CENTRAL DISTRICT • KISSIMMEE RIVER BASIN •
UPPER KISSIMMEE PLANNING UNIT

FINAL TMDL Report

Nutrient TMDL for Lake Kissimmee (WBID 3183B)

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http://www.epa.gov/storet/

Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Load for nutrients for Lake Kissimmee, located in the Kissimmee River Basin. This 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 Kissimmee was initially verified as impaired during the Cycle 1 assessment (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 40 (when color is 40 platinum cobalt units [PCU] or less) was exceeded in 2007, and the threshold of 60 (color greater than 40 PCU) was exceeded in 2008. 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 Kissimmee is located within Osceola County, Florida; however, the western edge of the lake is situated along the boundary between Polk County and Osceola County. The estimated average surface area of the lake is 37,000 acres, with a normal pool volume ranging between 216,000 acre-feet (ac-ft) and 368,000 ac-ft, with normal depths ranging between 8 and 12 feet. Lake Kissimmee receives the drainage from 831,208 acres through tributary inflow (Lake Hatchineha, Lake Rosalie, Tiger Lake, Lake Jackson, and unnamed waterbody [“Reach 410” of the HSPF model]) and has a directly connected subbasin surface water drainage area of approximately 70,321 acres, for a total watershed area of 901,529 acres (**Figure 1.1**). Land uses in the upstream drainage area are primarily wetland (29%), agriculture (24%), rangeland/upland forest (21%), pasture (9%), and residential/commercial (17%). The Lake Kissimmee watershed’s land uses are rangeland/upland forest (32.1%), wetland (31.2%), agriculture (25.6%), pastureland (10.1%), and residential/commercial (1.1%). Water leaves Lake Kissimmee through the S65 structure, flowing into the Kissimmee River.

For assessment purposes, the Department 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 Kissimmee is WBID 3183B.

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

1.3 Background Information

As depicted in **Figure 1.1**, the Lake Kissimmee watershed has a total surface water drainage area of approximately 901,529 acres (831,208 acres upstream and 70,321 acres directly tributary to the lake). The Lake Kissimmee watershed includes upstream connections to Tiger Lake, Lake Rosalie, Lake Jackson, Lake Hatchineha, and unnamed model "Reach 410," as well as a downstream connection to the Kissimmee River. Thus, water quality and quantity in Lake Kissimmee directly influence the water quality and quantity of the Kissimmee River (**Figure 1.1**).

Several upstream waterbodies that contribute significant total nitrogen (TN) and total phosphorus (TP) loads to Lake Kissimmee (Lake Cypress [WBID 3180A], Lake Jackson [WBID 3183G], and Lake Marian [WBID 3184]) were verified as impaired by excessive nutrients using the methodology in the IWR, Rule 62-303, F.A.C., and were included on the Cycle 1, Group 4 Verified List of impaired waters for the Kissimmee River Basin that was adopted by Secretarial Order on May 12, 2006. The impairment for nutrients was documented as still present during the Cycle 2 verified period from January 1, 2003, to June 30, 2010. The draft TMDLs for these lakes are documented in the following reports: *Nutrient TMDL For Lake Cypress, WBID 3180A; Nutrient and Dissolved Oxygen TMDL for Lake Jackson, WBID 3183G;* and *Nutrient TMDL For Lake Marian, WBID 3184,* and are available on the Florida Department of Environmental Protection's TMDL Program website at: http://www.dep.state.fl.us/water/tmdl/index.htm.

The nutrient TMDL developed for Lake Cypress consisted of a 5% reduction in TN and a 35% reduction in TP from all watershed sources. The nutrient TMDL for Lake Marian consisted of a 55% reduction in TN and a 53% reduction in TP from all watershed sources. The nutrient TMDL for Lake Jackson consisted of a 20% reduction in TN and a 25% reduction in TP from the Lake Jackson sub-watershed. After the water quality model for Lake Kissimmee was calibrated to existing conditions, the development of the TMDL proceeded under the presumption that the TN and TP load reductions proposed for the upstream impaired Lakes Marian, Jackson, and Cypress had been achieved. The

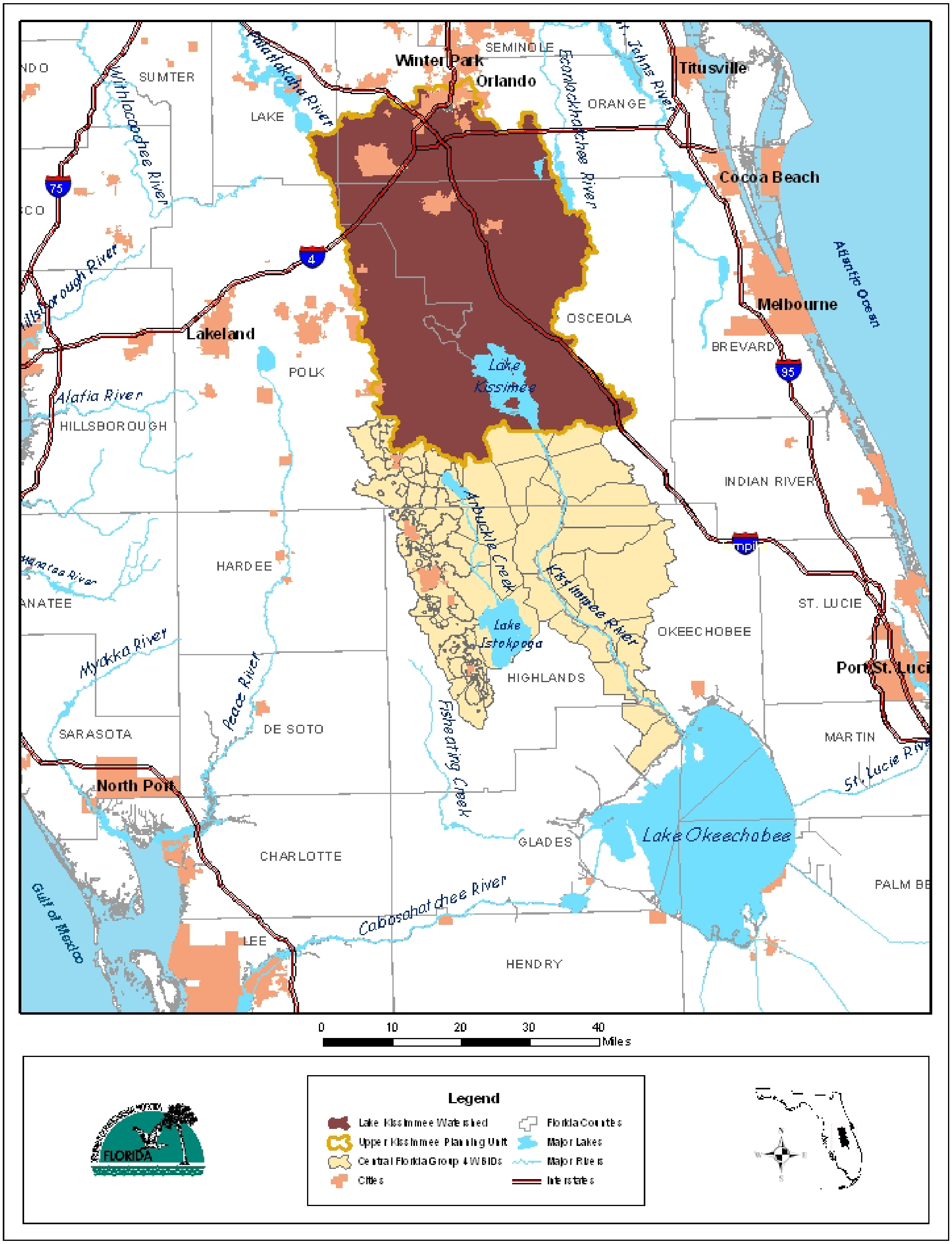

Figure 1.1. Upper Kissimmee Planning Unit and Lake Kissimmee Watershed

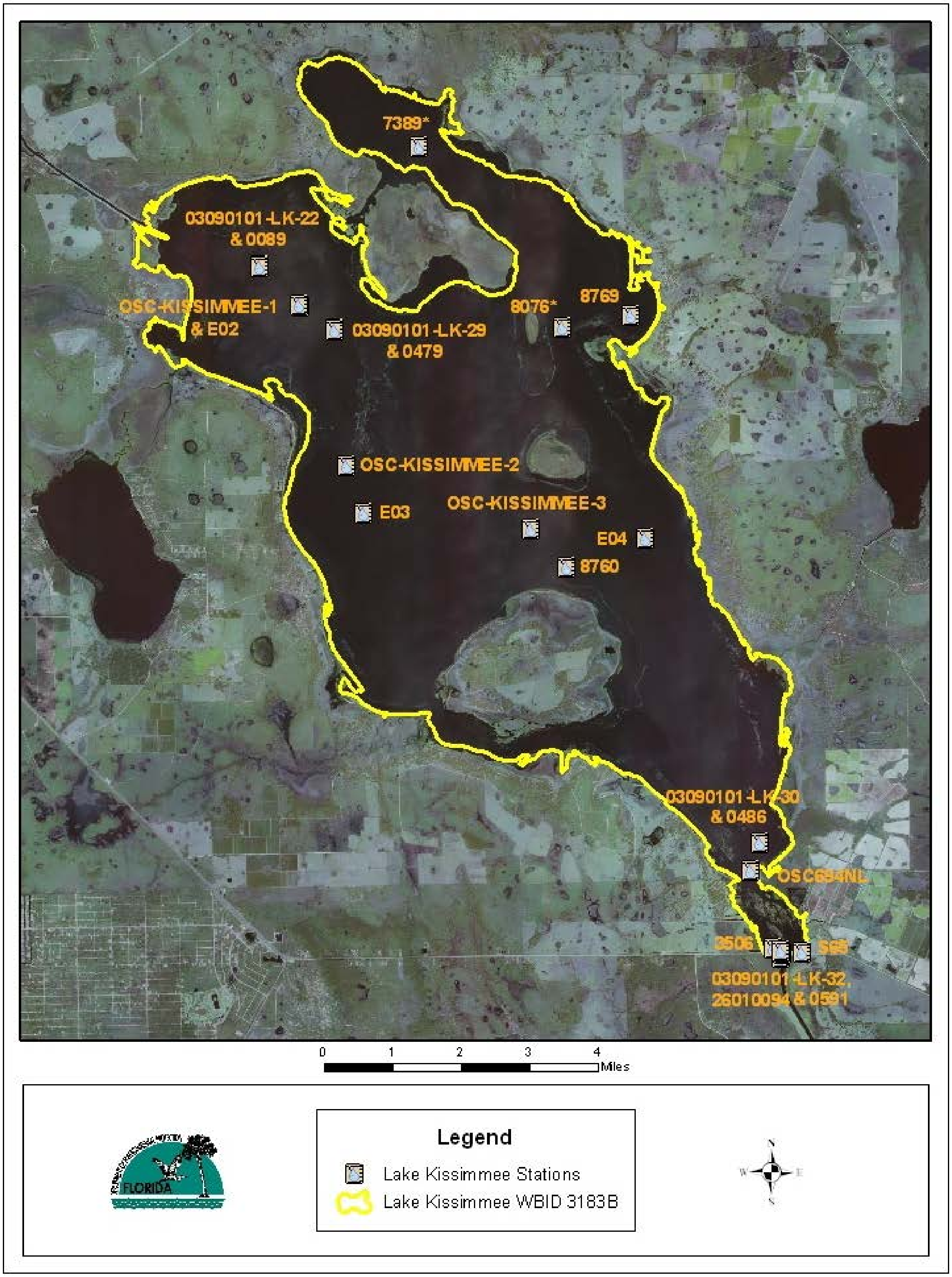

Figure 1.2. Lake Kissimmee (WBID 3183B) and Monitoring Stations

TMDL for Lake Kissimmee establishes the allowable loadings to the lake that would restore the waterbody so that it meets its applicable water quality narrative criterion for nutrients.

The TMDL report for Lake Kissimmee is part of the implementation of the Department's 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 Orange County, Polk County, 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 TMDL 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 Kissimmee was included on Florida's 1998 303(d) list. However, the FWRA, Section 403.067, F.S., states 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. (the 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 Kissimmee. All data presented in this report are from IWR Run 42. The lake was verified as impaired for nutrients based on an elevated annual average TSI value over the Cycle 1 verified period for the Group 4 basins, which was January 1, 1998, to June 30, 2005. The impairment for nutrients 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 TN, TP, and corrected chlorophyll *a* (cchl*a*) (a measure of algal mass) in calculating annual TSI values and in interpreting Florida's narrative nutrient threshold.

For Lake Kissimmee, data were available for the 3 water quality variables for all 4 seasons in each year of the Cycle 1 verified period: from 1998 to 2005 and for the years 2003 to 2009 of the Cycle 2 verified period. In fact, such data were available for all 10 years included in the model (1997 to 2006). During Cycle 1, the annual average color of the lake was greater than 40 PCU for each year, and the IWR TSI threshold of 60 was exceeded during 1998, 1999, and 2001. During Cycle 2, the annual average color for 2007 was less than 40 PCU (38 PCU), and the TSI threshold of 40 was exceeded (TSI 59) in this year. Based on the 40-year period of record, annual average color fell below 40 PCU only 3 times. Additionally, in Cycle 2, the IWR threshold of 60 (color 57 PCU) was exceeded in 2008 (TSI 64). Under the IWR methodology, exceeding the TSI threshold in any one year of the verified period is sufficient in determining nutrient impairment for a lake.

Data reduction followed the procedures in Rule 62-303, F.A.C. Data were further reduced by calculating daily averages. 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.

Annual average results for data from outside the combined verified periods (1998 to 2009) are displayed but were not used in the assessment of impairment. Similarly, any results flagged as “M<” are displayed but were not used in the assessment of impairment regardless of the year.

Tables 2.1a through **2.1d** provide summary statistics for the lake for TN, TP, and chl*a* from 1993 to 2006. Individual water quality measurements (raw data) for TN, TP, and chl*a* used in the assessment are provided in **Appendix D**.

As depicted in **Figures 2.1** and **2.2**, the data for color (true color) show a slight, but not significant, increase over the period of record (1970 to 2009). As shown in **Tables 2.1a-d**, the color in Lake Kissimmee ranges from just above 12 to nearly 350 PCU, with an overall average of 73.7 PCU. The average color for the 5-year period used to calibrate the water quality model was 58 PCU, well below the long-term average. The average color for the 5-year model validation period was 111 PCU, well above the long-term average.

The data for alkalinity (1970 to 2009) depicted in **Figure 2.3** and **Tables 2.1a-d** show a slight, but not significant, increase over time. The data for pH (1970 to 2010) depicted in **Figure 2.4** and **Tables 2.1a-d** show a slight, but not significant, increase over time. The data for Secchi disk depth (1973 to 2010) depicted in **Figure 2.5** and **Tables 2.1a-d** show a slight, but not significant, decrease over time, as both the mean and median values of 0.8 meters from the period before 1997 have decreased to 0.7 meters for the calibration period and to 0.6 meters during the validation period.

Key to Figure Legends in Chapter 2

C = Results for calibrated/validated model
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

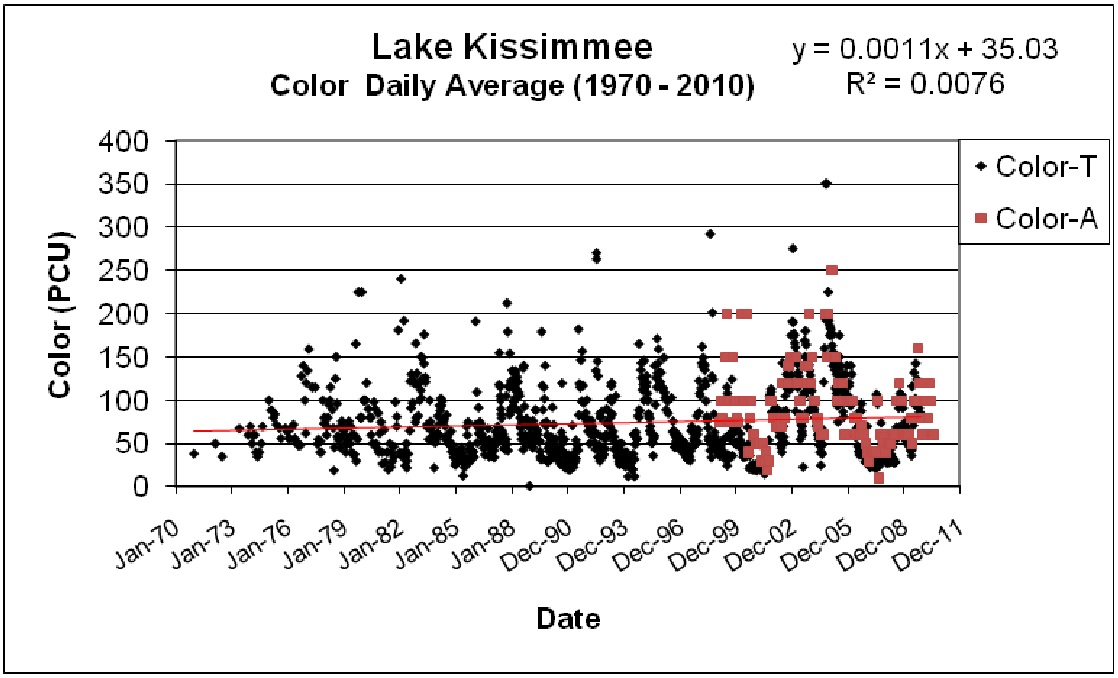

Figure 2.1. Daily Average Color (PCU) for the Period of Record, 1970–2009

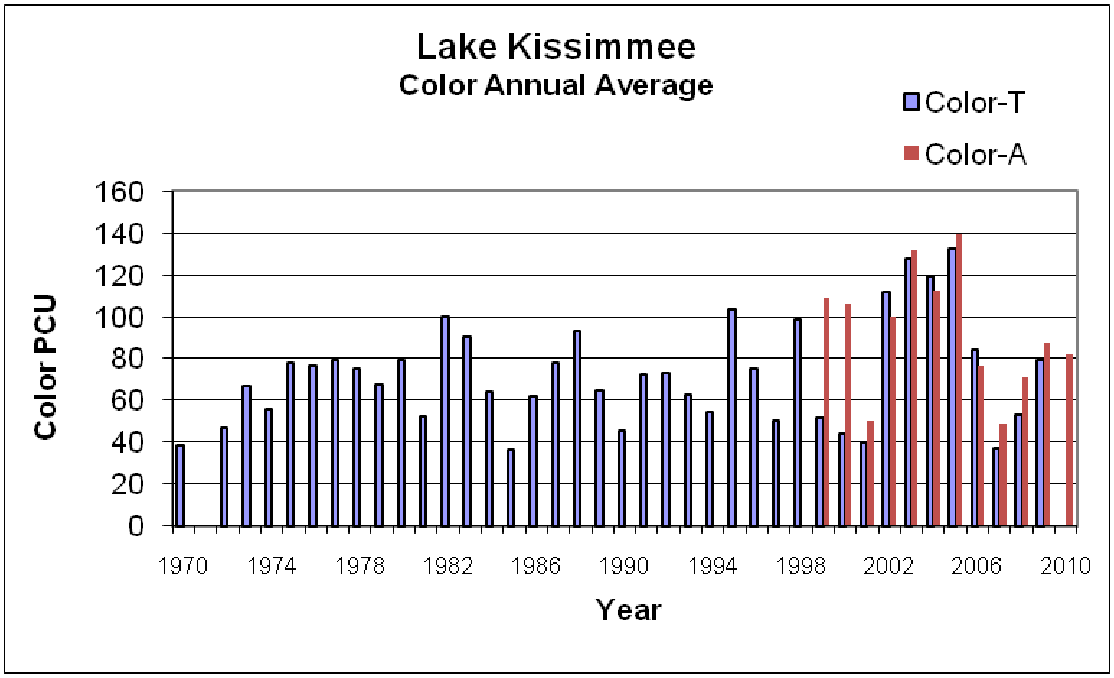

Figure 2.2. Annual Average Color (PCU) for the Period of Record, 1970–2009

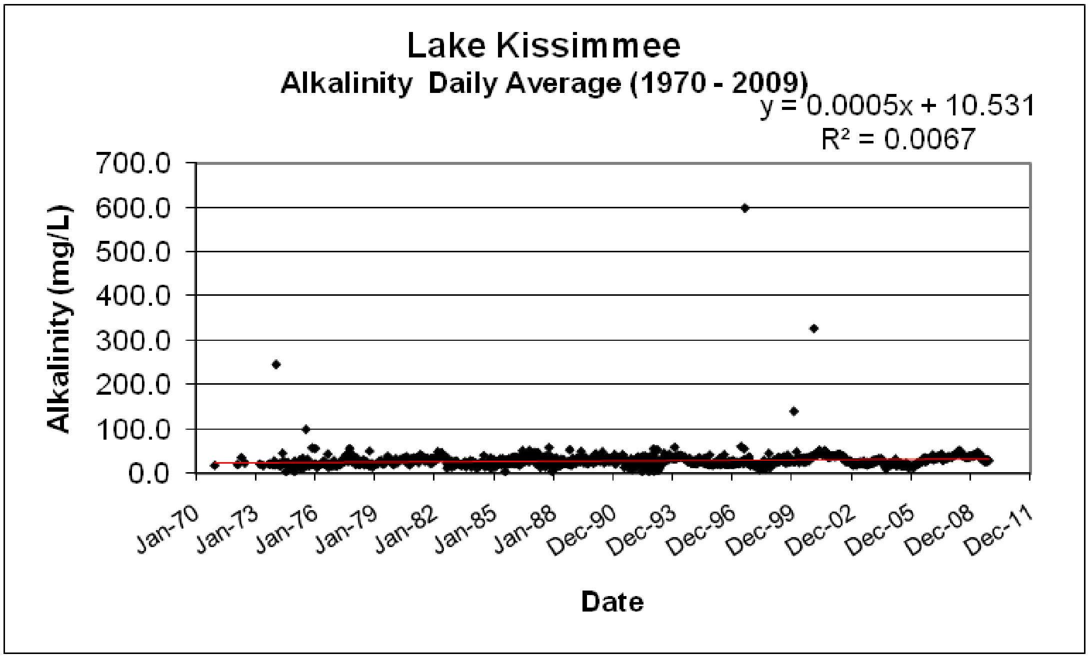

Figure 2.3. Daily Average Alkalinity (mg/L) for the Period of Record, 1970–2009

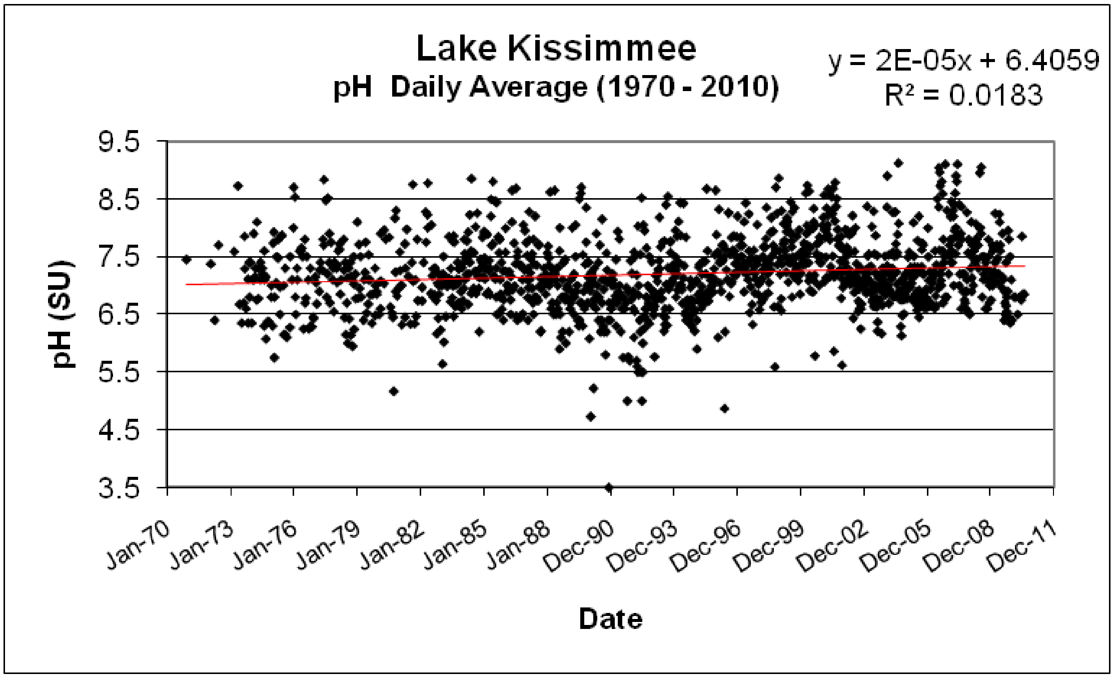

Figure 2.4. Daily Average pH (SU) for the Period of Record, 1970–2010

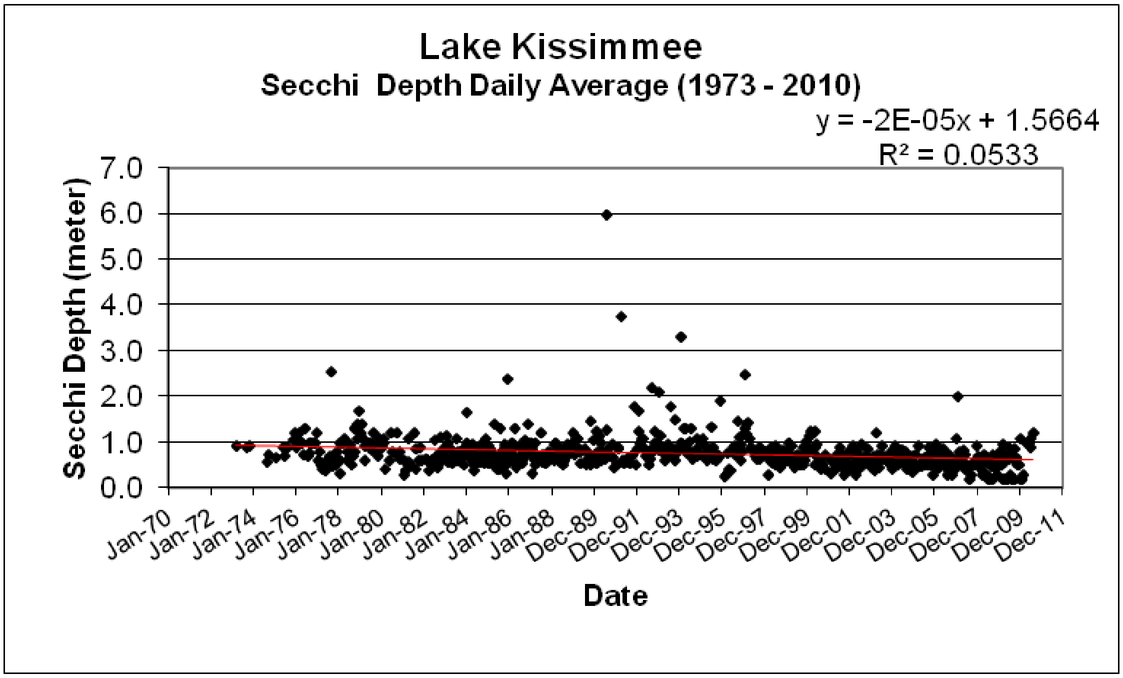

Figure 2.5. Daily Average Secchi Depth (meters) for the Period of Record, 1973–2010

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

CHLATSI = 16.8 + 14.4 * LN(Chla)	Chlorophyll a in micrograms per liter (µg/L)
TNTSI = 56 + 19.8 * LN(N)	Nitrogen in milligrams per liter (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 1996 to 2006. However, 1996 was used to allow the model to establish antecedent conditions, and model comparisons to measured data were only conducted for the period from 1997 to 2006. For modeling purposes, the analysis of the eutrophication-related data presented in this report for Lake Kissimmee used all of the available data from 1997 to 2006 for which records of TP, TN, and cchl*a* were sufficient to calculate seasonal and annual average conditions.

However, the data used for the determination of impairment and in the Camp Dresser and McKee (CDM) 2008 report do not contain any LakeWatch data. Additionally, to calculate the TSI for a given year under the IWR, there must be at least one sample of TN, TP, and cchl*a* taken within the same quarter (each season) of the year. For Lake Kissimmee, data were present for at least one of the four seasons in all years (1997 to 2006).

Figure 2.6 displays the annual average TSI values for all data from 1975 to 2010 (the figure includes LakeWatch data, while the assessment of impairment did not). During the combined verified periods (January 1998 to June 2009) the annual average TSI values exceeded the IWR threshold level of 60 from 1998 to 2001 and from 2004 to 2009, with a mean TSI result of 61.3. While the annual average TSI has declined from the value of 68 reported during 1996, it remains above the IWR threshold value of 60, indicating a need for nutrient reductions.

The daily, annual, and monthly average TN results for Lake Kissimmee from 1970 to 2010 are displayed in **Figures 2.7** through **2.9** and summarized in **Tables 2.1a-d**. These data indicate that while the daily and annual average TN results have improved slightly since the mid-1970s through 1988, the mean of 1.31 mg/L for the combined verified periods (1998 to 2009) remains at a level that is expected to be contributing to the elevated TSI results. The monthly average TN results appear highest in April (1.47 mg/L) and lowest during December (1.23 mg/L)

The daily average total ammonia (NH3-N) results (1970 to 2010) are displayed in **Figure 2.10** and summarized in **Tables 2.1a-d**. These data indicate that while the annual mean (0.043 mg/L) and maximum (0.66 mg/L) NH3-N concentration for the period from 1970 to 1995 had improved between 1996 and 2010 to 0.024 and 0.28 mg/L, respectively, the concentrations are still in the range that could be contributing to nutrient impairment.

