CENTRAL DISTRICT • KISSIMMEE RIVER BASIN •
UPPER KISSIMMEE PLANNING UNIT

FINAL TMDL Report

Nutrient TMDL for Lake Holden (WBID 3168H)

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2012 Integrated 305(b) Report
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U.S. Environmental Protection Agency, National STORET Program

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 Holden, located in the Kissimmee River Basin. This TMDL constitutes the site-specific numeric interpretation of the narrative nutrient criterion pursuant to Paragraph 62-302.531(2)(a), Florida Administrative Code (F.A.C.). Lake Holden 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 was exceeded during both 2003 and 2007. The TMDL establishes the allowable loadings to the lake that would restore the waterbody so that it meets its applicable water quality narrative criterion for nutrients.

1.2 Identification of Waterbody

Lake Holden is located in Orange County, Florida, with portions of the drainage area extending into the city of Orlando. Based on information from Camp Dresser McKee (CDM) (2008), the estimated average surface area of the lake is 179 acres, with a normal pool volume of 1,140 acre/feet (ac/ft) and an average depth of 12 feet. Several reports by Environmental Research & Design (ERD) provide an excellent source of information on the historical condition, water and nutrient sources and sinks, the need for and most cost-effective restoration approaches, and documentation of the effectiveness of Best Management Practices (BMPs) for Lake Holden.[1] The studies by ERD (1992; 2004) report a surface area of 266 acres when the lake is at an average of 12 feet deep. The stage-area-discharge information from ERD (1992; 2004) was integrated with the information from CDM and used during the model setup and calibration, and in the development of the TMDL.

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[1] The ERD reports are as follows: (1) *Lake Holden Water Quality and Restoration* (1992), (2) *Lake Holden Revised Hydrologic/Nutrient Budget and Management Plan* (2004), (3) *Evaluation of the Current Operational Status of the Lake Holden Stormwater Treatment System and Recommendations for Improvement* (2008), and (4) *Evaluation of the Current Status and Potential Water Quality Improvement Options for Lake Holden* (2010).

Lake Holden receives drainage from the directly connected subbasin drainage area of approximately 766.4 acres. **Figure 1.1** depicts the location of Lake Holden within the larger Upper Kissimmee River Planning Unit.

The Lake Holden watershed's land use designations are primarily medium-density residential (51.5%), with all residential (52.8%), commercial/industrial (35.2%), forest (5.7%), wetlands (5.1%), and agriculture (1.2%). Lake Holden lies within a closed hydrologic basin and drains to several drainage wells located within the lake.

For assessment purposes, the Florida Department of Environmental Protection has divided the Kissimmee River Basin into water assessment polygons with a unique **w**ater**b**ody i**d**entification (WBID) number for each watershed or stream reach. Lake Holden is WBID 3168H.

Figure 1.2 shows the Lake Holden WBID and its sampling/monitoring stations. Data were collected by the city of Orlando, Orange County, the Department, LakeWatch, and the St. Johns River Water Management District (SJRWMD).

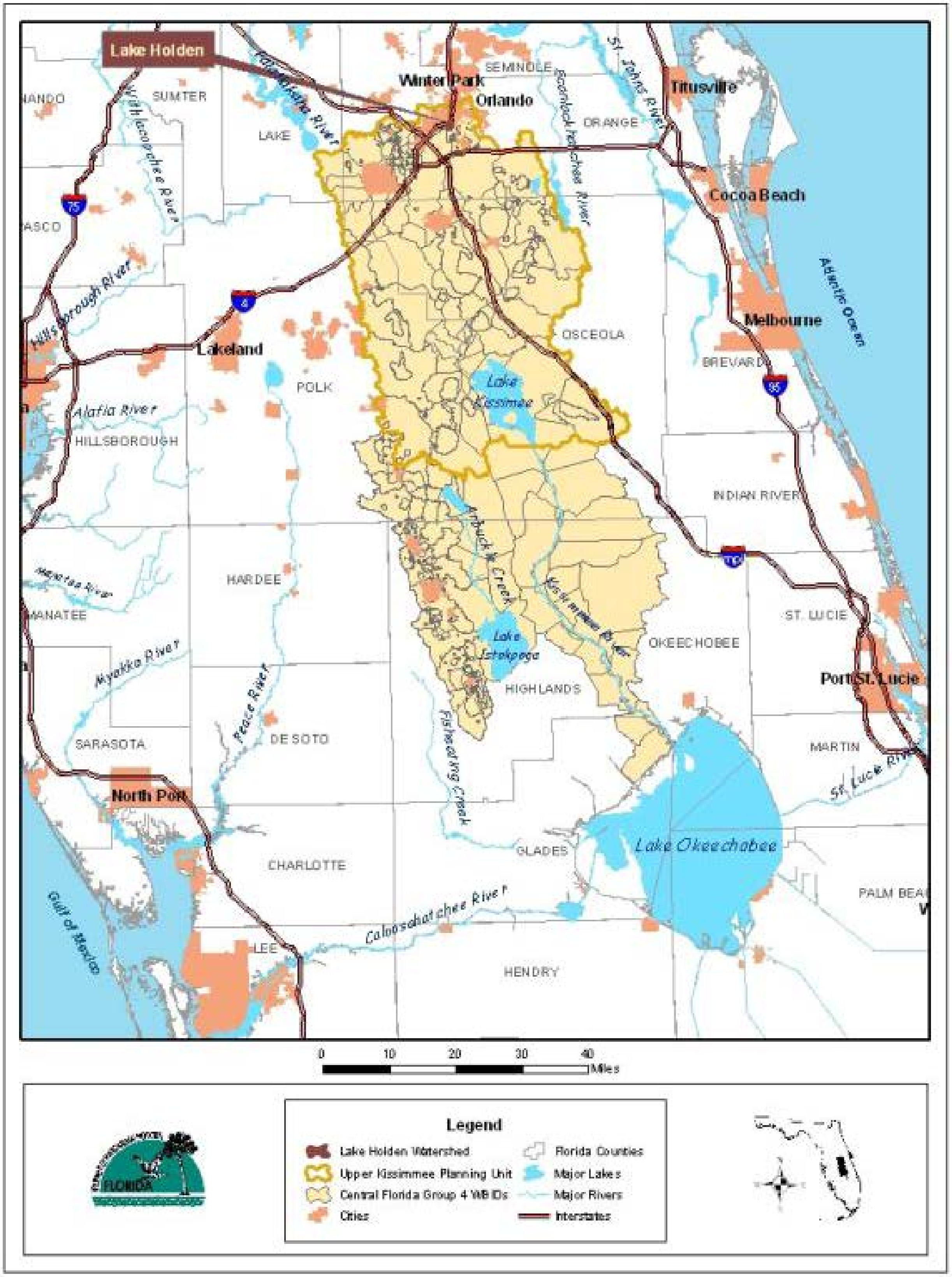

Figure 1.1. Upper Kissimmee Planning Unit and Lake Holden Watershed

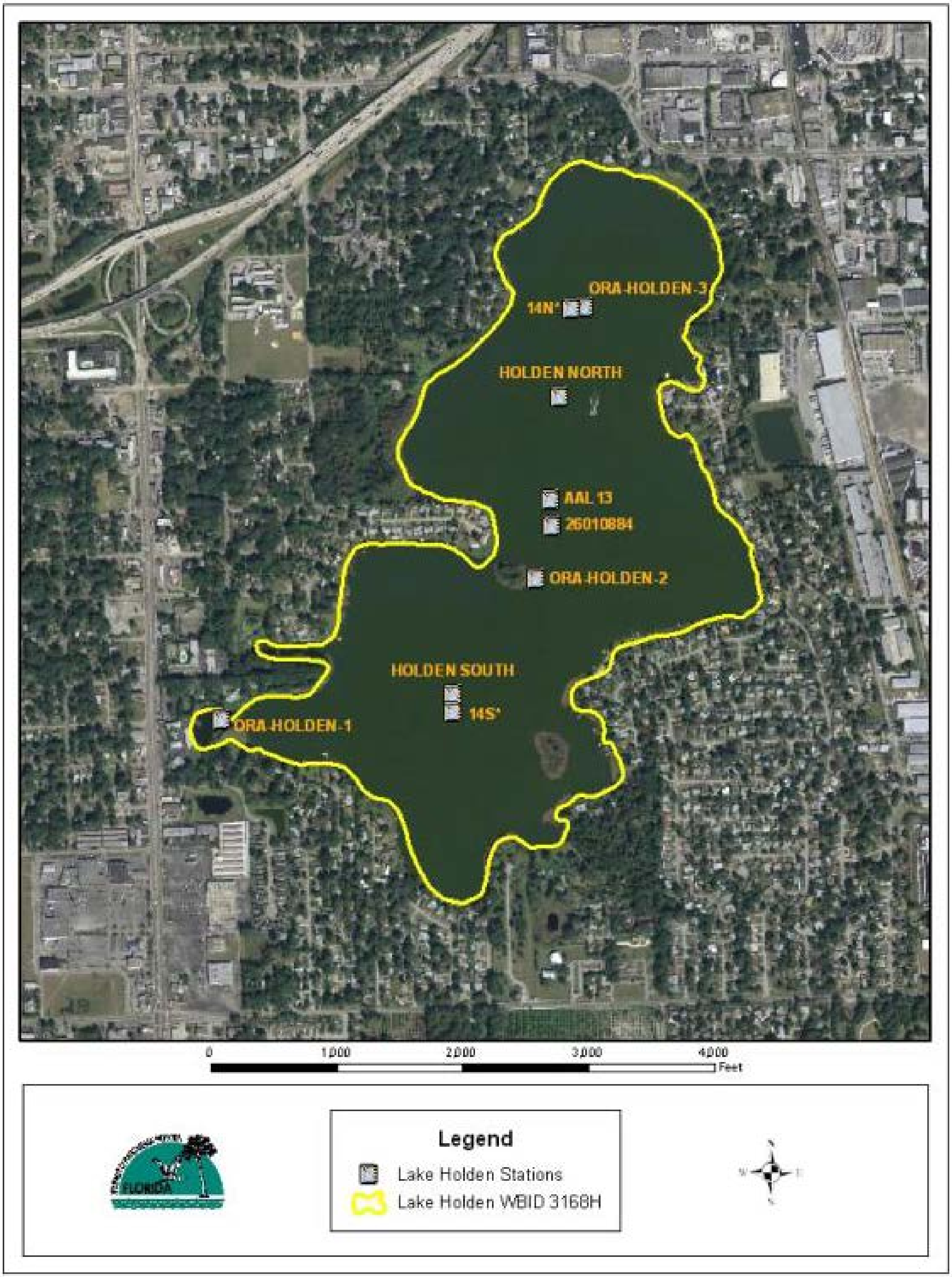

Figure 1.2. Lake Holden (WBID 3168H) and Monitoring Stations

1.3 Background Information

The TMDL report for Lake Holden is part of the implementation of the Department's watershed management approach for restoring and protecting water resources and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (FWRA) (Chapter 99-223, Laws of Florida).

A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet the waterbody's designated uses. A waterbody that does not meet its designated uses is defined as impaired. TMDLs must be developed and implemented for each of the state's impaired waters, unless the impairment is documented to be a naturally occurring condition that cannot be abated by a TMDL or unless a management plan already in place is expected to correct the problem.

The development and implementation of a Basin Management Action Plan, or BMAP, to reduce the amount of pollutants that caused the impairment will follow this TMDL report. These activities will depend heavily on the active participation of Orange County, the city of Orlando, the St. Johns River Water Management District (SJRWMD), 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 Holden is on Florida's 1998 303(d) list. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. The Environmental Regulation Commission adopted the new methodology as Rule 62-303, F.A.C. (Identification of Impaired Surface Waters Rule, or IWR), in April 2001; the rule was amended in 2006 and January 2007.

2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in Lake Holden. All data presented in this report are from IWR Run 40 and 46 (total nitrogen [TN], total phosphorus [TP], chlorophyll *a* [chl*a*]). Data were collected by the city of Orlando, Orange County, the Department, LakeWatch, and the SJRWMD. All data for TN, TP, and corrected chlorophyll *a* (cchl*a*) and chl*a* (shown in **Appendix D)** were processed by examining each result for appropriateness. All chl*a* results before July 14, 1998, are uncorrected; all other results are for cchl*a*. Any results that were rejected are highlighted and shown in boldface type with an asterisk.

Data reduction followed the procedures in Rule 62-303, F.A.C. ERD (2004) conducted an analysis of variance comparison (ANOVA) on all the data from each station (surface samples) in the lake to determine if there were any statistically significant differences. The results of this analysis indicated that the stations were ". . . statistically similar for all measured parameters, supporting the conclusion to average separate measurements performed on a single monitoring date."

For this analysis, all data were further reduced by calculating daily averages from all stations in the lake. These are the data from which graphs and summary statistics were prepared. The annual averages were calculated from these data by averaging for each calendar quarter and then averaging the four quarters to establish the annual average. 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 (January 1, 1998, to June 30, 2005). The impaired condition was documented as still present during the Cycle 2 verified period (January 1, 2003, to June 30, 2010).

The IWR methodology uses the water quality variables TN, TP, and chl*a* (a measure of algal mass, corrected and uncorrected) in calculating annual TSI values and annual average color in platinum cobalt units (PCU) in interpreting Florida's narrative nutrient threshold for lakes. Per the IWR methodology, exceeding a TSI of 40 in lakes with a color of 40 or less in any one year of the verified period is sufficient in determining nutrient impairment for a lake.

For Lake Holden, data were available for the 3 water quality variables and color for all 4 seasons in 1998, 2000, 2001, 2002, 2003, and 2007 of the Cycle 1 and Cycle 2 verified periods (**Figure 2.1**). The figure also shows that as the TSI has decreased over time (perhaps in response to the implementation of BMPs), the TN/TP ratio and the degree of TP limitation have gone up. The lowest TSI in 2006 (31.8) was recorded after the first whole-lake alum treatment to reduce the benthic flux of TP. The annual average color and TSI values for the Cycle 1 and Cycle 2 verified periods for the lake were 35 PCU/63 TSI (1998), 8 PCU/52 TSI (2000), 10 PCU/64 TSI (2001), 6 PCU/46 TSI (2002), 7 PCU/48 TSI (2003), 6 PCU/58 TSI (2004), and 7 PCU/44 TSI (2007). Per the IWR methodology, in a low-color environment, exceeding a TSI of 40 in any one year of the verified period is sufficient in determining nutrient impairment for a lake. Based on the data evaluated, Lake Holden is impaired for TSI, related to nutrients.

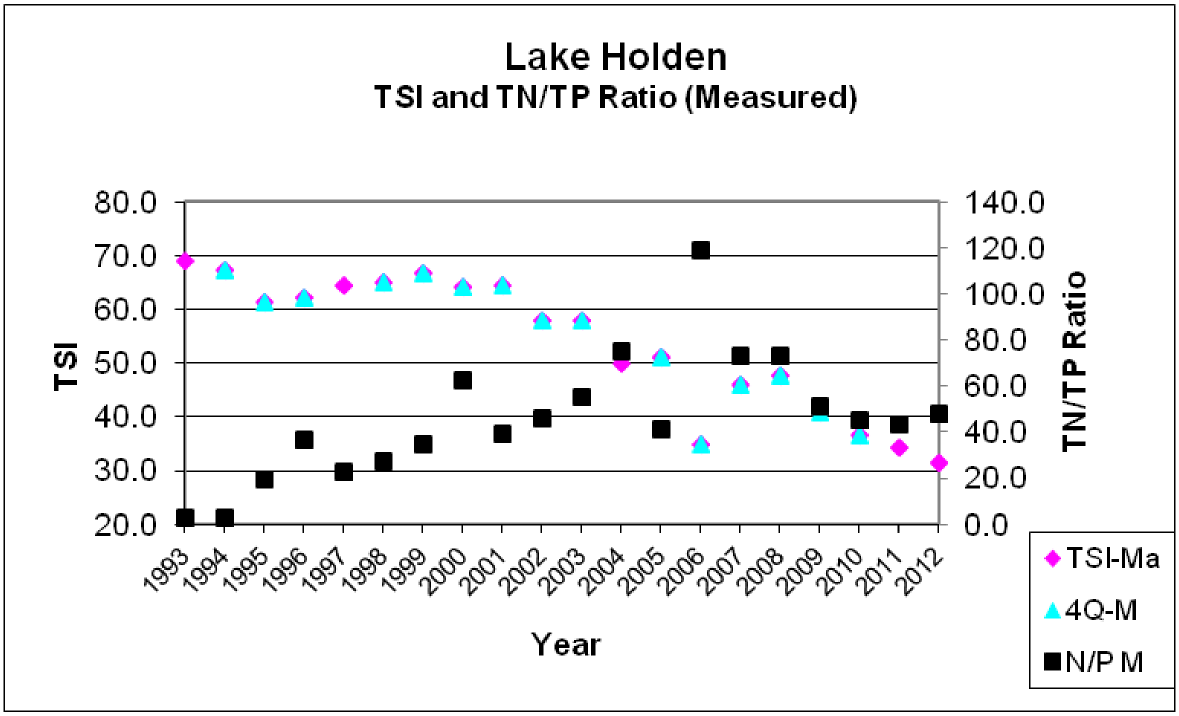

Figure 2.1. TSI and TN/TP Ratio Results for Lake Holden Calculated from Annual Average Concentrations of TP, TN, and Chl*a*, 1993–2012

TSI-Ma = TSI calculated from measured data; missing one or more of the four quarters of data.
4Q-M = TSI calculated from measured data, with data in all four calendar quarters.
N/P M = Nitrogen to phosphorus ratio using all available measured data.

2.3 Implementation of BMPs in the Lake Holden Watershed

Local stakeholders, Orange County, and the city of Orlando have been implementing BMPs in the Lake Holden watershed since 1983 (**Table 2.1**). ERD (2010) contains an excellent review of these BMPs and their effectiveness. Beginning in 1996 and 1997, alum injection systems were installed on three of the subbasins generating the largest per-acre loadings of TP to the lake. Although these BMPs have significantly improved water quality over time, Lake Holden was still impaired in 2007.

As shown in **Figure 2.2**, color in the lake was dramatically reduced beginning in 2000 and has remained below 15 PCU for all subsequent years. This information suggests a fundamental shift in the lake that started to become apparent around 2000.

