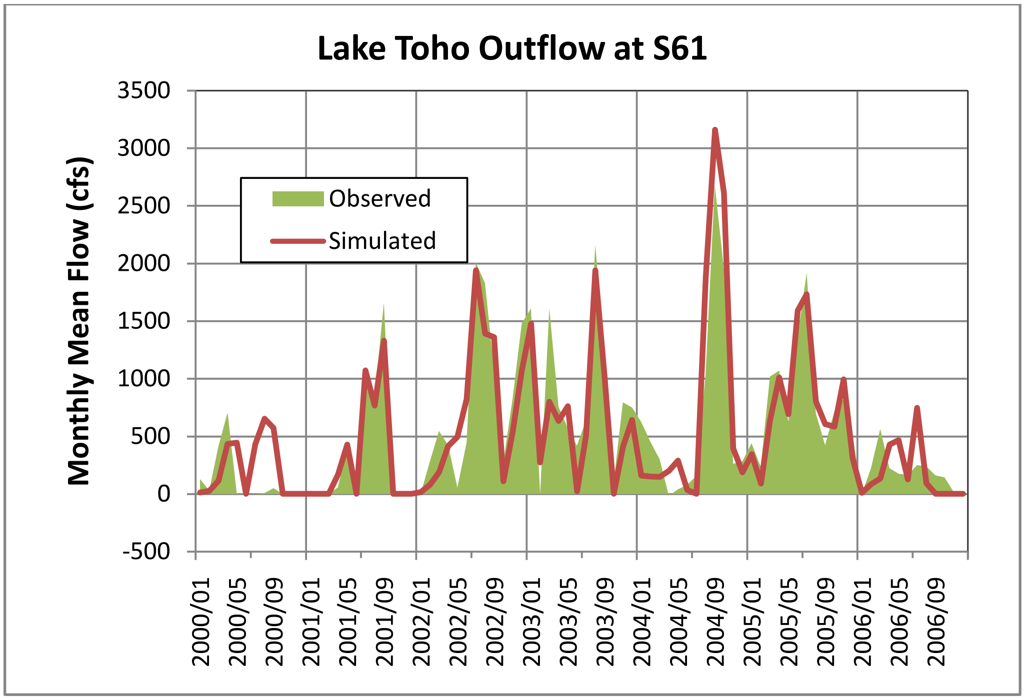

Figure D-18. Observed Versus Simulated Monthly Flows for Lake Tohopekaliga Outflow at S61, 2000–06