The daily, annual, and monthly average TP results for Lake Kissimmee from 1973 to 2010 are displayed in **Figures 2.11** through **2.13** and summarized in **Tables 2.1a-d**. These data indicate a slight increase in TP over time. During the period from 1997 to 1999, the lake experienced the highest TP in the dataset (1997 and 1999 TP over 0.12 mg/L). The TP averaged 0.108 mg/L during the calibration period (high color) and 0.079 during the validation period (low color). The mean of 0.084 mg/L for the modeled period from 1997 to 2006 remains at a level that is expected to be contributing to the elevated TSI results. The monthly average TP results appear highest in late summer and early fall (July to October), averaging 0.89 mg/L, and lowest during December through June, averaging 0.071 mg/L.

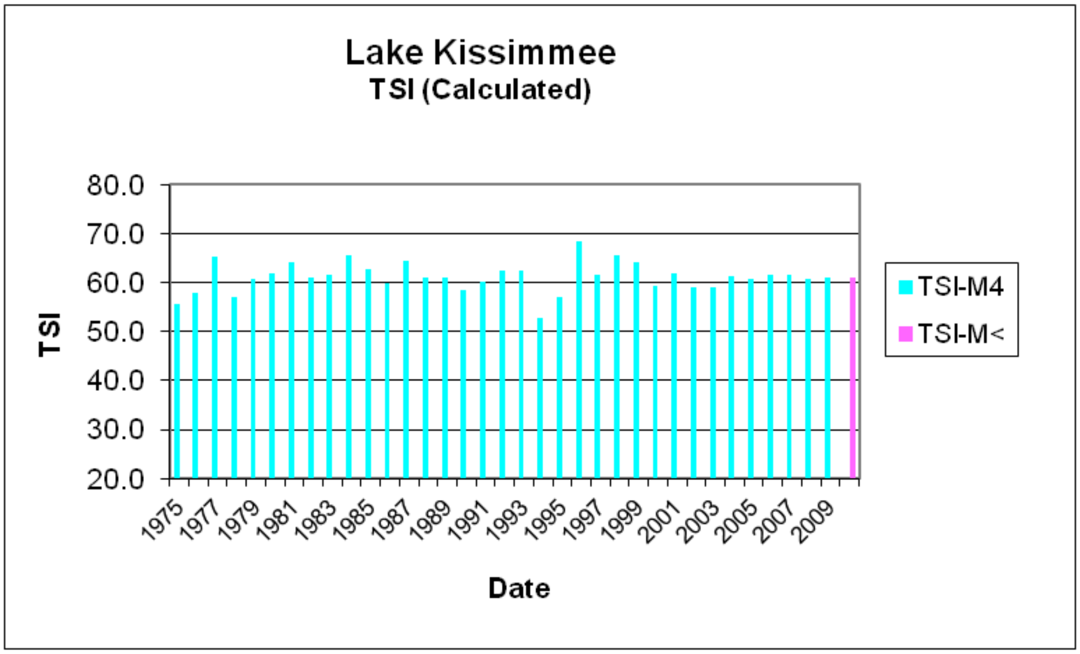

Figure 2.6. TSI Calculated Annual Average, 1979–2009

The daily average orthophosphate-P (PO4-P) results (1973 to 2008) are displayed in **Figure 2.14** and summarized in **Tables 2.1a-d**. These data indicate that a slight increase in the PO4-P concentrations has occurred over the period of record. **Figure 2.14** depicts 2 periods between 1988 and 2000 when concentrations were greater than 0.20 mg/L. The overall mean was 0.011 mg/L. The mean during the calibration period was 0.014 mg/L and 0.016 mg/L during the validation period, both means greater than the mean value of 0.009 mg/L for the period before 1997. The pattern and elevated concentrations are supportive of a periodic benthic release of PO4-P.

The daily, annual, and monthly average corrected cchl*a* results for Lake Kissimmee from 1975 to 2010 are displayed in **Figures 2.15** through **2.17** and summarized in **Tables 2.1a-d.** These data indicate that while the daily and annual average cchl*a* results have improved slightly since data collection began, the mean of 38 µg/L for 1996 and 31 µg/L for 2008, taken together with daily average concentrations over 100 µg/L that have occurred during the combined verified periods, is indicative of nutrient enrichment. The mean for the calibration period was 24.1 µg/L and was 19.8 µg/L during the validation period. The monthly average cchl*a* results peak during May to August (average 29.1 µg/L) from a seasonal winter low (December to February) of 20.9 µg/L.

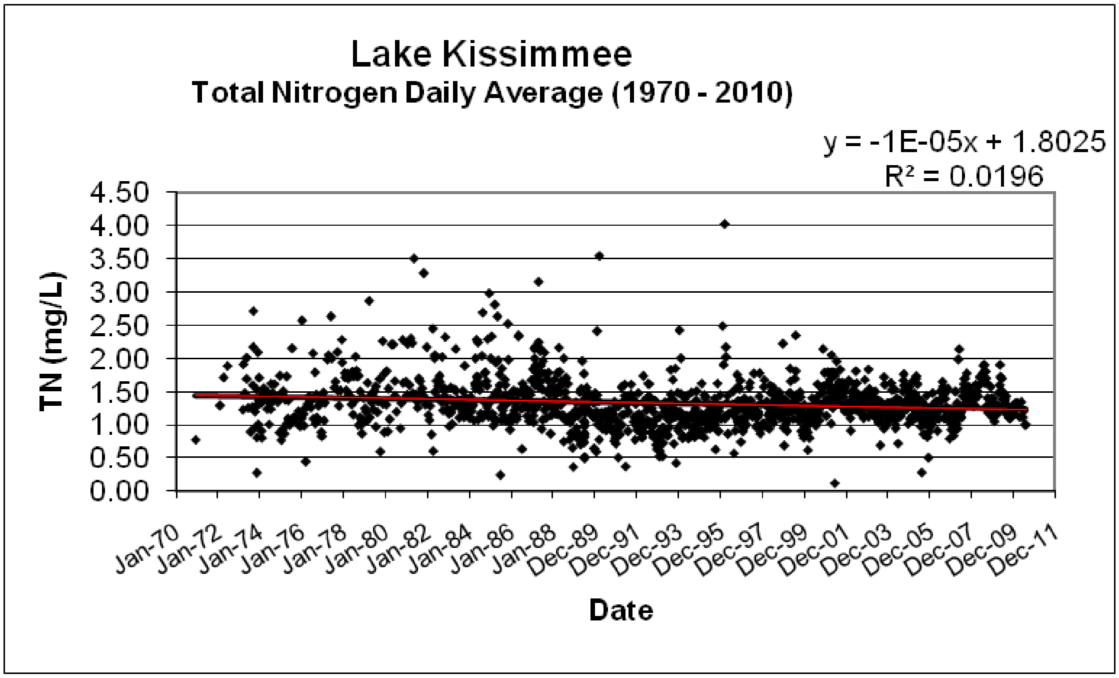

Figure 2.7. TN Daily Average Results, 1970–-2010

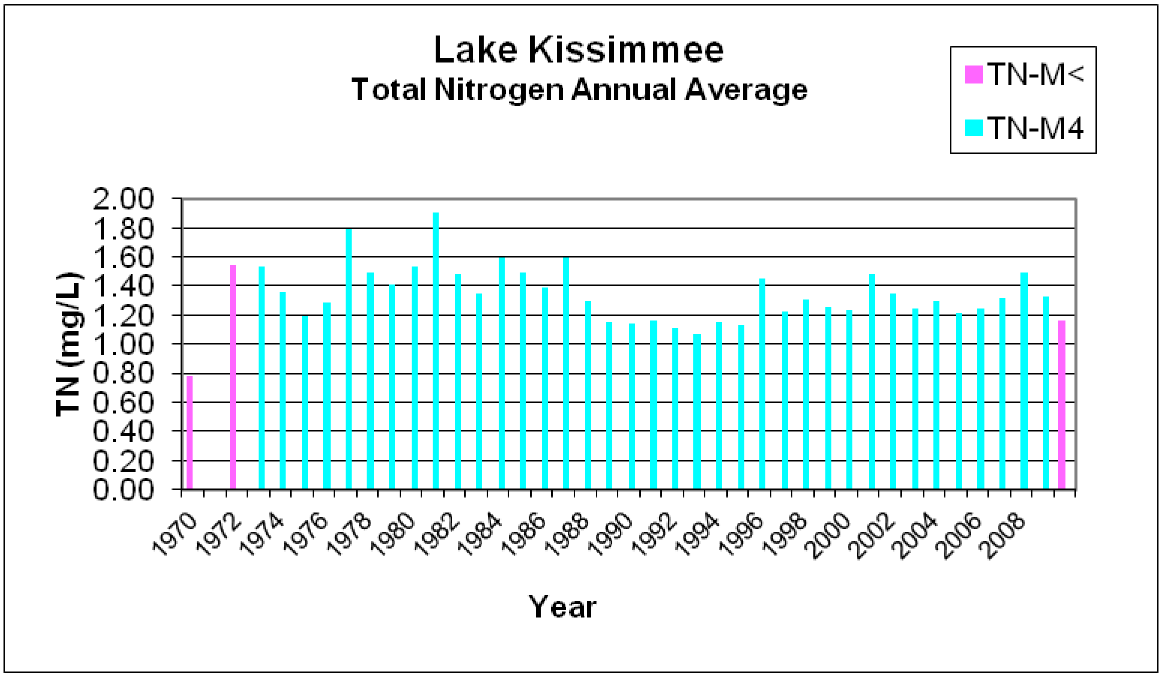

Figure 2.8. TN Annual Average Results, 1970–2010

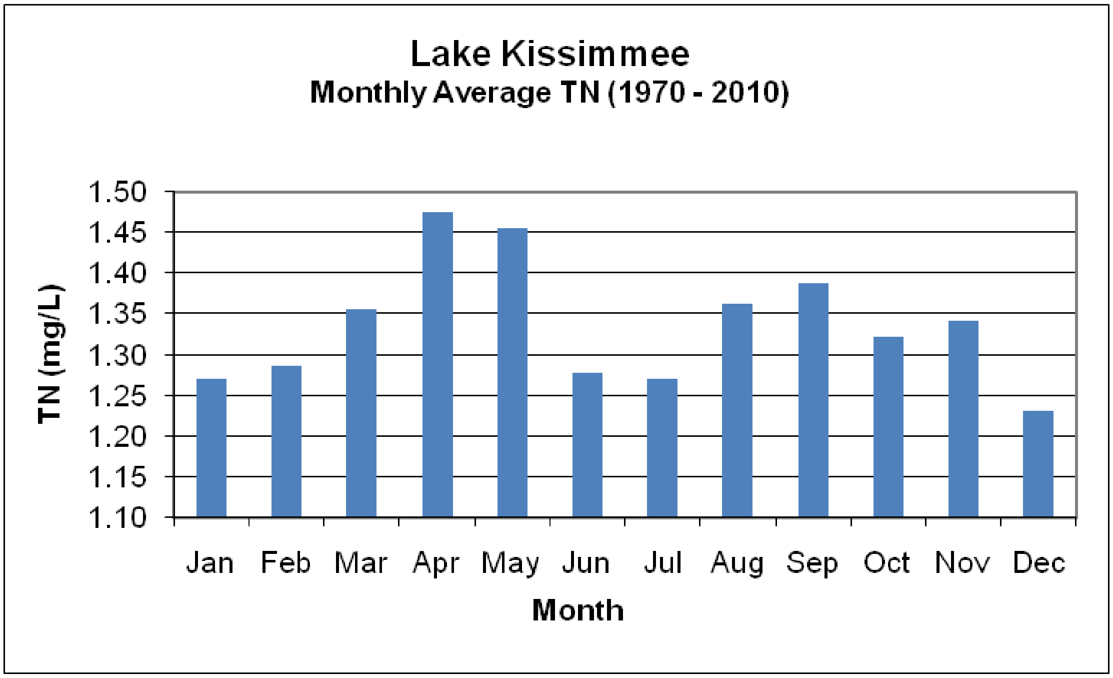

Figure 2.9. TN Monthly Average Results, 1970–2010

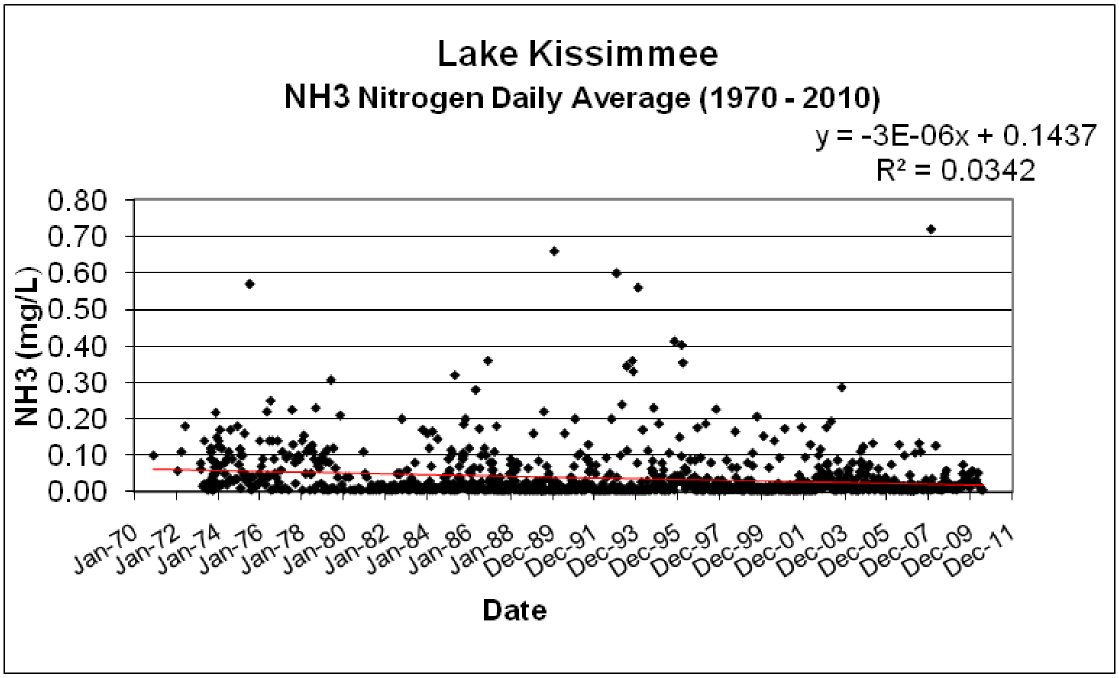

Figure 2.10. Total Ammonia Nitrogen Daily Average Results, 1970–2010

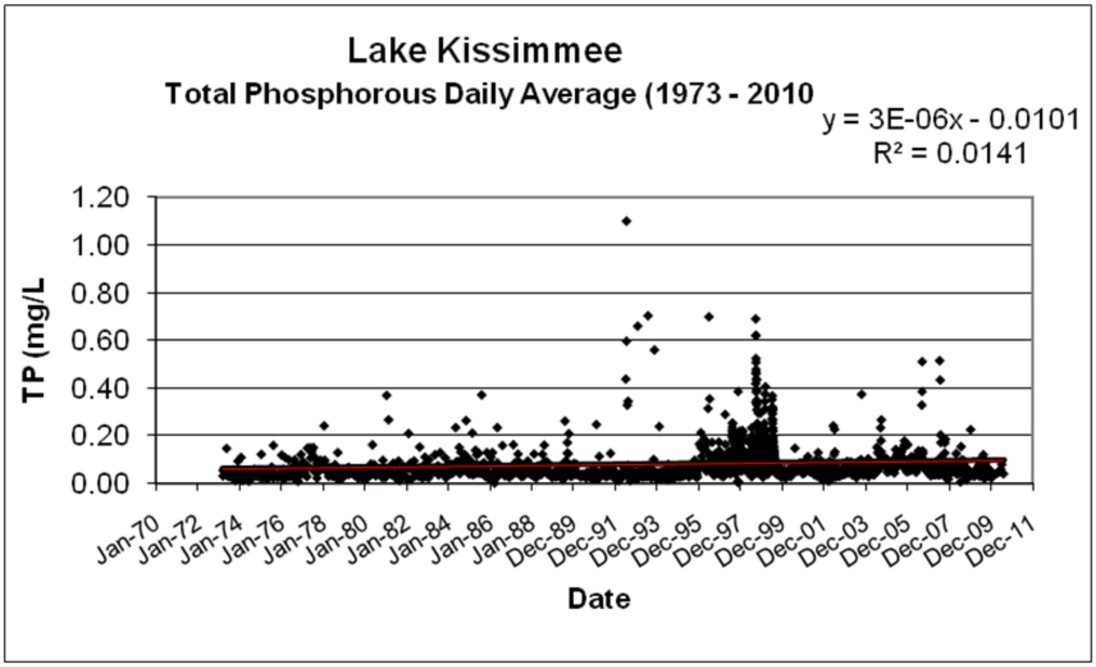

Figure 2.11. TP Daily Average Results, 1973–2010

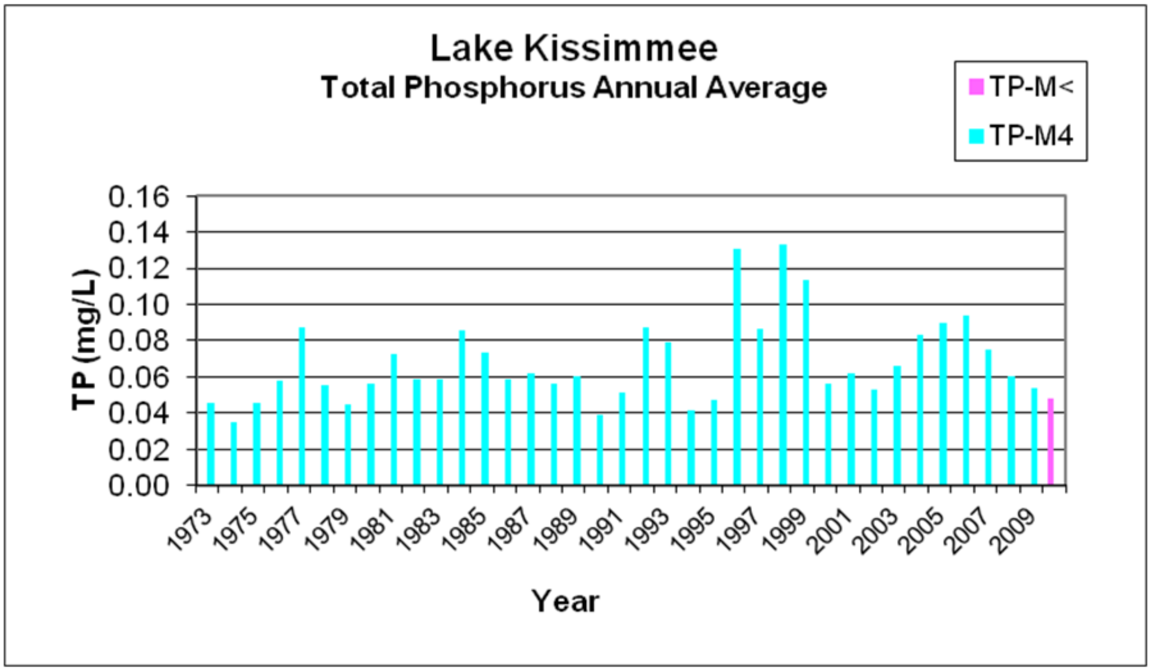

Figure 2.12. TP Annual Average Results, 1973–2010

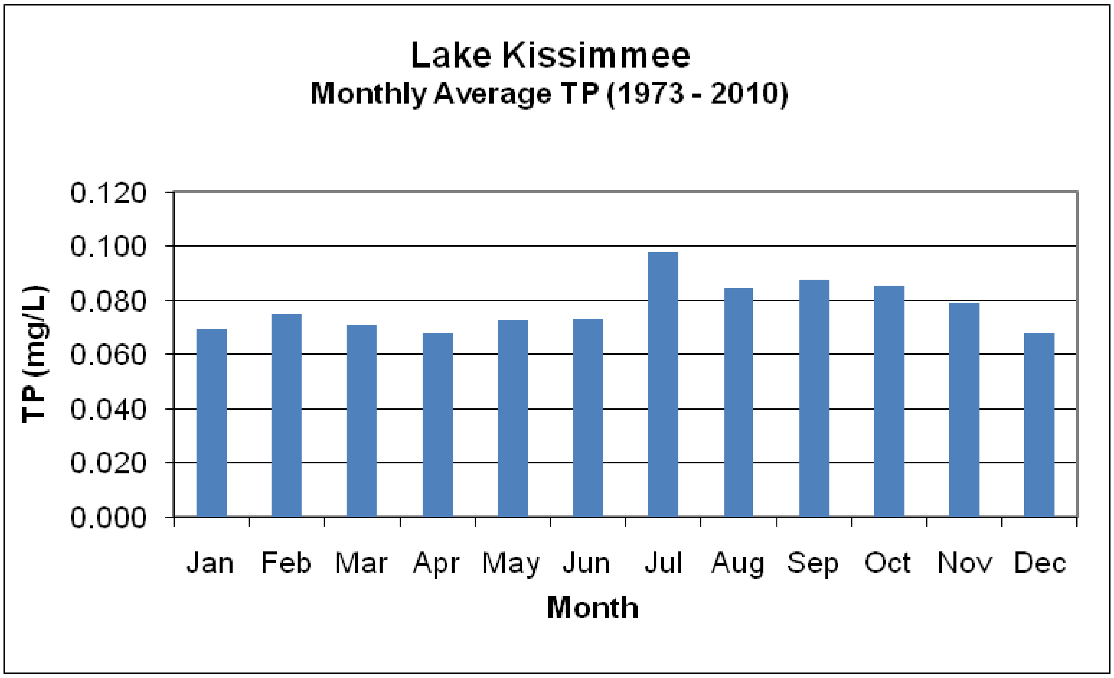

Figure 2.13. TP Monthly Average Results, 1973–2010

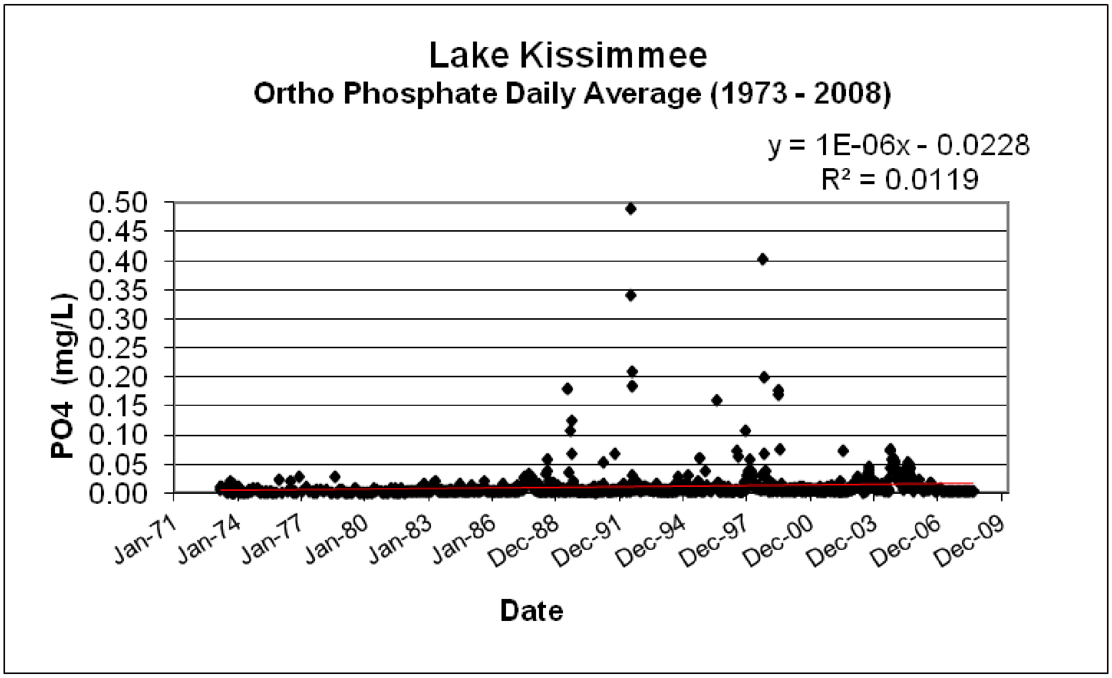

Figure 2.14. Orthophosphate - Phosphorus Daily Average Results, 1973–2008

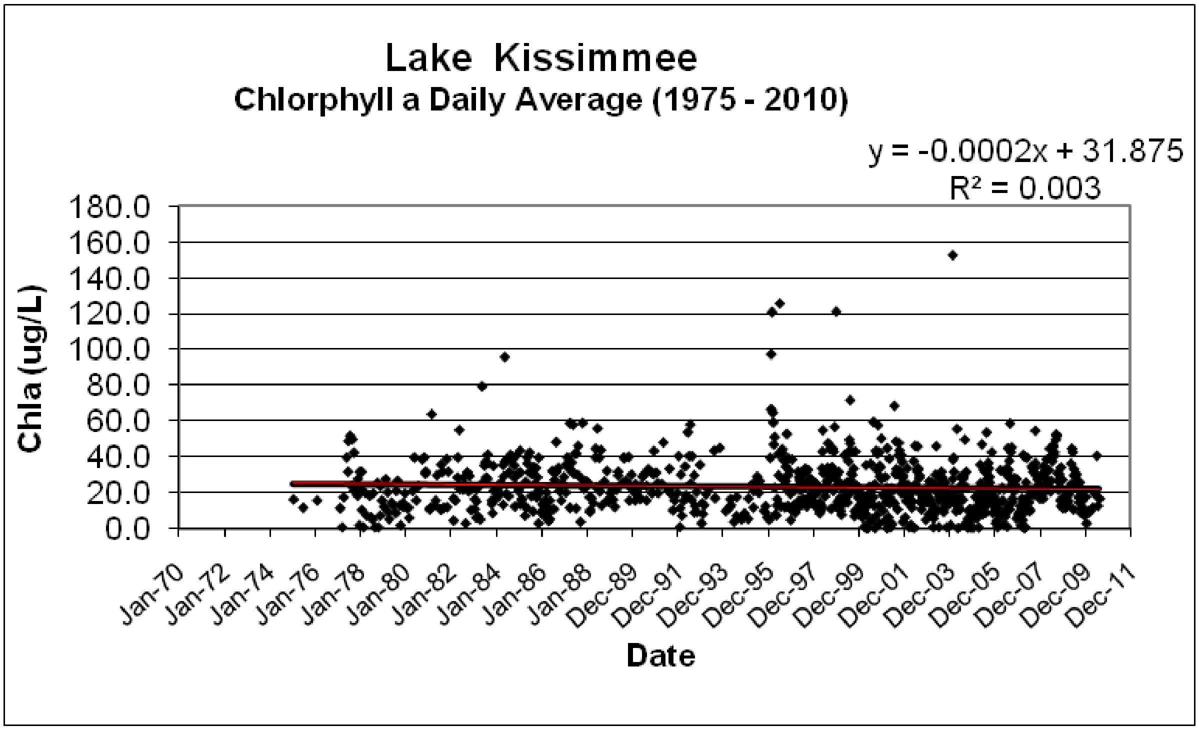

Figure 2.15. CChl*a* Daily Average Results, 1975–2010

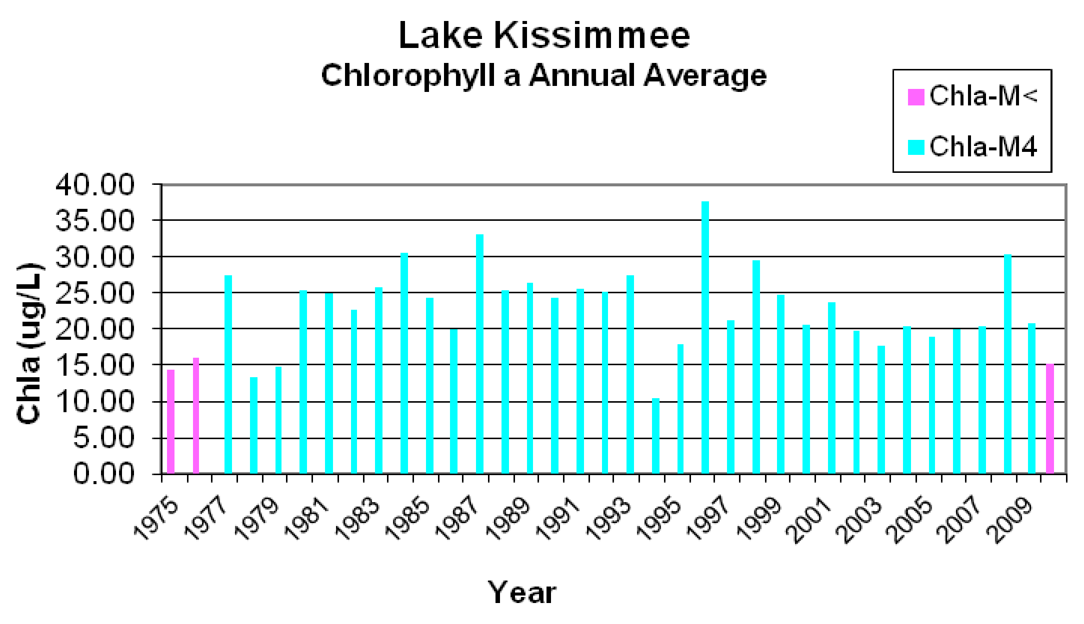

Figure 2.16. CChl*a* Annual Average Results, 1975–2010

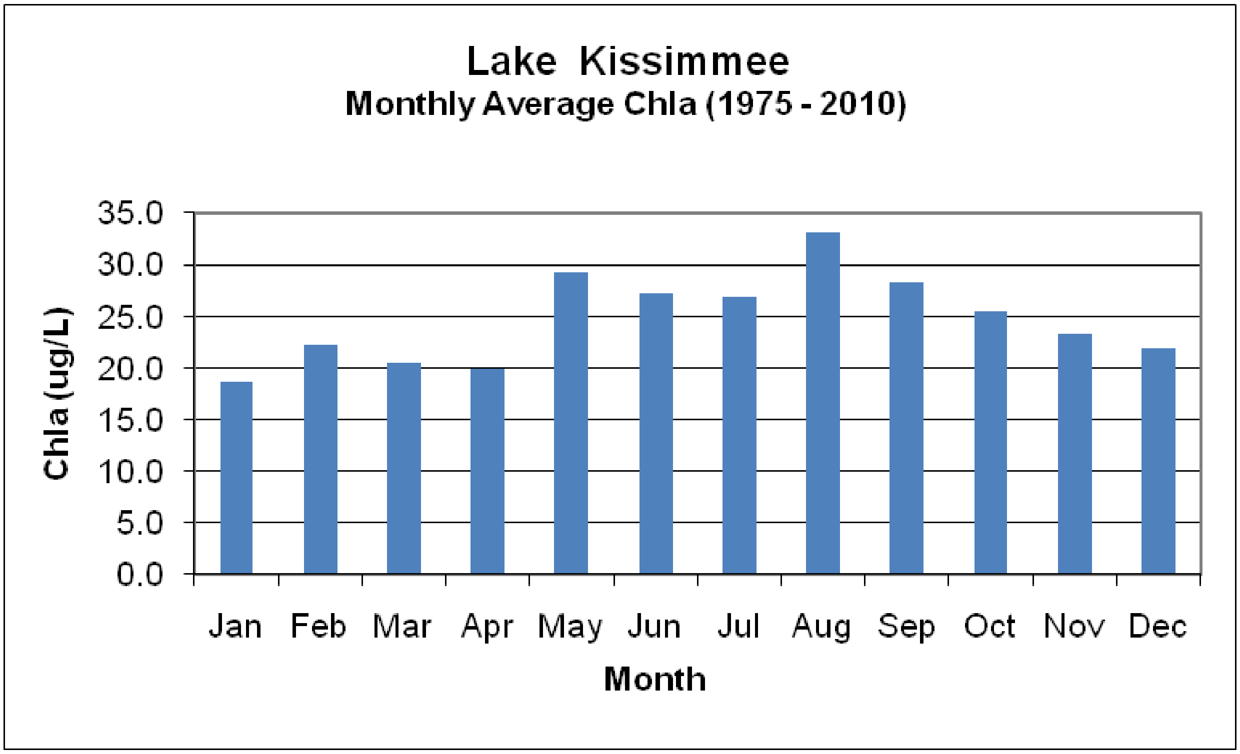

Figure 2.17. CChl*a* Monthly Average Results, 1975–2010

Table 2.1a. Water Quality Summary Statistics for the Period of Record for TN, NH3, TP, PO4, Chl*a*, Color, Alkalinity, pH, and Secchi Depth