Table 2.1. Lake Holden BMP Implementation Timeline

Approximate Year	Description	BMP Type	Area Treated
1983	Aeration (discontinued 2 years later)	Aeration	In-lake
1988	Westmoreland Pond	Dry Detention	Sub-basin 19 (all)
1997	In-line Alum Injection	Alum Stormwater Treatment	Sub-basins 1, 2, and 21 (all)
1997	Florida Department of Transportation (FDOT) Pond	Dry Detention	Subbasin 13 (all)
1997	Westmoreland Pond	Wet Retention	Subbasin 20 (partial)
1997	Start of Weekly Street Sweeping	Elgin Eagle	Various
2000	43rd Street Pond	Wet Retention	Subbasin 12 (all)
2002	Minor Submerged Aquatic Vegetation (SAV) Planting	Submerged Plants	In-lake
2005	Holden Terrace Continuous Deflective Separation (CDS) Unit	CDS	Subbasin 2 (all)
2006	Surface Alum Treatment	Liquid Alum 768 Dry Tons (approximately)	Whole lake
2008	First Installation of Approximately 60 Catch Basin Inserts	Curb/Grate Basket Inserts	Various
2009	Second Installation of Approximately 60 Additional Catch Basin Inserts	Curb/Grate Basket Inserts	Various
2009	Weekly Sweeping 32 Events/Year; Biweekly Sweeping 32 Events/Year	Elgin Eagle	Various
2010	Surface Alum Treatment	Liquid Alum 260 Dry Tons (approximately)	Whole lake

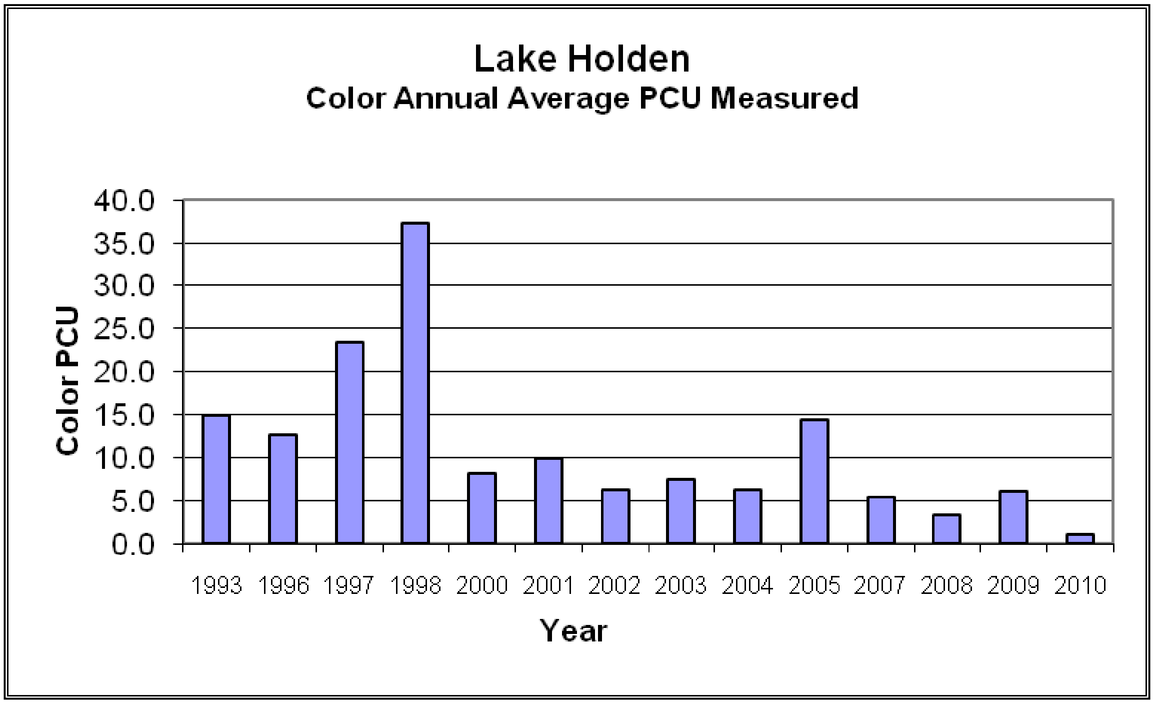

Figure 2.2. Annual Average Color (PCU), 1993–2010

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

$CHLA_{TSI} = 16.8 + 14.4 * LN(Chla)$ Chlorophyll *a* (chl*a*) in micrograms per liter (µg/L)
$TN_{TSI} = 56 + 19.8 * LN(N)$ Nitrogen in milligrams per liter (mg/L)
$TN2_{TSI} = 10 * [5.96 + 2.15 * LN(N + 0.0001)]$ Phosphorus in mg/L
$TP_{TSI} = 18.6 * LN(P * 1000) – 18.4$
$TP2_{TSI} = 10 * [2.36 * LN(P * 1000) – 2.38]$

If $N/P > 30$, then $NUTR_{TSI} = TP2_{TSI}$
If $N/P < 10$, then $NUTR_{TSI} = TN2_{TSI}$
if $10 < N/P < 30$, then $NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2$

$TSI = (CHLA_{TSI} + NUTR_{TSI})/2$ **Note:** TSI has no units

The Hydrologic Simulation Program FORTRAN (HSPF) model was run for 1996 through 2006. For modeling purposes, the analysis of the eutrophication-related data presented in this report for Lake Holden used all of the available data from 1996 to 2006 for which records of TP, TN, and chl*a* were sufficient to calculate seasonal and annual average conditions. However, the comparisons in the CDM report (2008) 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 chl*a* taken within the same quarter (each season) of the year.

Key to Figure Legends

C = Results for calibrated/validated model

Ma = Results for measured data; does not include data from all four quarters

4Q-M = Results for measured data; at least one set of data from all four quarters

Figure 2.3 illustrates the results of a comparison of monthly average TN data over two different periods: 1993 to 2000 and 2001 to 2009. These results indicate that not only was TN reduced after 2000 but that the improvement occurred during all months.

Figures 2.4 (daily) and **2.5** (annual) show the decline in TN over time within the lake. These graphs illustrate that prior to 2000 (the driest year in the period from 1996 to 2006), TN increased to a maximum in 2000 and then steadily declined. A steep reduction was seen in 2006, potentially in response to the whole-lake alum treatment to reduce internal fluxes of TP. While lake TN increased in 2007 to 2008, current data (2009 to 2012) indicate that lake TN concentrations are averaging around 0.6 mg/L.

Figure 2.6 shows the results of a comparison of monthly average TP data over two different periods: 1993 to 2000 and 2001 to 2009. These data demonstrate that the improvement after 2000 has reduced seasonal variability within the lake and resulted in improvements during all months.

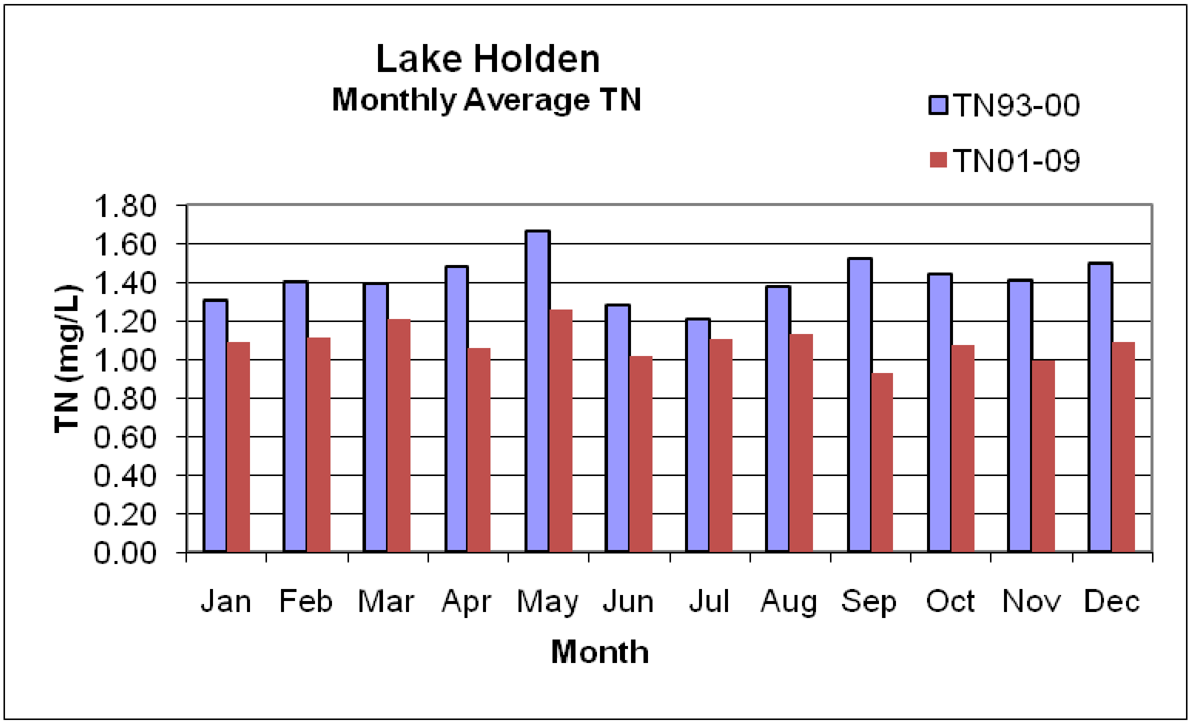

Figure 2.3. **TN Monthly Average Results for Lake Holden, 1993–2009**

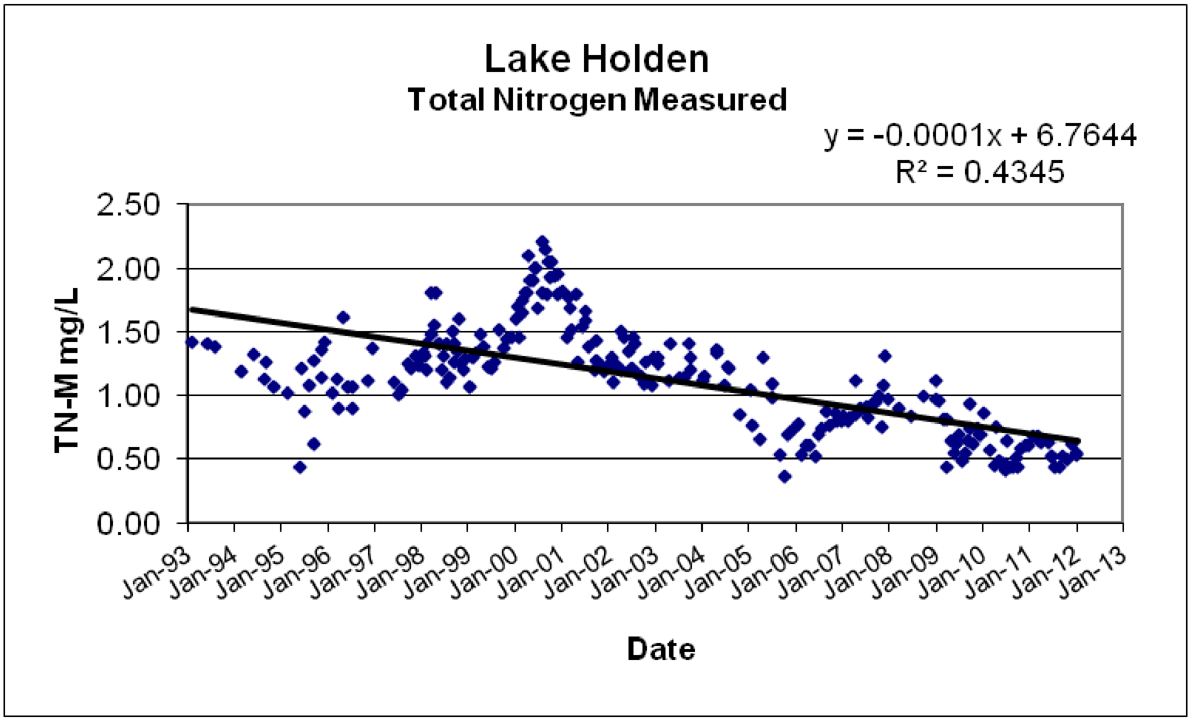

Figure 2.4. **TN Daily Average Results for Lake Holden, 1993–2012**

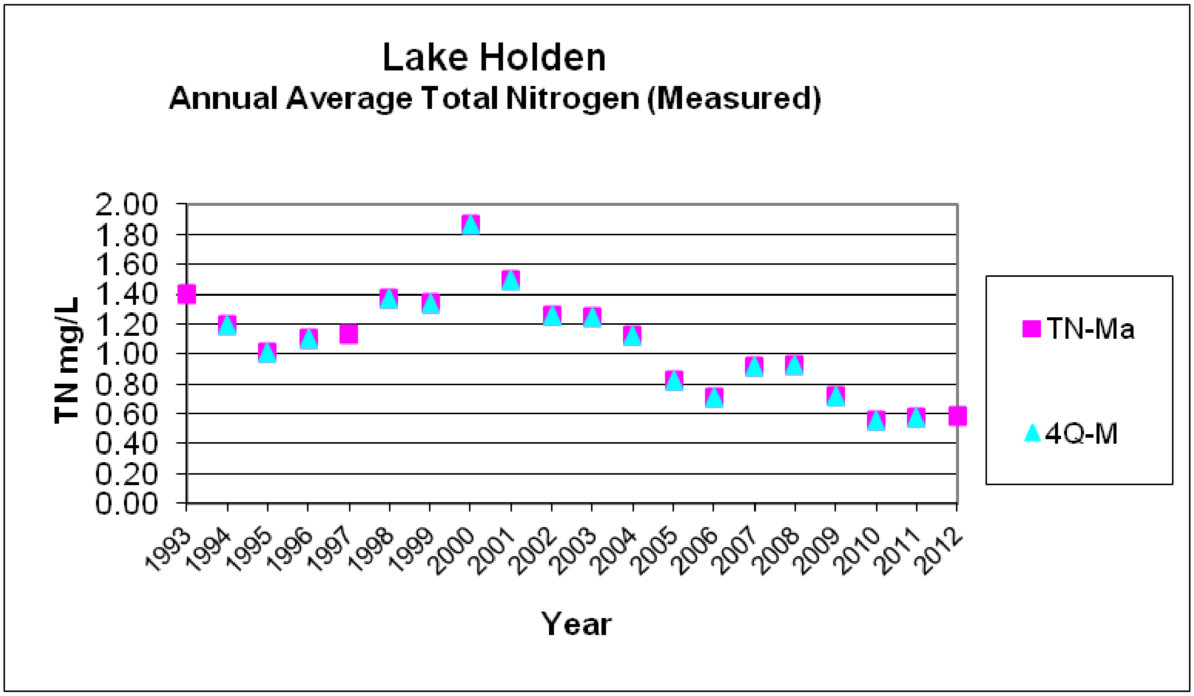

Figure 2.5. **TN Annual Average Results for Lake Holden, 1993–2012**

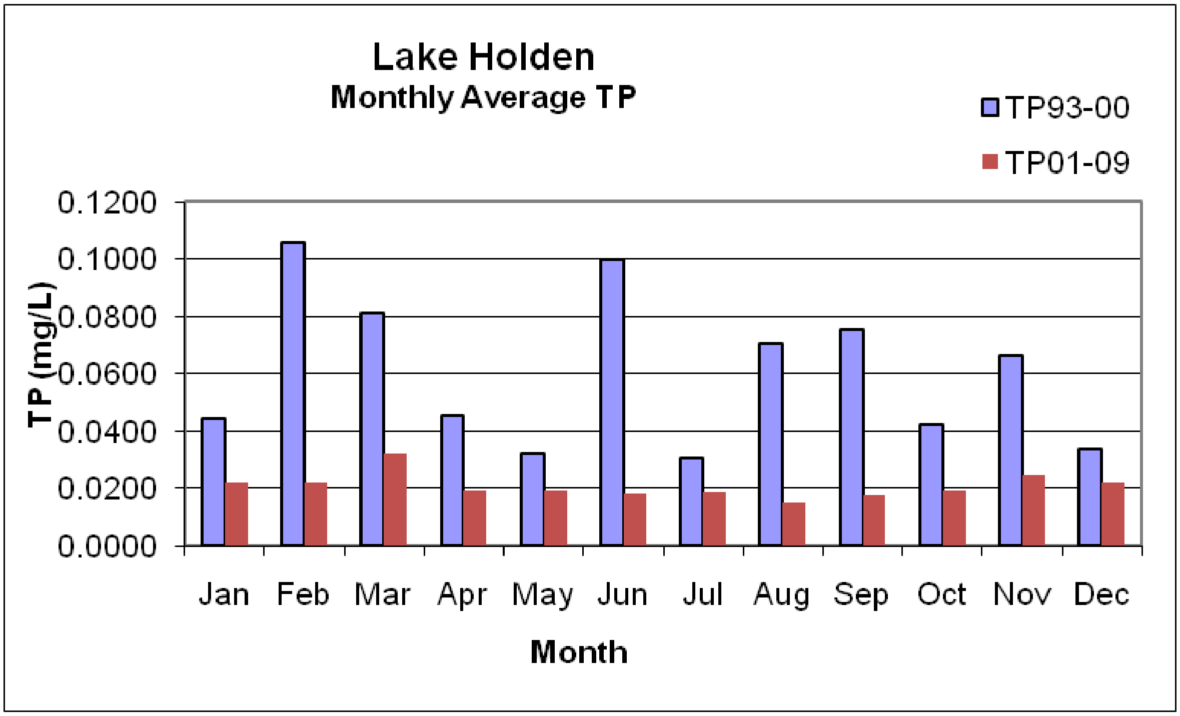

Figure 2.6. **TP Monthly Average Results for Lake Holden, 1993–2009**

Figures 2.7a (daily from 1993 to 2012), **2.7b** (daily from 1995 to 2012), **2.8a** (annual from 1993 to 2012), and **2.8b** (annual from 1995 to 2012) show that TP has declined over time within the lake and that since 1995, the decline has been even more pronounced than over the whole period of record. From **Figure 2.8a**, it can be seen that prior to 1995, TP in the lake was nearly 0.4 mg/L. As shown in **Figure 2.8b**, beginning in 1996, annual averages ranged from about 0.03 to 0.04 mg/L through 2000, and then began to decline significantly (2000 was the driest year between 1996 and 2006). A steep reduction was seen in 2006 (annual average 0.006 mg/L), potentially in response to the whole-lake alum treatment to reduce internal fluxes of TP. While lake TP increased after 2006, it has not returned to pre-2005 levels and appears to have stabilized between 0.12 and 0.15 mg/L.

Figure 2.9 shows the results of a comparison of monthly average chl*a* data over two different periods: 1993 to 2000 and 2001 to 2009. These data demonstrate that the improvement after 2000 has reduced seasonal variability within the lake and resulted in improvements during all months.

Figures 2.10 (daily) and **2.11** (annual), show the decline in chl*a* over time within the lake. From these graphs it can be seen that prior to 2000, chl*a* in the lake was highly variable, with measurements frequently over 50 µg/L. Beginning around 2000, annual average chl*a* began to decline significantly, with a slight upturn in 2007. Current data (2009 to 2012) indicate that the chl*a* has not returned to pre-2005 levels and remains below the 12.1 µg/L TMDL target concentration.