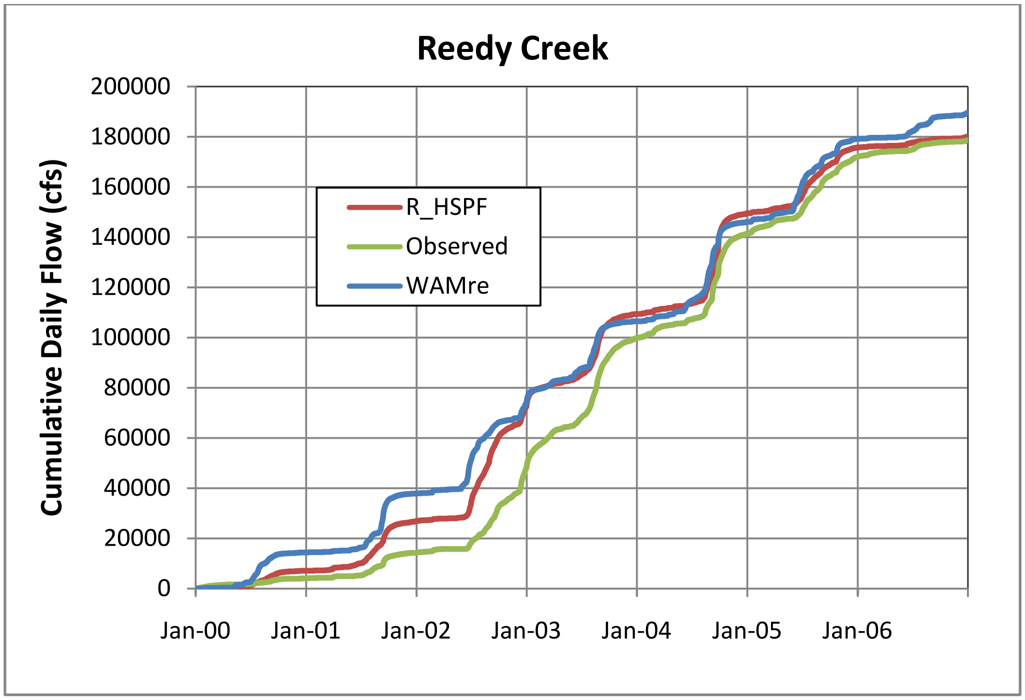

Figure D-19. Observed Versus Simulated Cumulative Daily Flows for Reedy Creek, 2000–06

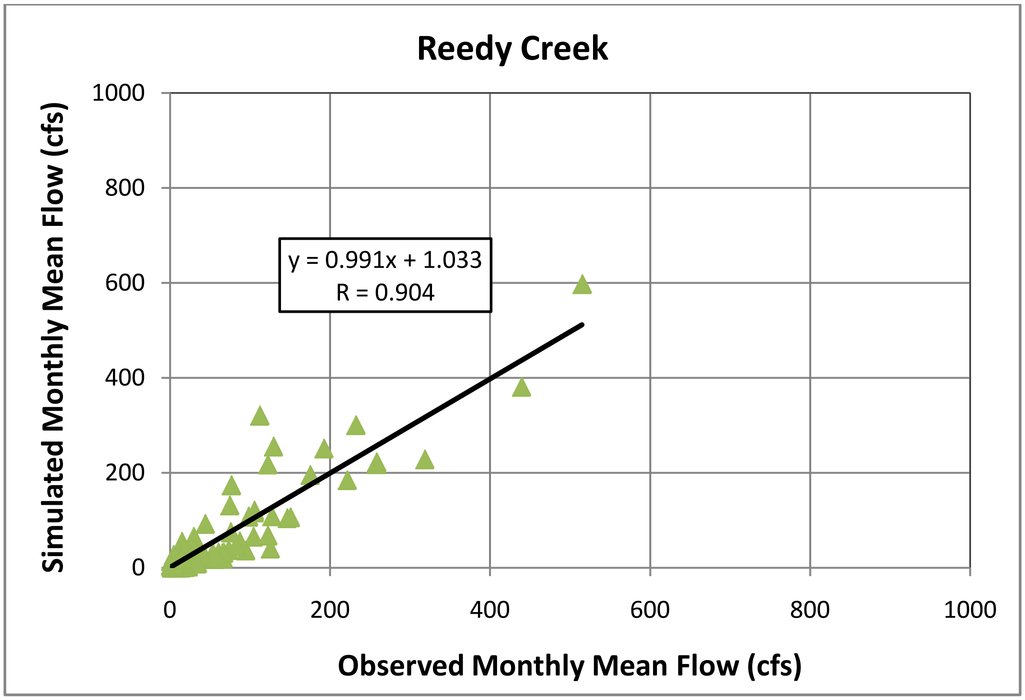

Figure D-20. Relationship Between Observed and Simulated Monthly Flows for Reedy Creek, 2000–06