Statistic	TN (mg/L)	NH3-N (mg/L)	NO23-N (mg/L)	TP (mg/L)	PO4-P (mg/L)	Chl*a* (µg/L)	Color (true) (PCU)	Alkalinity (mg/L)	pH (SU)	Secchi Depth (meter)
Period of Record	1970–2010	1970–2010	1973–2010	1973–2010	1973–2008	1975–2010	1970–2009	1970–2009	1970–2010	1973–2010
Count	1385	1289	1200	2576	969	942	1077	1234	1352	732
Minimum	0.13	0.003	0.002	0.002	0.001	0.50	12.0	2.5	3.2	0.2
Mean	1.32	0.035	0.031	0.083	0.011	23.23	73.7	27.6	7.2	0.8
Median	1.28	0.013	0.007	0.067	0.005	21.00	61.0	25.5	7.2	0.7
Maximum	4.02	0.720	0.780	1.100	0.488	153.10	350.0	599.7	9.1	6.0

Table 2.1b. Water Quality Summary Statistics for the Precalibration Period for TN, NH3, TP, PO4, Chl*a*, Color, Alkalinity, pH, and Secchi Depth

Statistic	TN (mg/L)	NH3-N (mg/L)	NO23-N (mg/L)	TP (mg/L)	PO4-P (mg/L)	Chl*a* (µg/L)	Color (true) (PCU)	Alkalinity (mg/L)	pH (SU)	Secchi Depth (meter)
Precalibration	1970–96	1970–96	1973–96	1973–96	1973–96	1975–96	1970–96	1970–96	1970–96	1973–96
Count	769	708	663	909	571	366	644	746	761	405
Minimum	0.25	0.005	0.002	0.002	0.001	1.00	12.0	2.5	3.5	0.3
Mean	1.33	0.043	0.031	0.065	0.009	24.97	70.7	26.2	7.1	0.8
Median	1.27	0.016	0.010	0.048	0.004	22.19	60.0	25.0	7.1	0.8
Maximum	4.02	0.660	0.780	1.100	0.488	126.10	270.0	245.0	8.9	6.0

Table 2.1c. Water Quality Summary Statistics for the Calibration Period, 1997–2001, for TN, NH3, TP, PO4, Chl*a*, Color, Alkalinity, pH, and Secchi Depth

Statistic	TN (mg/L)	NH3-N (mg/L)	NO23-N (mg/L)	TP (mg/L)	PO4-P (mg/L)	Chl*a* (µg/L)	Color (true) (PCU)	Alkalinity (mg/L)	pH (SU)	Secchi Depth (meter)
Count	232	214	195	985	198	209	171	190	194	96
Minimum	0.13	0.004	0.002	0.005	0.002	0.50	15.0	7.1	3.2	0.3
Mean	1.30	0.021	0.014	0.108	0.014	24.10	58.3	32.6	7.5	0.7
Median	1.27	0.010	0.005	0.086	0.006	22.00	48.0	25.7	7.5	0.7
Maximum	2.35	0.227	0.141	0.690	0.403	121.60	292.0	599.7	8.9	2.5

Table 2.1d. Water Quality Summary Statistics for the Validation Period, 2002–06, for TN, NH3, TP, PO4, Chla, Color, Alkalinity, pH, and Secchi Depth

Statistic	TN (mg/L)	NH3-N (mg/L)	NO23-N (mg/L)	TP (mg/L)	PO4-P (mg/L)	Chl*a* (µg/L)	Color (true) (PCU)	Alkalinity (mg/L)	pH (SU)	Secchi Depth (meter)
Count	254	243	225	430	179	237	172	191	254	150
Minimum	0.29	0.005	0.002	0.011	0.001	0.55	23	8.0	6.1	0.3
Mean	1.27	0.027	0.059	0.079	0.016	19.78	111	24.0	7.2	0.6
Median	1.27	0.016	0.020	0.072	0.011	18.00	103	22.0	7.1	0.6
Maximum	1.84	0.287	0.424	0.511	0.074	153.10	350	41.4	9.1	1.2

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 Kissimmee is classified as 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 Kissimmee is 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 under Paragraph 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 is used to identify the limiting nutrient(s) in streams and lakes:

The individual ratios over the entire verified period (*i.e.*, January 1998 to June 2005 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. For Lake Kissimmee, the mean TN/TP ratio was 18.3 for the verified period (2003 to 2009), 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 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. In recognition that the IWR thresholds were developed using statewide average conditions, the IWR (Subsection 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, the use of 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 Kissimmee 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 Kissimmee 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 Kissimmee 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 Kissimmee. 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 the 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 Kissimmee 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 Kissimmee. The NPDES facilities listed in **Table 4.1** and shown in **Figure 4.1** are within the extended Lake Kissimmee watershed but were not included in the model as they are not surface water dischargers.

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.

The stormwater collection systems in the Lake Kissimmee watershed, which are owned and operated by Polk County in conjunction with the Florida Department of Transportation (FDOT) District 1, are covered by NPDES Phase I MS4 Permit Number FLS000015. The collection systems which are owned and operated by Osceola County and the city of St. Cloud, are covered by NPDES Phase II MS4 Permit Number FLR04E012. The collection system for the city of Orlando is covered by NPDES Phase I Permit Number FLS000014. The collection systems for Orange County, FDOT District 5, and the city of Belle Isle are covered by NPDES Phase 1 Permit Number FLS000011. The collection system for the city of Kissimmee is covered by NPDES Phase II Permit Number FLR04E64. The collection system for the Florida Turnpike is covered by NPDES Phase II-C Permit Number FLRO4E049

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 Kissimmee 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:

Table 4.1. NPDES Facilities in the Extended Lake Kissimmee Drainage Basin

CBP = Concrete batch plant; DW = Domestic waste; PET = Petroleum Cleanup; IW = Industrial waste; - = MGD = Million gallons per day

Facility ID	Facility Name	Type	NPDES	MGD	County	Receiving Water
FLG110685	CEMEX LLC - Lake Wales Sand Mine	CBP	Yes	0.000	Polk	None
FLG110259	Florida Rock Industries Inc - Poinciana Plant	CBP	Yes	0.000	Polk	None
FL0036862	TWA-Walnut Drive WRF	DW	Yes	0.850	Osceola	None
FLG110429	CEMEX LLC - Davenport 17/92	CBP	Yes	0.000	Polk	None
FLG110719	Maschmeyer Concrete Company	CBP	Yes	0.000	Osceola	None
FLG110347	CEMEX LLC - Davenport Sand Mine	CBP	Yes	0.000	Polk	None
FLG110833	Jahna Ranch Facility II	CBP	Yes	0.000	Polk	None
FLG110834	Jahna Ranch Readymix Facility I	CBP	Yes	0.000	Polk	None
FLG110650	CEMEX Construct Materials FL LLC - St Cloud Ready Mix Plant	CBP	Yes	0.000	Osceola	None
FLG110179	Florida Rock - Campbell City CBP	CBP	Yes	0.002	Osceola	None
FLG110234	CEMEX Cnstr Mtrls FL LLC- Kissimmee Pug Mill Ready Mix Plant	CBP	Yes	0.000	Osceola	None
FLG110007	CEMEX Construct Mtrls FL LLC - Smith Street Ready Mix Plant	CBP	Yes	0.000	Osceola	None
FLG110490	Prestige - Kissimmee CBP	CBP	Yes	0.000	Osceola	None
FLG914151	South & East Service Area	PET	Yes	0.000	Orange	None
FLG110226	CEMEX Construct Materials FL LLC - W Orange Ready Mix Plant	CBP	Yes	0.000	Orange	None
FLG110327	Florida Rock - CR 545 CBP	CBP	Yes	0.000	Orange	None
FL0169986	WDW - Produced Groundwater Discharge	IW	Yes	0.000	Orange	None
FLG110581	Tarmac - South Orange CBP	CBP	Yes	0.018	Orange	None
FLG110613	CEMEX Construction Materials FL LLC - Regency	CBP	Yes	0.000	Orange	None
FL0622648	Seaworld - Discovery Cove	IW	Yes	0.000	Orange	None
FL0629332	Sea World Of Florida	IW	Yes	0.000	Orange	None
FL0622591	SeaWorld-Aquatica	IW	Yes	0.000	Orange	None
FLG110269	Bedrock Industries	CBP	Yes	0.044	Orange	None
FL0037711	Kinder Morgan LLC	IW	Yes	1.500	Orange	None
FLG110805	Orlando Ready Mix	CBP	Yes	0.000	Orange	None
FLG110159	Florida Rock Industries - Taft CBP	CBP	Yes	0.003	Orange	None
FLG914113	Avis Rent A Car	PET	Yes	0.000	Orange	None
FLG110496	Preferred Materials-East Orlando CBP	CBP	Yes	0.004	Orange	None
FLG110268	Florida Rock Industries - East Orlando CBP	CBP	Yes	0.000	Orange	None
FLG110217	CEMEX Construction Materials FL LLC - East Orlando CBP	CBP	Yes	0.003	Orange	None
FL0037133	OCUD-Orange County Landfill Leachate NPDES	IW	Yes	3.700	Orange	None
FLG110786	Tarmac-Orlando Downtown CBP	CBP	Yes	0.000	Orange	None
FLG110787	CEMEX Construct Mtrls FL LLC - Grant Street Ready Mix Plant	CBP	Yes	0.000	Orange	None
FLG110116	Preferred Materials-Division Street Ready Mix Plant	CBP	Yes	0.000	Orange	None
FLG110825	A - 1 Block Corp	CBP	Yes	0.000	Orange	None

Facility ID	Facility Name	Type	NPDES	MGD	County	Receiving Water
FLG110735	CEMEX Construct Mtrls FL LLC - Atlanta Ave Ready Mix Plant	CBP	Yes	0.000	Orange	None

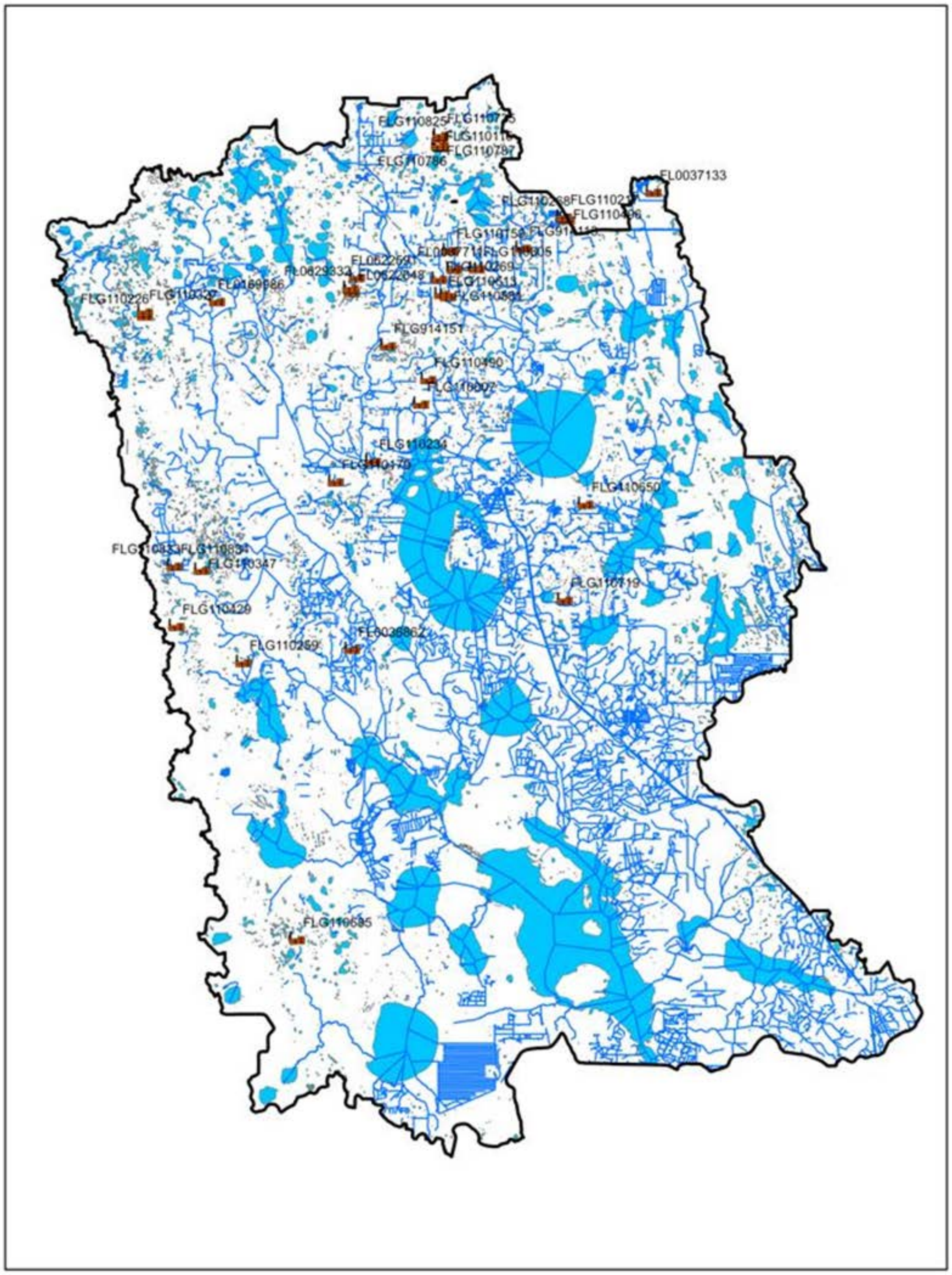

Figure 4.1. NPDES Facilities in the Extended Lake Kissimmee Basin

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 coverages for the entire Lake Kissimmee extended watershed and lake subbasin combined are wetland (29.3%), agriculture (24.5%), forest/rangeland (21.5%), pastureland (9.4%), commercial/industrial (4.9%), MDR (4.5%), LDR (3.2%), and HDR (2.7%). **Table 4.2** shows the existing area of the various land use categories in the extended Lake Kissimmee watershed and the lake subbasin (surface area of water not included). **Figure 4.2** shows the drainage area of Lake Kissimmee and the spatial distribution of the land uses shown in **Table 4.2**.

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. As the model was run from 2000 to 2006, the 2000 census data were used to estimate the total population in 2000 for Osceola County, which includes (but is not exclusive to) the Lake Kissimmee watershed and subbasin. The population estimate was 172,493. The population density in Osceola County in 2000 was at or less than 130.5 people per square mile. The Bureau estimated the 2006 Osceola County population at 244,045 (185 people/per 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.

Polk County Population

According to the U.S Census Bureau (2008), the county occupies an area of approximately 1,875 square miles. The total population in 2000 for Polk County, which includes (but is not exclusive to) the Lake Kissimmee watershed and subbasin, was 483,924. The population density in Polk County in 2000 was at or less than 258.2 people per square mile. The Bureau estimated the 2006 Polk County population at 561,606 (299 people/square mile). For all of Polk County (2006), the Bureau reported a housing density of 134 houses per square mile. Polk County is just below the average housing density for Florida counties of 158, with 134 housing units per square mile.

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 Kissimmee 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.

Table 4.2. Lake Kissimmee Extended Watershed and Lake Subbasin Existing Land Use Coverage in 2000

Lake Kissimmee Extended Watershed and Lake Subbasin Existing Land Use Coverage	Extended Watershed (acres)	Extended Watershed (%)	Lake Subbasin (acres)	Lake Subbasin (%)	Total Watershed (acres)	Total Watershed (%)
Agriculture	202,454.0	24.36%	18,037.2	25.65%	220,491.2	24.46%
Wetland	242,163.0	29.13%	21,952.4	31.22%	264,115.4	29.30%
Forest/rangeland	171,156.0	20.59%	22,559.9	32.08%	193,715.9	21.49%
Pastureland	78,040.0	9.39%	7,079.0	10.07%	85,119.0	9.44%
Commercial/industrial	43,960.0	5.29%	79.8	0.11%	44,039.8	4.89%
High-density residential	24,122.0	2.90%	38.3	0.05%	24,160.3	2.68%
Medium-density residential	40,479.0	4.87%	255.2	0.36%	40,734.2	4.52%
Low-density residential	28,833.0	3.47%	319.1	0.45%	29,152.1	3.23%
Sum	**831,207.0**	**100.0%**	**70,320.9**	**100.0%**	**901,527.9**	**100.0%**

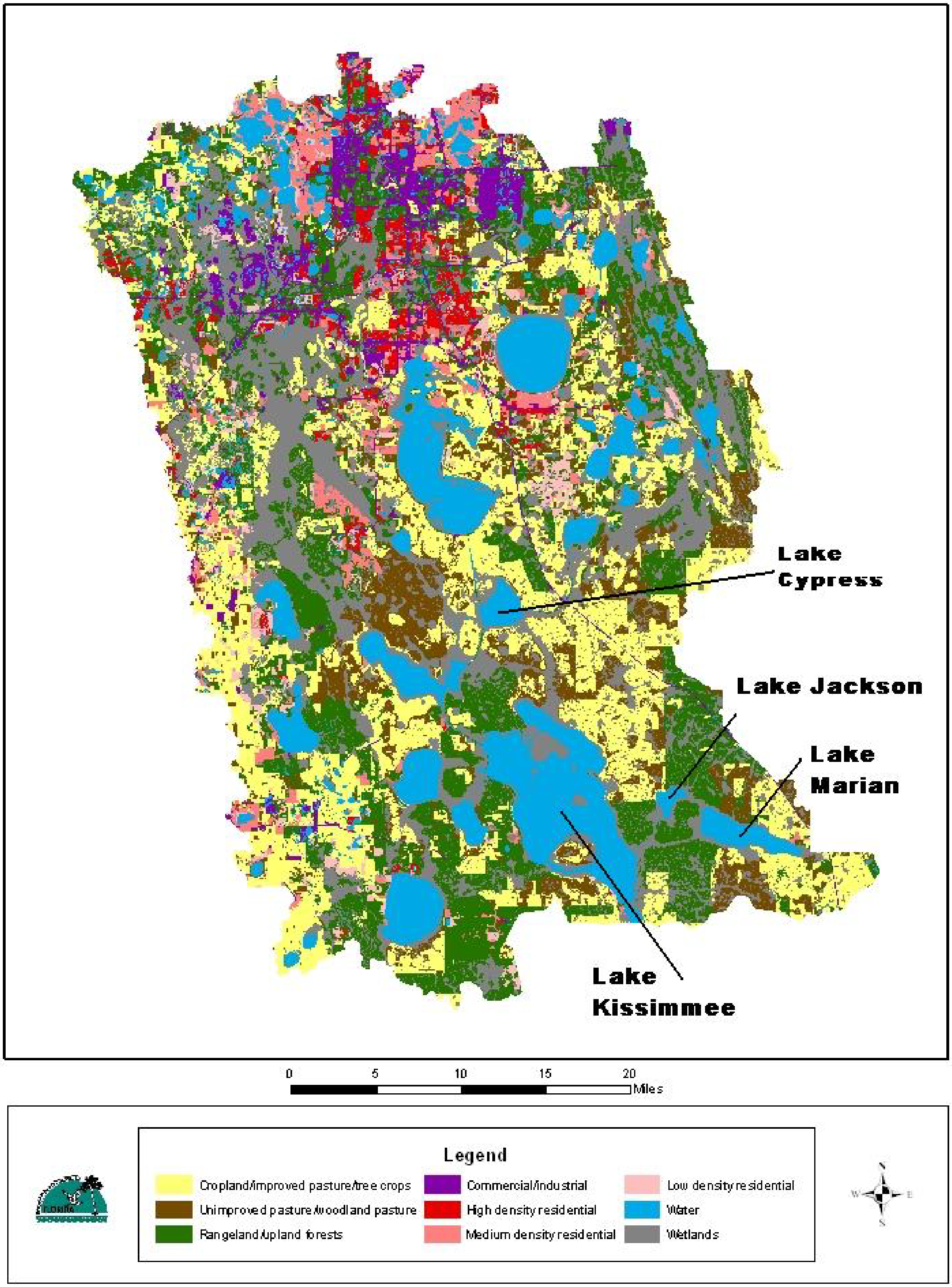

Figure 4.2. Lake Kissimmee Watershed Existing Land Use Coverage in 2000

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.

Polk County Septic Tanks

As of 2006, Polk County had a cumulative registry of 115,838 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 1,246 permits per year for repairs was issued in Polk County (FDOH 2008). Based on the estimated number of permitted septic tanks (115,838) and housing units (269,410) located in the county, approximately 57% of the housing units are connected to a central sewer line (*i.e.*, wastewater treatment facility), with the remaining 43% utilizing septic tank systems. **Table 4.3** lists the percent area of septic tanks used for each model basin.

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 Kissimmee 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 Kissimmee include water quantity (surface runoff, interflow, and baseflow), and water quality (TN, organic nitrogen, ammonia nitrogen, nitrogen oxides [NO_X], TP, organic phosphorus, orthophosphorus, 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.

Table 4.3. Septic Tank Coverage for Urban Land Uses in the Lake Kissimmee 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
Reedy Creek	100	14	1	30	7
Lake Speer	110	3	0	25	57
Lake Tibet & Sheen	120	2	13	32	15
Clear Lake	130	10	10	1	4
Lake Conway	140	7	9	23	17
Reedy Creek	150	9	2	20	9
Reedy Creek	160	10	10	9	17
Big Sand Lake	170	2	5	27	12
Shingle Creek	180	7	3	28	10
Boggy Creek	190	22	3	0	3
Boggy Creek	200	15	5	2	11
Reedy Creek	210	1	5	22	5
Shingle Creek	220	8	3	19	20
Shingle Creek	230	56	1	9	25
City Ditch Canal	240	29	3	0	7
Shingle Creek	250	11	3	31	25
Shingle Creek	260	10	17	15	19
Boggy Creek	270	0	0	29	21
Lake Myrtle	280	0	0	32	6
Lake Hart	290	9	0	17	16
East Lake Tohopekaliga	300	14	1	25	15
Lake Tohopekaliga	310	9	7	35	16
Alligator Lake	320	17	17	34	26
Lake Marion	330	18	2	22	12
Lake Marion Creek	340	23	3	15	8
Reedy Creek	350	8	1	4	4
Lake Gentry	360	0	0	0	0
S-63A	370	0	0	0	0
Cypress Lake	380	0	10	0	0

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%

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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 Kissimmee 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.

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 Kissimmee 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.

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.

Table 5.1. General Information on Weather Station 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

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.

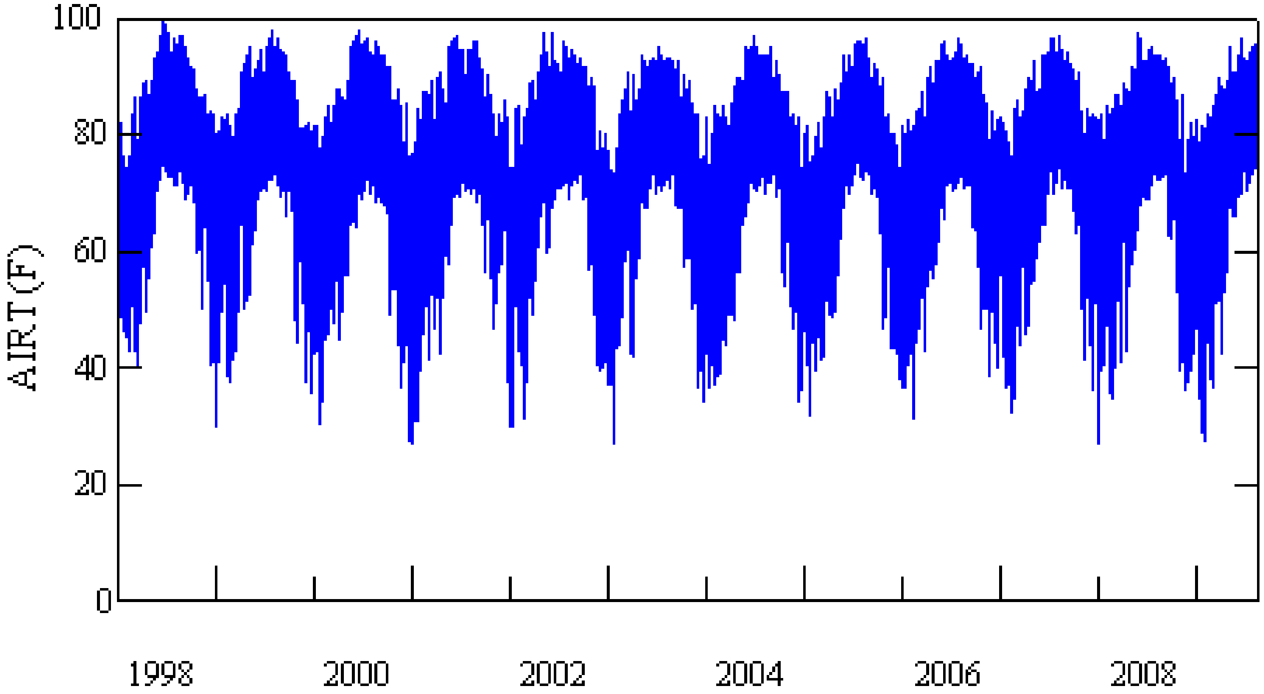

Figure 5.1. Hourly Observed Air Temperature (°F.) Observed from the FAWN Station, 1998–2009

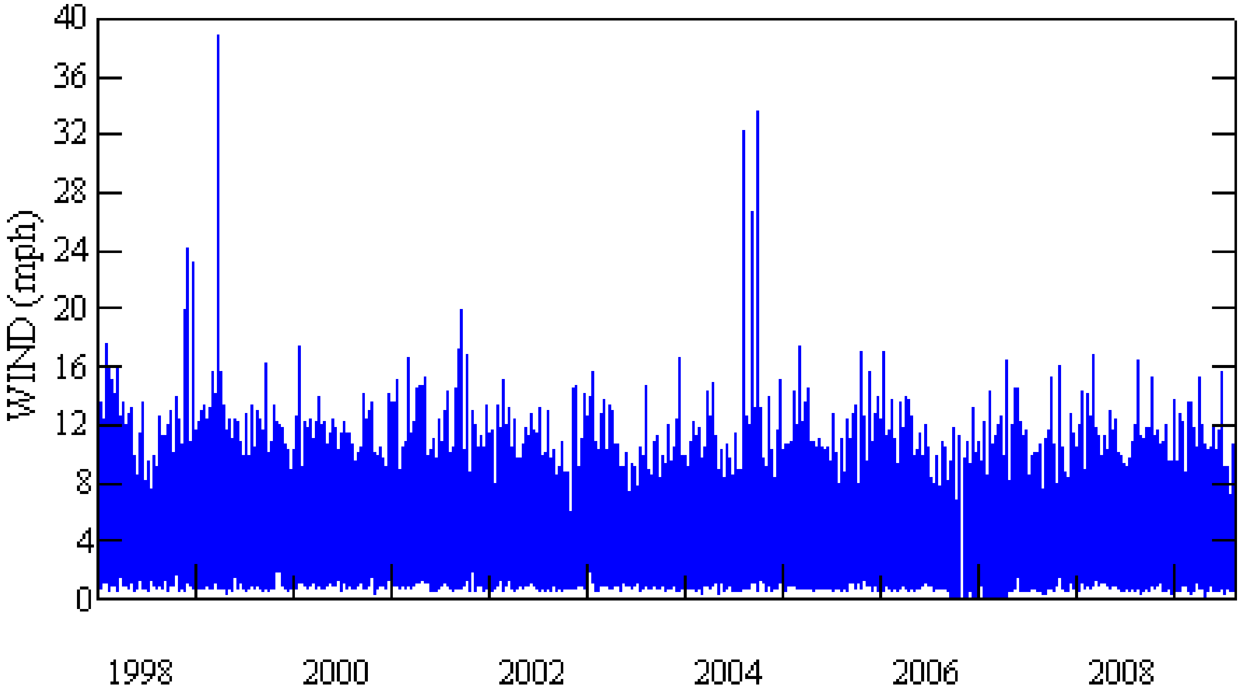

Figure 5.2. Hourly Observed Wind Speed (miles per hour) Observed from the FAWN Station, 1998–2009

Figure 5.3 shows hourly rainfall assigned in the model to the Lake Kissimmee subbasin. During the period of model simulation from 2000 to 2006, the total annual average rainfall varied from 26.3 to 67.0 inches, with an average annual rainfall of 44.9 ± 13.9 inches (**Figure 5.4**). The 7-year average rainfall during this period was lower than the 100-year state average rainfall (54 inches/year) (Southeast Regional Climate Center [SERCC] 2010). The noticeable deficiency in annual rainfall from the long term (100-yr) average was identified in 2000, 2001 and 2006, when the annual rainfall recorded was 26.3, 40.0, and 31.9 inches, respectively. The comparison between the local 7-year rainfall data and the state's long-term average rainfall data indicated that 2000, 2001 and 2006 were dry years, while 2004 and 2005 were considered wet years during the simulation period.