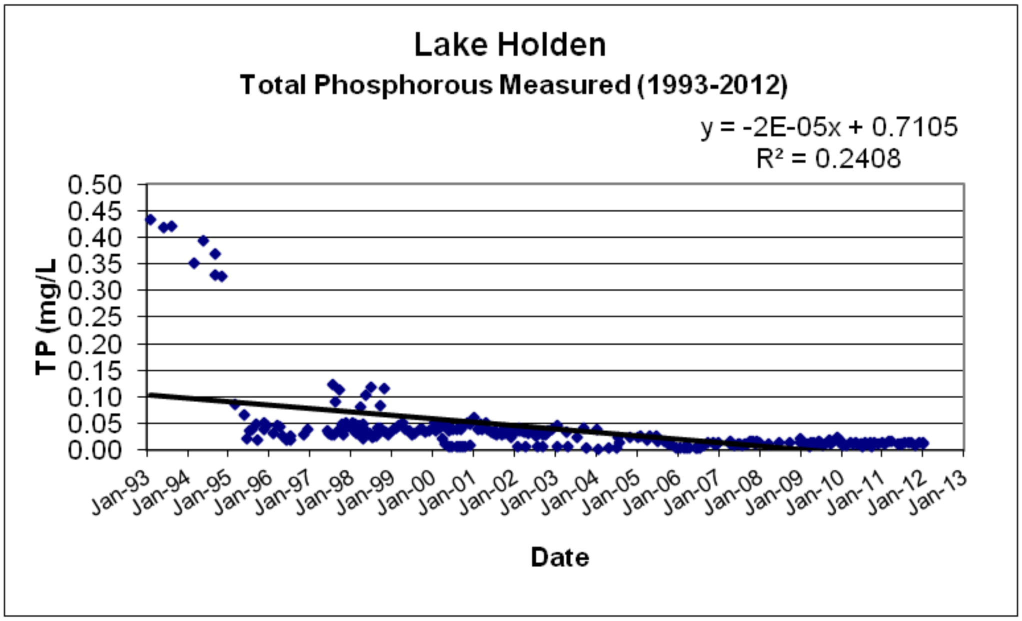

Figure 2.7a. TP Daily Average Results for Lake Holden, 1993–2012

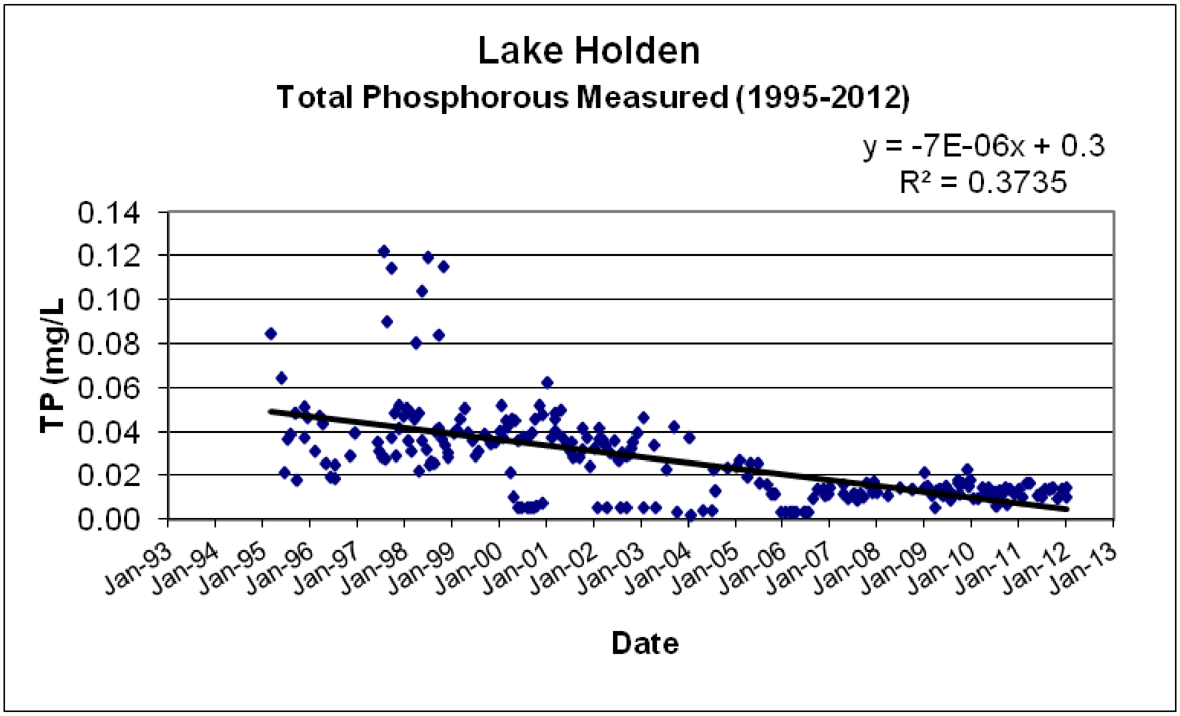

Figure 2.7b. TP Daily Average Results for Lake Holden, 1995–2012

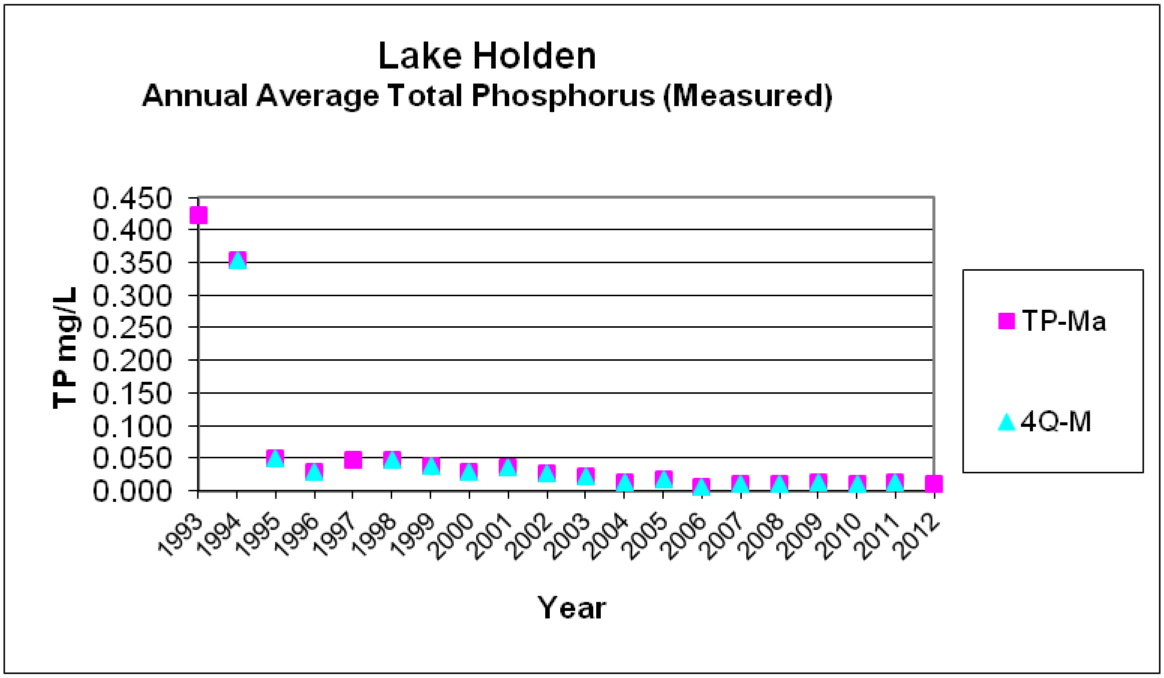

Figure 2.8a. TP Annual Average Results for Lake Holden, 1993–2012

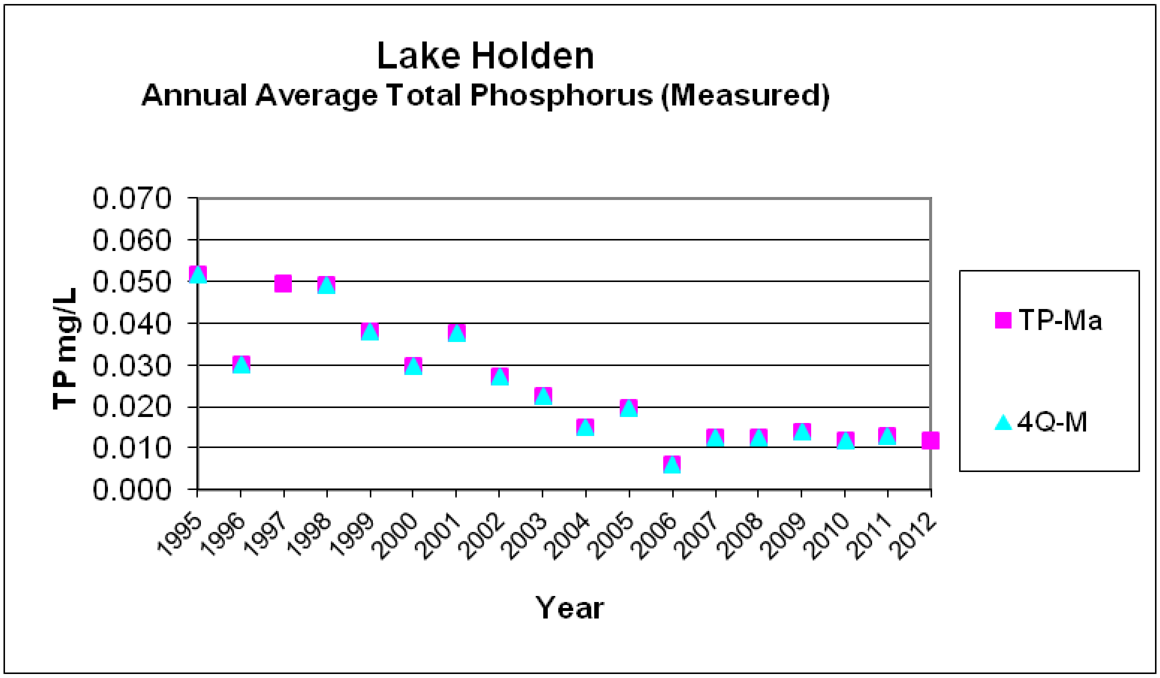

Figure 2.8b. **TP Annual Average Results for Lake Holden, 1995–2012**

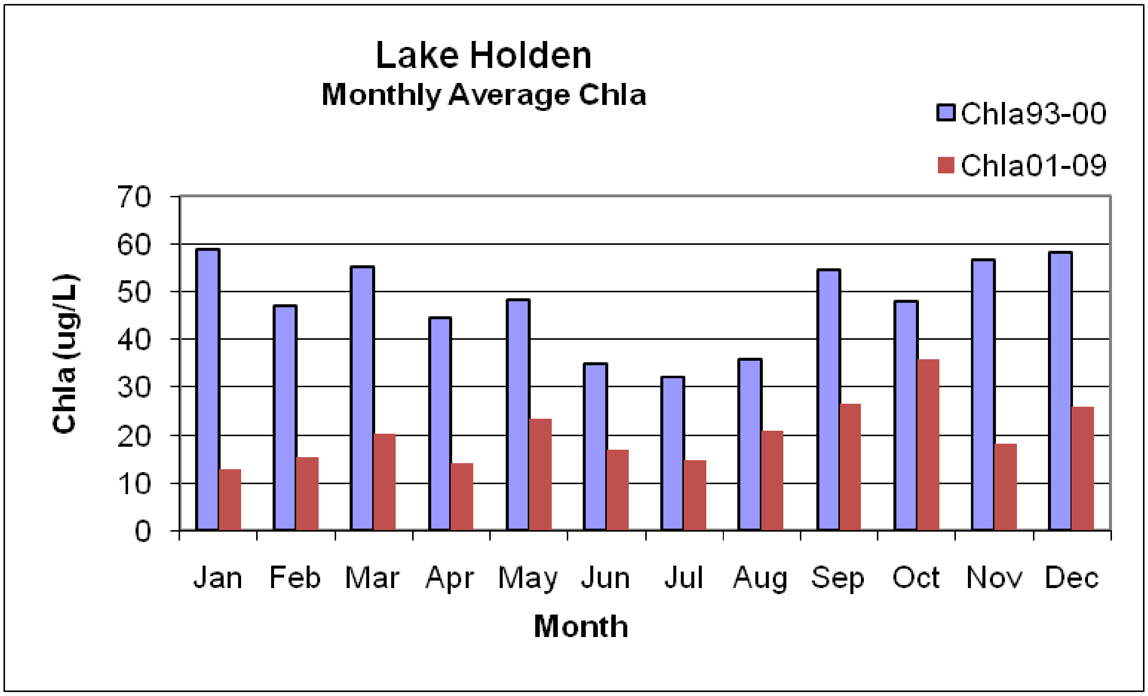

Figure 2.9. **Chl*a* Monthly Average Results for Lake Holden, 1993–2009**

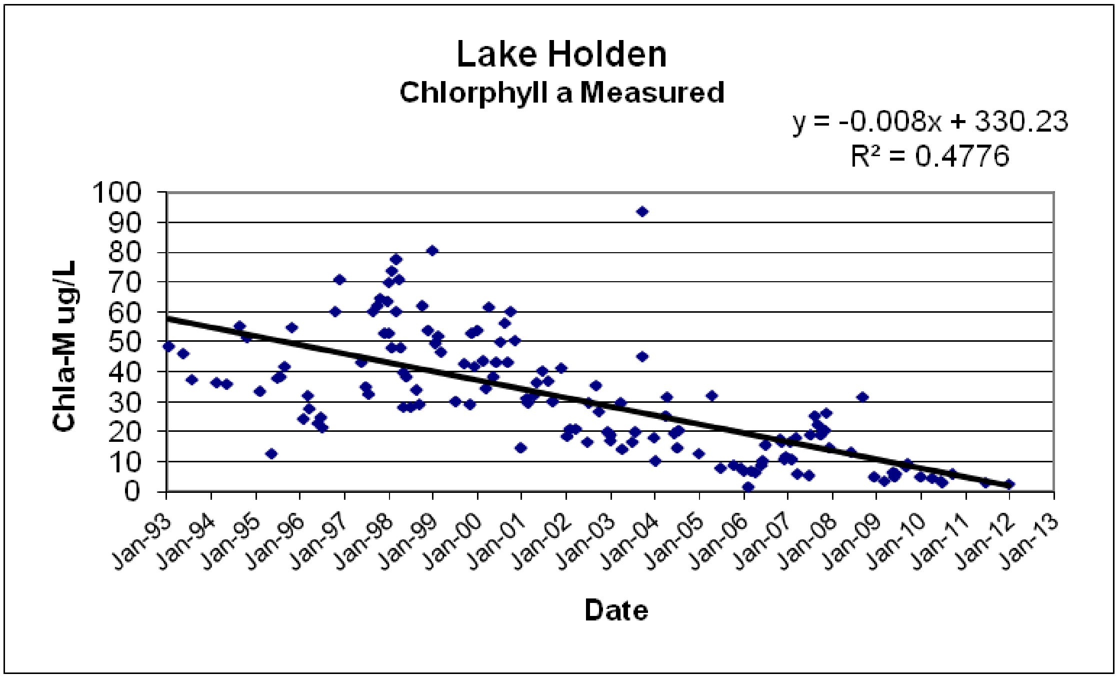

Figure 2.10. Chl*a* Daily Average Results for Lake Holden, 1993–2012

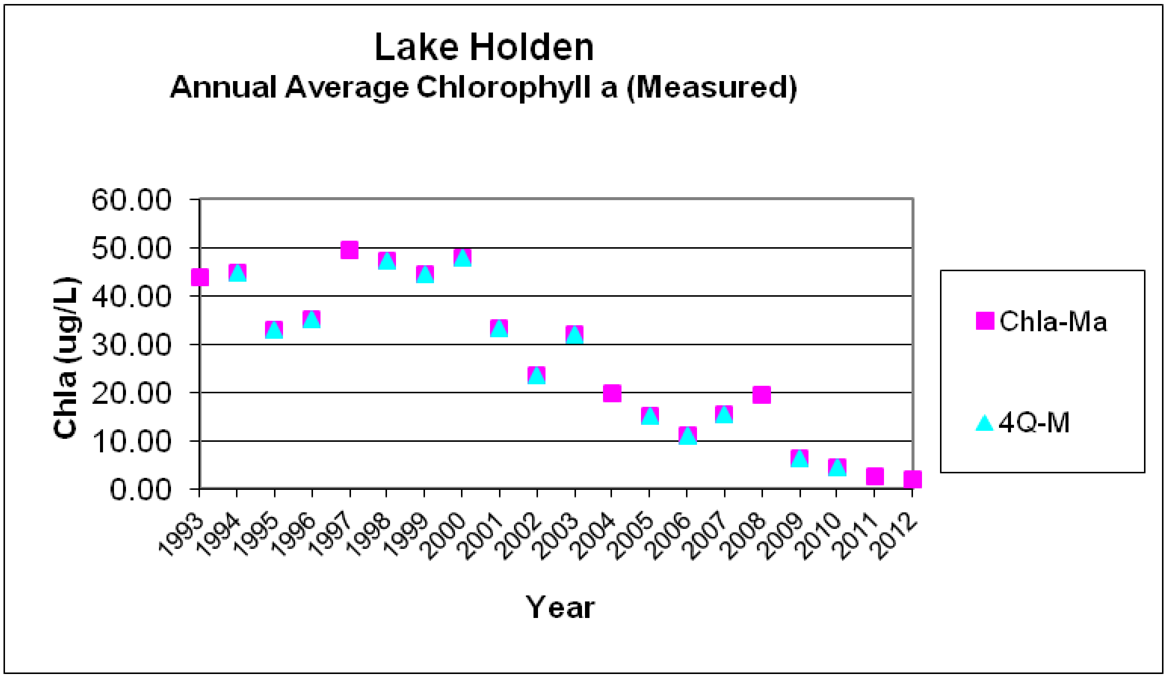

Figure 2.11. Chl*a* Annual Average Results for Lake Holden, 1993–2012

The data depicted for alkalinity and pH in **Figures 2.12** and **2.13** illustrate some potential issues with the extended use of alum to remove TP. The alkalinity results show a dramatic decline after the whole-lake alum treatment, and reductions in pH over time may be related to alum injection to stormwater. These issues are covered in more detail in the ERD reports (2008; 2010).

Figure 2.14 depicts the changes in Secchi disk depth over time. Again, from these data it appears that increases in Secchi depth (light penetration) started to be pronounced in 2000, increased sharply in response to the whole-lake alum treatment, and remain higher than pre-2000 levels.

Table 2.2 provides summary statistics for the lake for TN, TP, chl*a*, color, alkalinity, pH, and Secchi depth from 1993 to 2009. Individual water quality measurements (raw data) for these TN, TP, and chl*a* used in the assessment are provided in **Appendix D**.