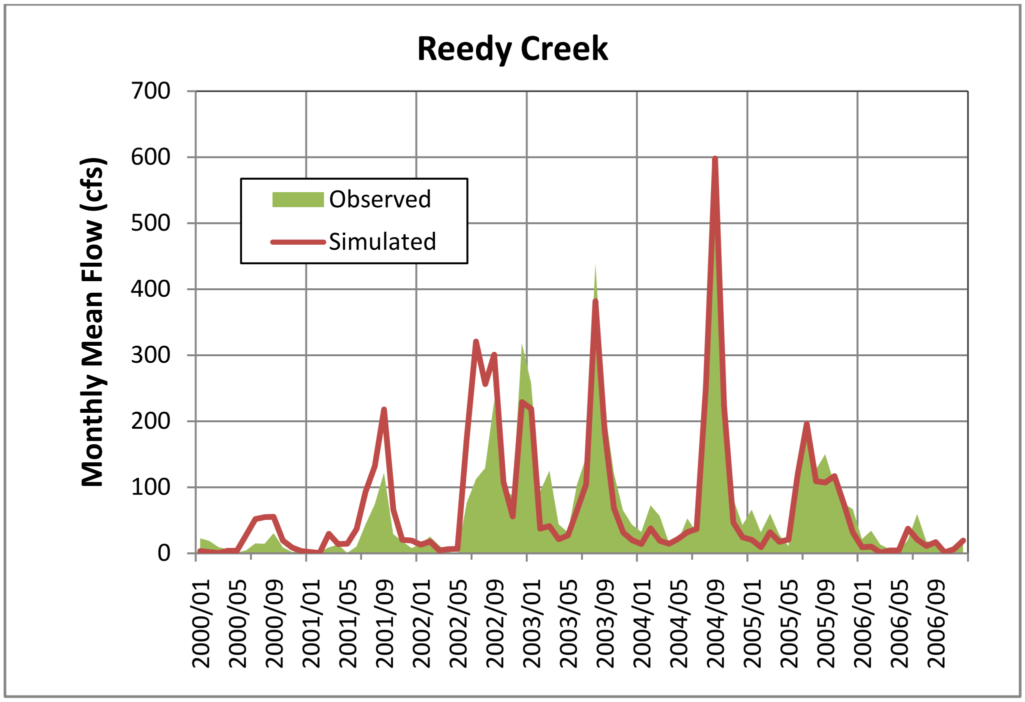

Figure D-21. Observed Versus Simulated Monthly Flows for Reedy Creek, 2000–06

Stage Calibration

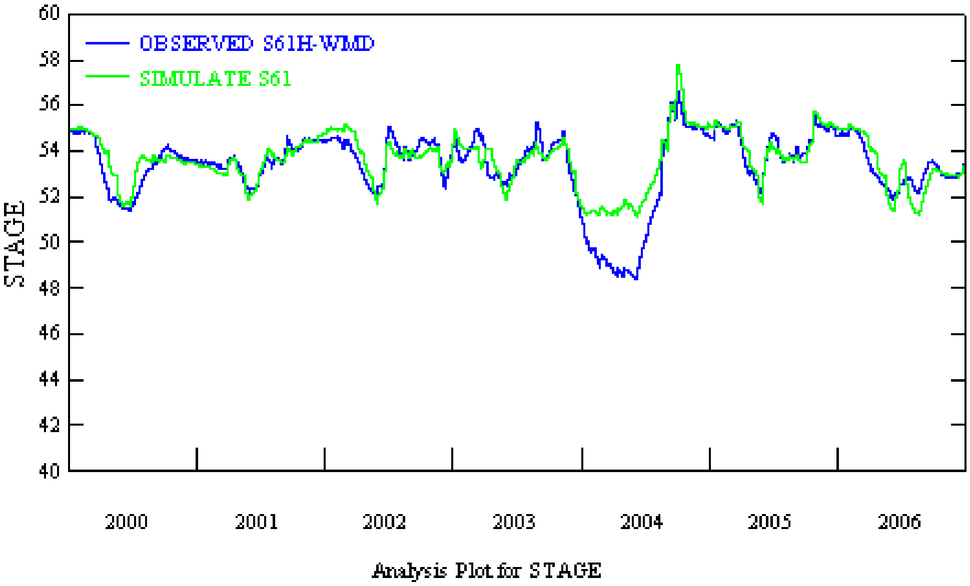

Figure D-22. Observed Versus Simulated Lake Elevation in Lake Tohopekaliga, 2000–06