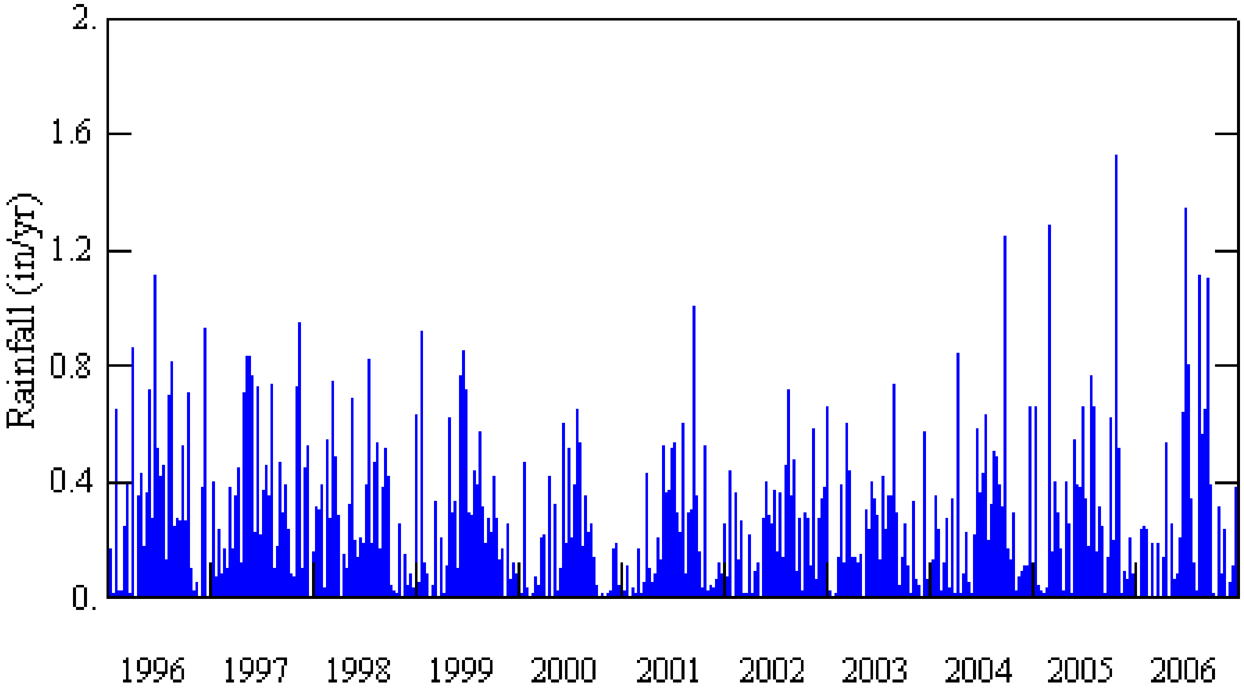

Figure 5.3. **Hourly Rainfall (inches/hour) for the Lake Kissimmee Subbasin, 1996–2006**

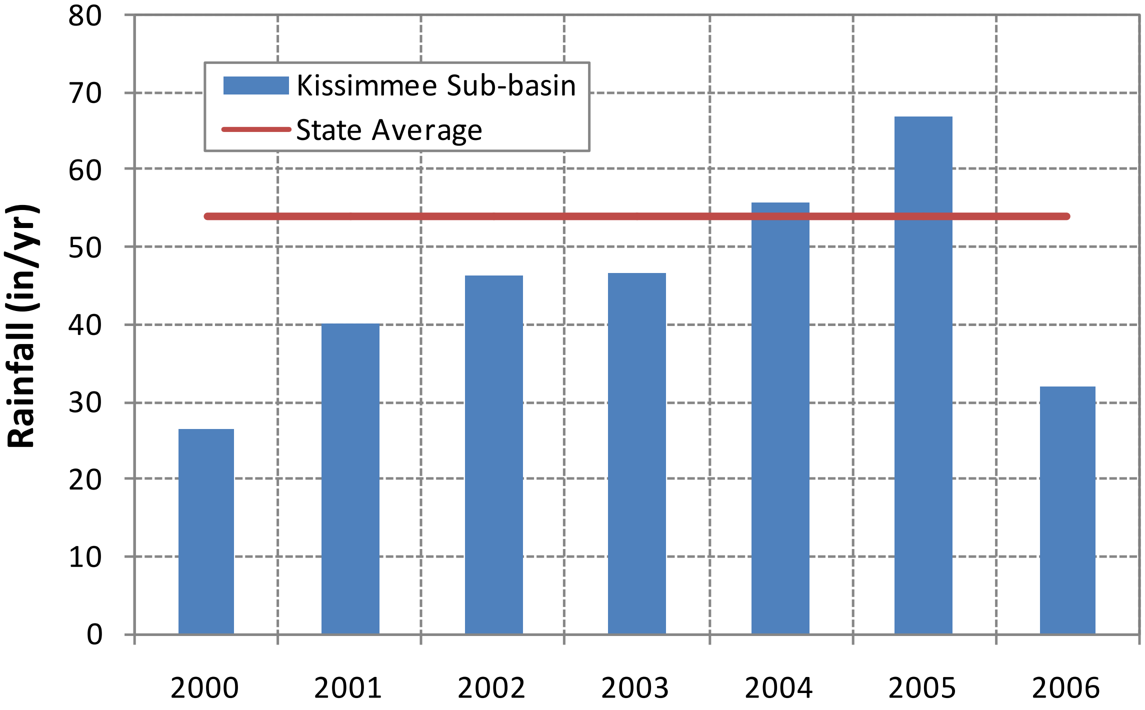

Figure 5.4. **Annual Rainfall (inches/year) for the Lake Kissimmee Subbasin during the Simulation Period and Long-Term (1909–2009) State Average Annual Rainfall (54 inches/year)**

5.2 Model Calibration

5.2.1 Temperature Calibration for Lake Kissimmee

Water temperature itself is considered 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 Kissimmee, 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 shows that the 7-year mean (24.3 °C.) of the observed lake temperature was similar to that (23.3 °C.) of the simulated lake temperature (**Figure 5.7**). Overall, it was decided that the model calibration for temperature was acceptable.

5.2.2 Hydrology Calibration for Lake Kissimmee

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).

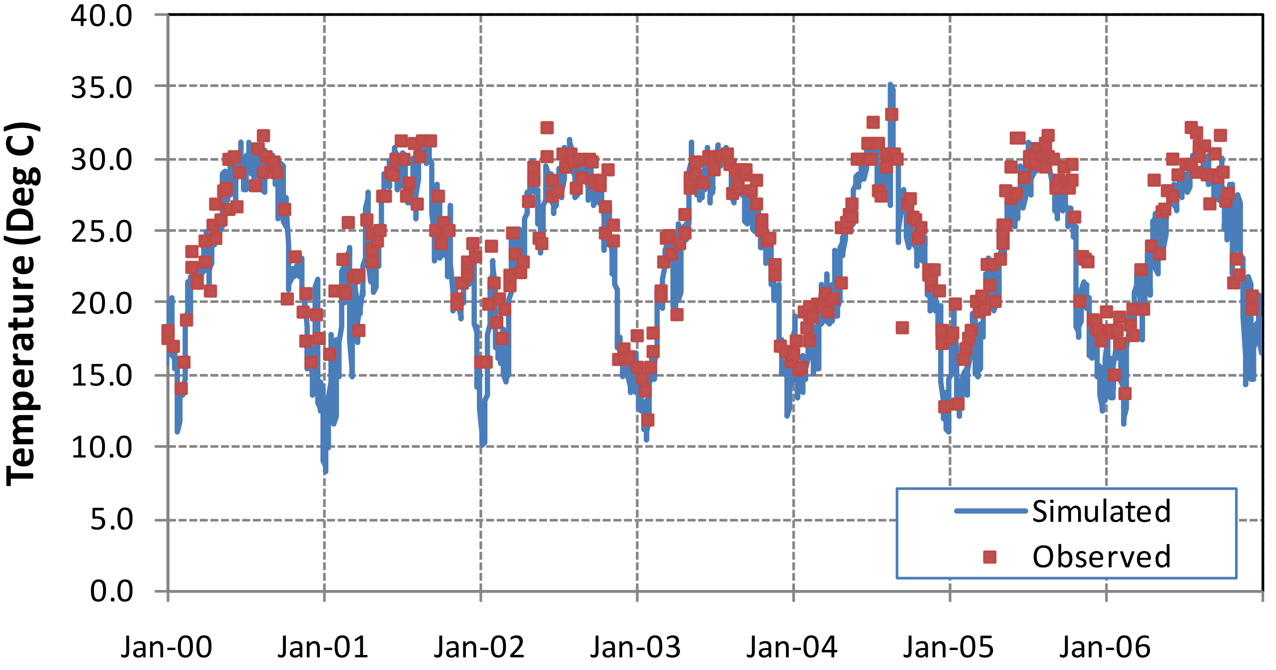

Figure 5.5. **Observed Versus Simulated Daily Lake Temperature (°C.) in Lake Kissimmee During the Simulation Period, 2000–06**

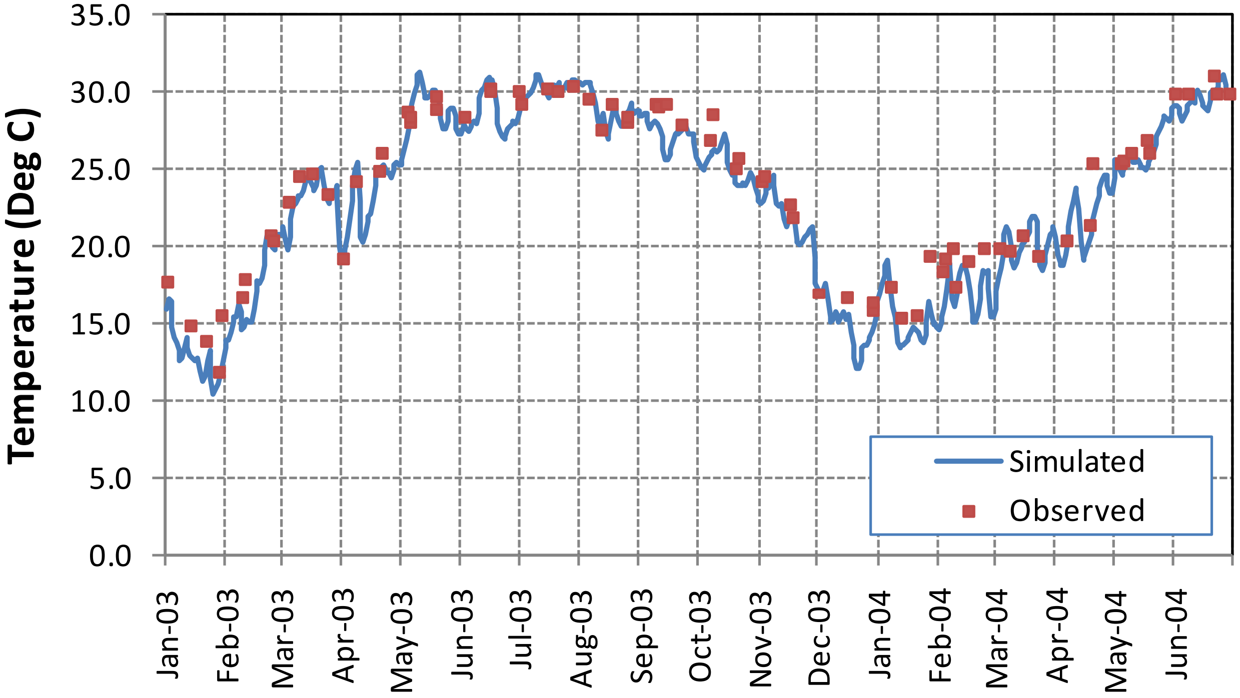

Figure 5.6. **Monthly Variation of Observed Versus Simulated Daily Lake Temperature (°C.) in Lake Kissimmee During the Selected Simulation Period, January 2003–June 2004**

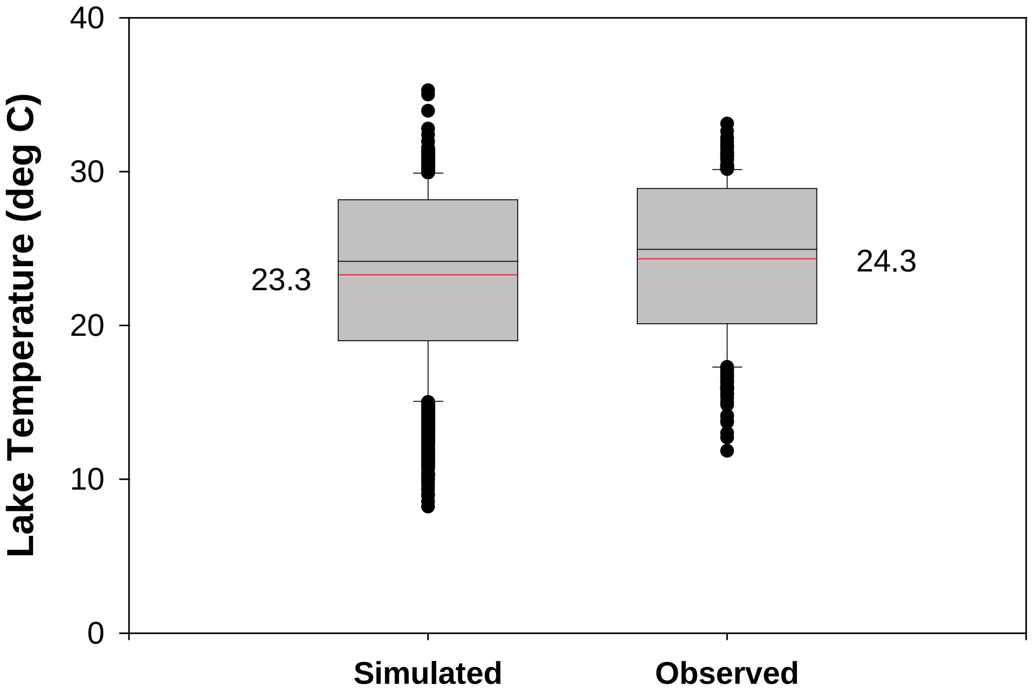

Figure 5.7. Daily Measured Versus Simulated Lake Temperature for Lake Kissimmee During the Selected Period, January 2003–June 2004

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.

To increase the reliability of the model, calibration efforts focused on several key stations. For the Lake Cypress watershed, reliable hydrologic calibration for the key stations has been achieved for Lake Cypress, as reported in the Lake Cypress TMDL report. Other calibration stations within the Lake Kissimmee watershed were selected in this report to address the model's performance. For example, as Lake Hatchineha, a major tributary of Lake Kissimmee, is connected to Lake Kissimmee, its lake levels and outflows to Lake Kissimmee were first calibrated by comparisons between observed and simulated results by both HSPF and WAM, and then the lake elevation and the outflow of Lake Kissimmee were calibrated to obtain the water budgets of Lake Kissimmee.

Table 5.2 shows model calibration stations for flows and lake levels of the connected lakes contributing to Lake Kissimmee. 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. *Appendix D* of the Lake Cypress TMDL report shows all hydrologic outputs and model calibrations for the impaired lake and its connected lakes.

The predicted lake level was a result of the water balance between water input from the watershed and losses from the lake. The simulated lake levels in Lake Kissimmee were calibrated with the observed lake levels obtained from January 2000 to December 2006. **Figure 5.8** shows a good agreement between the 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 0.92 (n = 2554). In general, simulated lake levels varied from 48.1 to 54.3 feet, with a 7-year average of 50.2 feet (n = 2557) over the simulation period (**Table 5.3**). Similarly, the observed data showed that lake levels ranged from 48.3 to 53.3 feet and averaged about 50.2 feet (n = 2554). Of note is the fact that both simulated and observed annual lake levels were lowest at in 2006 (**Table 5.3**). This is attributable to the dry conditions that occurred in 2006, when annual rainfall was only 31.9 inches. Overall, the model simulation for lake level well represents the short- and long-term average stage for Lake Kissimmee.

Table 5.2. General Information on Key Stations for Model Calibration

NA = Not applicable, as no observed data were collected

Station	Station Name	Agency	County	Type
S65_H	Lake Kissimmee	SFWMD	Osceola	Stage
LHATCH	Lake Hatchineha	SFWMD	Osceola	Stage
LJACKSON	Lake Jackson	SFWMD	Osceola	Stage
S65	Kissimmee outflow S65	SFWMD	Osceola	Flow
LCYPRE	Cypress outflow	NA	Osceola	Flow
LHATCH	Lake Hatchineha outflow	NA	Osceola	Flow
LROSALI	Lake Rosalie outflow	NA	Osceola	Flow
LJACKSON	Lake Jackson outflow	NA	Osceola	Flow

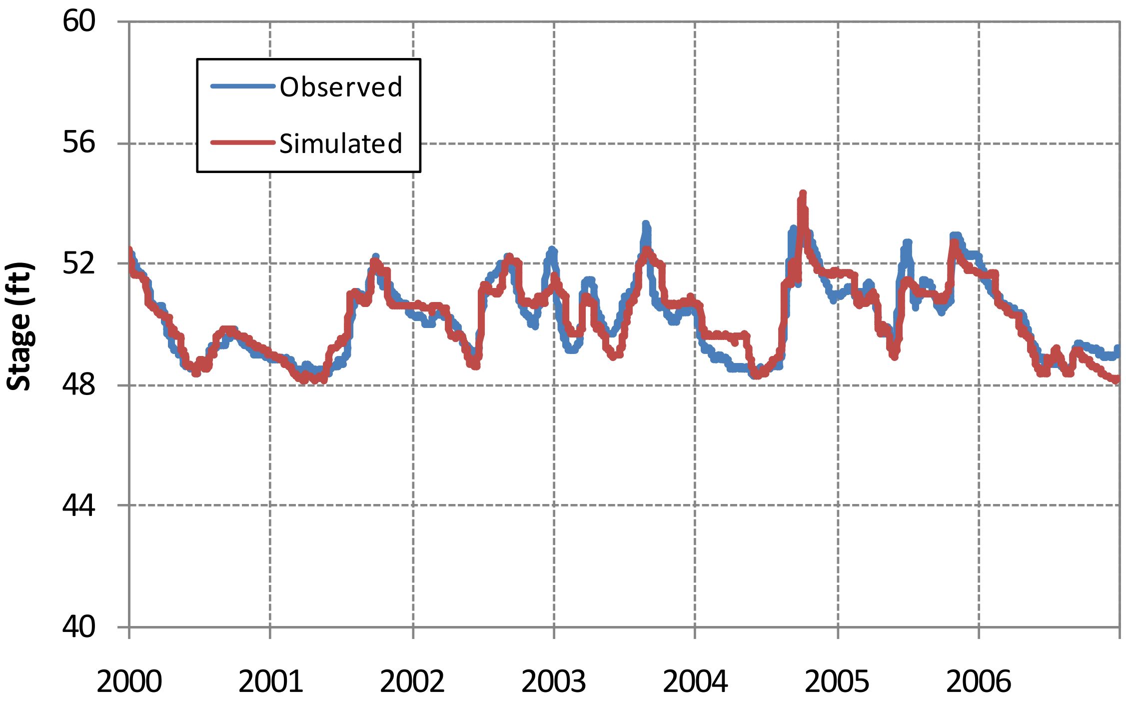

Figure 5.8. Time-Series Observed Versus Simulated Lake Stage (feet, National Geodetic Vertical Datum [NGVD]) in Lake Kissimmee During the Simulation Period, 2000–06

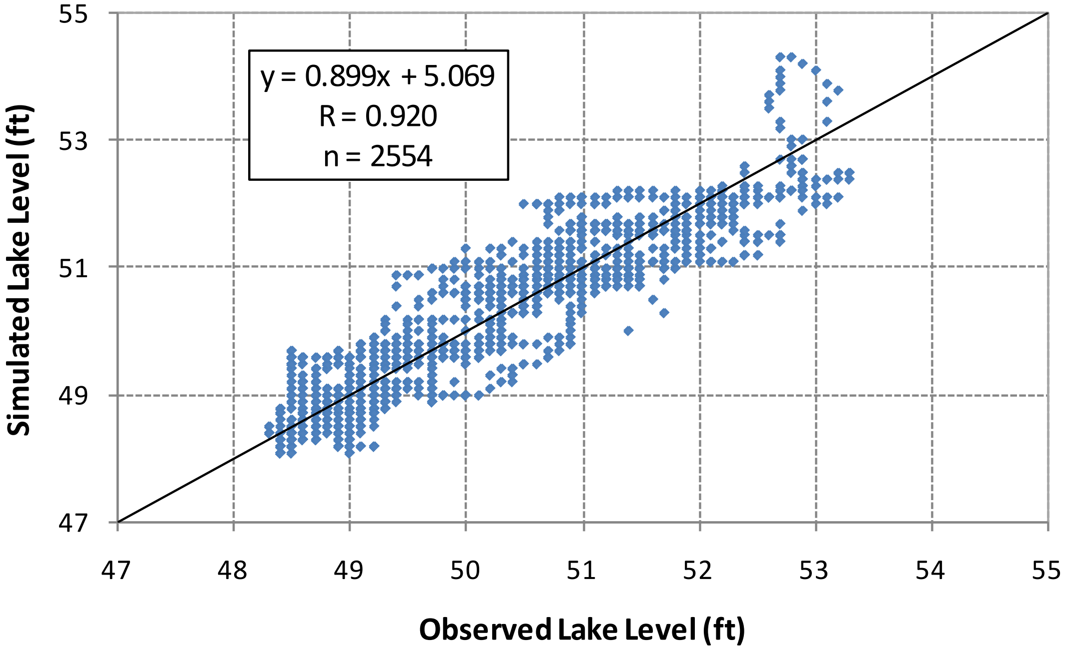

Figure 5.9. Daily Point-to-Point Paired Calibration of Lake Level (feet) During the Simulation Period, 2000–06 (solid line indicates the ideal 1-to-1 line, R represents a correlation coefficient of the best fit between observed and simulated lake levels, and n indicates the number of observations)

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

Year	Observed Stage (ft)	Standard Deviation (+/-)	Simulated Stage (ft)	Standard Deviation (+/-)
2000	49.7	1.0	49.8	0.9
2001	49.7	1.2	49.7	1.3
2002	50.6	0.9	50.6	0.9
2003	50.6	0.9	50.6	0.9
2004	50.0	1.6	50.3	1.5
2005	51.2	0.9	51.1	0.8
2006	49.6	1.0	49.4	1.1
Average	**50.2**	**1.2**	**50.2**	**1.2**

Flow comparisons of observed daily flow and simulated daily flow were also performed at several calibration stations where incoming and outgoing flows of the impaired lakes primarily occur (**Table 5.2**). As Lake Hatchineha is a major contributor of water and nutrients to Lake Kissimmee, major incoming and outgoing flows to and from Lake Hatchineha were first calibrated. The outgoing flow from Lake Hatchineha was calibrated with the WAM-generated outflow because no measured flow data are available for the comparison. Two other incoming flows to Lake Kissimmee, Lake Jackson outflow and Lake Rosalie outflow, and an outgoing flow from Lake Kissimmee through S65, were simulated and compared with both observed flow values and simulated flow results by WAM. **Figures 5.10** through **5.14** show selected comparison results and calibration statistics for the Lake Kissimmee hydrology calibration.

Figure 5.10 shows the observed and simulated cumulative daily flows at S65, the Lake Kissimmee outlet, from 2000 to 2006. The simulated flow results obtained from WAM were also compared with the observed flow obtained for the same period as the simulation. The observed cumulative daily flow at S65 was 3,249,467 cubic feet per second (cfs) over the 7-year period, similar to 3,187,114 cfs simulated by HSPF and 3,278,779 cfs obtained by WAM (**Table 5.4**). Percent error, calculated as 100 x ((the observed daily cumulative flow - the simulated daily cumulative flow)/the observed daily cumulative flow), was estimated to be 2% for HSPF and 1% for WAM, indicating that both models performed well. The simulated monthly mean flows by HSPF were compared with the observed monthly flow to show monthly and seasonal variations in the outgoing flow from Lake Kissimmee (**Figure 5.11**). Seasonality in both the simulated and observed monthly flows was well matched, showing that most peak flows occur during the third quarter each year. The simulated monthly flow correlates well to the observed monthly flow, with a correlation coefficient of 0.865 (n = 84) (**Figure 5.12**).

Overall, the 7-year simulated flow had similar patterns to the observed flow for S65, indicating that the long-term and seasonal variations in the outgoing flow from Lake Kissimmee were well represented. For the outflow from Lake Hatchineha, a major tributary contributing to Lake Kissimmee, the simulated flow results from HSPF were compared with the independent flow results obtained by WAM (**Figures 5.13** and **5.14**). Simulated annual flows by HSPF are similar to those by WAM, showing that both results indicate similar flow patterns representative of dry and wet years throughout the modeling period (**Figure 5.14**). Although no outgoing flow leaving Lake Hatchineha was measured, the simulated outgoing flow estimated by HSPF was validated by the results from WAM.

Based on the simulated results, the Department was able to construct a water budget for Lake Kissimmee, indicating that incoming and outgoing waters are reasonably balanced (**Table 5.5**). The estimated annual total inflow to Lake Kissimmee varied from 277,409 ac-ft/yr in 2000 to 1,566,206 ac-ft/yr in 2005, with a 7-year average of 916,643 ac-ft/yr. As shown in **Table 5.5**, during wet years in 2004 and 2005 when annual rainfall was high (56 inches in 2004 and 67 inches in 2005), the simulated total annual inflows via upstream inflow (runoff and stream flow), local basin surface runoff, interflow, and baseflow were estimated to be five times higher than in the dry years of 2000 and 2006. As a result, the lake discharged more in 2004 and 2005, peaking at 1,590,356 ac-ft/yr in 2005.

Figure 5.15 shows the relative importance of incoming flows to the lake. Total annual inflows and outflows were estimated to construct the water budget of Lake Kissimmee during the simulation period. On average, upstream flow is the largest contributor of water (81%), followed by direct rainfall (12.5%), subbasin interflow (3.3%), subbasin baseflow (2.0%), and subbasin runoff (0.9%). Therefore, incoming flows via Lake Hatchineha are the major pathway carrying water and its constituents, including nutrients and other pollutants, to the lake.

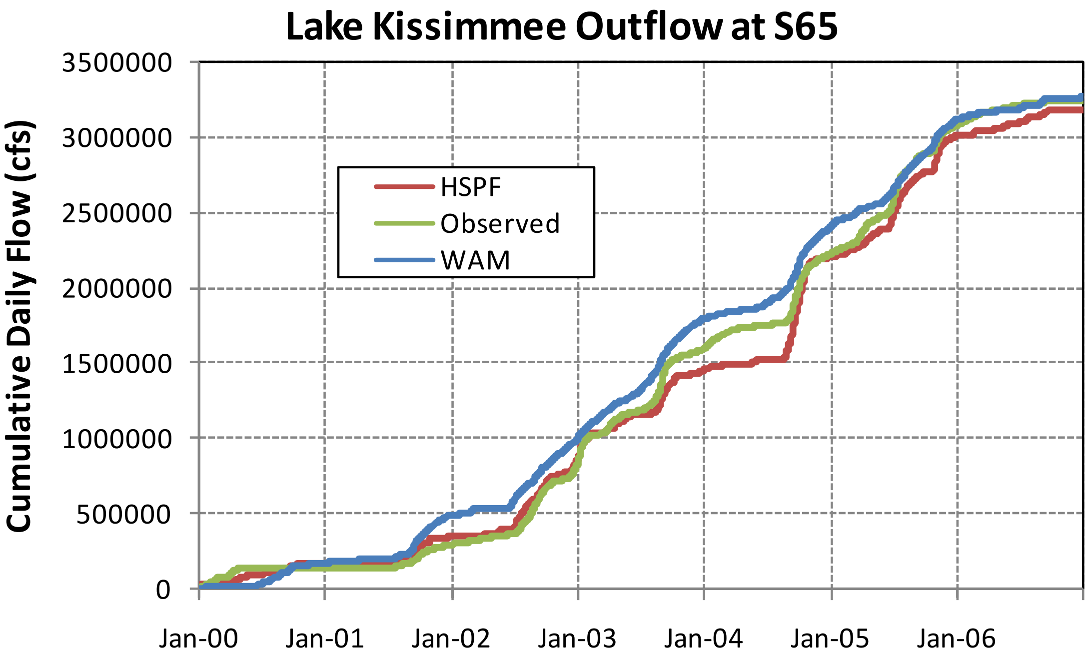

Figure 5.10. Comparison Between Cumulative Observed Flow and Simulated Flows Using HSPF and WAM at S65, Lake Kissimmee Outflow, 2000–06

Table 5.4. Cumulative Daily Mean Flow (cfs) Obtained by Observed Flow Data, HSPF, and WAM, 2000–06. Correlation coefficient (r) is based on observed monthly mean flow versus simulated monthly mean flow by HSPF.