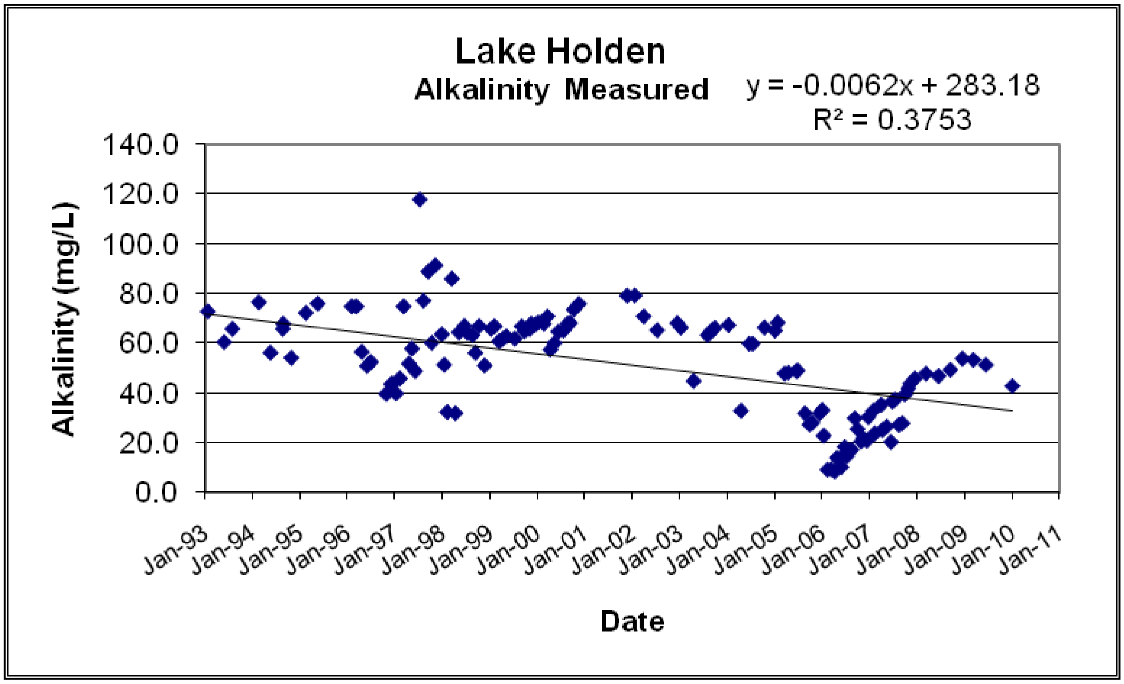

Figure 2.12. Alkalinity Daily Average Results for Lake Holden, 1993–2009

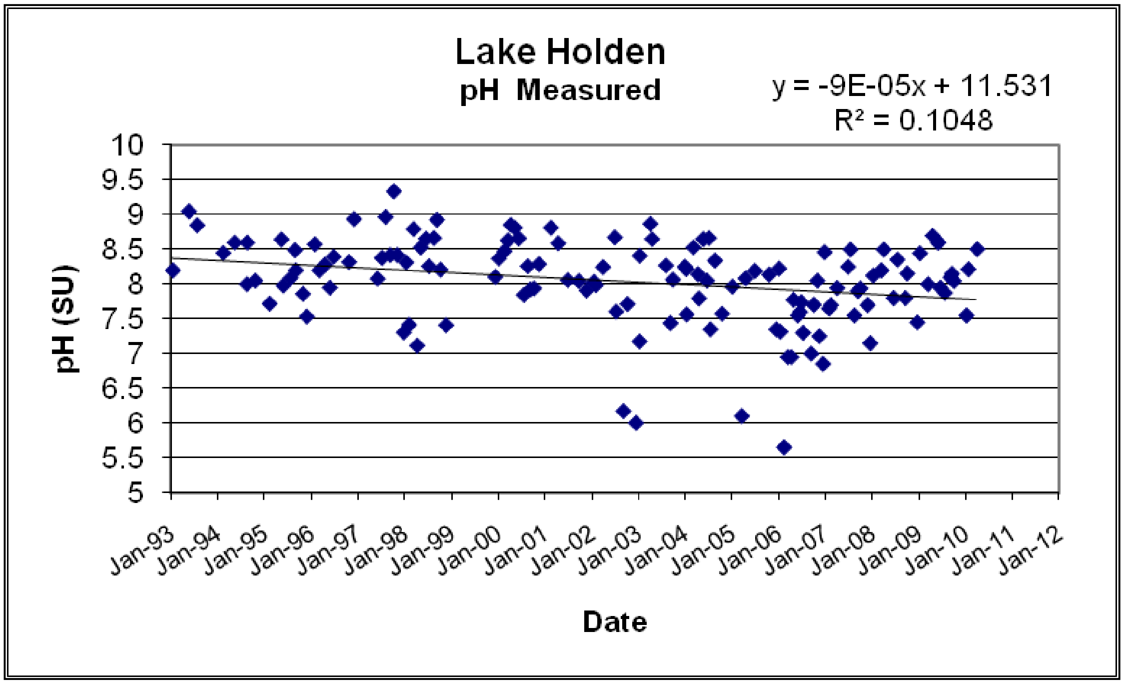

Figure 2.13. pH Daily Average Results for Lake Holden, 1993–2009

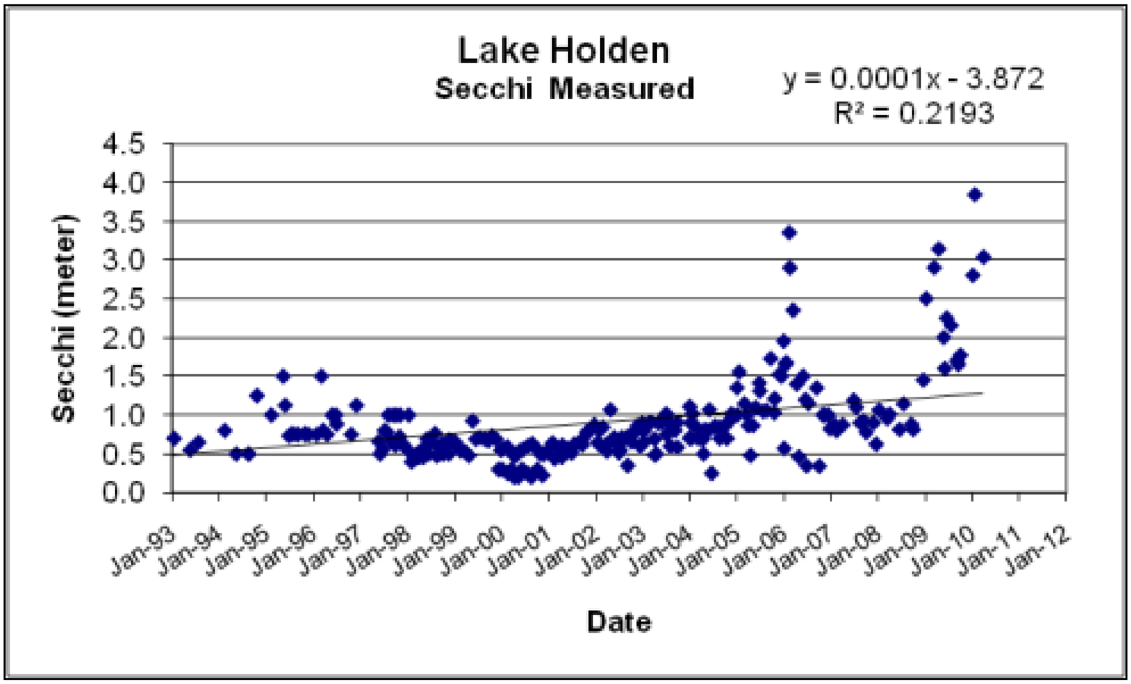

Figure 2.14. Secchi Depth Daily Average Results for Lake Holden, 1993–2009

Table 2.2. Water Quality Summary Statistics for TN, TP, Chla, Color, Alkalinity, pH, and Secchi Depth for Lake Holden, 1993–2009

Statistic	TN (mg/L)	TP (mg/L)	Chl*a* (µg/L)	Color (PCU)	Alkalinity (mg/L)	pH (standard units [SU])	Secchi Depth (meters)
Number of Samples (1993–2009)	424	433	267	130	258	257	555
Number of Samples (1996–2000)	177	182	103	58	92	65	190
Number of Samples (2001–09)	212	216	135	70	139	163	327
Minimum (1993–2009)	0.325	0.002	1.0	1.2	2.0	5.43	0.10
Minimum (1996–2000)	0.880	0.005	8.6	5.0	3.2	5.43	0.20
Minimum (2001–09)	0.353	0.002	1.0	1.2	2.0	5.53	0.10
Mean (1993–2009)	1.246	0.041	33.3	13.0	49.7	8.02	0.87
Mean (1996–2000)	1.453	0.038	48.9	20.0	62.6	8.31	0.60
Mean (2001–09)	1.090	0.021	19.7	7.1	37.7	7.86	1.03
Median (1993–2009)	1.240	0.031	31.0	10.0	54.0	8.10	0.75
Median (1996–2000)	1.380	0.037	49.0	10.0	63.9	8.39	0.61
Median (2000–09)	1.120	0.017	17.7	5.0	37.2	7.98	0.85
Maximum (1993–2009)	2.400	0.446	94.1	220.0	121.0	9.34	3.88
Maximum (1996–2000)	2.400	0.122	83.0	220.0	121.0	9.34	1.50
Maximum (2000–09)	1.880	0.086	94.1	25.0	79.8	8.94	3.88

As can be seen in **Tables 2.2** and **2.3**, the mean and median TN concentrations were reduced from 1996 to 2000 by 25% and 19%, respectively. The mean and median TP concentrations were reduced from 1996 to 2000 by 45% and 54%, respectively. The mean and median chl*a* concentrations were reduced from 1996 to 2000 by 60% and 64%, respectively. The mean and median color concentrations were reduced from 1996 to 2000 by 64% and 50%, respectively. The mean and median alkalinity concentrations were reduced from 1996 to 2000 by 40% and 42%, respectively. The mean and median pH concentrations were reduced from 1996 to 2000 by 5%. The mean and median Secchi depths increased from 1996 to 2000 by 72% and 40%, respectively.

All of these data support the conclusion that the implementation of BMPs in the Lake Holden watershed has resulted in significant improvements in water quality. Given that the initial effects of the BMPs were not immediately apparent in lake water quality, the in-lake effects of the continued implementation of BMPs since 2000 may not yet be fully realized in the lake data.

Table 2.3. Percent Change for TN, TP, Chl*a*, Color, Alkalinity, pH, and Secchi Depth for Lake Holden, 1996–2000 and 2001–09

Change	TN	TP	Chl*a*	Color	Alkalinity	pH	Secchi Depth
Mean	-25.0%	-45.4%	-59.8%	-64.4%	-39.8%	5.4%	72.0%
Median	-18.8%	-54.1%	-63.9%	-50.0%	-41.8%	-4.9%	40.0%

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criterion 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 Holden 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 Holden is the state of Florida's narrative nutrient criterion (Paragraph 62-302.530[48][b], F.A.C.). This TMDL constitutes the site-specific numeric interpretation of the narrative nutrient criterion pursuant to 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 combined verified periods for Cycle 1 (i.e., January 1, 1998, to June 30, 2005) and Cycle 2 (i.e., January 1, 2003, to June 30, 2010) were evaluated to determine the limiting nutrient(s). If all the sampling event ratios were less than 10, nitrogen was identified as the limiting nutrient, and if all the ratios were greater than 30, phosphorus was identified as the limiting nutrient. Both nitrogen and phosphorus were identified as limiting nutrients if the ratios were between 10 and 30. For Lake Jackson, the mean TN/TP ratio was 15.2 for the combined verified periods, indicating co-limitation of TP and TN for the lake.*

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

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

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

The Florida-specific TSI was determined based on the analysis of data from 313 Florida lakes. The index was adjusted so that a chl*a* concentration of 20 μg/L was equal to a chl*a*-TSI value of 60. The final TSI for any lake may be higher or lower than 60, depending on the TN- and TP-TSI values. A TSI of 60 was then set as the threshold for nutrient impairment for most lakes (for those with color higher than 40 PCU) because, generally, phytoplankton communities may become dominated by blue-green algae at chl*a* levels above 20 µg/L. These blue-green algae are often an undesirable food source for zooplankton and many other aquatic animals. Some blue-green algae may even produce toxins, which could be harmful to fish and other animals. In addition, excessive phytoplankton growth and the subsequent death of these algae may consume large quantities of dissolved oxygen (DO) and result in anaerobic conditions in a lake, resulting in unfavorable conditions 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 Holden TMDL, the Department applied the HSPF model to simulate water quality discharges and eutrophication processes in order to determine the appropriate nutrient target. The HSPF model was used to estimate existing conditions in the Lake Holden watershed and the background TN, TP, and cchl*a* concentrations by setting land uses to natural or forested land. The results for the background condition were used in association with information published by the EPA (2009a; 2009b) to develop the TMDL target.

3.3 Narrative Nutrient Criteria 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 for 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 regulate 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 Holden watershed is a closed-basin lake located within Orange County. As TMDLs are being developed for several other lakes within Orange County and the city of Orlando, the Department contracted with CDM to gather all available information and to set up, calibrate, and validate HSPF model projects for these lakes. **Appendix B** provides contact information to obtain the CDM report (2008) and modeling files.

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 Jackson. 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 Holden 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 NPDES wastewater treatment facilities or industrial wastewater facilities that discharge directly to Lake Holden. The facilities listed in **Table 4.1** are within the Lake Holden watershed but were not included in the model, as they are not surface water dischargers.

Table 4.1. NPDES/Florida-Permitted Facilities

NPDES Permit ID	Facility Name	Receiving Water	Permitted Capacity (million gallons per day [mgd])	Downstream Impaired WBID	Comments
FLG110116	Preferred Materials-Division Street Ready Mix Plant	None	Not Applicable	3168H Lake Holden	No surface water discharge
FLG110787	CEMEX Construction Materials FL LLC – Grant Street Ready Mix Plant	None	Not Applicable	3168H Lake Holden	No surface water discharge
FLG110786	Tarmac-Orlando Downtown Concrete Batch Plant	None	Not Applicable	3168H Lake Holden	No surface water discharge

Municipal Separate Storm Sewer System Permittees

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

The stormwater collection systems in the Lake Holden watershed, which are owned and operated by the city of Orlando, are covered by NPDES Phase I MS4 Permit Number FLS000014. The collection systems for FDOT District 5 are covered by NPDES Permit Number FLR04E024. The collection systems for the Florida Turnpike are covered by NPDES Permit Number FLR04E049. The collection systems for Orange County are covered by Phase 1 NPDES Permit Number FLS000011.

4.2.2 Nonpoint Sources and Land Uses

Unlike traditional point source effluent loads, nonpoint source loads enter at so many locations and exhibit such large temporal variation that a direct monitoring approach is often infeasible. For the Lake Holden TMDL, significant studies of stormwater and the lake have been conducted by ERD (1992; 2004; 2008; 2010). The information contained in these documents was used to explain changes in water quality over time and to set up and calibrate the HSPF model for Lake Holden.

The TMDL was produced by the use of a watershed and lake modeling approach utilizing HSPF. Land use coverages in the watershed and subbasin were aggregated using the Florida Land Use, Cover, and Forms Classification System (FDOT 1999) into nine different land use categories: cropland/improved pasture/tree crops (agriculture), unimproved pasture/woodland pasture (pasture), rangeland/upland forests, commercial/industrial, high-density residential, low-density residential, medium-density residential, water, and wetlands. The spatial distribution and acreage of different land use categories for HSPF were initially identified using the 2000 land use coverage (scale 1:24,000) provided by the South Florida Water Management District (SFWMD) and refined using the data contained in ERD (1992; 2004).

Table 4.2 shows the existing area of the various land use categories in the Lake Holden watershed (the surface area of water not included). **Figure 4.1** shows the drainage area of Lake Holden and the spatial distribution of the land uses shown in **Table 4.2**. **Figure 4.2** (from ERD [2004]) depicts the location of each of the 24 subbasins (based on the stormwater drainage network) that are identified in **Table 4.3** (from ERD [2004]).

The predominant land coverages for the Lake Holden watershed include medium-density residential (51.5%), with all residential (52.8%), commercial/industrial (35.2%), forest (5.7%), wetlands (5.1), and limited amounts of agriculture (1.2%). Lake Holden is a closed basin and drains to several drainage wells located within the lake.

Orange County Population

According to the U.S. Census Bureau (U.S. Census Bureau 2010), the county occupies an area of approximately 907.45 square miles. The total population estimate in 2000 (2010 Census data were not yet available) for Orange County, which includes (but is not exclusive to) the Lake Holden watershed, was 896,354; the estimate for 2009 is 1,086,480, a 21% increase. The population density in Orange County in 2000 was at or less than 988 people per square mile. For all of Orange County (2009), the

Bureau reported a housing density of 511 houses per square mile. Orange County is well above the average housing density for Florida counties of 164 housing units per square mile.

Septic Tanks

Onsite sewage treatment and disposal systems (OSTDS), including septic tanks, are commonly used 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. *Section 2.5.2.1, Septic Tanks*, of the CDM report (2008) describes in detail how septic tanks were included in the HSPF model and identifies the estimated number of septic tanks in the watershed (**Table 4.4**).

In general, the HSPF 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 Holden and therefore these were not explicitly included in the model because (1) there is a limited number of septic tanks 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. ERD (1992) reported that septic tanks in the Lake Holden watershed could be contributing 17% of the estimated 790 kilograms per year (kg/yr) of TP, and 35% of the estimated 4,677 kg/yr of TN. ERD (1992) estimated that stormwater accounted for 82% of TP and 58% of TN, with direct precipitation contributing the final 1% of the TP and 7% of the TN going to the lake.

Orange County Septic Tanks

As of 2010, Orange County had a cumulative registry of 106,238 septic systems. Data for septic tanks are based on 1971 to 2010 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. For fiscal years 2000 to 2010, an average of 1,141 permits/year for repairs was issued in Orange County (Florida Department of Health [FDOH] 2011). Based on the number of permitted septic tanks estimated for 2010 (106,238) and housing units (463,707) located in the county, approximately 78% of the housing units are connected to a central sewer line (*i.e.*, WWTF), with the remaining 22% utilizing septic tank systems.

Table 4.2. Lake Holden Watershed Existing Land Use Coverage in 2004

Existing Land Use Coverage	Watershed (acres)	Watershed (%)
Agriculture	9.1	1.2%
Wetland	39	5.1%
Forest/rangeland	43.4	5.7%
Pastureland	0	0%
Commercial/industrial	269.7	35.2%
High-density residential	0.7	0.1%
Medium-density residential	395	51.5%
Low-density residential	9.5	1.2%
Sum	**766.4**	**100%**

Table 4.3. Lake Holden 24 Subbasins from ERD (2004), Table 3.2

\- = Empty cell/no data
Note: Subbasin 15 is landlocked and not included in the total.