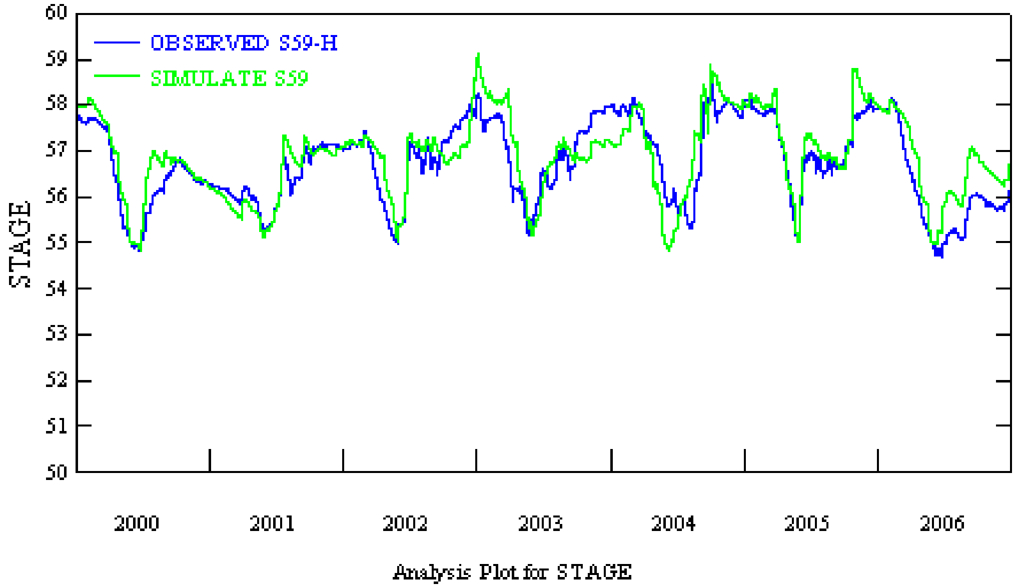

Figure D-23. Observed Versus Simulated Lake Elevation in East Lake Tohopekaliga, 2000–06

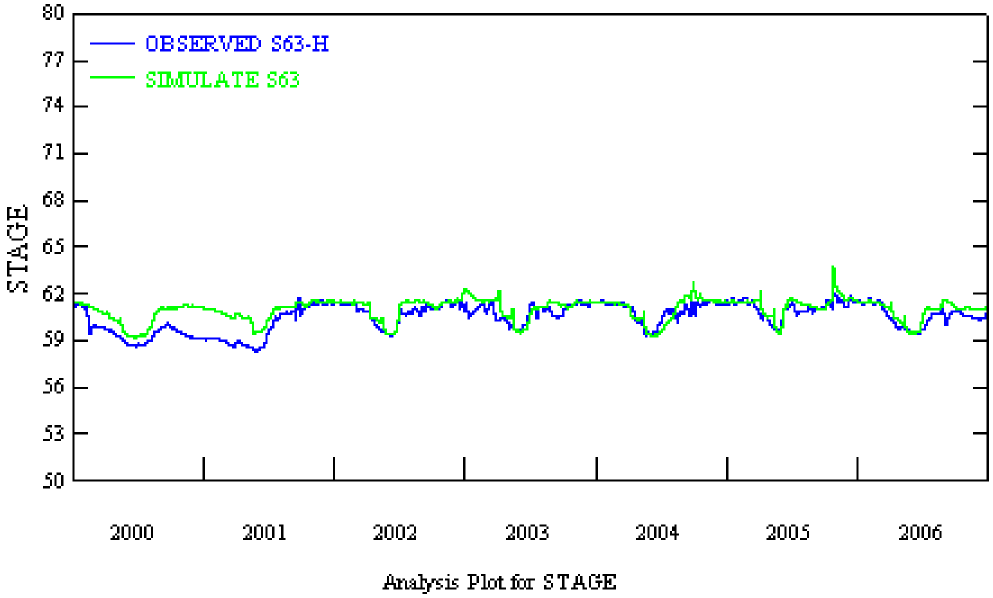

Figure D-24. Observed Versus Simulated Lake Elevation in Lake Gentry, 2000–06