NA = Not available

Station ID	Observed Cumulative Daily Flow (cfs), 2000–06	HSPF Cumulative Daily Flow (cfs), 2000–06	WAM Cumulative Daily Flow (cfs), 2000–06	% Error HSPF	% Error WAM	Correlation Coefficient (r) in Monthly Mean Flow Observed Versus Simulated
Kissimmee outflow S65	3,249,467	3,187,114	3,278,779	2%	1%	0.865
Cypress outflow	NA	1,675,048	1,690,282	NA	NA	NA
Lake Hatchineha outflow	NA	2,604,524	2,888,749	NA	NA	NA
Lake Rosalie outflow	NA	168,130	184,857	NA	NA	NA
Lake Jackson outflow	NA	151,451	149,946	NA	NA	NA

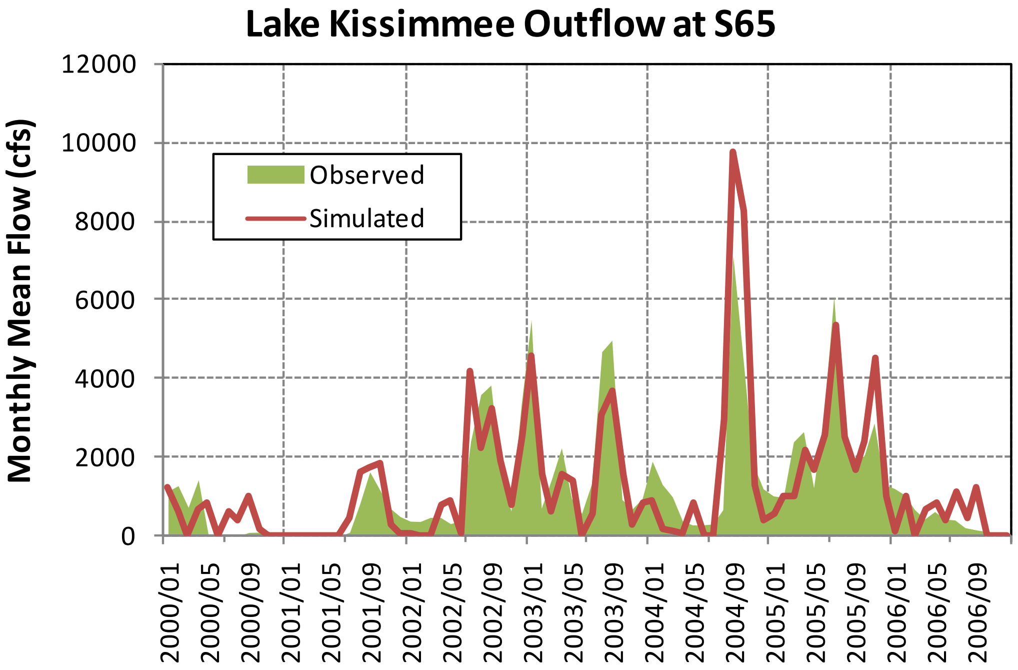

Figure 5.11. Comparison Between Monthly Observed Mean Flow and Monthly Simulated Mean Flow at S65, Lake Kissimmee Outflow, 2000–06

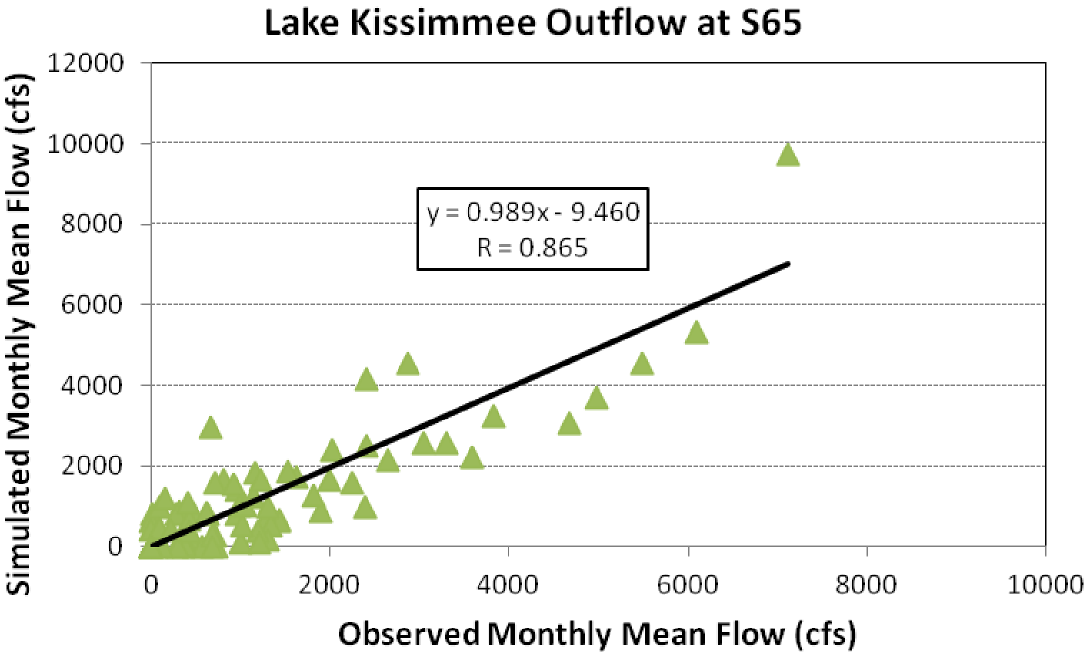

Figure 5.12. Correlation Between Observed and Simulated Monthly Mean Flows at S65. R represents a correlation coefficient of the best-fit equation.

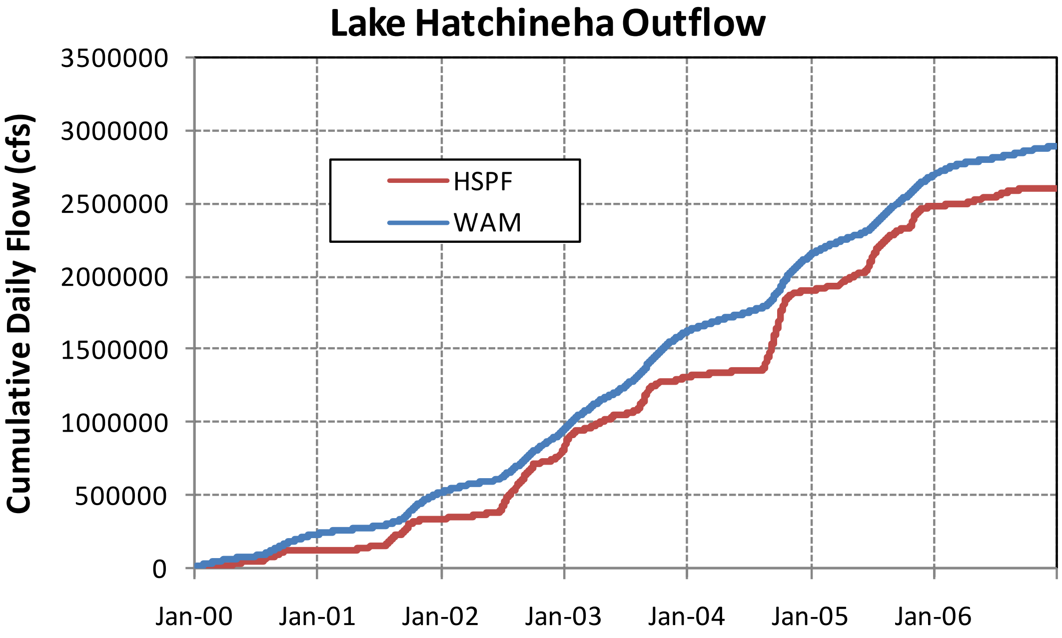

Figure 5.13. Cumulative Daily Flows Obtained by HSPF and WAM at Lake Hatchineha Outflow, 2000–06

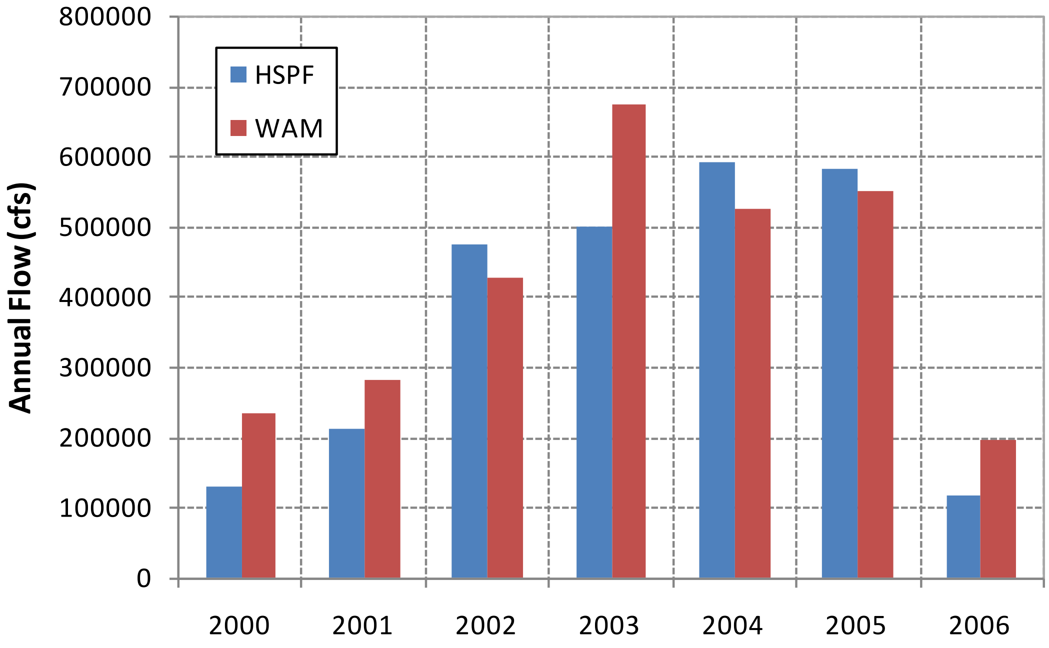

Figure 5.14. Simulated Annual Flows Obtained by HSPF and WAM at Lake Hatchineha Outflow, 2000–06

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

Year	Subbasin Runoff (ac-ft/yr)	Subbasin Interflow (ac-ft/yr)	Subbasin Baseflow (ac-ft/yr)	Upstream Inflow (ac-ft/yr)	Direct Precipitation (ac-ft/yr)	Evaporation (ac-ft/yr)	Outflow (ac-ft/yr)
2000	349	5,209	12,038	259,813	70,019	-166,218	-332,609
2001	967	17,623	11,644	437,703	113,206	-167,100	-362,446
2002	1,067	32,127	21,558	1,013,586	137,259	-170,671	-1,014,955
2003	2,437	32,172	26,287	1,130,836	141,384	-164,434	-1,186,083
2004	30,162	54,780	25,399	1,424,353	169,158	-174,089	-1,490,292
2005	24,551	73,296	39,595	1,428,764	203,988	-181,858	-1,590,356
2006	2,995	27,525	10,912	268,750	84,754	-163,233	-344,522
Average	**8,933**	**34,676**	**21,062**	**851,972**	**131,395**	**-169,657**	**-903,037**

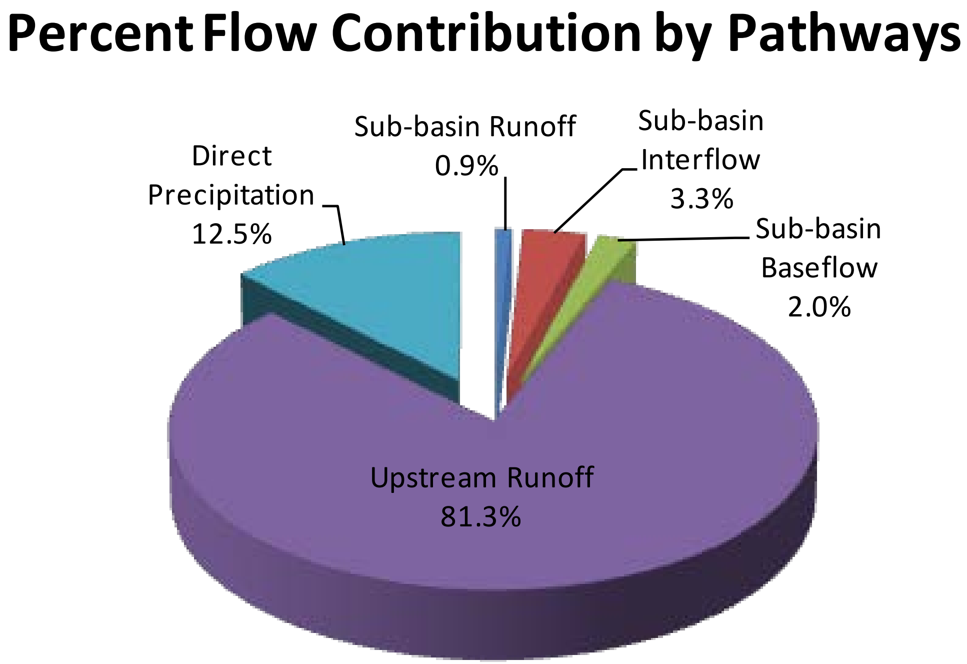

Figure 5.15. Long-Term (7-year) Averaged Annual Percent Inflows to Lake Kissimmee During the Simulation Period, 2000–06

5.2.3 Lake Kissimmee Nonpoint Source Loadings

Nonpoint source loads of TN and TP from different land use types were estimated for the existing conditions of the Lake Kissimmee 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 for Lake Kissimmee were estimated to be 2.2 and 0.07 lbs/ac/yr, respectively. These estimated coefficients are comparable to the literature values for the forest land use type, 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 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 Kissimmee are acceptable. For cropland/improved pasture/tree crops, average export coefficients of TN and TP during the simulation period were estimated to be about 7.7 and 0.69 lbs/ac/yr, respectively. For unimproved pastureland/woodland pastureland, estimated TN and TP loading rates were about 5.1 and 0.32 lbs/ac/yr, respectively. These rates for anthropogenic land uses are comparable to the literature values 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 Kissimmee, indicating that upstream runoff is the major contributor delivering a 7-year average annual TN load of 2,901,285 lbs/yr and TP load of 155,370 lbs/yr. These TN and TP loads accounted for about 84.3% of the total TN loads and about 85.7% of the total TP loads to the lake during the simulation period (**Figures 5.16** and **5.17**). TN and TP contributions from the immediate Lake Kissimmee subbasin accounted for only 8% for TN and 10% for TP of the total watershed.

The model results show that existing TN and TP loads are strongly associated with annual rainfall (**Figures 5.18** and **5.19**). For example, greater nutrient loads were found during wet years, especially in 2004 and 2005, while lower TN and TP loads were estimated during the dry years in 2000 and 2006. Overall, rainfall-driven runoff such as surface runoff and interflow is 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 Kissimmee, as a long-term 7-year average, were estimated to be 3,165,571 and 172,961 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 Kissimmee Subbasin and Nonpoint TN Loading Rates with the Expected Ranges from the Literature

Land Use Type	Simulated TN Loading Rate for the Lake Kissimmee Subbasin (lbs/ac/yr)	TN Loading Rate (lbs/ac/yr) by Donigian (2002)
High-density residential	4.7	8.5 (5.6-15.7) for Urban
Low-density residential	6.3	8.5 (5.6-15.7) for Urban
Medium-density residential	5.8	8.5 (5.6-15.7) for Urban
Commercial/industrial	3.6	8.5 (5.6-15.7) for Urban
Unimproved pastureland/woodland pasture	5.1	5.9 (3.4-11.6) for Agriculture
Cropland/improved pasture/tree crops	7.7	5.9 (3.4-11.6) for Agriculture
Wetlands	1.7	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 Kissimmee Subbasin and Nonpoint TP Loading Rates with the Expected Ranges from the Literature

Land Use Type	Simulated TP Loading Rate for the Lake Kissimmee Subbasin (lbs/ac/yr)	TP Loading Rate (lbs/ac/yr) by Donigian (2002)
High-density residential	0.50	0.26 (0.20-0.41) for Urban
Low-density residential	0.45	0.26 (0.20-0.41) for Urban
Medium-density residential	0.46	0.26 (0.20-0.41) for Urban
Commercial/industrial	0.49	0.26 (0.20-0.41) for Urban
Unimproved pastureland/woodland pasture	0.32	0.30 (0.23-0.44) for Agriculture
Cropland/improved pasture/tree crops	0.69	0.30 (0.23-0.44) for Agriculture
Wetlands	0.05	0.03 (0.02-0.05)
Rangeland/upland forest	0.07	0.04 (0.03-0.08)

Table 5.8. Simulated Annual TN Loads (lbs/yr) to Lake Kissimmee 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 Upstream Runoff (lbs/yr)	TN Load by Direct Precipitation (lbs/yr)	Total Incoming TN Load (lbs/yr)
2000	4,417	23,795	23,591	956,405	146,723	1,154,930
2001	28,885	77,689	23,267	1,615,870	237,369	1,983,080
2002	27,321	134,491	42,112	3,311,998	287,844	3,803,765
2003	69,189	130,830	51,559	3,723,462	296,450	4,271,490
2004	134,347	220,576	49,795	4,877,223	355,695	5,637,637
2005	203,993	297,694	76,188	4,773,835	428,869	5,780,579
2006	93,456	115,704	21,104	1,050,200	177,766	1,458,230
Average	**80,230**	**142,968**	**41,088**	**2,901,285**	**275,817**	**3,441,387**

Table 5.9. Simulated Annual TP Loads (lbs/yr) to Lake Kissimmee 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 Upstream Runoff (lbs/yr)	TP Load by Direct Precipitation (lbs/yr)	Total Incoming TP Load (lbs/yr)
2000	100	2,539	1,337	44,950	4,383	53,309
2001	277	8,146	1,327	86,568	7,090	103,409
2002	283	13,715	2,385	181,184	8,598	206,164
2003	643	13,122	2,924	197,195	8,855	222,739
2004	1,561	22,003	2,823	267,350	10,625	304,361
2005	2,036	29,842	4,293	255,922	12,810	304,904
2006	762	11,831	1,191	54,420	5,310	73,514
Average	**809**	**14,457**	**2,326**	**155,370**	**8,239**	**181,200**

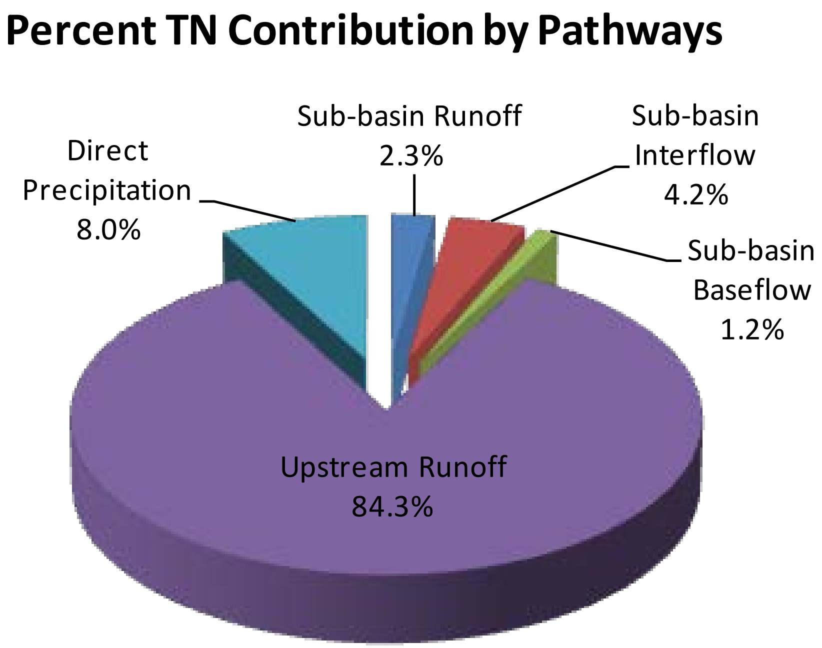

Figure 5.16. Percent TN Contribution to Lake Kissimmee under the Existing Condition During the Simulation Period, 2000–06

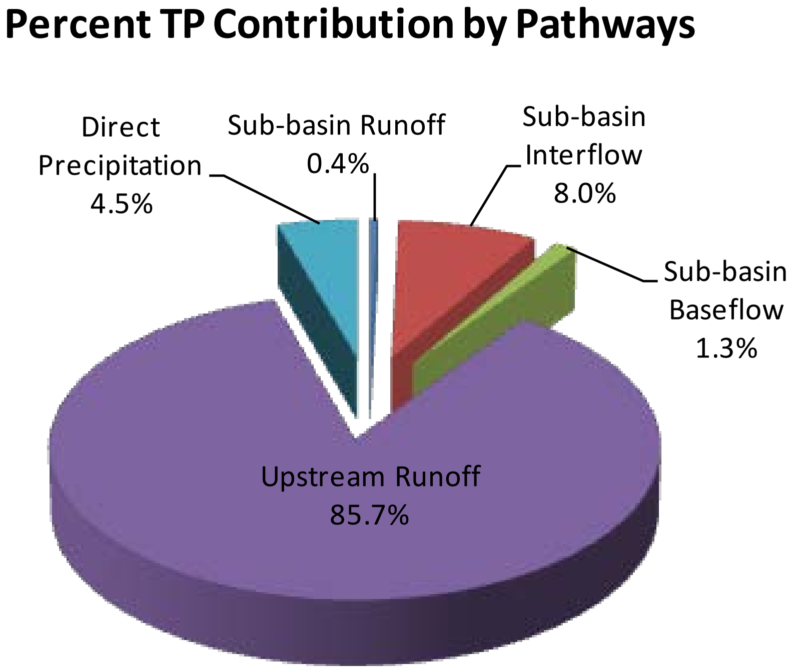

Figure 5.17. Percent TP Contribution to Lake Kissimmee under the Existing Condition During the Simulation Period, 2000–06

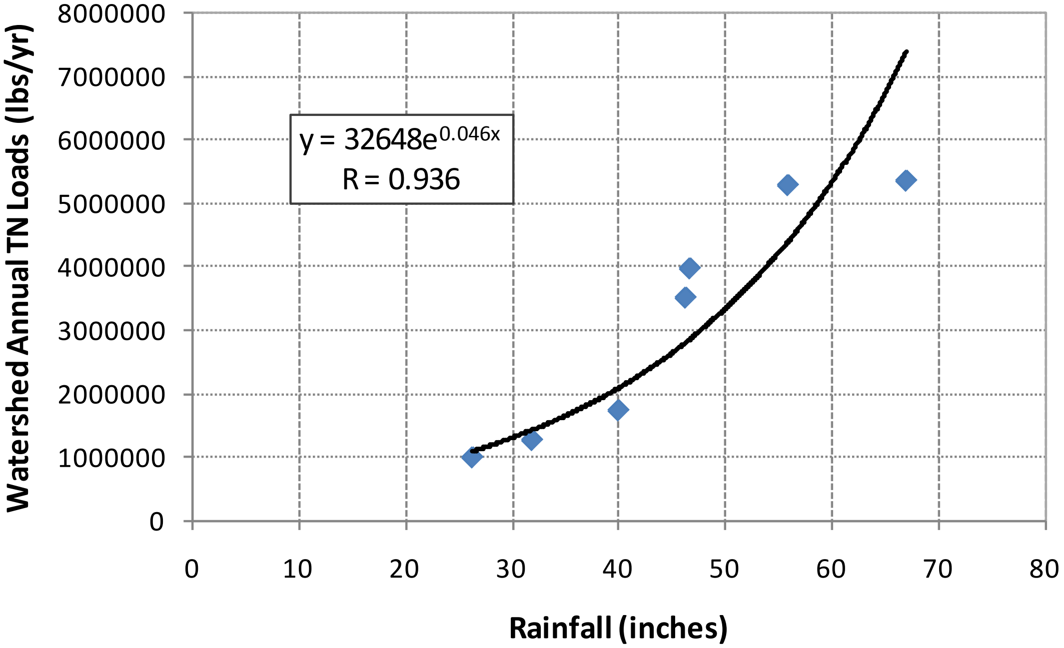

Figure 5.18. Relationship Between Rainfall Versus Watershed Annual TN Loads to Lake Kissimmee under the Existing Condition During the Simulation Period, 2000–06

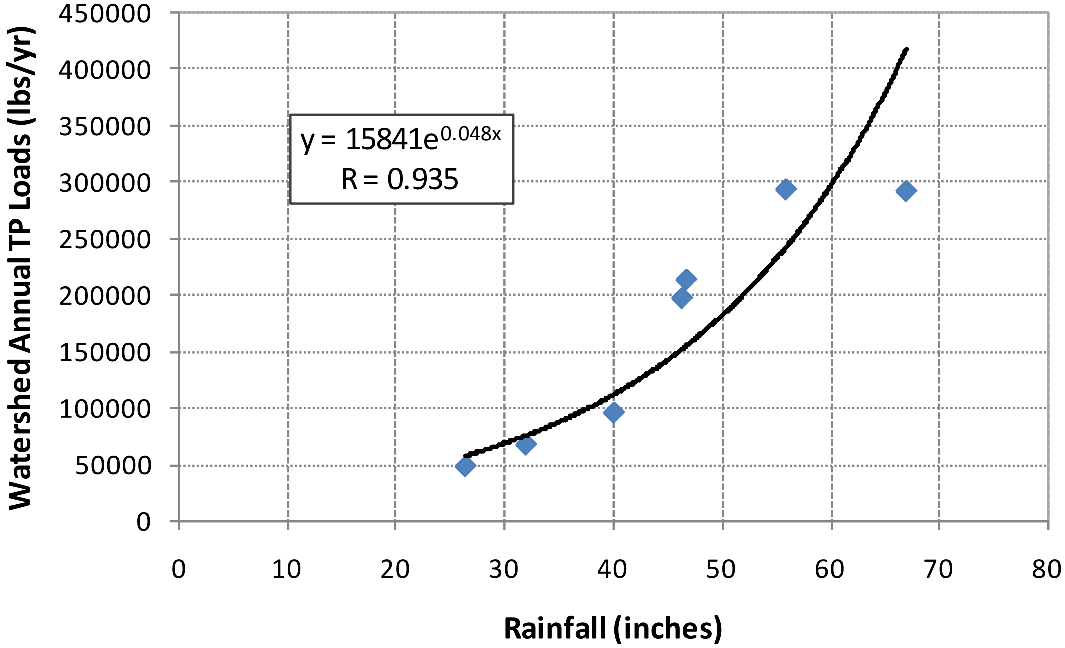

Figure 5.19. Relationship Between Rainfall Versus Watershed Annual TP Loads to Lake Kissimmee under the Existing Condition During the Simulation Period, 2000–06

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.

Lake Kissimmee has an extended watershed, including other lakes and streams. 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. Lake Kissimmee has an average residence time less than one month and under more natural loading conditions (as discussed later) would not be expected to have the elevated levels of cchl*a* that are evident in the measured data.

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 Lake Kissimmee (RCHRES 480) 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 Kissimmee. After communication with SFWMD staff, the Department excluded the water quality data collected from the S65 station from the model calibrations due to abrupt spike concentrations observed at S65 that may not be representative in assessing in-lake water quality in Lake Kissimmee.

The time series of simulated TN over the simulation period reasonably predicted both the seasonal variation and annual trends (**Figures 5.20** through **5.22)**. Based on the box and whisker plot (**Figure 5.21**), the mean, median, and distribution percentiles of simulated TN matched to those of observed TN. The 7-year mean and standard deviation for the observed TN were 1.29 ± 0.28mg/L, similar to those of simulated TN (1.32 ± 0.14 mg/L). The 10th and 90th percentiles of the observed TN were 1.03 and 1.60 mg/L, respectively. Similarly, the 10th and 90th percentiles of the simulated TN values were 1.20 and 1.56 mg/L, respectively. On annual average, as calculated based on quarterly means for each year, a similar annual variation within 1 standard deviation was observed, ranging from 1.19 ± 0.218 mg/L to 1.54 ± 0.065 mg/L for observed TN and from 1.23 ± 0.025 mg/L to 1.52 ± 0.079 mg/L for simulated TN (**Figure 5.22**).

Following the same procedures, the time series of simulated TP was calibrated against the observed TP (**Figure 5.23**). 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 5.24** and **5.25**). The mean and median of the simulated TP of 0.067 ± 0.012 mg/L and 0.069 mg/L, respectively, matched reasonably well the mean (0.064 ± 0.033 mg/L) and median (0.059 mg/L) of observed TP over the simulation period. Annual variations of observed and simulated annual TP were also in reasonable agreement within 1-sigma standard deviations (**Figure 5.25**). For example, a mean concentration of observed TP in 2000 was 0.052 ± 0.013 mg/L, with the coefficient of variance (CV) of about 25%, while the annual mean of 0.045 ± 0.016 mg/L was simulated by the model for 2000, with a CV of about 35%.

The time series of simulated chl*a* for Lake Kissimmee, plotted against the observed chl*a*, showed a reasonable agreement over the simulation period (**Figure 5.26**). The model reasonably predicted both the peak concentrations of observed chl*a* during the growing season and the lower concentrations of observed chl*a* in the winter. The box and whisker plots also indicated that the mean, median, and distribution percentiles of simulated chl*a* over the simulation period were very similar to those of observed chl*a* (**Figure 5.27**). There were excellent agreements in mean, median, and 10^{th} and 90^{th} percentiles of simulated versus observed chl*a* . For example, the mean and median for the observed chl*a* were 19.9 ± 14.8 and 17.7 µg/L, similar to 19.5 ± 7.5 and 17.8 µg/L for the simulated chl*a* . The 10^{th} and 90^{th} percentiles of observed chl*a* values were 2.1 and 43.0 µg/L, respectively, while the 10^{th} and 90^{th} percentiles of simulated values in the range were 10.9 and 29.9 µg/L, respectively. Predicted annual mean concentrations for each year also agreed with the observed annual mean concentration within 1 standard error over the simulation period (**Figure 5.28**).