Drainage Subbasin	Area (acres)	Storm Sewer System
1	98.8	54" reinforced concrete pipe (RCP) along Division Avenue
2	65.7	48" x 76" RCP along Lake Holden Terrace
3	19.7	18" culvert at west end of Pineloch Avenue
4A	89.3	36" RCP west of detention pond
4B	12.8	Pumped overflow from wet detention pond
5	10.4	24" culvert along MacArthur Drive
6	8.8	Two 18" culverts along DeKalb Drive
7	52.9	48" RCP along Krueger Street
8	7.8	Drainage canal
9	6.8	24" culvert along Springwood Drive
10A	10.9	24" culvert to canal along Raymar Drive
10B	8.0	18" culvert to canal along South Shore Road
11	10.8	24" culvert at end of Almark Road
12	26.3	48" RCP into small west lobe
13	81.5	60" RCP along U.S. Highway 441 to FDOT Pond
14	3.6	30" RCP from Days Inn
15	-4.5	Land-locked basin
16	12.1	18" RCP along 38th Street
17	4.4	18" RCP along 37th Street
18	35.9	Vegetated channel
19	16.8	36" RCP from detention basin
20	60.9	36" culvert at end of 33rd Street
21	19.4	42" RCP along Paseo Street
22	105.5	Overland flow
Total	**769.2**	**-**

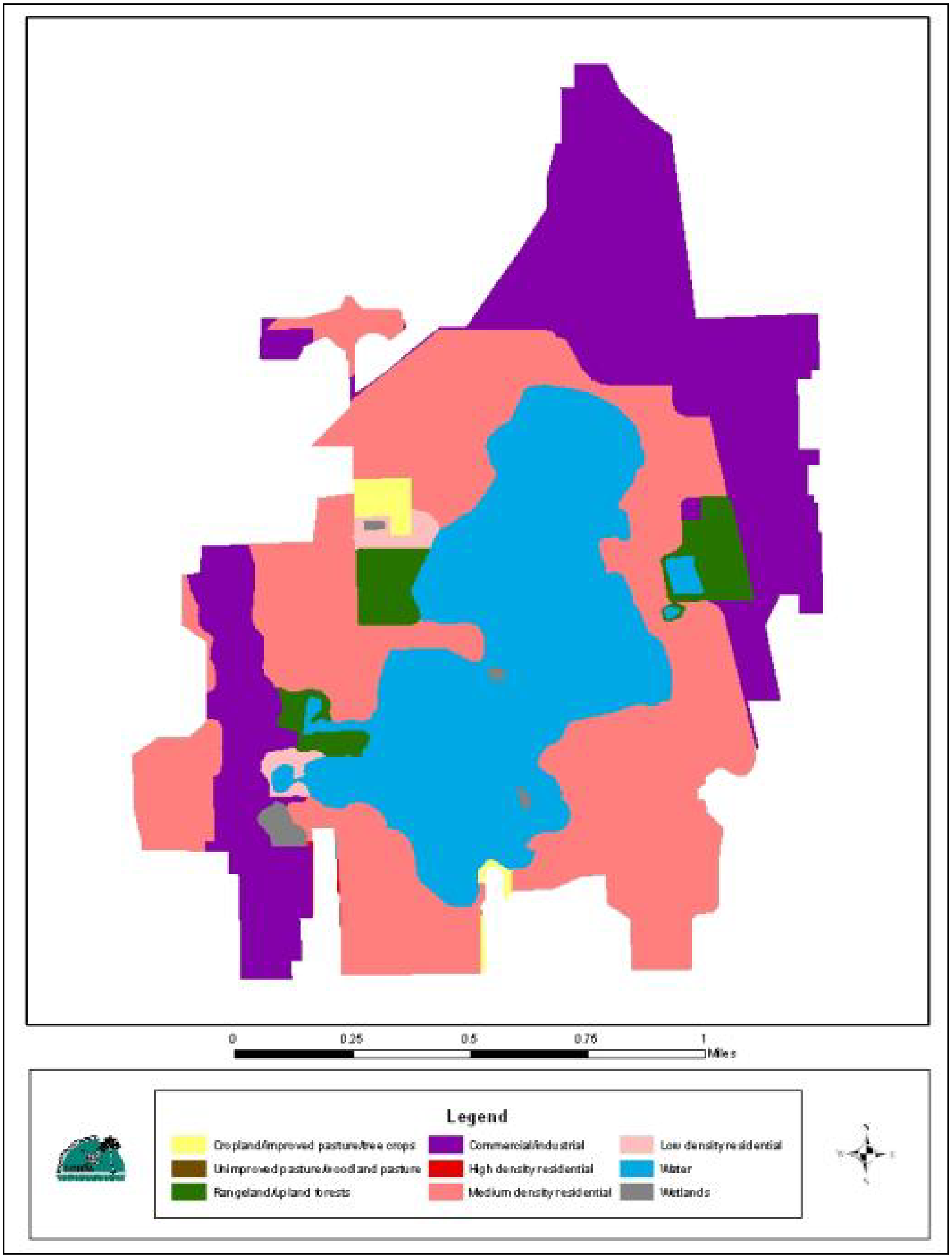

Figure 4.1. Lake Holden Watershed Existing Land Use Coverage in 2004

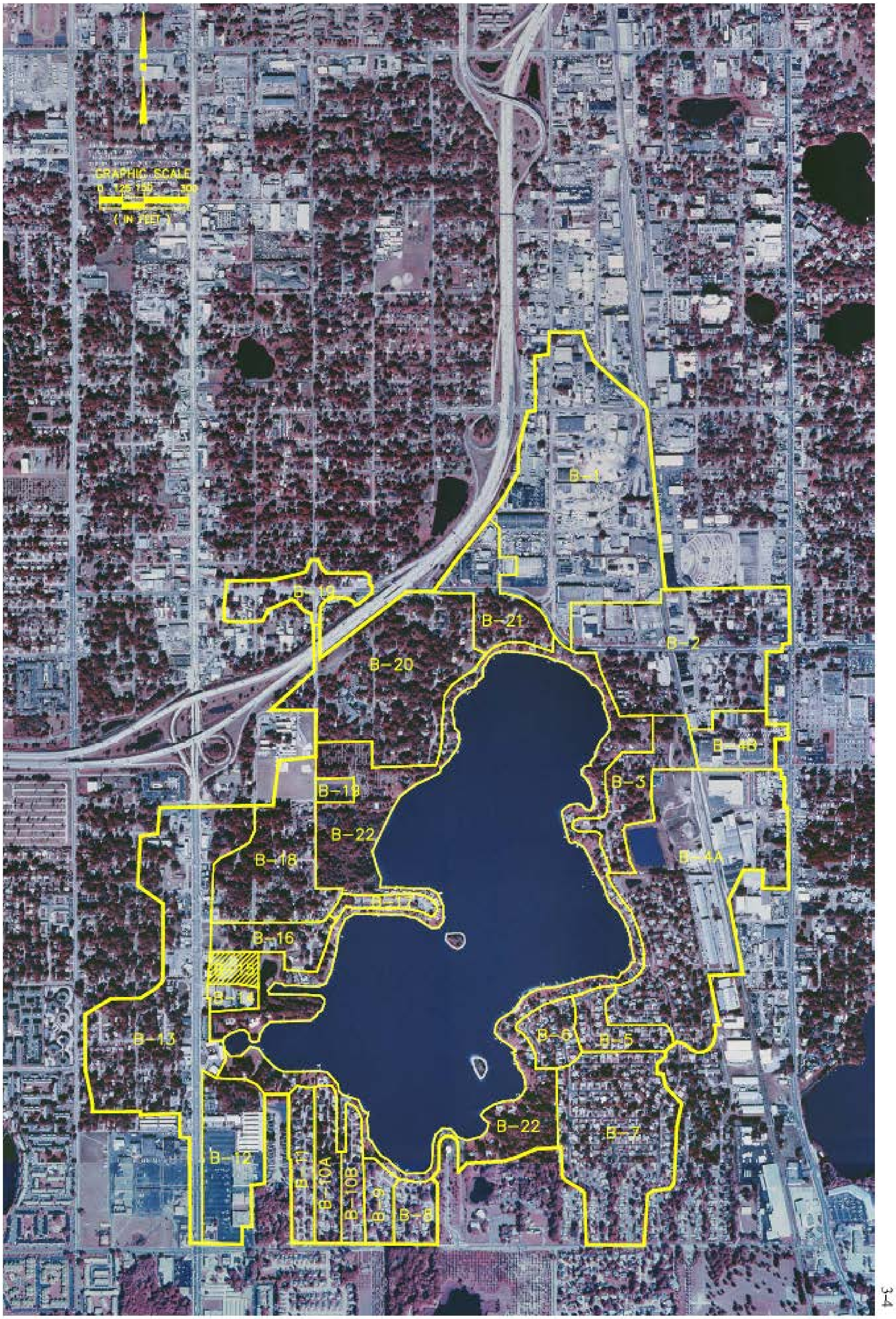

Figure 4.2. Lake Holden 24 Subbasins from ERD (2004), *Figure 3.1*

Table 4.4. Septic Tank Coverage in the Lake Holden Watershed

Note: Septic tank coverage estimated by CDM (2008) based on available septic tank and sewer service area information.

Receiving Water	HSPF Model Reach	Number of Commercial OSTDS	Number of High-Density Residential OSTDS	Number of Low-Density Residential OSTDS	Number of Medium-Density Residential OSTDS
Lake Holden	590	13	38	1	26

Figure 4.3 depicts the property boundaries within the Lake Holden watershed identified by Orange County Utilities as “septic parcels.” This Geographic Information System (GIS) graphic was produced as a “negative” of the county sanitary sewer data and represents the maximum potential for septic tanks in the watershed. It should be noted that while some of the parcel boundaries extend into the lake, there are no septic tanks located within the lake. If all of these parcels are on active septic tanks, an opportunity may be available to further reduce nutrient loadings to the lake. The actual presence of active septic tanks on each parcel would need to be verified with the Orange County Department of Health.

In addition to septic tanks, ERD (2004) identified fertilizer as a significant source of phosphorus. The 2010 report stated the following: “It appears that highly variable and elevated phosphorus concentrations continue to persist within these areas” (*i.e.,* the Division Avenue, Holden Terrace, and Paseo Street subbasins).

ERD (2010) stated: “It appears that baseflow is a significant contributor of phosphorus loadings to Lake Holden, and it is extremely important that the treatment system be fine-tuned to treat the lowest possible inflow rates to ensure that at least a portion of the dry weather baseflow is treated.“ Developing strategies targeting fertilizer use, treating dry weather baseflow drainage to the lake, and eliminating septic tanks may provide significant additional reductions in nutrients to Lake Holden.

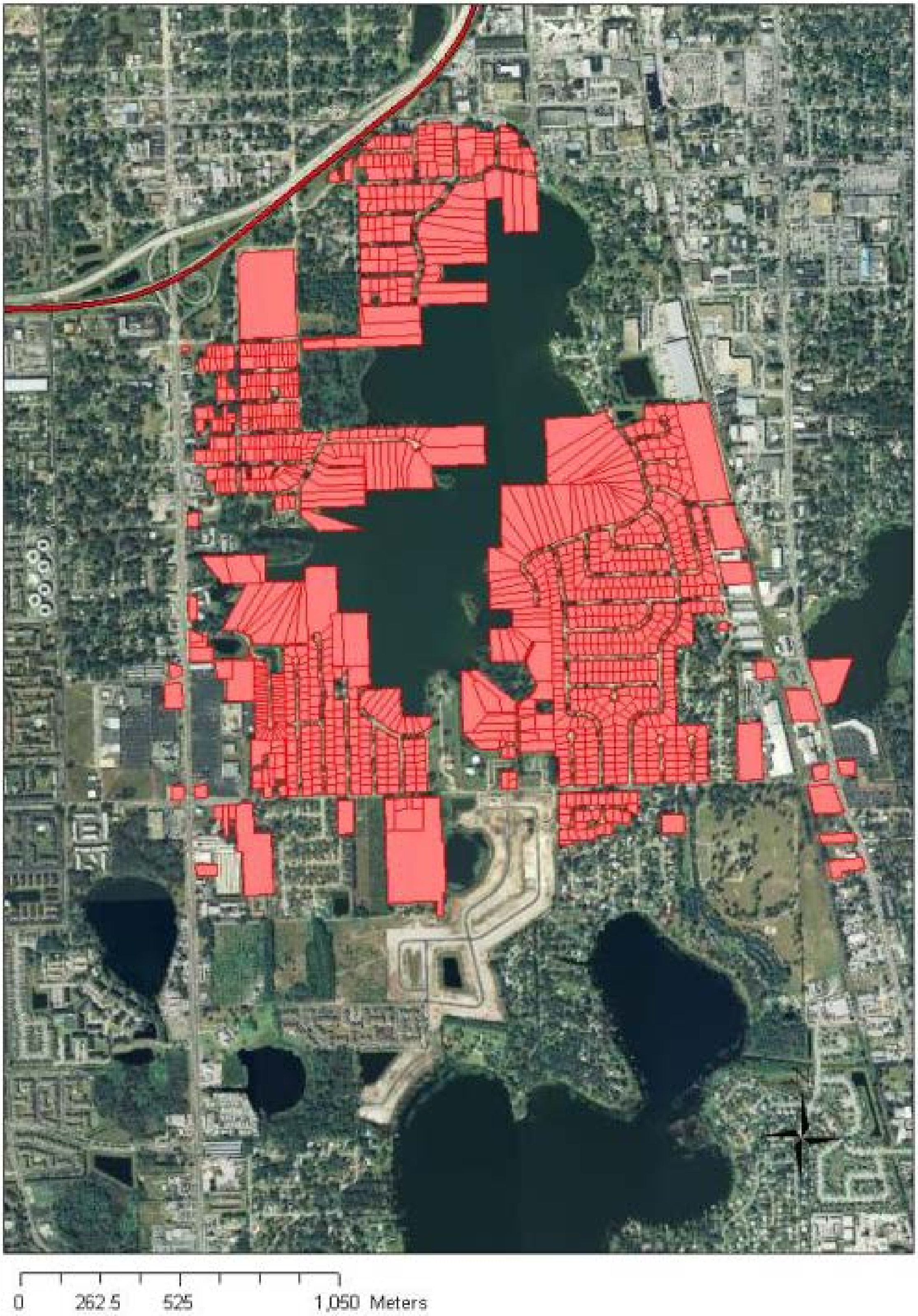

Figure 4.3. Septic Tank Coverage for Urban Land Uses from Orange County Utilities in 2011

Internal Recycling

ERD (1992) notes that during periods of "calm weather," the lake has low DO levels at depths below three to four meters. The report states that decades of high algal production have resulted in an accumulation of loose organic muck on the lake bottom, made up primarily of decomposing algal cells (in 1991 Orange County ranked Lake Holden as the second most polluted lake system in the county, with Lake Apopka ranking first). ERD (1992) reported high levels of TN and TP near the lake bottom, indicating the release of both TN and TP into the water column. Subsequent studies (ERD 2004) confirmed the potential for significant orthophosphorus (ortho-P) flux from the bed.

A whole-lake alum treatment in 2005 and 2006 resulted in such a dramatic decline in TP in the lake that it seems to have confirmed the presence of the TP flux. Based on information from ERD (1992; 2004), the HSPF model included the internal recycling of TN and TP. The level of TP recycling was based on the TP budget in ERD (2004).

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 Holden watershed. The HSPF model allows the Department to interactively simulate and assess the environmental effects of various land use changes and associated land use practices. The model was run for 1996 through 2006. Model calibration was performed for January 1996 through December 2000, with the period from January 2001 to December 2006 used for model validation.

ERD (2004) noted that the "lower total phosphorus concentrations observed since 1995 appear to reflect new equilibrium conditions within the lake as a result of recent water quality improvement projects. Since water quality appears to be relatively stable over this period, mean water quality characteristics in Lake Holden from 1995 to 2003 are used to represent existing ambient conditions within the lake."

The water quality parameters (impact parameters) simulated within the model for Lake Holden include water quantity (surface runoff, interflow, and baseflow), and water quality (TN, organic nitrogen, ammonia nitrogen, NO_X nitrogen, TP, organic phosphorus, orthophosphorus, phytoplankton as biologically active cchl*a*, temperature, total suspended solids [TSS], DO, and ultimate carbonaceous biological oxygen demand [CBOD]). Datasets of land use, soils, and rainfall were 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.

Lake Holden receives runoff from the local basin and discharges to 3 drainage wells located within the lake. Well 1 is a 10-inch well that initiates drainage when the lake surface is at 94.0 feet National Geodetic Vertical Datum (NGVD). Wells 2 and 3 are 16-inch wells and initiate drainage at 90.7 and 90.2 feet NGVD, respectively. Outflow from the lake in the model is controlled by discharging to these wells at rates provided by ERD (1992) and were incorporated into the HSPF F-Table.

The GIS and model dataset used to derive the inputs for HSPF included land use, soils, topography and depressions, hydrography, U.S. Geological Survey (USGS) gauge and flow data, septic tanks, water use pumpage, point sources, rainfall, ground water, atmospheric deposition, solar radiation, control structures, and stream reaches.

IMPLND Module for Impervious Tributary Area

The IMPLND module of HSPF accounts for surface runoff from impervious land areas (*e.g.*, parking lots and highways). For the purposes of this model, each land use was assigned a typical percentage of directly connected impervious area (DCIA), as shown in **Table 4.5,** based on published values (CDM 2002). Four of the nine land uses contain some impervious areas.

Table 4.5. Percentage of DCIA

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

Land Use Category	% DCIA
1. Commercial/industrial	80%
2. Cropland/improved pasture/tree crops	0%
3. High-density residential	50%
4. Low-density residential	10%
5. Medium-density residential	25%
6. Rangeland/upland forests	0%
7. Unimproved pasture/woodland pasture	0%
8. Wetlands	0%
9. Water	0%

PERLND Module for Pervious Tributary Area

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

HSPF uses the Stanford Watershed Model methodology as the basis for hydrologic calculations. This methodology calculates soil moisture and water flow 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 wetland 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 CDM report [2008]). 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 Lake Holden were developed based on the lake's bathymetry data and information contained in ERD (1992; 2004).

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 3 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 Holden Existing Land Use Loadings

The HSPF simulation of pervious lands (PERLND) and impervious lands (IMPLND) calculates the hourly values of runoff from pervious and impervious land areas, and interflow and baseflow from pervious lands, plus the loads of water quality constituents associated with these flows. For PERLND, 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 PERLND, concentrations of constituents in baseflow were assigned based on typical values observed in several tributaries in the area such as Boggy Creek and Reedy Creek, and interflow concentrations were set at values between the estimated runoff and baseflow concentrations. For IMPLND, TSS (sediment) is simulated by a "buildup-wash off" approach (buildup during dry periods, wash off with runoff during storm events), and again the "potency factor" approach was used in the IQUAL module for other constituents except DO, which again was analyzed at saturation.

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

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

One feature of HSPF is that the CBOD concentration has associated concentrations of organic-N and organic-P. Consequently, the TN concentration is equal to the sum of ammonia-N, nitrate-N, refractory organic-N, and a fraction of the CBOD concentration. Similarly, the TP concentration is equal to the sum of ortho-P and a fraction of the CBOD concentration.

The total loadings of nitrogen and phosphorus for Lake Holden were estimated using the HSPF model and calibrated to the estimated nutrient budget contained in ERD (2004). Internal releases of ortho-P and ammonia nitrogen were included in the model based on information from ERD (1992, 2004, 2008, and 2010). Modeling frameworks were designed to simulate the period 1996 through 2006. This period is inclusive of the Cycle 1 verified period for Group 4 waterbodies located in the Kissimmee River Basin and several years (2003 to 2006) of the Cycle 2 verified period.

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.

As discussed in **Chapter 4**, the HSPF model was selected as the watershed and waterbody model. It was run dynamically through the 10-year period (1996 to 2006) on an hourly time-step.

5.1.1 Climate

Rainfall, air temperature, wind speed and direction, solar radiation, cloud cover, relative humidity, evaporation, and dew point temperature directly influence the hydrologic balance and receiving water quality within a watershed. Automatic measuring stations, situated in various locations within the watershed, quantify the climatological data to allow for modeling or other analysis. Spatial and temporal distributions of climatological data are important factors in accurately modeling hydrologic flow conditions within a watershed. As a result, these data are perhaps the most important inputs to the hydrologic and water quality models (CDM 2008).

Rainfall

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 (1996 to 2005) 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. Hourly rainfall from Station BEELNE and SHING.RG (SCRG in **Figure 5.1**) was used with the WSR-88 data to generate the hourly rainfall dataset used in the Lake Holden model runs for 2006.

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 collected from these stations range from January 1991 to December 2006. **Table 5.1** provides a summary of these stations along with the maximum intensity recorded at each station. The CDM report (2008) contains additional information and describes how the data were used in the model. **Figure 5.2** depicts daily rainfall. As seen in this figure, the modeling period encompasses a variety of rainfall patterns from wet to dry. **Figure 5.3** shows monthly average rainfall.

Based on this information, the period from June through September has nearly twice the rainfall (averaging nearly six inches per month), while October through May average just over two inches of rainfall. **Figure 5.4** depicts annual average rainfall for 1996 to 2006. During this period, the average rainfall was 46.6 inches/year. The years 1997, 1998, 1999, and 2001 are considered average. The years 2000 and 2006 are dry, while 2002, 2003, 2004, and 2005 are considered wet years.

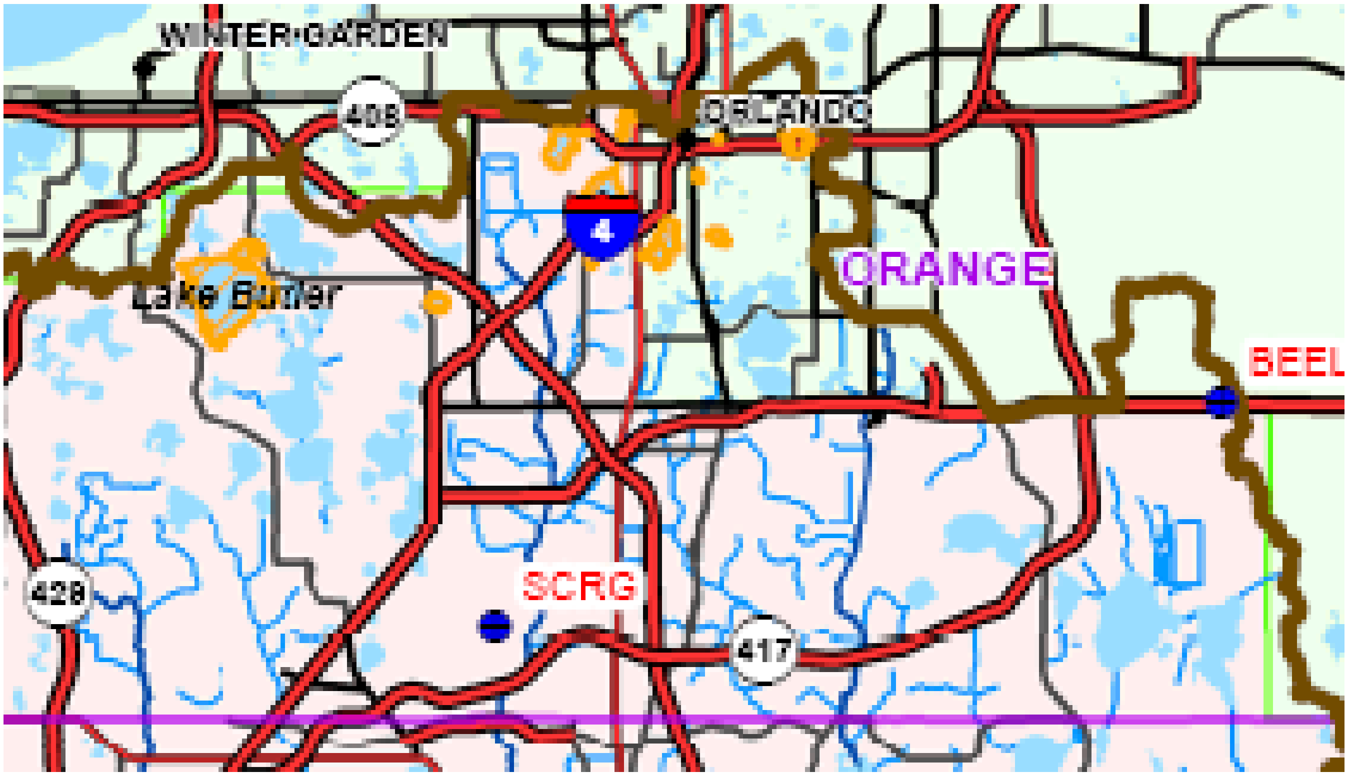

Figure 5.1. Daily Rainfall Stations

Table 5.1. Hourly Rainfall Stations

Station	Location (County)	Begin Period of Record	End Period of Record	Maximum Intensity (inches/hour)
ALL2R	Osceola	02/19/1998	12/31/2006	2.38
ARS_B0_R	Okeechobee	10/06/1992	12/31/2006	3.29
BASING_R	Okeechobee	11/20/2003	12/31/2006	1.49
BASSETT_R	Okeechobee	06/30/1992	12/31/2006	4.18
BEELINE_R	Orange	04/12/2006	12/31/2006	1.45
CREEK_R	Polk	12/12/2002	12/31/2006	2.72
ELMAX_R	Osceola	08/08/2006	1231/2006	1.80
EXOTR	Osceola	02/11/1998	12/31/2006	2.88
FLYGW_R	Okeechobee	02/22/2000	12/31/2006	2.63
FLYING_G_R	Okeechobee	01/01/1991	12/31/2006	1.79
GRIFFITH_R	Okeechobee	07/08/2004	12/31/2006	2.26
INDIAN_L_R	Polk	01/25/2003	12/31/2006	1.89
INRCTY_R	Osceola	03/05/2003	12/31/2006	2.32
KENANS1_R	Osceola	12/14/2004	12/31/2006	2.95
KIRCOF_R	Osceola	08/09/2000	12/31/2006	2.55
KISSFS_R	Osceola	07/04/2002	12/31/2006	2.82
KRBNR	Highlands	05/15/1997	12/31/2006	2.69
KREFR	Polk	05/16/1997	12/31/2006	2.69
LOTELA_R	Highlands	12/02/2004	12/31/2006	1.87
MAXCEY_N_R	Osceola	06/20/2006	12/31/2006	1.96
MAXCEY_S_R	Okeechobee	08/04/2006	12/31/2006	1.07
MCARTH_R	Highlands	05/26/2006	12/31/2006	1.14
MOBLEY_R	Okeechobee	09/03/1992	12/31/2006	3.30
OPAL_R	Okeechobee	10/23/1992	12/31/2006	3.21
PC61_R	Okeechobee	04/17/2002	12/31/2006	2.08
PEAVINE_R	Okeechobee	07/05/2004	12/31/2006	4.12
PINE_ISL_R	Osceola	07/21/2004	12/31/2006	2.34
ROCK_K_R	Okeechobee	11/23/2003	12/31/2006	3.06
RUCKGW_R	Okeechobee	02/22/2000	12/31/2006	2.59
RUCKSWF_R	Okeechobee	01/01/1991	12/31/2006	4.73
S59_R	Osceola	12/26/1995	12/31/2006	2.91
S61W	Osceola	10/20/1992	12/31/2006	2.92
S65A_R	Polk	01/30/2003	11/05/2004	1.91

Station	Location (County)	Begin Period of Record	End Period of Record	Maximum Intensity (inches/hour)
S65C_R	Okeechobee	01/01/1991	11/12/1991	1.41
S65CW	Okeechobee	10/20/1992	12/31/2006	3.45
S65D_R	Okeechobee	02/23/1995	04/02/2002	2.37
S65DWX	Okeechobee	02/23/2000	12/31/2006	2.44
S68_R	Highlands	03/18/1997	12/31/2006	2.71
S75_R	Glades	03/18/1997	12/31/2006	2.69
S75WX	Glades	09/01/2002	12/31/2006	4.02
S82_R	Highlands	03/18/1997	12/31/2006	1.93
S83_R	Highlands	03/18/1997	12/31/2006	2.87
SEBRNG_R	Highlands	11/30/2004	12/31/2006	1.57
SHING.RG	Orange	03/12/1992	12/31/2006	3.16
SNIVELY_R	Polk	07/14/2004	12/31/2006	1.86
TAYLC_R	Okeechobee	09/18/1995	12/31/2006	8.10
TICK_ISL_R	Polk	01/16/2001	12/31/2006	2.43
TOHO2_R	Osceola	06/25/1996	12/31/2006	2.82
TOHO10_R	Osceola	06/24/1999	12/31/2006	2.50
TOHO15_R	Osceola	07/02/1999	12/31/2006	2.39
WRWX	Polk	04/16/1997	12/31/2006	3.04

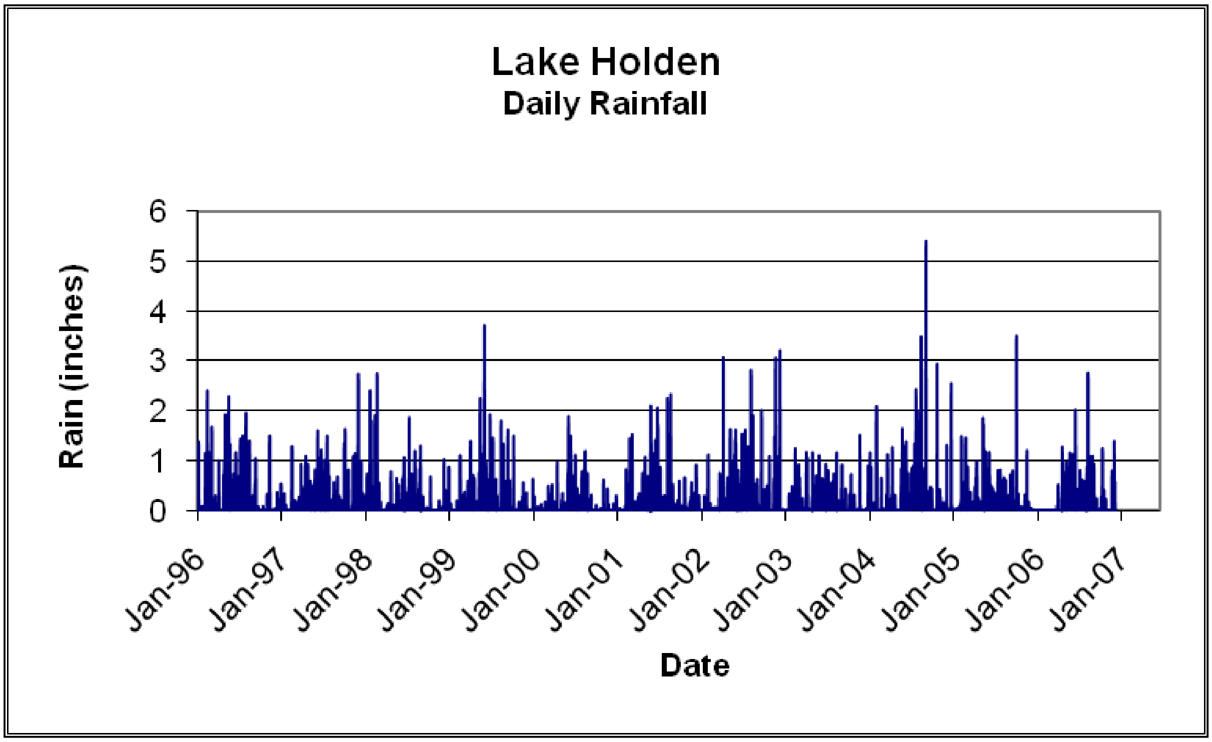

Figure 5.2. **Daily Rainfall Used in Model, 1996–2006**

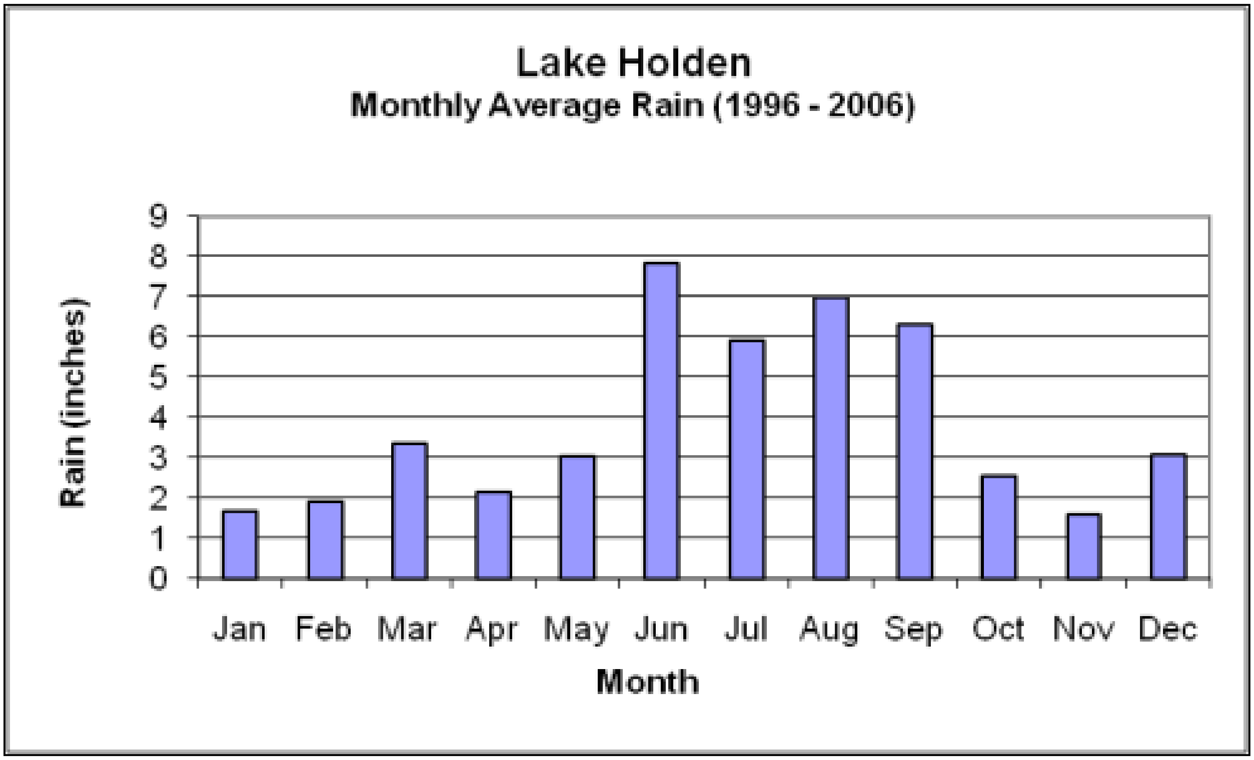

Figure 5.3. **Monthly Average Rainfall from Model Dataset, 1996–2006**

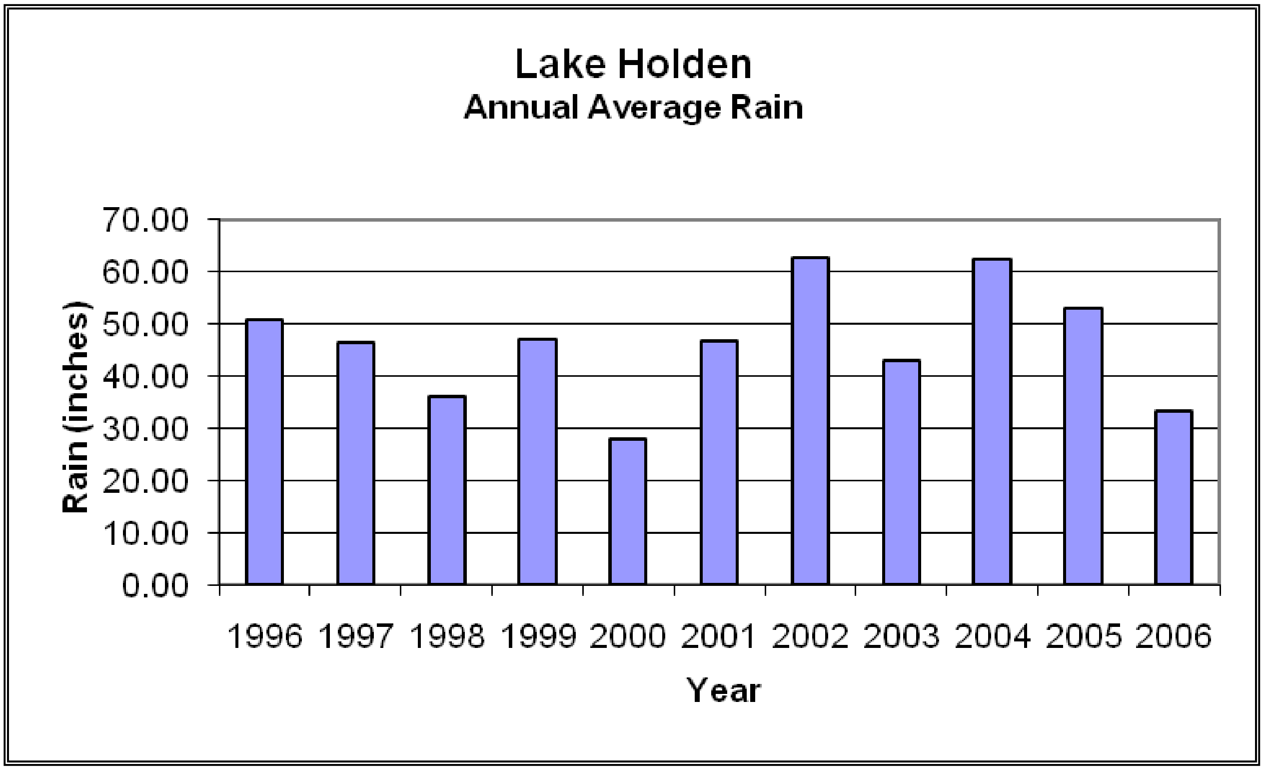

Figure 5.4. **Annual Average Rainfall from Model Dataset, 1996–2006**

Evaporation/Evapotranspiration

Evaporation data and evapotranspiration (ET) rates are important factors in determining hydrologic balances and modeling, since they provide estimates of hydrologic losses from land surfaces and waterbodies within the watershed. As a result, daily Class A pan evaporation data and potential ET data were obtained from Station KISS.FS_E (**Figure 5.5**) for Lake Holden. The data were downloaded from the SFWMD database DBHYDRO, and the monitoring dates range from January 1991 to December 2006 (**Table 5.2**). If there were data gaps of a few days, they were filled by linear interpolation. For longer gaps, ET data from the next closest station (WRWX) were used.

Figure 5.6 illustrates the two weather station locations used to model the Lake Holden watershed. CDM (2008) contains additional information and describes how the data were used in the model.