Based on the simulated TN, TP, and chl*a* concentrations, simulated annual TSIs for Lake Kissimmee were calculated and compared with those calculated based on the observed TN, TP, and cchl*a* concentrations (**Figure 5.29**). The simulated TSI for the lake ranged from 58.0 to 61.6, with a 7-year average of 59.6 ± 1.4 (n = 7). This long-term predicted average TSI agreed with the 7-year average observed TSI of 60.3 ± 1.1 (n = 7), indicating that the model calibration was acceptable.

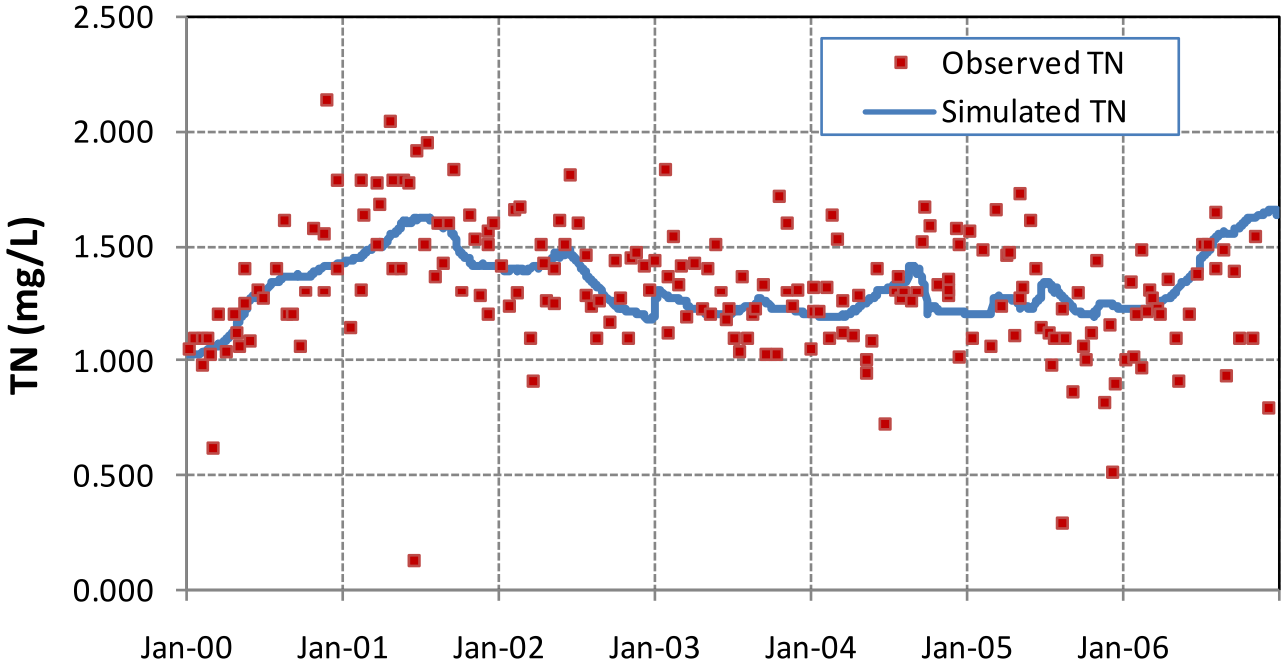

Figure 5.20. Time-Series of Observed Versus Simulated Daily TN Concentrations in Lake Kissimmee During the Simulation Period, 2000–06

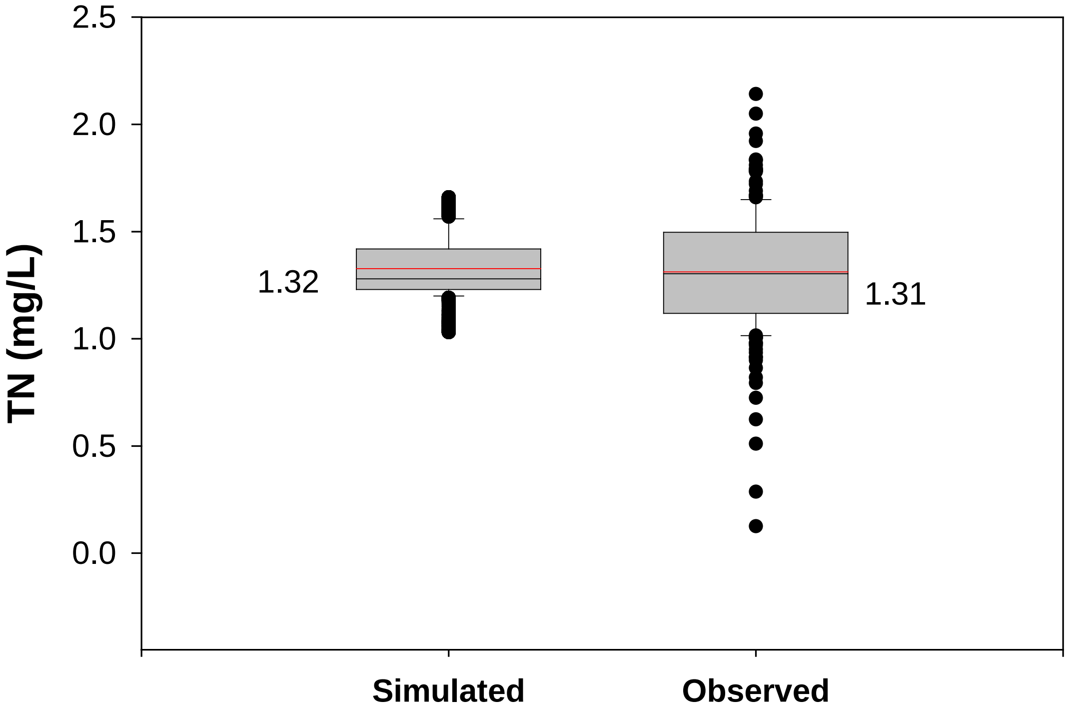

Figure 5.21. Box and Whisker Plot of Simulated Versus Observed TN in Lake Kissimmee, 2000–06 (red line represents mean concentration of each series)

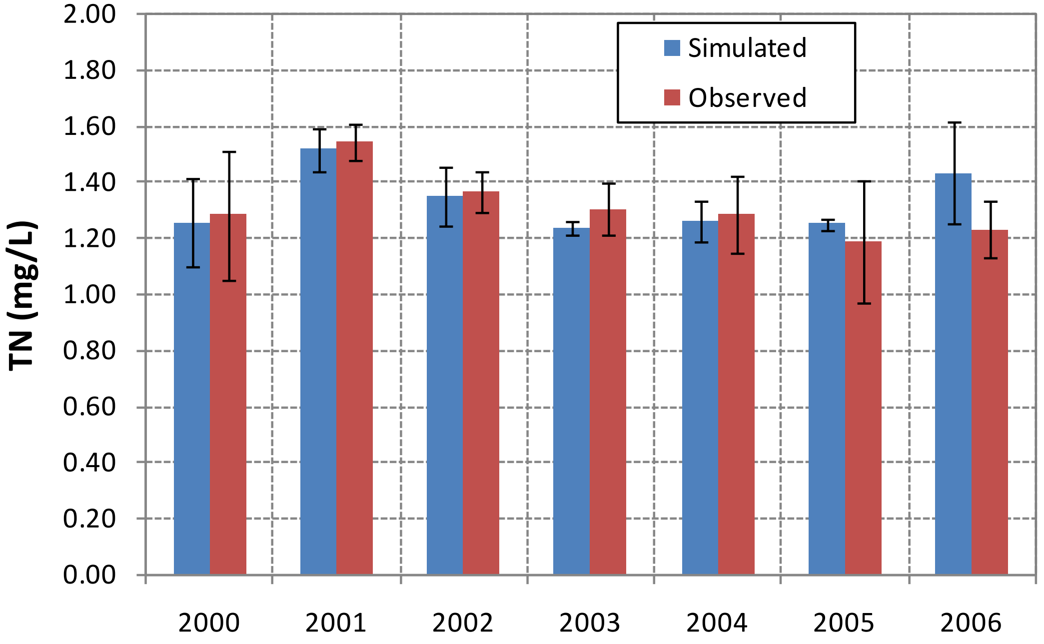

Figure 5.22. Annual Mean Concentrations of Observed Versus Simulated TN in Lake Kissimmee During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviations)

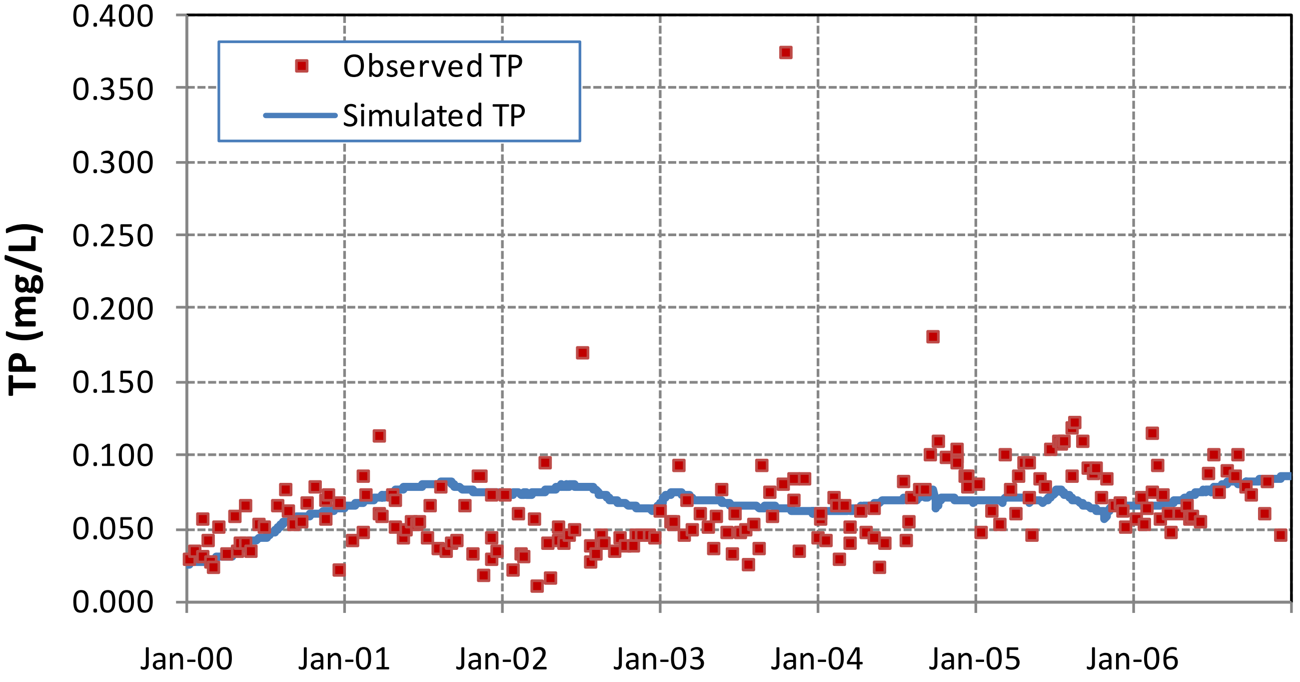

Figure 5.23. Time-Series of Observed Versus Simulated Daily TP Concentrations in Lake Kissimmee During the Simulation Period, 2000–06

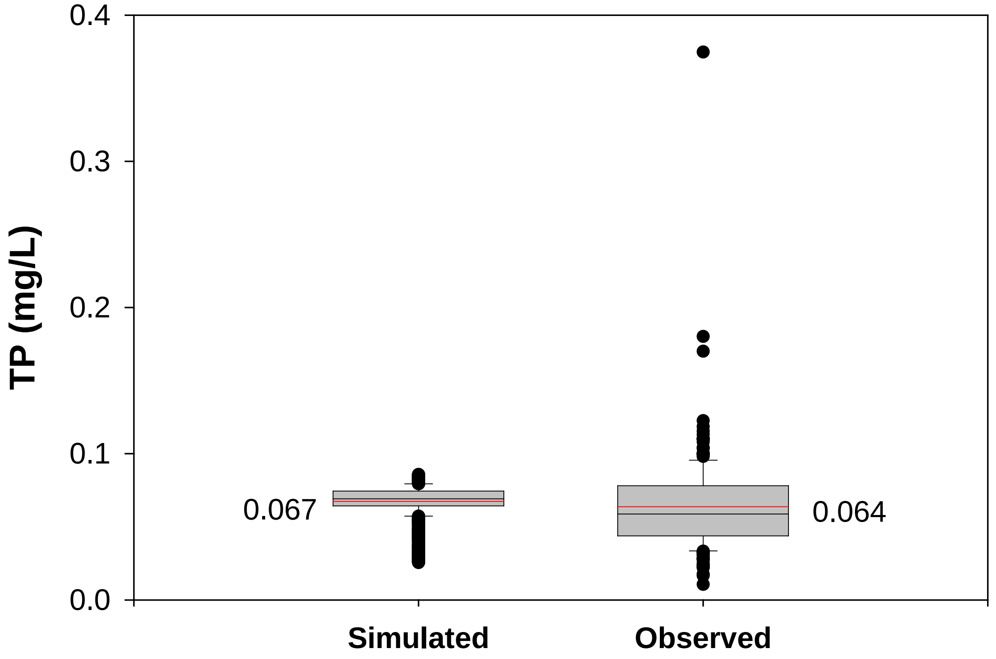

Figure 5.24. Box and Whisker Plot of Simulated Versus Observed TP in Lake Kissimmee, 2000–06 (red line represents mean concentration of each series)

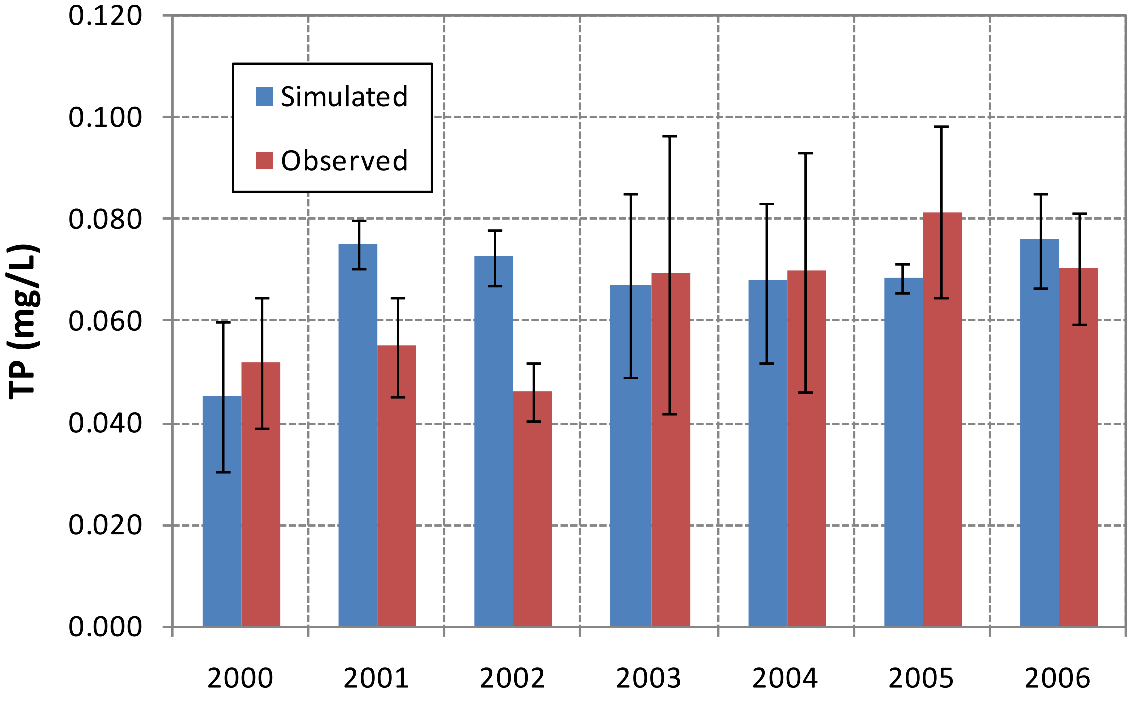

Figure 5.25. Annual Mean Concentrations of Observed Versus Simulated TP in Lake Kissimmee During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviations)

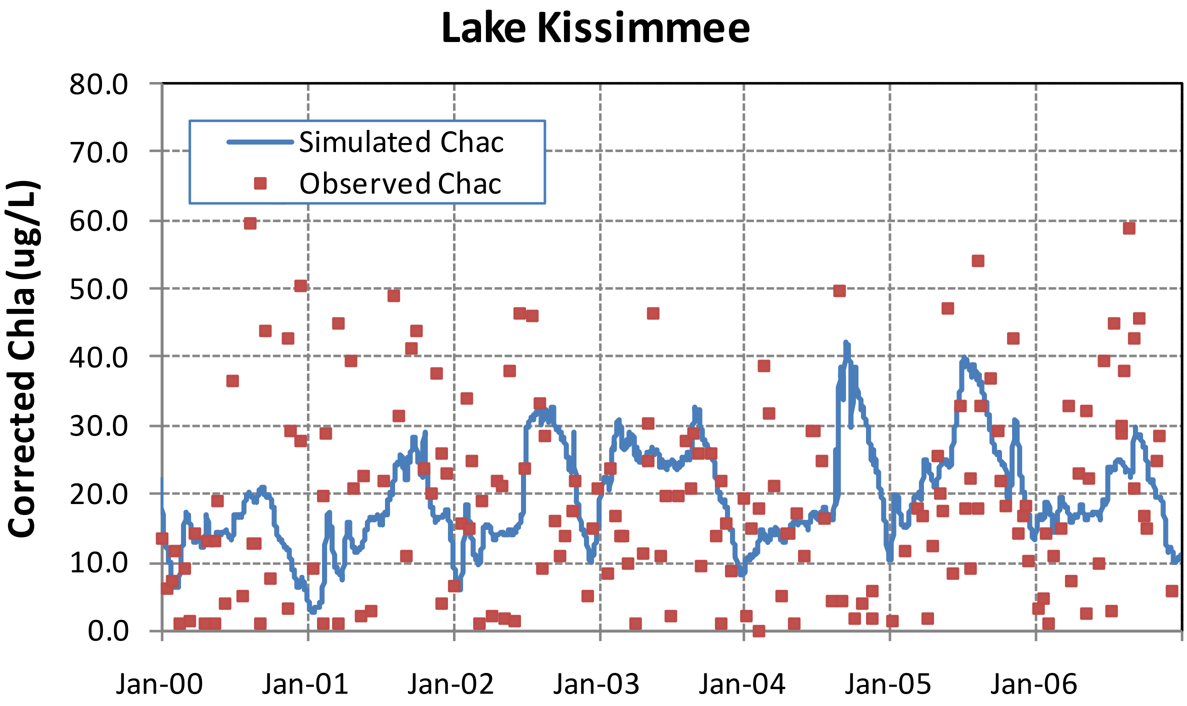

Figure 5.26. Time-Series of Observed Versus Simulated Daily CChl*a* Concentrations in Lake Kissimmee During the Simulation Period, 2000–06

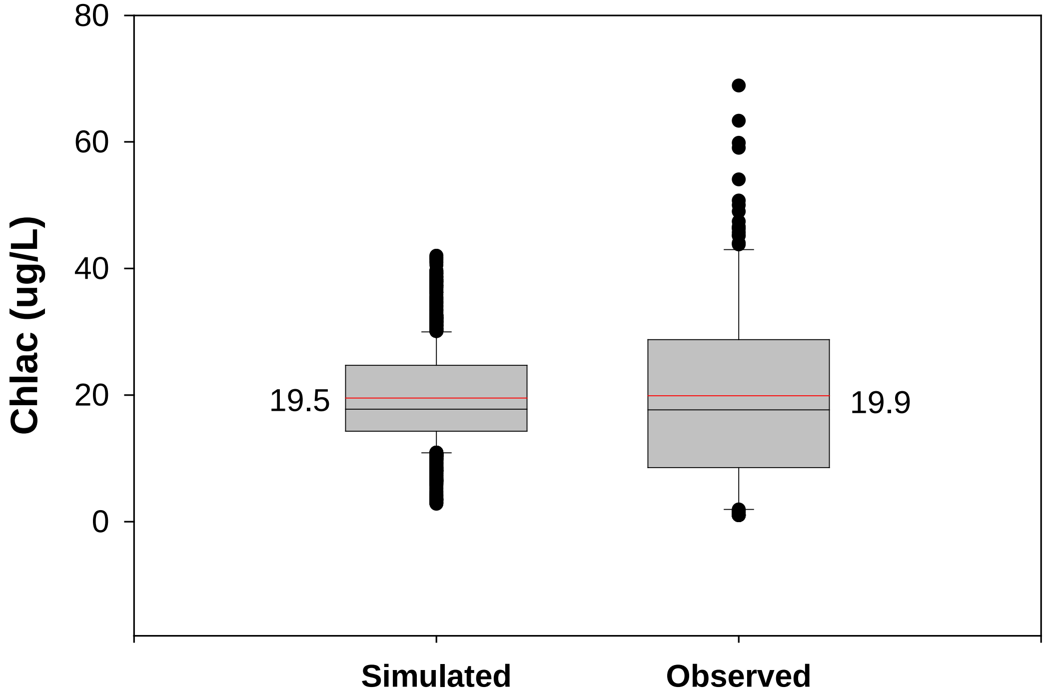

Figure 5.27. Box and Whisker Plot of Simulated Versus Observed CChl*a* in Lake Kissimmee, 2000–06 (red line represents mean concentration of each series)

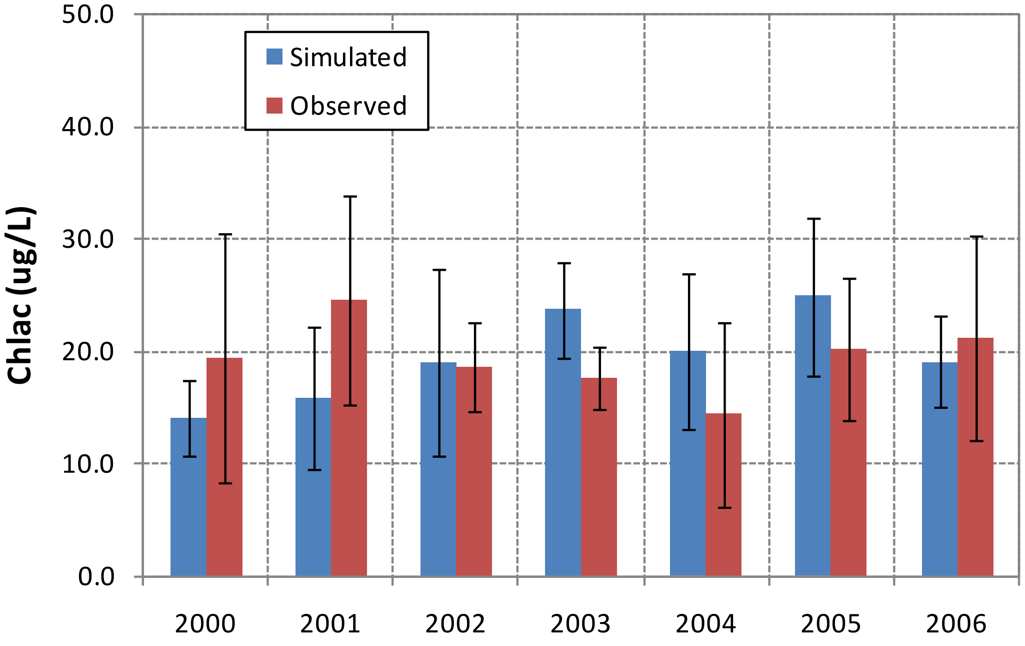

Figure 5.28. Annual Mean Concentrations of Observed Versus Simulated CChl*a* in Lake Kissimmee During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviations)

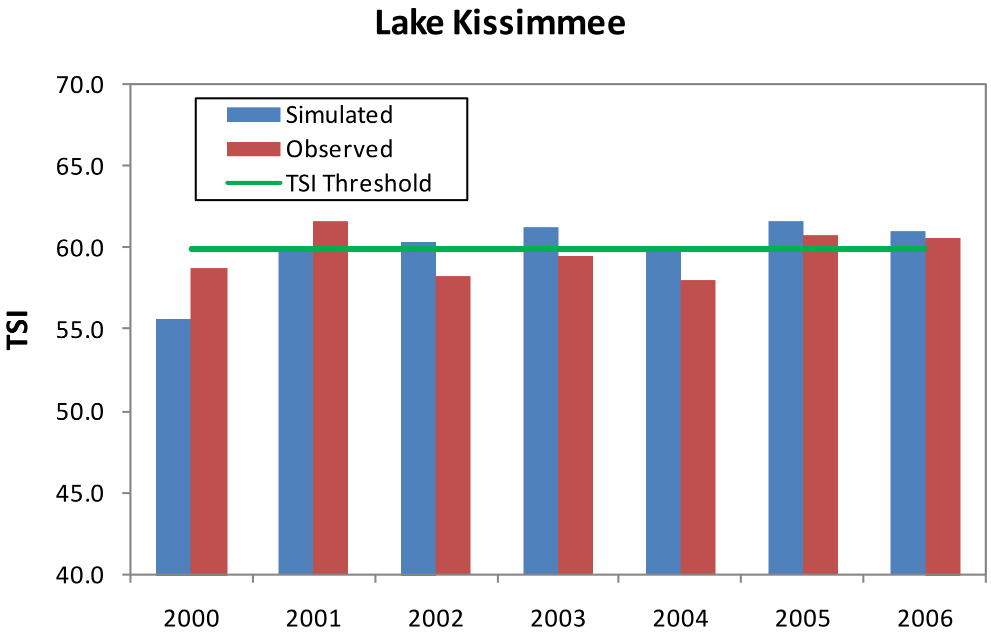

Figure 5.29. Observed Versus Simulated Annual TSIs in Lake Kissimmee During the Simulation Period, 2000–06 (solid line indicates TSI threshold of 60)

5.3 Background Conditions

HSPF was used to evaluate the "natural land use background condition" for the Lake Kissimmee 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, 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 20). Based on the background model run results, the predevelopment lake should have had long-term averages of 0.032 mg/L for TP, 1.09 mg/L for TN, and 6.7 µg/L for cchla. The resulting annual average TSI values ranged between 46.6 and 53.3, with a long-term average of 50.1.

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.

Applying the attainment of the TMDL condition for Lake Cypress, water quality in both Lake Hatchineha and Lake Kissimmee is also expected to improve from the existing TSI of 59.7 to 56.8 and from the existing TSI of 60.0 to 58.0, respectively. However, as shown in **Table 5.10**, additional reductions of TN and TP in the Lake Kissimmee watershed, except for the Lake Cypress and Lake Jackson watersheds, will be required to meet the Lake Kissimmee TSI target. The final target developed for the restoration of Lake Kissimmee includes achieving a long-term average TSI less than or equal to 55.1 (background of 50.1 plus 5). Serial reductions in loadings were implemented until the load reduction resulted in the lake meeting the requirements of the TSI target.

Figure 5.30 depicts the TSI results for the existing condition, 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 55.1, the existing watershed TN and TP loads need to be reduced by 15% for TN and

17% for TP, resulting in a long-term average TSI of 50.0. Under these reduction conditions, the long-term average in-lake concentrations in Lake Kissimmee are expected to be 1.10 mg/L for TN, 0.044 mg/L for TP, and 13.7 µg/L for cchl*a*. Therefore, it was decided that the watershed load reductions of 15% TN and 17% for TP, which met the TSI target, would best represent the assimilative capacity for the waterbody, resulting in achieving aquatic life–based water quality criteria.

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

- = Empty cell/no data

TSI and % Reduction	Lake Cypress	Lake Kissimmee	Lake Jackson	Lake Marian	Lake Hatchineha
Background TSI (2000–06)	54.9	50.1	54.7	53.1	50.1
Target TSI (Background TSI+5)	59.9	55.1	59.7	58.1	55.1
Calibrated Existing TSI	65.3	60.0	67.1	70.3	59.7
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	**59.7 (TN05/TP35)**	58.0 (by Cypress)	-	-	56.8 (by Cypress)
Lake Kissimmee TMDL % Reduction	-	**55.0 (TN15/TP17)**	-	-	-

The 7-year averaged existing watershed loads of TN and TP, not including direct precipitation, were estimated to be 3,165,571 and 172,961 lbs/year, respectively. Under the Lake Cypress TMDL condition, and a 15% reduction of TN and a 17% reduction of TP for the Lake Hatchineha watershed, Lake Hatchineha discharges 7-year averages of 2,221,958 lbs/yr TN and 94,359 lbs/yr TP (**Tables 5.12** and **5.13**). Percent reductions of 15% for TN and 17% for TP were applied to the existing subbasin and other upstream watersheds of Lake Rosalie and Lake Tiger, resulting in the 7-year average allowable load of 456,653 lbs/year for TN and 26,663 lbs/year for TP. For the entire Lake Kissimmee watershed, the percent reductions resulted in the total allowable load of 2,795,484 lbs/yr for TN and 126,517 lbs/yr for TP. 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.