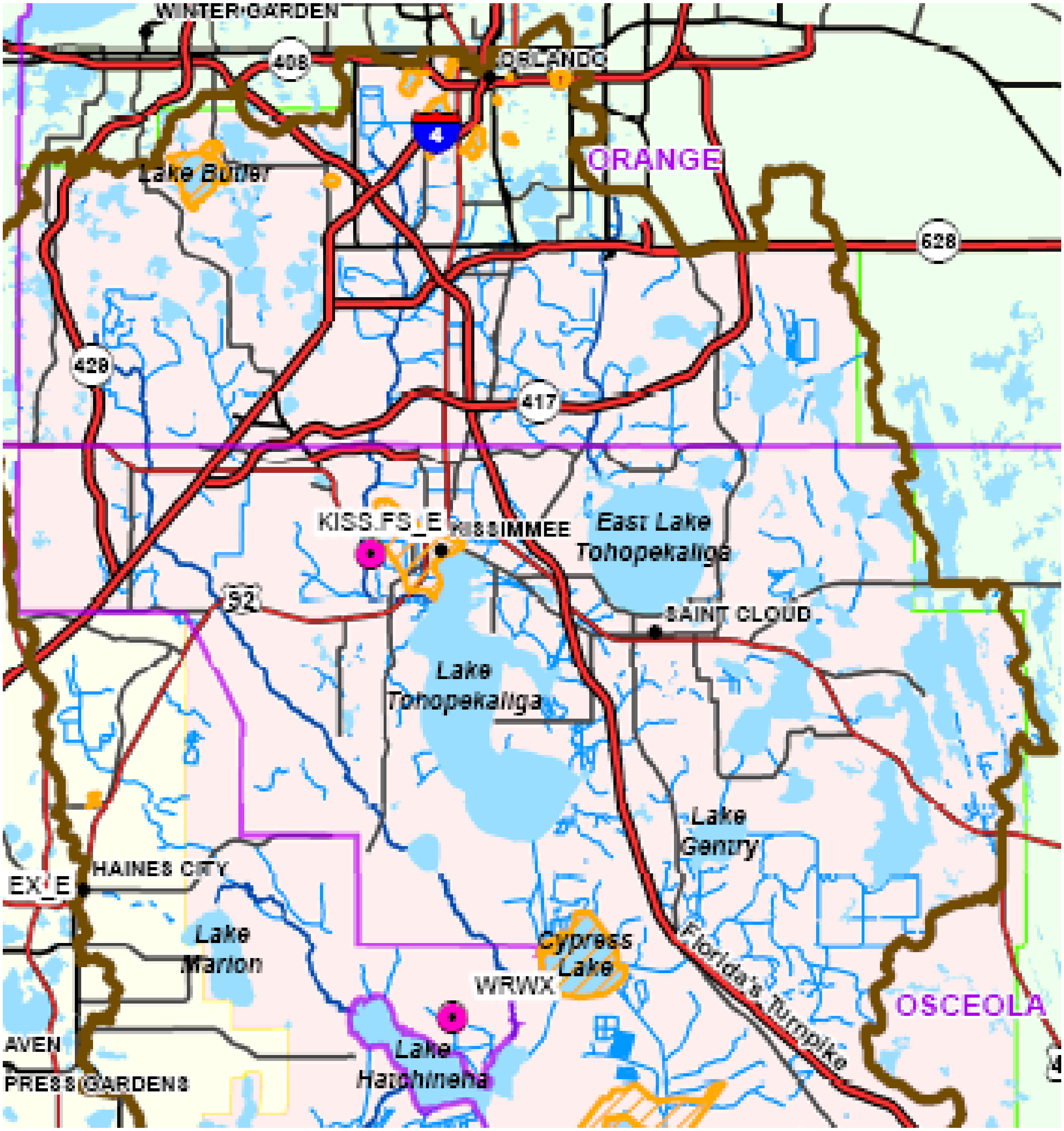

Figure 5.5. SFWMD Pan Evaporation and Potential Evapotranspiration Monitoring Stations Near Lake Holden

Table 5.2. SFWMD Pan Evaporation and Potential Evapotranspiration Monitoring Stations

Station	Begin Period of Record	End Period of Record	Data Type
ARCHBO 2	01/01/1991	11/30/1994	Pan Evaporation
BIRPMWS	01/01/1998	12/31/2006	Potential ET
BIRPSW	01/01/2002	12/31/2006	Potential ET
BIRPWS2	01/01/2002	12/31/2006	Potential ET
EVP376NE	05/01/2005	12/31/2006	Pan Evaporation
KISS.FS_E	01/01/1991	04/30/1999	Pan Evaporation
L ALF EX_E	01/01/1991	11/30/1998	Pan Evaporation
OKEE FIE_E	01/01/1991	04/30/2005	Pan Evaporation
S65C_E	01/01/1991	09/13/1992	Pan Evaporation
S65CW	10/21/1992	12/31/2006	Potential ET
S65DWX	02/23/2000	12/31/2006	Potential ET
S65_E	01/01/1991	12/31/2006	Pan Evaporation
S75WX	09/02/2002	12/31/2006	Potential ET
WRWX	04/17/1997	12/31/2006	Potential ET

Other Climate Data

Daily air temperature, solar radiation, and wind speed data were obtained from eight monitoring stations located within Okeechobee, Osceola, and Polk Counties, as summarized in **Table 5.3** and shown in **Figure 5.6**. The data were downloaded from DBHYDRO and range from October 1992 to December 2006. Daily cloud cover and dew point temperature data from five monitoring stations were obtained from NOAA.

Table 5.3. SFWMD Air Temperature, Solar Radiation, and Wind Speed Monitoring Stations

Station	Begin Period of Record	End Period of Record
BIRPMWS	01/01/1998	12/31/2006
BIRPSW	01/01/2002	12/31/2006
BIRPWS2	01/01/2002	12/31/2006
L001	08/04/1994	12/31/2006
S61W	10/20/1992	12/31/2006
S65CW	10/20/1992	12/31/2006
S65DWX	02/23/2000	12/31/2006
WRWX	04/17/1997	12/31/2006

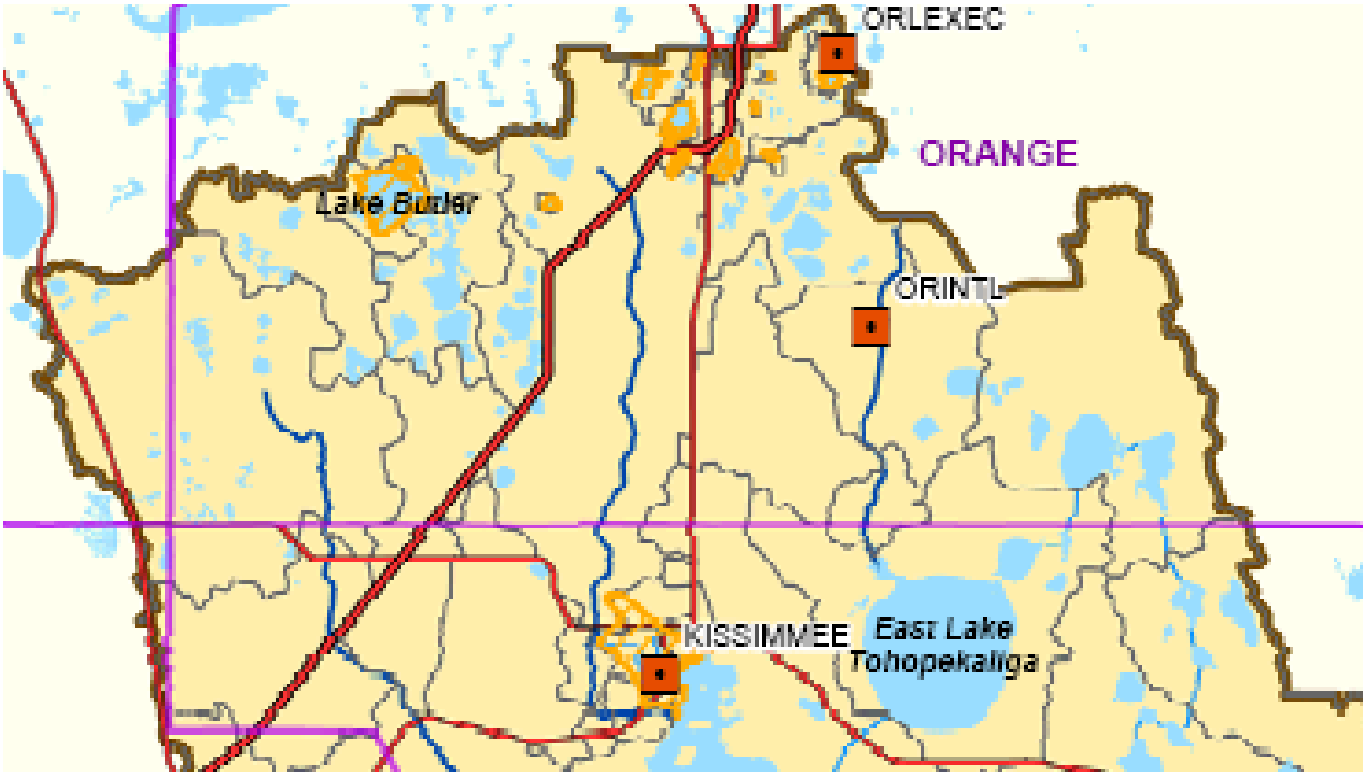

Figure 5.6. **SFWMD Air Temperature, Solar Radiation, and Wind Speed Monitoring Stations Closest to Lake Holden**

5.1.2 Model Calibration/Validation

Hydrologic Calibration/Validation

The HSPF model for the Lake Holden watershed was calibrated using the simulation period of January 1996 through December 2000. Model validation (2001 to 2006) was used to apply the calibrated model to a different period without changing the calibrated hydrologic and hydraulic parameters. This step was taken to further confirm that those calibrated hydrologic parameters were still applicable to the new period of model application, and statistically similar results were expected. The model validation period for this project was selected as the period from 2001 through 2006, with one dry, two wet, and three average years.

Because the 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 based on ERD (2004) to further improve the match between measured and modeled results. 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).

Based on the comparison of measured stage with predicted stage, the HSPF water budget was considered calibrated. The reasonableness of the HSPF results is supported by the comparison with the ERD (2004) water budget (**Table 5.4**).

Table 5.4. HSPF Simulated Annual Water Budget for Lake Holden

- = Empty cell/no data

Year	Baseflow (ac-ft)	Interflow (ac-ft)	Runoff (ac-ft)	Rainfall (ac-ft)	Total Inflow (ac-ft)	ET (ac-ft)	Outflow (ac-ft)	Change (ac-ft)
1996	325	48	1,200	948	2,521	-960	-1,698	-138
1997	218	17	1,081	848	2,164	-931	-1,011	222
1998	289	25	842	669	1,825	-921	-1,328	-424
1999	259	61	1,084	860	2,264	-966	-1,186	111
2000	126	5	609	492	1,232	-1,022	-517	-307
2001	276	62	1,036	844	2,218	-986	-1,057	176
2002	524	101	1,489	1,173	3,287	-1,029	-2,060	198
2003	268	24	949	799	2,040	-971	-1,420	-351
2004	524	187	1,474	1,181	3,367	-1,025	-2,256	86
2005	386	20	1,155	989	2,550	-992	-1,681	-123
2006	154	12	785	589	1,541	-992	-596	-47
Average 1996–2006	**304**	**51**	**1,064**	**854**	**2,273**	**-981**	**-1,346**	**-46**
Percent	**15.6%**	**-**	**46.8%**	**37.6%**	**100%**	**42.2%**	**57.8%**	**-**
ERD (2004)	**565**	**-**	**1,073**	**1,101**	**2,739**	**1,108.7**	**1,630.5**	**-**
ERD (2004)	**20.6**	**-**	**39.2**	**40.2**	**-**	**40.5**	**59.5**	**-**

Figure 5.7 depicts the results for calibration (1996 to 2000) and validation (2001 to 2006) for stage in Lake Holden. As can be seen in the figure, the model predictions are reasonable, except for the period from 2001 to 2002, when the actual stage decreased by more than a foot below the level predicted by the model.

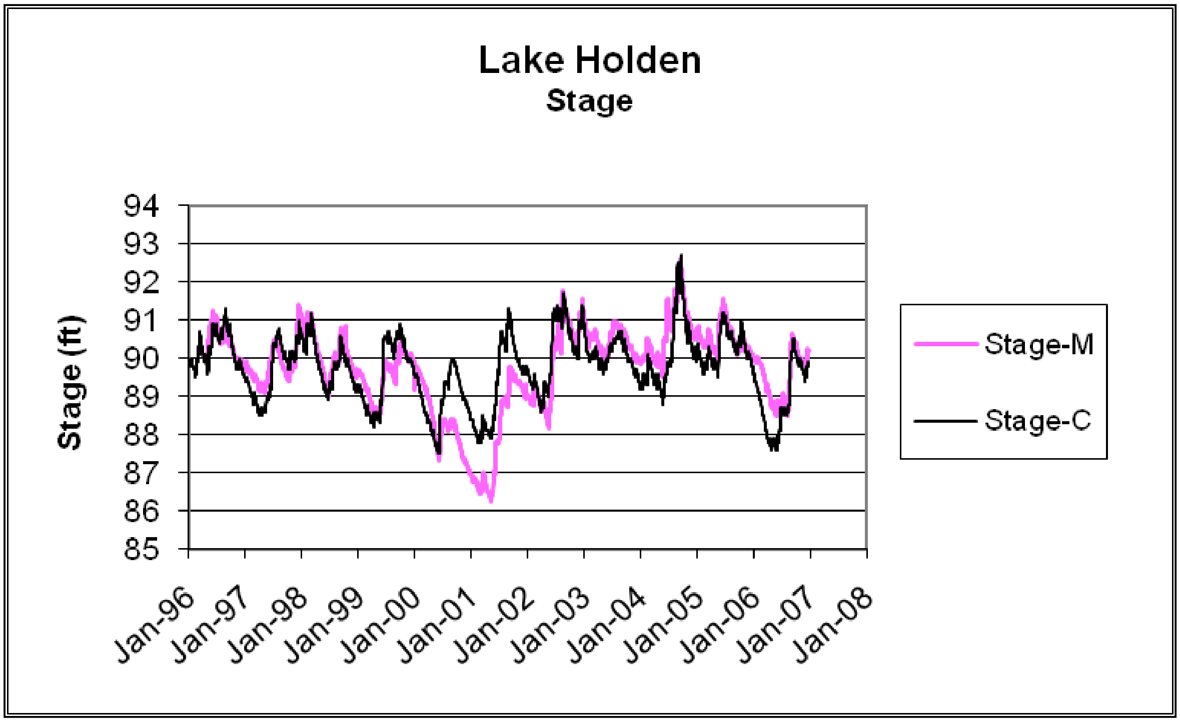

Figure 5.7. Measured and Simulated Lake Stage

Table 5.4 depicts the model-generated water budget for the lake. Surface runoff, interflow, and baseflow generate an average of 1,419 ac-ft/yr, or 62.4% of the total inflowing water, compared with the ERD (2004) estimate of 1,638 ac-ft/yr, or 59.8% of the total inflow to the lake. The two models differ in these components by 13%.

The HSPF model estimate of direct rainfall on the lake is 854 ac-ft/yr, or 37.6%, compared with the ERD (2004) estimate of 1,101 ac-ft/yr, or 40.2% of the total inflow of water to the lake. The overall total inflow to the lake from HSPF is 2,273 ac-ft/yr, while the ERD (2004) model generated 2,739 ac-ft/yr. The two estimates differ by 17%, with almost 50% of the difference due to the estimates of direct rainfall on the lake.

The calibrated HSPF model predicted water losses by ET at 42.2% of the total losses, with the ERD (2004) model estimating ET at 40.5%. Losses down the drainage wells were estimated in the HSPF model at 57.8%, with the ERD (2004) model estimating these losses at 59.5%. While the overall average water budgets differ by 16.9%, the two averages are based on different periods. Based on the comparison of measured stage with predicted stage, the HSPF water budget was considered calibrated. The calibration was supported by the comparison with the ERD (2004) water budget.

Based on the HSPF model, the annual pool volumes for the lake averaged 1902 ac-ft, ranging between 1,736 and 2,027 ac-ft/yr. The annual average mean outflow is estimated at 2,328 ac-ft/yr, ranging between 1,539 and 2,673 ac-ft/yr. The mean residence time of a lake can be estimated as follows:

Residence time (years) = lake volume (acre-ft) / mean outflow (acre-ft/yr).

In this case, the HSPF estimate of residence time for the period from 1996 to 2006 is 10 months, ranging between a low of 7.3 months and a high of 1.13 years (13.5 months). ERD (2004) estimated the residence time at 1.17 years. The primary difference between the two estimates is related to the different estimates of annual average pool volumes, with the ERD water budget estimating this component of the water budget as substantially greater than the HSPF estimate.

Water Quality Calibration/Validation

Table 5.5 presents input parameters that include assigned potency factors (the ratio of constituent yield to sediment [washoff or scour) outflow]), interflow concentrations, and baseflow concentrations. For values showing ranges, the lower end of the ranges are applicable to undeveloped areas (*e.g.*, forest, wetland), while the higher end of the ranges are applicable to agricultural areas.

Table 5.5. Land-Based Water Quality Input Parameter Values

HSPF Input Parameter	Ortho-P	Ammonia N	Nitrate N	CBOD	Refractory Organic N	TP	TN
Interflow Concentration (mg/L)	0.03 - 0.22	0.03 - 0.08	0.20 - 0.63	1.5 - 19	0.7 - 1.2	0.04 - 0.39	1.0 - 2.8
Baseflow Concentration (mg/L)	0.02 - 0.04	0.02 - 0.05	0.13 - 0.25	1.5 - 3.0	0.6 - 0.8	0.03 - 0.07	0.8 - 1.2
Potency Factor (lbs/ton sediment)	Started at 5.4 - 6.1; ended at 1.2 -1.3 to simulate alum treatment	4.1	23 - 25	350	23.8	8.6 - 9.3	52 - 53

The potency factors for ortho-P started at the values based on CDM (2008) and were adjusted downwards to "simulate" the load reductions from the three alum injection systems implemented in 1996 to 1997 and calibrated to the loadings calculated by ERD (2004) from local runoff data. Based on the values in **Table 5.5**, the typical results for average annual constituent loads for various land use types and soil groups are presented in **Table 5.6**. The table shows a range of values, which reflect the differences associated with a variety of soil types (*e.g.*, "A" soils generating less runoff than "D" soils).

The values shown in the table are consistent with respect to the loads estimated or measured in other studies (CDM 2008).