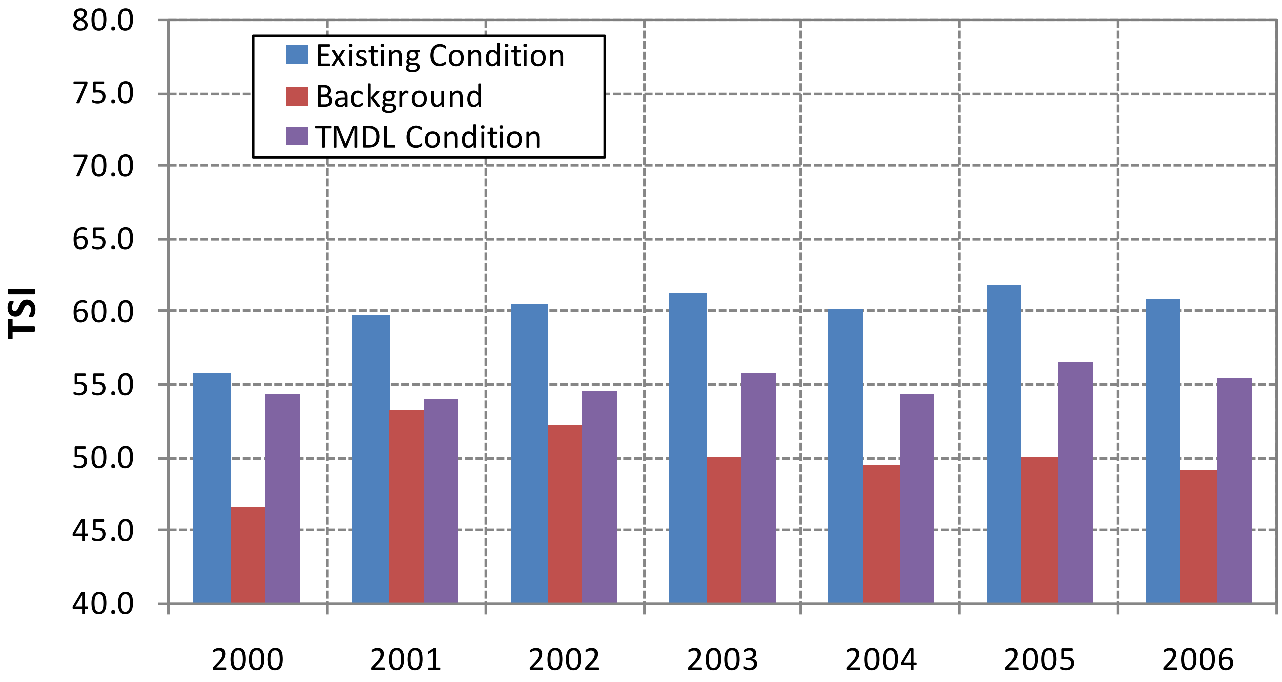

Figure 5.30. Simulated TSIs for the Existing Condition, Background Condition, and TMDL Condition for Lake Kissimmee During the Simulation Period, 2000–06

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

Statistic	Existing TSI	Background TSI	TMDL TSI
Count	7.0	7.0	7.0
Median	60.4	50.0	54.6
Average	60.0	50.1	55.0
Standard	2.0	2.2	0.9
Minimum	55.7	46.6	53.9
Maximum	61.7	53.3	56.5
CV (%)	3.3%	4.3%	1.7%

Table 5.12. Estimated Annual TN Loads to Lake Kissimmee from the Lake Kissimmee Subbasin, Lake Hatchineha, Lake Jackson, and Other Upstream Watersheds under the TMDL Condition

Year	Subbasin Runoff (lbs/yr)	Subbasin Interflow (lbs/yr)	Subbasin Baseflow (lbs/yr)	Other Upstream Watershed (lbs/yr)	Reduction in Lake Hatchineha Watershed (lbs/yr)	Reduction in Lake Jackson Watershed (lbs/yr)	Total Inflow (lbs/yr)
2000	3,754	20,226	20,052	12,356	878,263	0	934,651
2001	24,553	66,035	19,777	49,136	1,385,652	34,416	1,579,569
2002	23,222	114,317	35,795	147,658	2,694,381	112,357	3,127,730
2003	58,811	111,205	43,825	334,166	2,865,061	108,265	3,521,332
2004	114,195	187,490	42,326	523,910	3,540,814	217,391	4,626,126
2005	173,394	253,040	64,760	520,675	3,388,497	260,797	4,661,163
2006	79,438	98,348	17,938	36,168	801,039	84,887	1,117,818
Average	**68,195**	**121,523**	**34,925**	**232,010**	**2,221,958**	**116,873**	**2,795,484**

Table 5.13. Estimated Annual TP Loads to Lake Kissimmee from the Lake Kissimmee Subbasin, Lake Hatchineha, Lake Jackson, and Other Upstream Watersheds under the TMDL Condition

Year	Subbasin Runoff (lbs/yr)	Subbasin Interflow (lbs/yr)	Subbasin Baseflow (lbs/yr)	Other Upstream Watershed (lbs/yr)	Reduction in Lake Hatchineha Watershed (lbs/yr)	Reduction in Lake Jackson Watershed (lbs/yr)	Total Inflow (lbs/yr)
2000	83	2,108	1,110	1,022	30,405	0	34,728
2001	230	6,761	1,102	4,329	57,056	1,885	71,362
2002	235	11,383	1,980	9,091	114,794	5,914	143,397
2003	534	10,891	2,427	15,639	121,561	5,415	156,467
2004	1,295	18,262	2,343	26,204	158,092	10,097	216,293
2005	1,690	24,769	3,563	26,052	145,822	11,703	213,600
2006	633	9,820	989	2,094	32,784	3,450	49,770
Average	**671**	**11,999**	**1,931**	**12,062**	**94,359**	**5,495**	**126,517**

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 TMDL for Lake Kissimmee is expressed as loads and percent reductions and represents 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 Kissimmee Load Allocations

NA = Not applicable

WBID	Parameter	WLA for Wastewater (lbs/yr)	WLA for Stormwater (% reduction)	LA (% reduction)	MOS	TMDL (lbs/yr)
3183B	TN	NA	15%	15%	Implicit	2,795,484
3183B	TP	NA	17%	17%	Implicit	126,517

The LA and TMDL daily load for TN is 7,659 lbs/day, and for TP, 347 lbs/day.

Based on the TMDL modeling conducted for this report (reductions of watershed loadings), the 7-year long-term average lake concentrations for TP is 0.044 mg/L, for TN 1.10 mg/L, and for cchl*a* 13.7 µg/L. These reductions are based on data from 2000 to 2006. 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 17% reduction in TP and a 15% 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 SFWMD 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 Kissimmee watershed that discharge surface water within the watershed. Therefore, the

$WLA_{wastewater}$ for the Lake Kissimmee TMDL is not applicable because there are no wastewater or industrial wastewater NPDES facilities that discharge directly to Lake Kissimmee.

6.3.2 NPDES Stormwater Discharges

The stormwater collection systems in the Lake Cypress watershed, which are owned and operated by Polk County in conjunction with FDOT District 1, are covered by NPDES Phase I MS4 Permit Number FLS000015. The collection systems owned and operated by Osceola County and the city of St. Cloud are covered by NPDES Phase II MS4 Permit Number FLR04E012. The collection system for the city of Orlando is covered by NPDES Phase I Permit Number FLS000014. The collection systems for Orange County, FDOT District 5, and the city of Belle Isle are covered by NPDES Phase 1 Permit Number FLS000011. The collection system for the city of Kissimmee is covered by NPDES Phase II Permit Number FLR04E64. The collection system for the Florida Turnpike is covered by NPDES Phase II-C Permit Number FLRO4E049. The wasteload allocation for MS4 stormwater discharges is a 17% reduction in TP and a 15% reduction in TN of the total watershed loading from 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 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 MOS was used in the development of the Lake Kissimmee TMDL because the TMDL was based on the conservative decisions associated with a number of the modeling assumptions and allows only a 5 TSI unit increase above background conditions in determining the assimilative capacity (*i.e.,* loading and water quality response) for Lake Kissimmee.

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 Kissimmee 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 Kissimmee is included in the HSPF model project termed UKL_Open.UCI.

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

Douglas Gilbert, Environmental Manager
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 Kissimmee

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

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

Flow Calibration

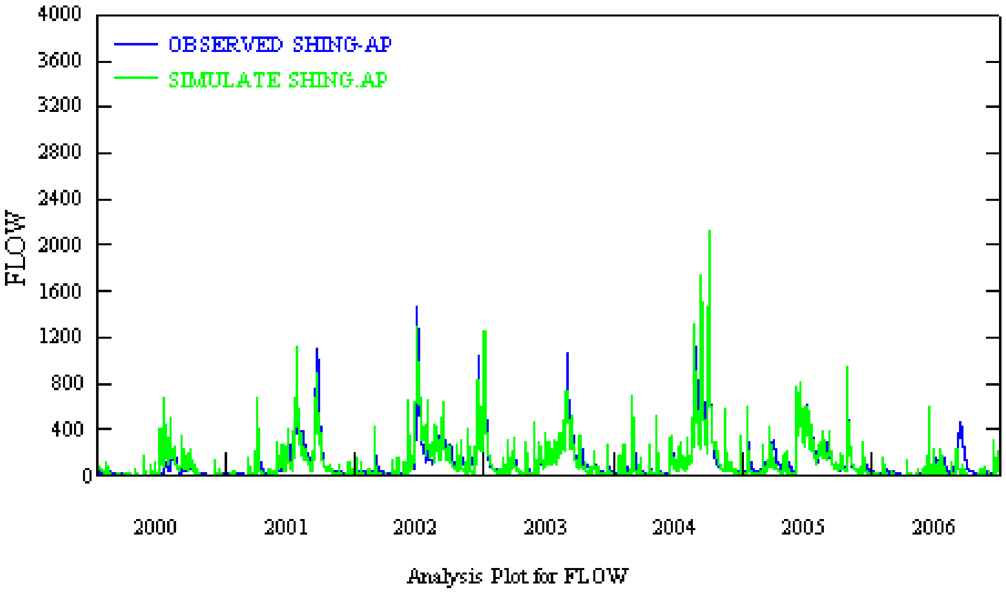

Figure D-1. Observed Versus Simulated Daily Flow (cfs) at Shingle Creek near Airport, 2000–06

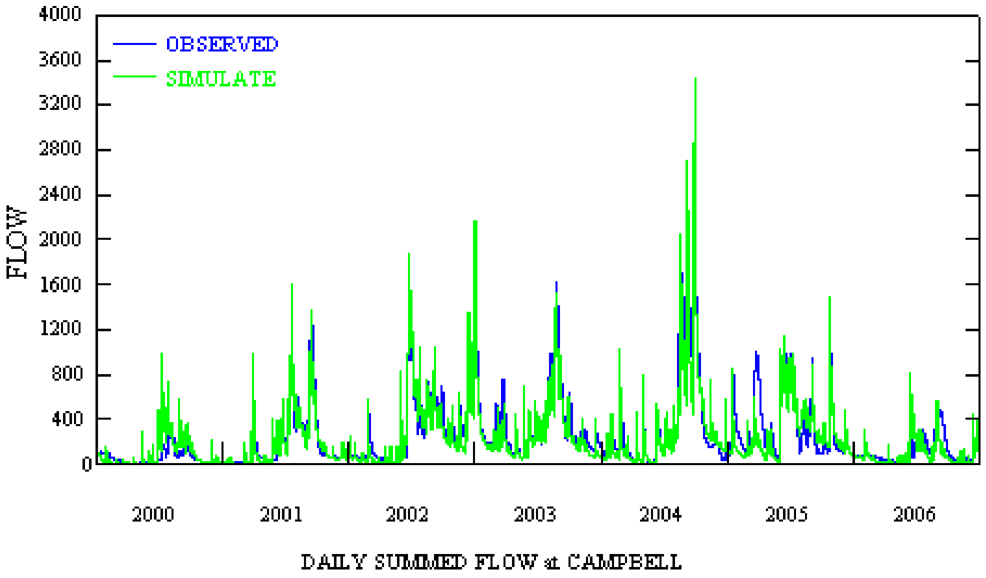

Figure D-2. Observed Versus Simulated Daily Flow (cfs) at Campbell Station in Shingle Creek, 2000–06

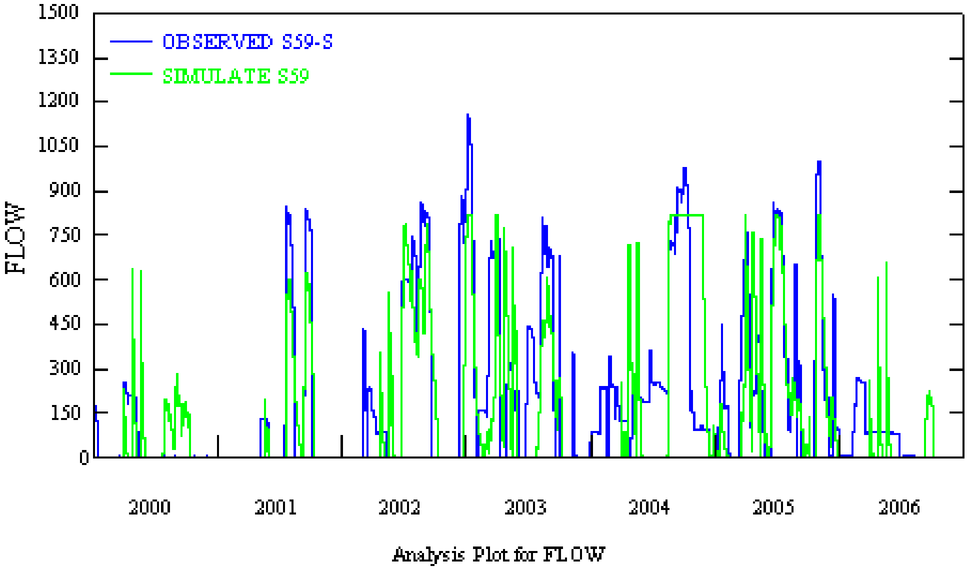

Figure D-3. Observed Versus Simulated Daily Flow (cfs) at S59 for East Lake Tohopekaliga Outflow, 2000–06

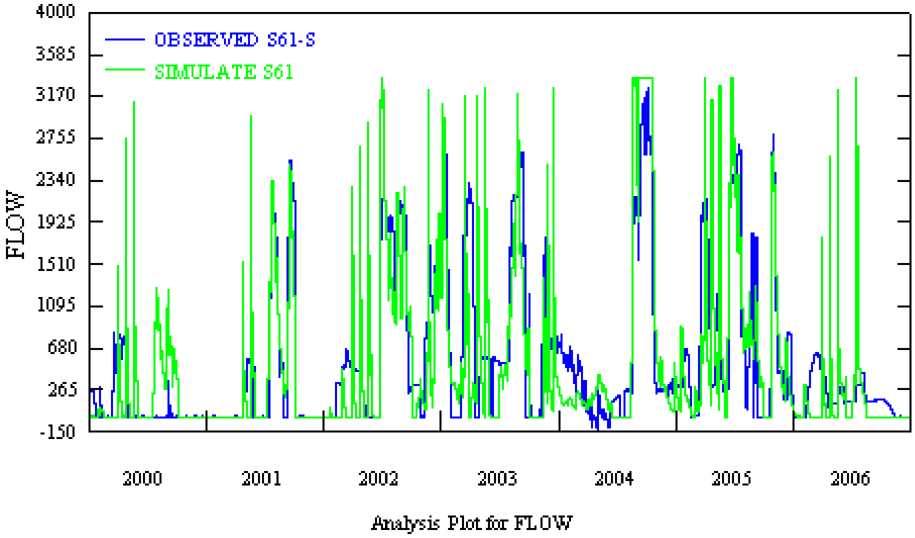

Figure D-4. Observed Versus Simulated Daily Flow (cfs) at S61-S for Lake Tohopekaliga Outflow, 2000–06

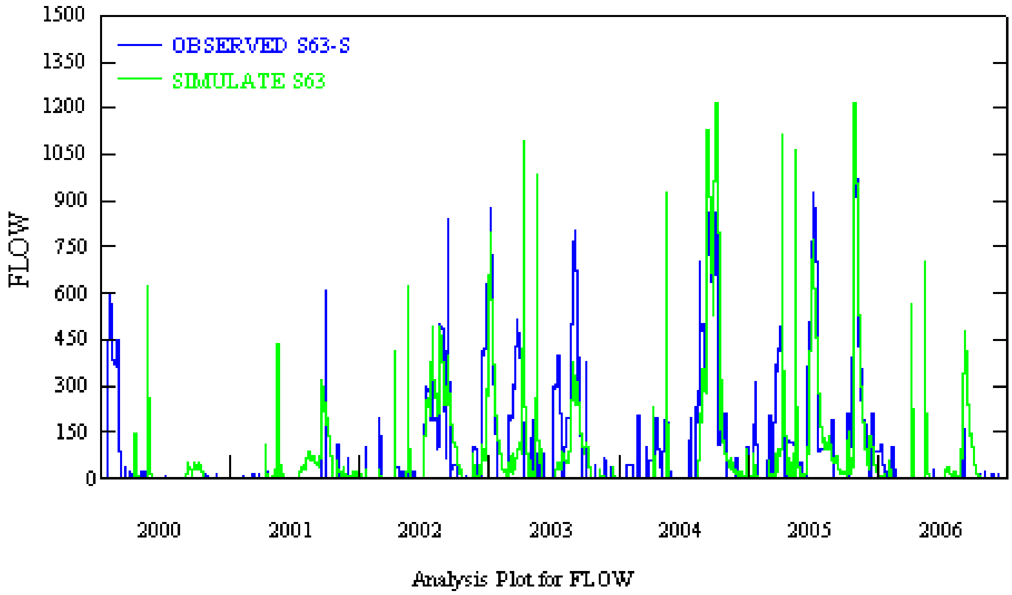

Figure D-5. Observed Versus Simulated Daily Flow (cfs) at S63 for Lake Gentry Outflow, 2000–06

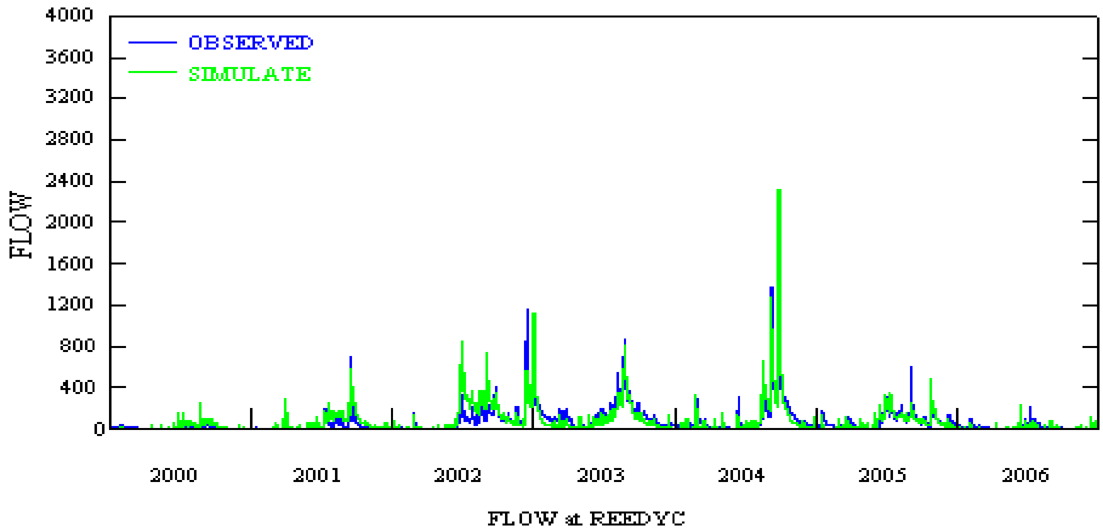

Figure D-6. Observed Versus Simulated Daily Flow (cfs) at Reedy Creek Station, 2000–06

Statistics for Hydrologic Calibration/Validation

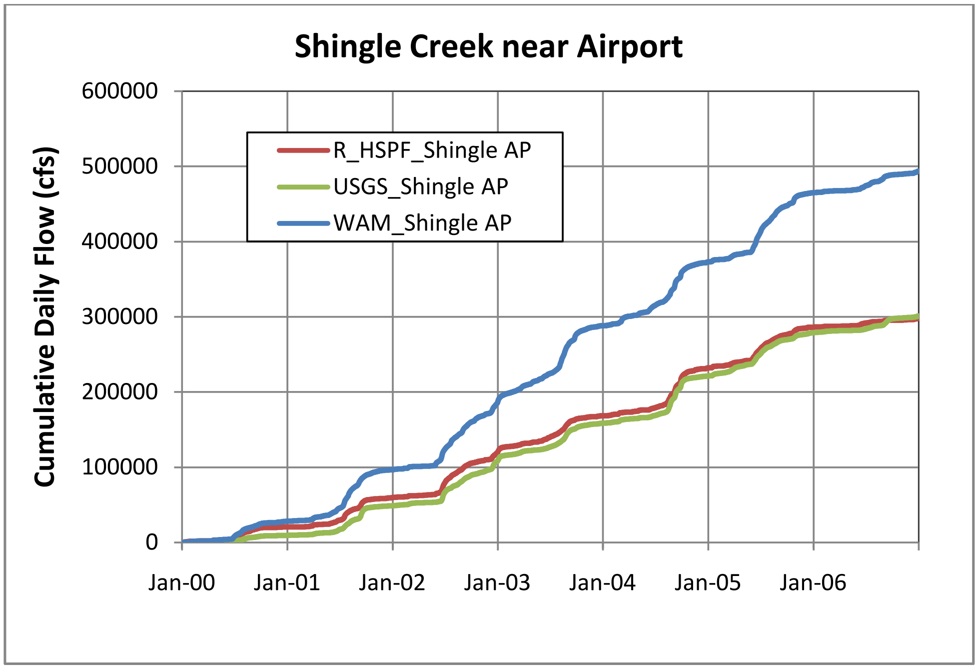

Figure D-7. Observed Versus Simulated Cumulative Daily Flows for Shingle Creek near Airport, 2000–06

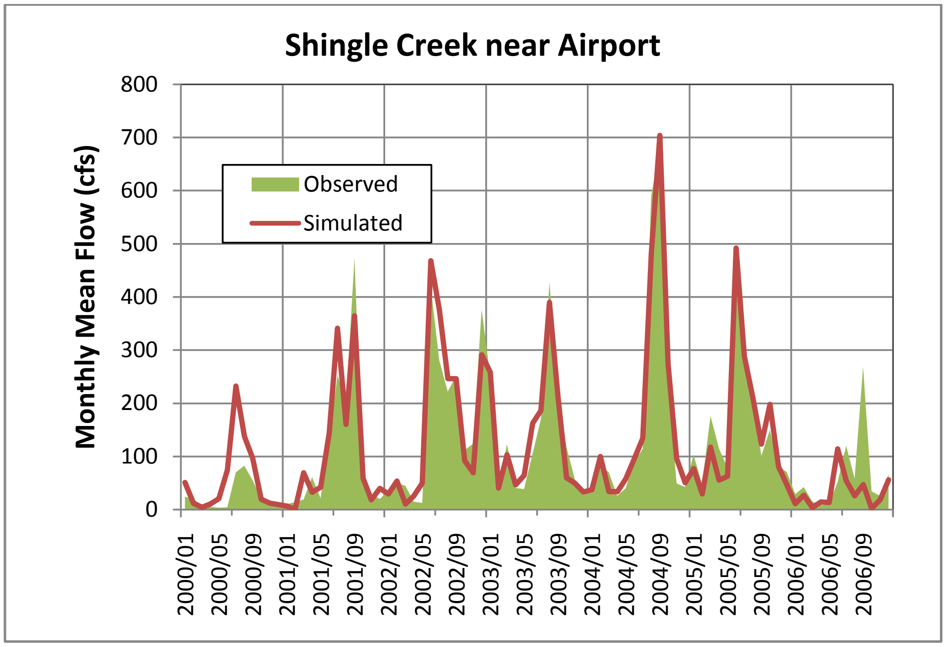

Figure D-8. Observed Versus Simulated Monthly Flows for Shingle Creek near Airport, 2000–06

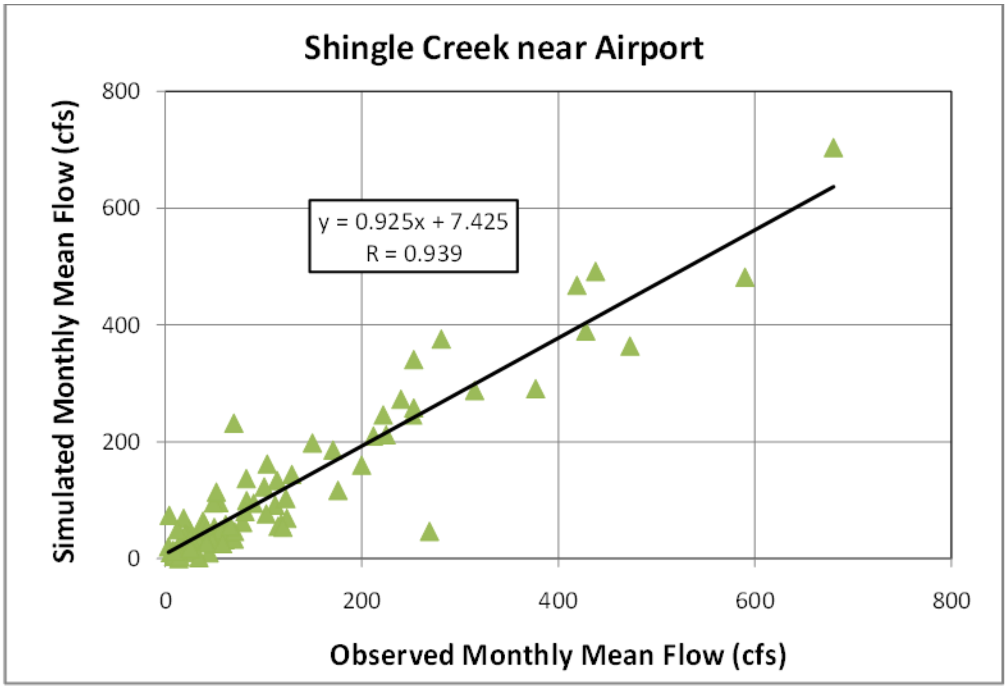

Figure D-9. Relationship Between Observed and Simulated Monthly Flows for Shingle Creek near Airport, 2000–06

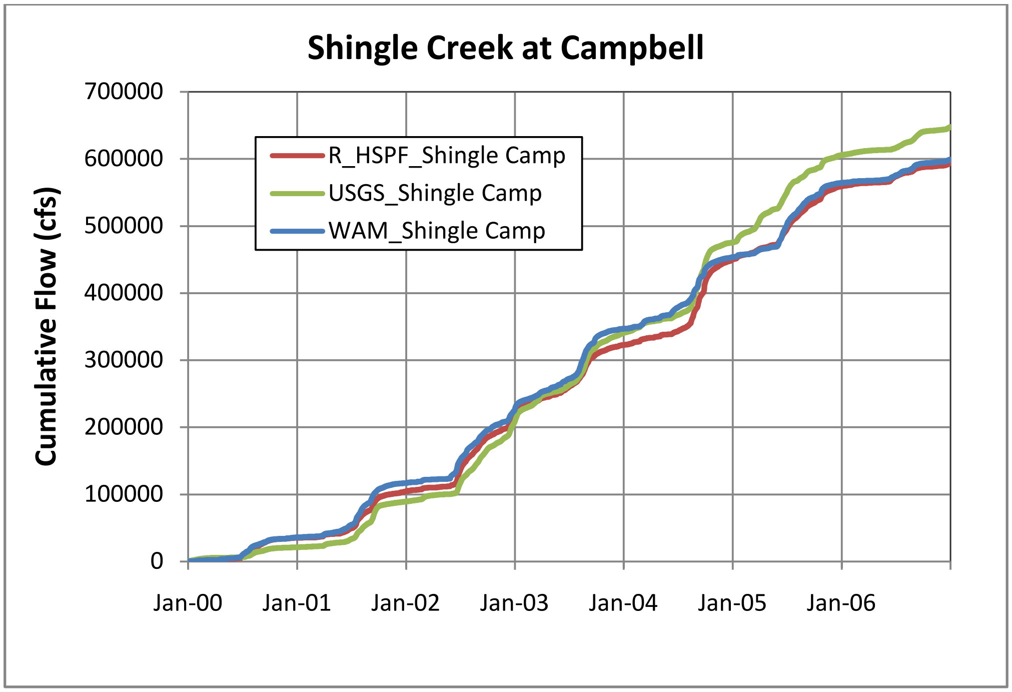

Figure D-10. Observed Versus Simulated Cumulative Daily Flows for Shingle Creek at Campbell, 2000–06

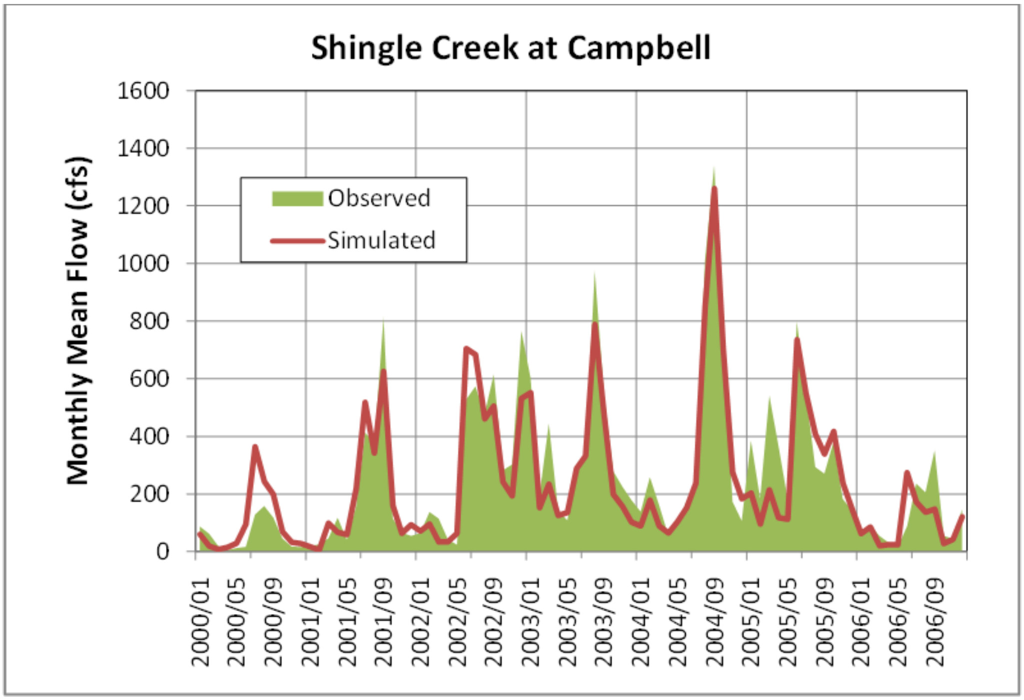

Figure D-11. Observed Versus Simulated Monthly Flows for Shingle Creek at Campbell, 2000–06

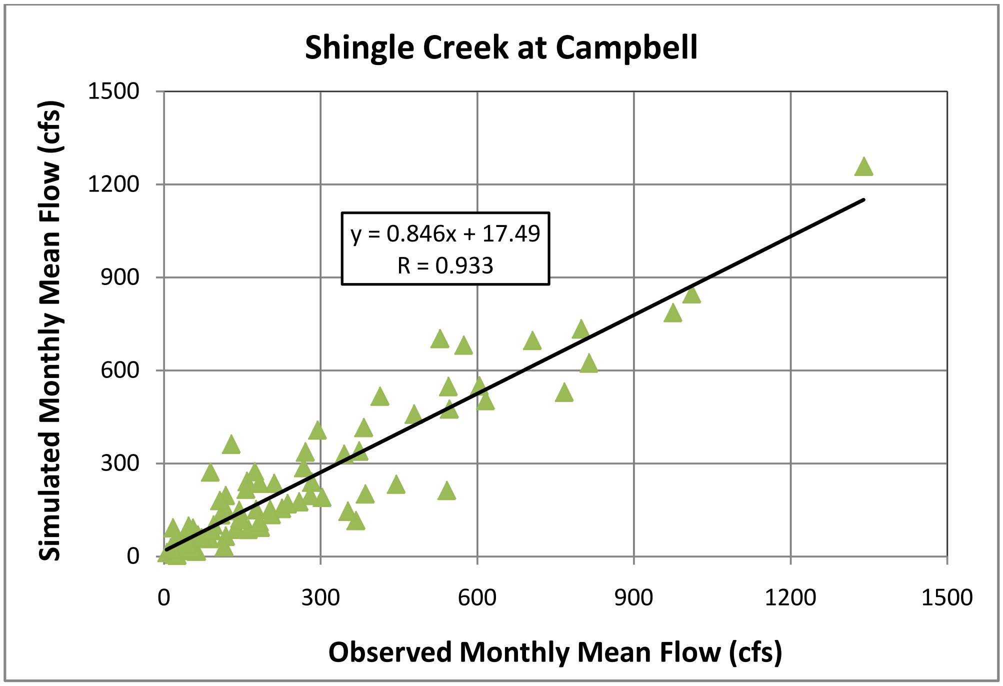

Figure D-12. Relationship Between Observed and Simulated Monthly Flows for Shingle Creek at Campbell, 2000–06

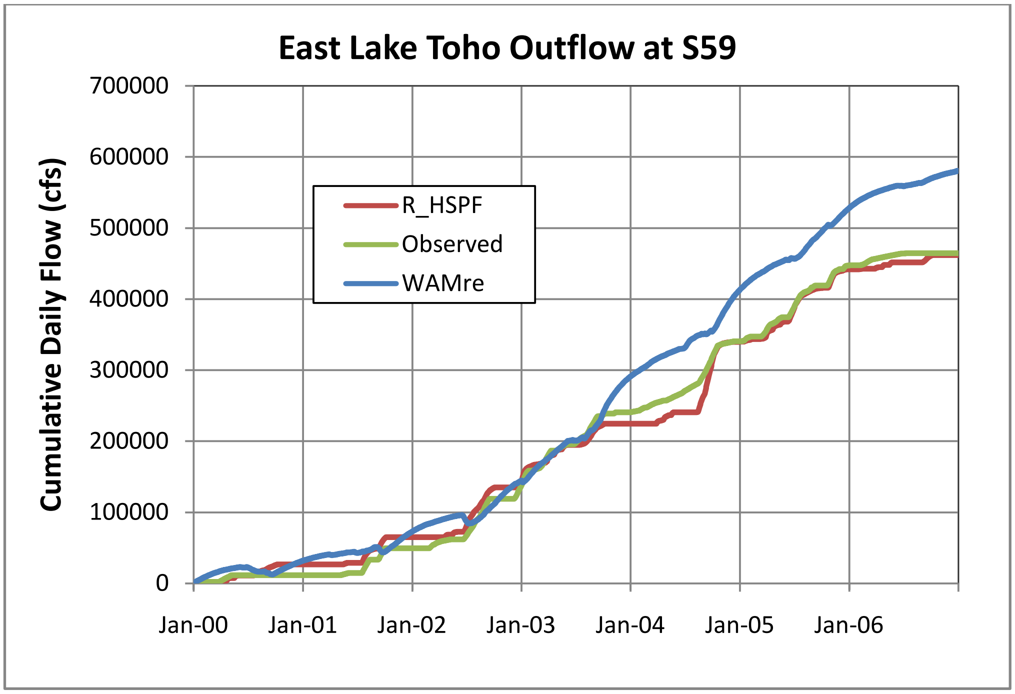

Figure D-13. Observed Versus Simulated Cumulative Daily Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

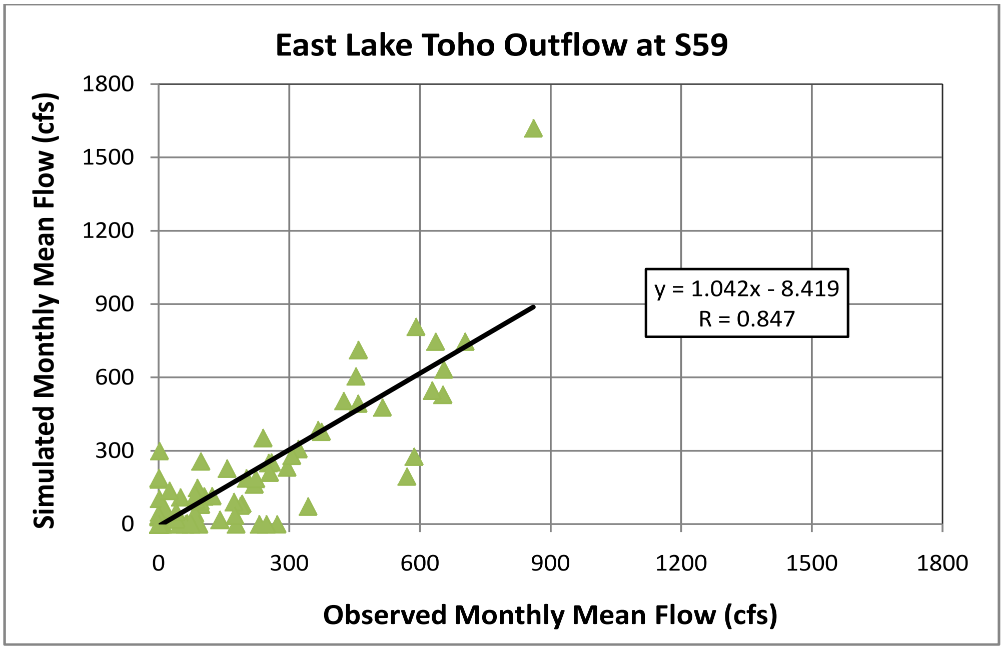

Figure D-14. Relationship Between Observed and Simulated Monthly Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

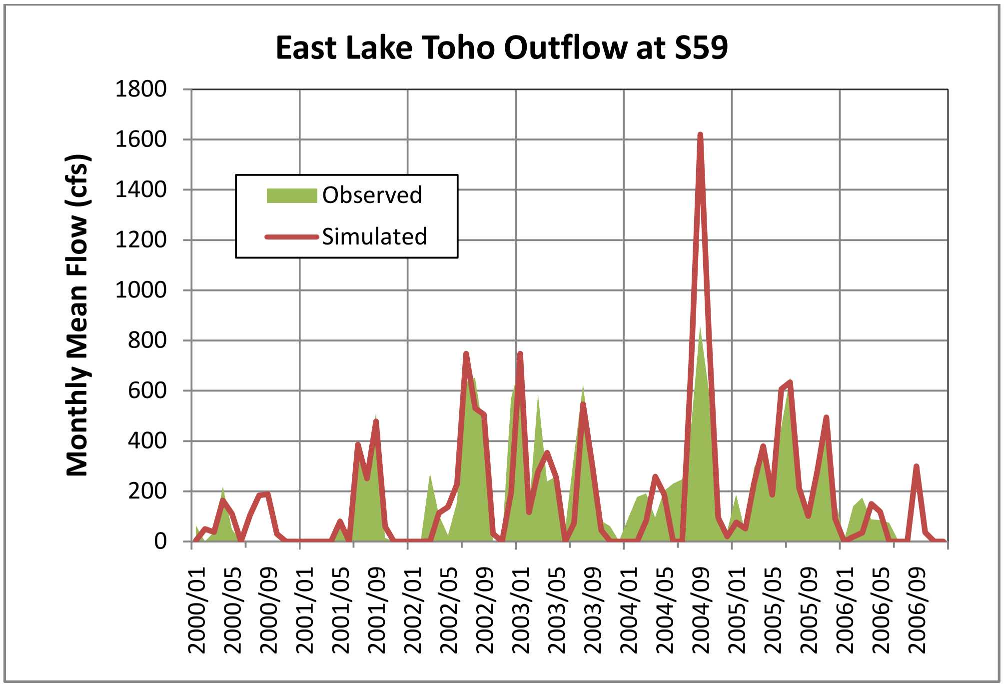

Figure D-15. Observed Versus Simulated Monthly Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

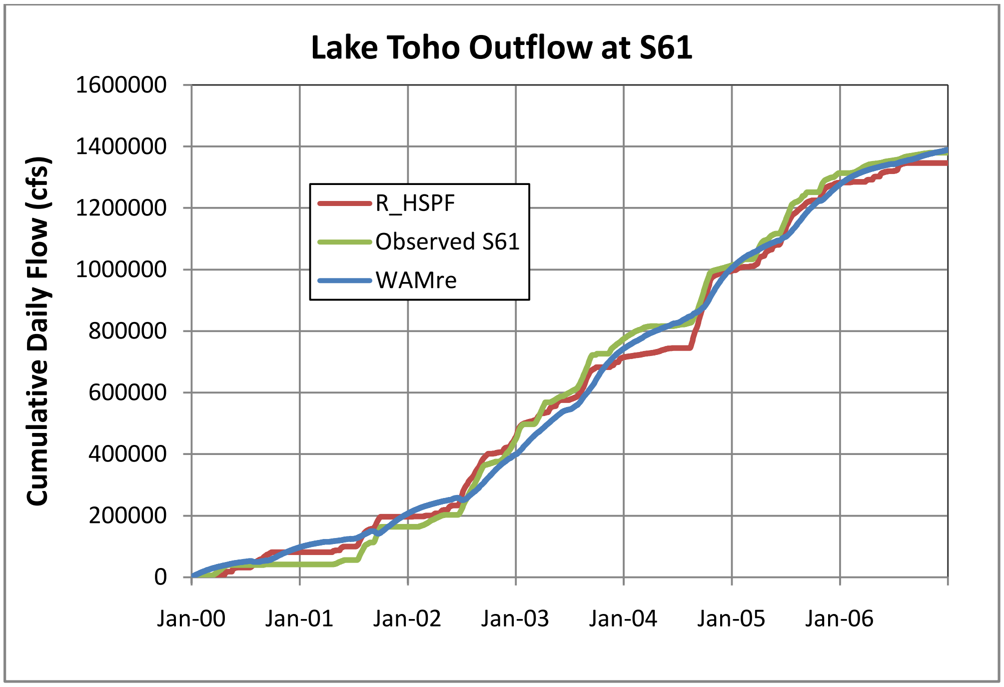

Figure D-16. Observed Versus Simulated Cumulative Daily Flows for Lake Tohopekaliga Outflow at S61, 2000–06

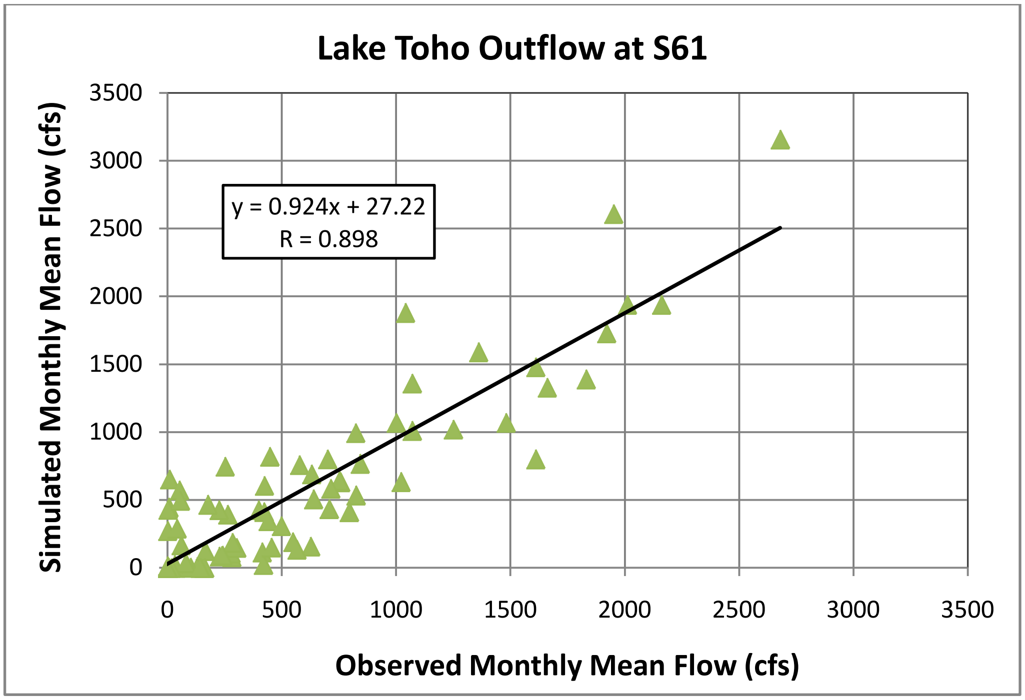

Figure D-17. Relationship Between Observed and Simulated Monthly Flows for Lake Tohopekaliga Outflow at S61, 2000–06

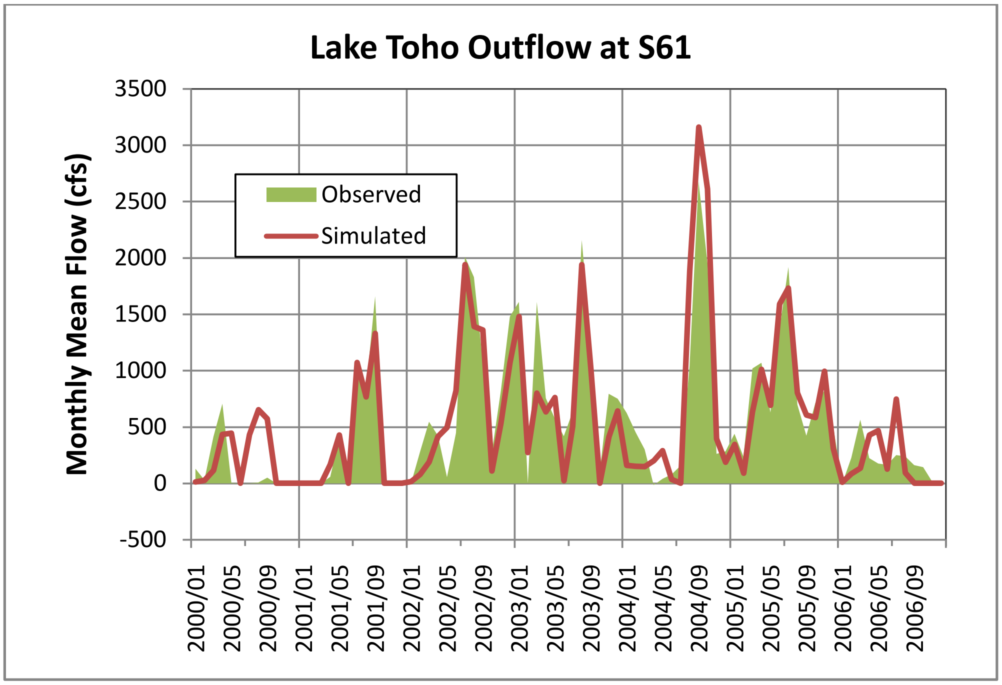

Figure D-18. Observed Versus Simulated Monthly Flows for Lake Tohopekaliga Outflow at S61, 2000–06

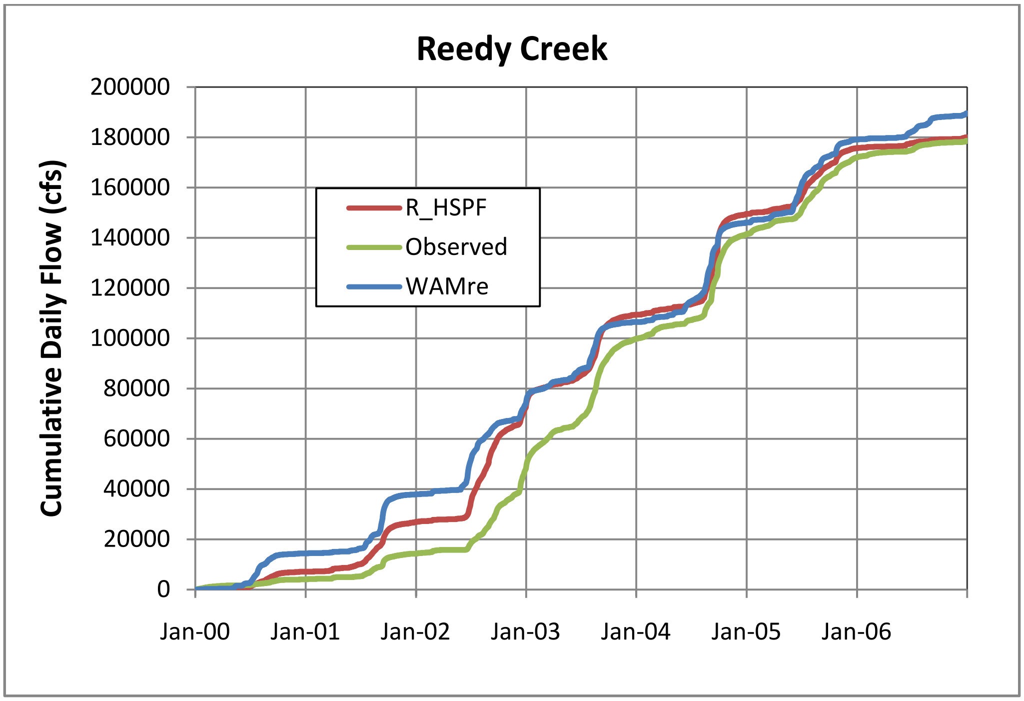

Figure D-19. Observed Versus Simulated Cumulative Daily Flows for Reedy Creek, 2000–06

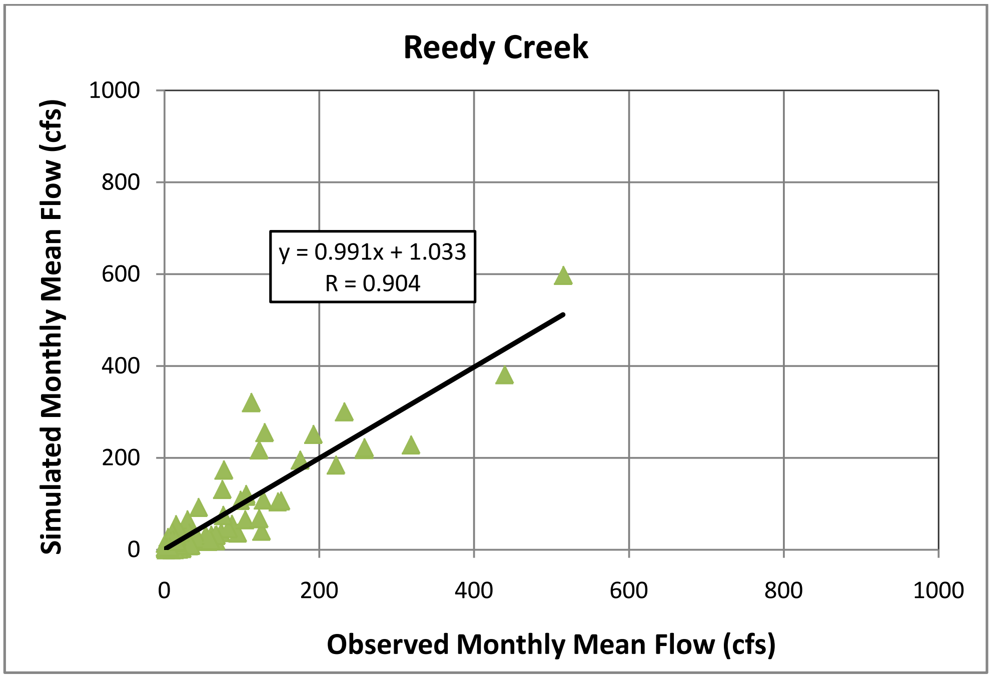

Figure D-20. Relationship Between Observed and Simulated Monthly Flows for Reedy Creek, 2000–06

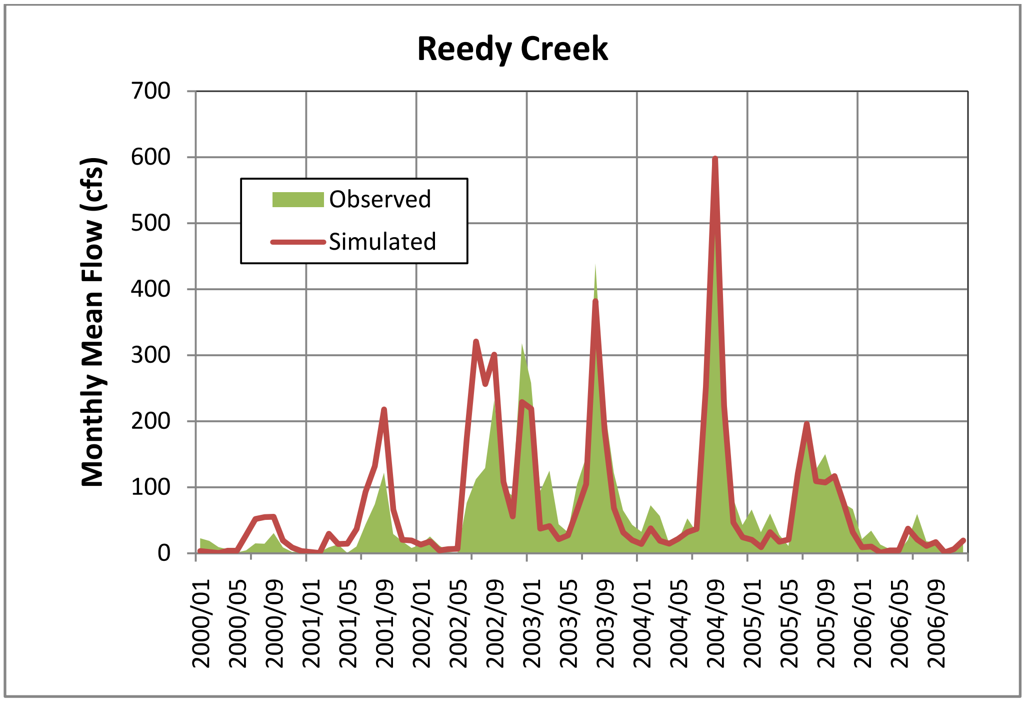

Figure D-21. Observed Versus Simulated Monthly Flows for Reedy Creek, 2000–06

Stage Calibration

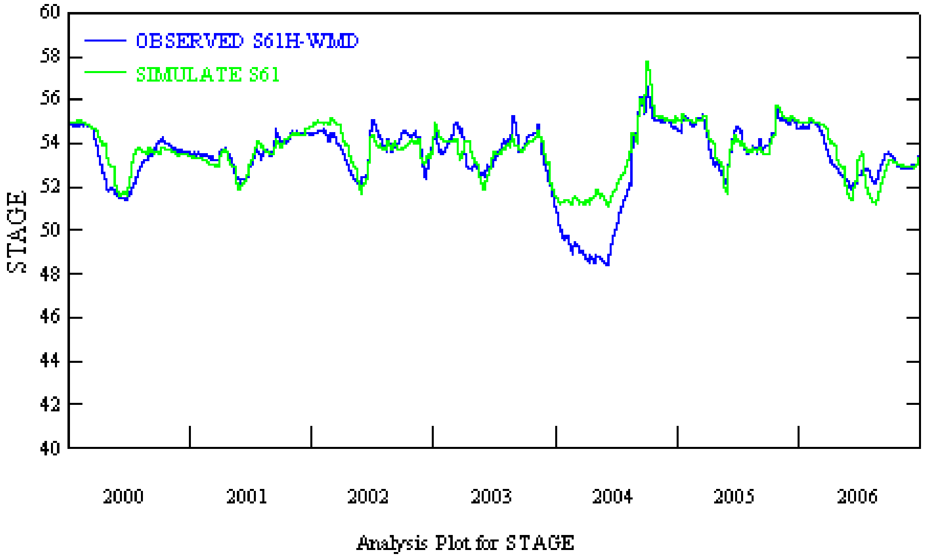

Figure D-22. Observed Versus Simulated Lake Elevation in Lake Tohopekaliga, 2000–06

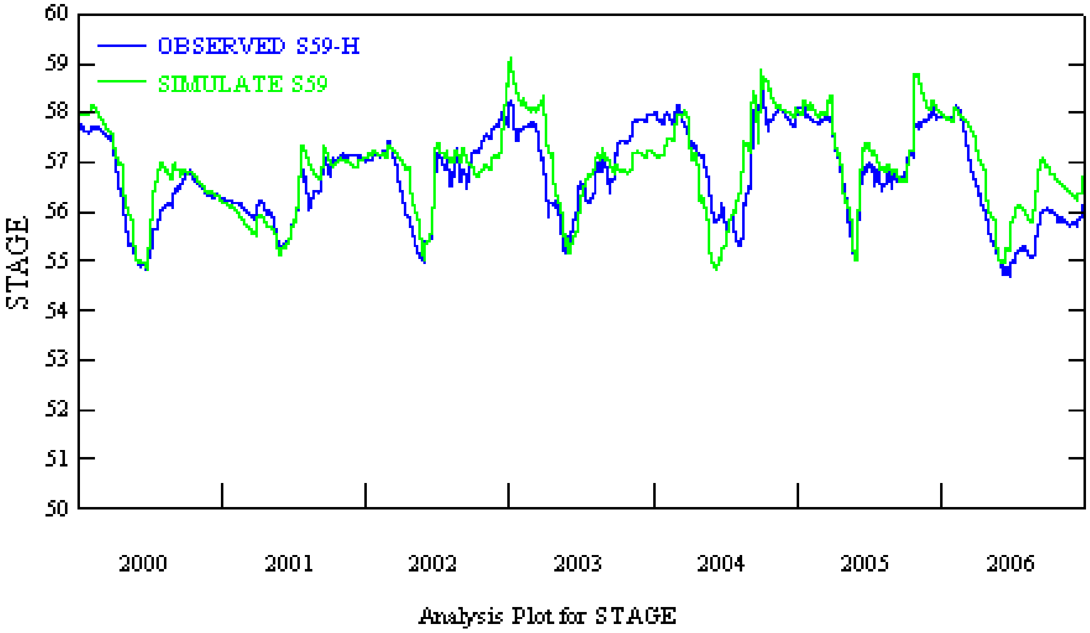

Figure D-23. Observed Versus Simulated Lake Elevation in East Lake Tohopekaliga, 2000–06

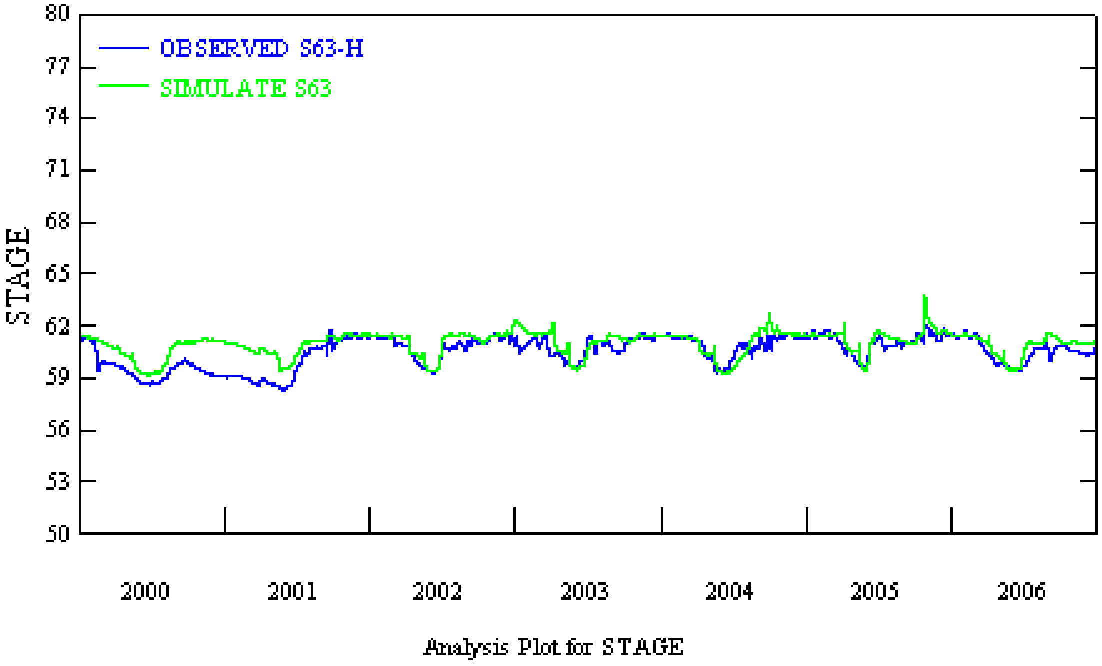

Figure D-24. Observed Versus Simulated Lake Elevation in Lake Gentry, 2000–06