Table 5.6. Average Annual Land-Based Loading (lbs/ac/yr) by Land Use Type and Soil Group

Land Use	Soil Group	Ortho-P	Ammonia N	Nitrate N	CBOD	Refractory Organic N	TSS	Total P	Total N
Commercial/Industrial	A	1.03	0.7	4.3	60	4.4	330	1.58	11.9
Commercial/Industrial	B	1.05	0.7	4.3	61	4.4	334	1.61	12.0
Commercial/Industrial	C	1.07	0.8	4.4	62	4.5	338	1.63	12.2
Commercial/Industrial	D	1.09	0.8	4.5	63	4.5	344	1.66	12.3
Cropland/Improved Pasture	A	0.18	0.1	0.8	14	2.4	1	0.30	3.9
Cropland/Improved Pasture	B	0.49	0.3	1.8	39	3.4	48	0.84	7.0
Cropland/Improved Pasture	C	0.75	0.4	2.7	58	4.4	111	1.28	9.9
Cropland/Improved Pasture	D	1.22	0.7	4.5	90	6.1	264	2.05	15.1
High-Density Residential	A	0.69	0.5	3.0	41	3.6	206	1.07	8.8
High-Density Residential	B	0.75	0.5	3.1	45	3.7	215	1.16	9.2
High-Density Residential	C	0.80	0.6	3.3	48	3.8	226	1.24	9.7
High-Density Residential	D	0.84	0.6	3.5	52	3.8	242	1.31	10.0
Low-Density Residential	A	0.24	0.2	1.2	17	2.5	42	0.39	4.6
Low-Density Residential	B	0.35	0.3	1.5	26	2.7	57	0.58	5.5
Low-Density Residential	C	0.44	0.3	1.8	33	2.9	77	0.74	6.5
Low-Density Residential	D	0.53	0.4	2.1	41	3.0	104	0.90	7.2
Medium-Density Residential	A	0.41	0.3	1.9	26	2.9	104	0.65	6.2
Medium-Density Residential	B	0.50	0.4	2.1	34	3.1	116	0.80	6.9
Medium-Density Residential	C	0.58	0.4	2.4	40	3.3	132	0.94	7.7
Medium-Density Residential	D	0.65	0.5	2.6	46	3.3	156	1.07	8.3
Forest/Rangeland	A	0.05	0.0	0.3	4	1.4	0	0.08	1.9
Forest/Rangeland	B	0.08	0.1	0.5	6	1.7	8	0.13	2.5
Forest/Rangeland	C	0.12	0.1	0.7	8	1.9	20	0.19	3.1
Forest/Rangeland	D	0.18	0.2	1.0	12	2.1	42	0.29	3.8
Unimproved Pasture	A	0.11	0.1	0.7	8	2.0	0	0.18	3.1
Unimproved Pasture	B	0.20	0.2	1.0	16	2.2	18	0.34	4.0
Unimproved Pasture	C	0.30	0.2	1.4	23	2.6	42	0.51	5.2
Unimproved Pasture	D	0.43	0.3	2.0	32	2.9	87	0.72	6.5
Wetlands	A	-	-	-	-	-	-	-	-
Wetlands	B	-	-	-	-	-	-	-	-
Wetlands	C	-	-	-	-	-	-	-	-
Wetlands	D	0.05	0.1	0.4	4	1.4	9	0.09	2.1

The development of model input parameter values is discussed below. **Appendix C** lists the complete set of HSPF calibration values and coefficients used in the modeling.

Water temperature is not a cause of impairment, but it affects water quality processes related to impairments. **Figure 5.9** depicts the measured versus modeled temperature results. DO concentrations tend to be lower in the summer months when the water temperature is high, in part because the saturation DO for water decreases as temperature increases, and in part because processes that deplete DO (BOD decay, sediment oxygen demand [SOD]) are also affected by water temperature. The modeling of water temperature in the reaches uses a number of meteorological time-series (as discussed earlier) and a set of four input parameters.

These parameters were all initially set at the default value, and one of the values was modified in the calibration process. The results showed that the water temperature simulations accurately captured the seasonal variability of water temperature in the receiving waters (**Figure 5.8**). As noted in Chapter 2, BMPs have been extensively implemented within the watershed beginning in 1988.

As described in **Chapter 2**, lake water quality was fairly stable between 1995 and 2000. By 2001, the effects of these BMPs were starting to show up in the lake water quality data. The data appear to show that the lake is responding to the implementation of BMPs (including three alum injection systems in the three subbasins delivering the greatest percentage of nutrient loadings and whole lake treatment [2005 to 2006] with alum) during the period from 2001 to 2006. All of the data evaluated indicate that there may be two Lake Holdens—the one that existed prior to 2001 and the lake as it is today.

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).*

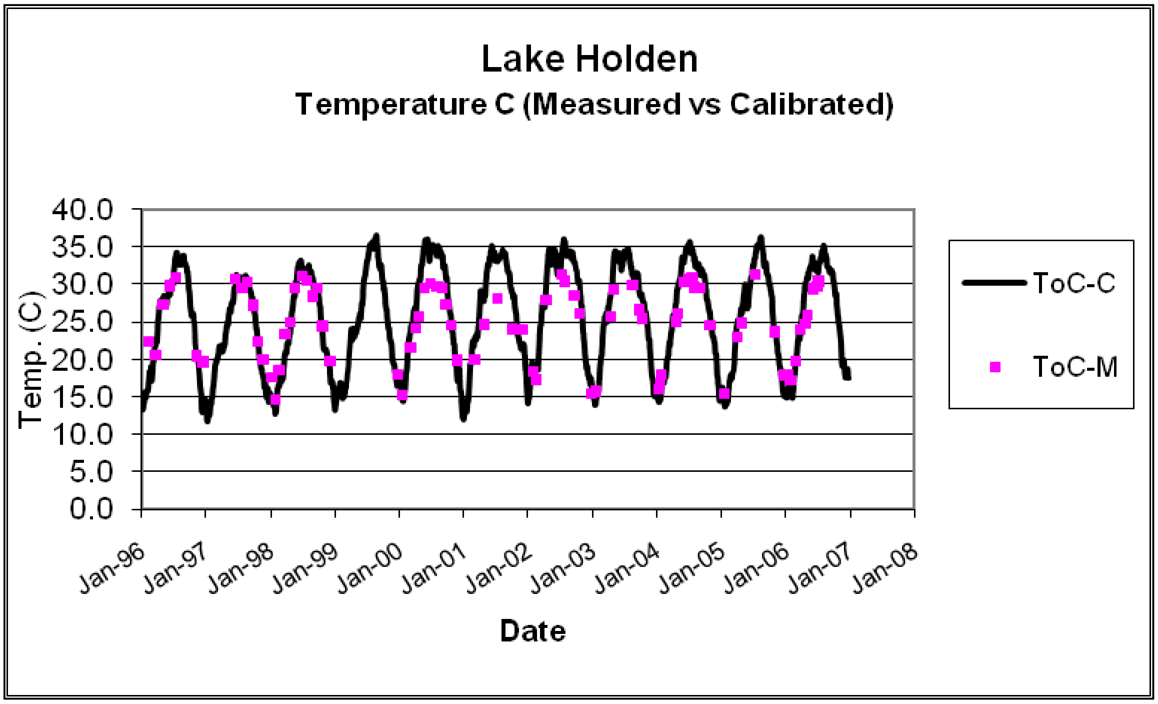

Figure 5.8. Measured and Simulated Lake Daily Average Water Temperature

Organic N and organic P in the model are associated with several water quality constituents, including ultimate CBOD, phytoplankton, and refractory organics that are the result of algae death.

The key processes that affect the model simulation of phytoplankton concentration in receiving waters include the following:

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

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

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

- *First-order decay of BOD (organic P associated with BOD is converted to inorganic P in this process).*
- *BOD settling (organic P associated with BOD is lost to lake sediments).*

- *Phytoplankton growth (inorganic P is converted to phytoplankton P).*
- *Phytoplankton respiration (phytoplankton P is converted to inorganic P).*
- *Phytoplankton death (phytoplankton P is converted to BOD and/or refractory organic P).*
- *Phytoplankton settling (phytoplankton P is lost to lake sediments).*
- *Refractory organic P settling to lake sediments.*
- *Sediment flux (inorganic P is released from sediment to overlying water).*

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

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

For DO, the key processes affecting concentrations in the reaches include the following:

- *Reaeration.*
- *Phytoplankton growth and respiration.*
- *BOD decay.*
- *Nitrification.*
- *SOD.*

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 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 simulates flows and associated loads from the tributary area into Lake Holden and then performs the 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 Holden.

The calibrated annual mass balance for TP in Lake Holden is presented in **Table 5.7** and compared with the TP budget developed by ERD (2004). For each year, the table shows the sources of TP (positive values) to the water in the lake and the losses of TP from the lake water (negative values), along with the net change in TP mass in the lake water. Based on the simulation results summarized in the table, inflow from the basin (interflow plus runoff) accounts for 43.4% of the TP load, baseflow (ground water) accounts for 4.5%, rainfall accounts for 4.6%, and sediment release makes up 47.4% of the total TP inflow budget. Overall, the model results show that about 89.4% of the TP load to the lake settles to the bottom, and 10.6% leaves the lake through the drainage wells.

Based on the comparison of measured data with predicted TP, the HSPF model was considered calibrated. The calibration is supported by the comparison with the ERD (2004) TP mass budget below. The total annual average inflow of TP to the lake of 1,160 lbs/yr differs from the ERD estimate of 1,186.4 lbs/yr by only 2.3%, and the estimates of internal loading differ by only 5.5%. The difference in outflows between the two models is 1.3%. Overall, based on these comparisons, the model TP loading budget is considered calibrated.

As a point of reference, the calibrated model was run without reductions in potency factors for TP to generate a prediction of TP loading without BMPs. The HSPF model predicted a pre-BMP long-term average TP loading of 1,746 lbs/yr. ERD (1992), based on data from 1991 to 1992 (pre-alum injection), estimated an annual average TP loading of 1,741.6 lbs/yr, a difference of only 0.25%.

Table 5.7. HSPF Simulated TP Budget (lbs/yr) for Lake Holden, 1996–2006

\- = Empty cell/no data

[1] Inflows include surface runoff, baseflow, and interflow.

[2] Outflow is discharge to drainage wells.

Year	Base-flow TP (lbs)	Inter-flow TP (lbs)	Runoff TP (lbs)	Rainfall TP (lbs)	Sediment Release TP (lbs)	Total Inflow TP (lbs)	Settling TP (lbs)	Outflow TP (lbs)	Change TP (lbs)
1996	56	24	619	59	561	1,319	-1,100	-173	46
1997	38	8	562	53	546	1,207	-1,057	-99	51
1998	50	11	456	42	553	1,112	-1,125	-145	-158
1999	44	30	574	54	546	1,249	-1,089	-131	29
2000	22	2	312	31	534	901	-943	-39	-81
2001	47	31	390	53	540	1,061	-972	-87	1
2002	90	47	538	74	557	1,304	-1,032	-177	95
2003	46	11	484	50	557	1,148	-1,123	-133	-108
2004	90	91	443	74	560	1,258	-1,064	-182	12
2005	66	8	419	62	560	1,114	-1,027	-144	-57
2006	27	6	477	37	534	1,081	-979	-54	48
Average 1996–2006	**52**	**24**	**479**	**54**	**550**	**1,160**	**-1,047**	**-124**	**-11**
%	**4.5%**	**2.1%**	**41.3%**	**4.6%**	**47.4%**	**100%**	**89.4%**	**10.6%**	**-**
ERD (2004)	**24.4**	**-**	**443.1**	**134.7**	**584.2**	**1,186.4**	**1,036.4**	**150.8**	**-**
ERD (2004) %	**11.1%**	**-**	**37.3%**	**61.1%**	**49.2%**	**-**	**87.3%**	**12.7%**	**-**

The calibrated TN annual mass balance for HSPF is presented and compared with the ERD (2004) mass budget in **Table 5.8**. For each year, the table shows the sources of TN (positive values) to the water in the lake and the losses of TN from the lake water (negative values), along with the net change in TN mass in the lake water. Based on the results of the simulation summarized in the table, inflow from the basin (interflow and runoff) accounts for 70.4 % of the TN load, baseflow accounts for 9.2%, rainfall accounts for 17.1%, and sediment release makes up 3.3% of the total TN inflow budget. Overall, the model results show that about 53.6% of the TN load to the lake settles to the bottom, and 46.4% leaves the lake through the drainage wells.

Based on the comparison of measured data with predicted TN, the HSPF model was considered calibrated. The calibration is supported by the comparison with the ERD (2004) TN mass budget below. The total annual average inflow of TN to the lake of 10,513 lbs/yr differs from the ERD (2004) estimate of 10,401.4 lbs/yr by only 1.1%. The difference in outflows between the two models is 2%. However, the ERD (2004) estimates of percent settling to the bottom versus percent leaving the lake through the drainage wells are different from the HSPF model estimates. The HSPF estimates have a greater percentage of the TN settling than leaving through the wells, while the ERD (2004) relationship is the opposite.

Table 5.8. HSPF Simulated TN Budget (lbs/yr) for Lake Holden, 1996–2006

- = Empty cell/no data

[1] Inflows include surface runoff, baseflow, and interflow.

[2] Outflow is discharge to drainage wells.

Year	Base-flow TN (lbs)	Inter-flow TN (lbs)	Runoff TN (lbs)	Rainfall TN (lbs)	Sediment Release TN (lbs)	Total Inflow TN (lbs)	Settling TN (lbs)	Outflow TN (lbs)	Change TN (lbs)
1996	1,036	210	9,280	1,991	351	12,868	-5,908	-5,948	1,012
1997	698	75	8,417	1,780	341	11,311	-5,764	-4,795	753
1998	919	105	6,838	1,405	346	9,614	-6,089	-5,430	-1,905
1999	825	269	8,604	1,808	341	11,847	-5,991	-5,248	608
2000	404	22	4,675	1,033	334	6,468	-5,346	-2,221	-1,099
2001	878	275	5,843	1,773	337	9,107	-5,479	-4,199	-571
2002	1,663	430	8,060	2,466	348	12,967	-5,592	-6,868	507
2003	856	102	7,246	1,675	348	10,228	-5,967	-5,053	-792
2004	1,667	815	6,635	2,481	350	11,948	-5,712	-7,189	-953
2005	1,230	79	6,278	2,075	350	10,011	-5,439	-5,144	-573
2006	494	54	7,150	1,238	334	9,269	-5,313	-2,043	1,914
Average 1996–2006	**970**	**222**	**7,184**	**1,793**	**344**	**10,513**	**-5,691**	**-4,922**	**-100**
%	**9.2%**	**2.1%**	**68.3%**	**17.1%**	**3.3%**	**100%**	**53.6%**	**46.4%**	**-**
ERD (2004)	**4,671.6**	**-**	**3,721.4**	**2,008.4**	**-**	**10,401.4**	**3,924.2**	**6477.2**	**-**
ERD (2004) %	**44.9%**	**-**	**35.8%**	**19.3%**	**-**	**-**	**37.7%**	**62.3%**	**-**

Several different graphical and statistical methods were used to compare simulated and observed lake concentrations. These included the following:

- *Graphical comparison of modeled and observed concentration time-series.*
- *"Box and whisker" plots graphically comparing the median and distribution of the observed data and the simulated concentrations.*
- *Tabular comparisons of annual means model versus measured values.*

These methods were applied to the calibration period (1996 to 2000) and validation period (2001 to 2006).

Figure 5.9 depicts the daily average model results against the individual measurements for TN. Overall, the model may be overestimating the daily TN within the lake during the 10-year period. **Figure 5.10** shows the annual average measured data with the model-predicted annual average across all years. On an annual average basis, the model over predicted TN for most years but generally followed the pattern in the measured data. The calibration results displayed in **Figure 5.11** and **Table 5.9** are based on a statistical analysis using the software package JMP 8.

The comparison of annual results is based on using only model results from the same day as the measured data and calculating annual averages based on this point-to-point comparison. The results show that while the model slightly over predicts TN during the calibration period, the annual means are not significantly different at an alpha of 0.05. **Figure 5.12** and **Table 5.10** depict the results for the verified period from 2001 to 2006. Based on the response of the lake to BMPs during the verified period, it was not expected the annual means would be similar. Even though the model over predicts TN by a fair amount, the difference is not significant at an alpha of 0.05. Considering all of the results, the model was determined to be suitably calibrated to the 5-year period from 1996 through 2000, and the TMDL is based on this time frame.

For the remaining figures, the following symbols are used:

- *-C indicates the results for model calibration/validation.*
- *-M indicates individual measured data points.*
- *-Ma indicates annual averages of measured data that did not include data in all four calendar quarters.*
- *4Q-M indicates annual averages that contained measured data in all four calendar quarters.*

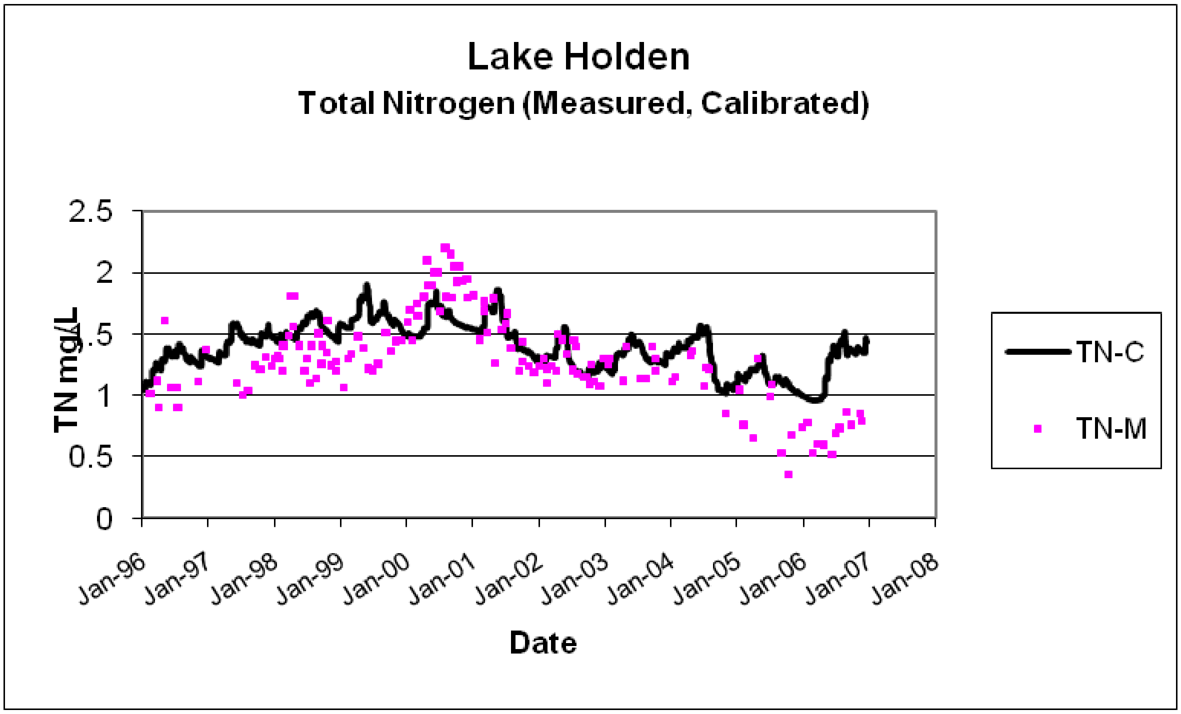

Figure 5.9. **Lake Holden Daily TN Measured Data and Calibration/Validation Results, 1996–2006**

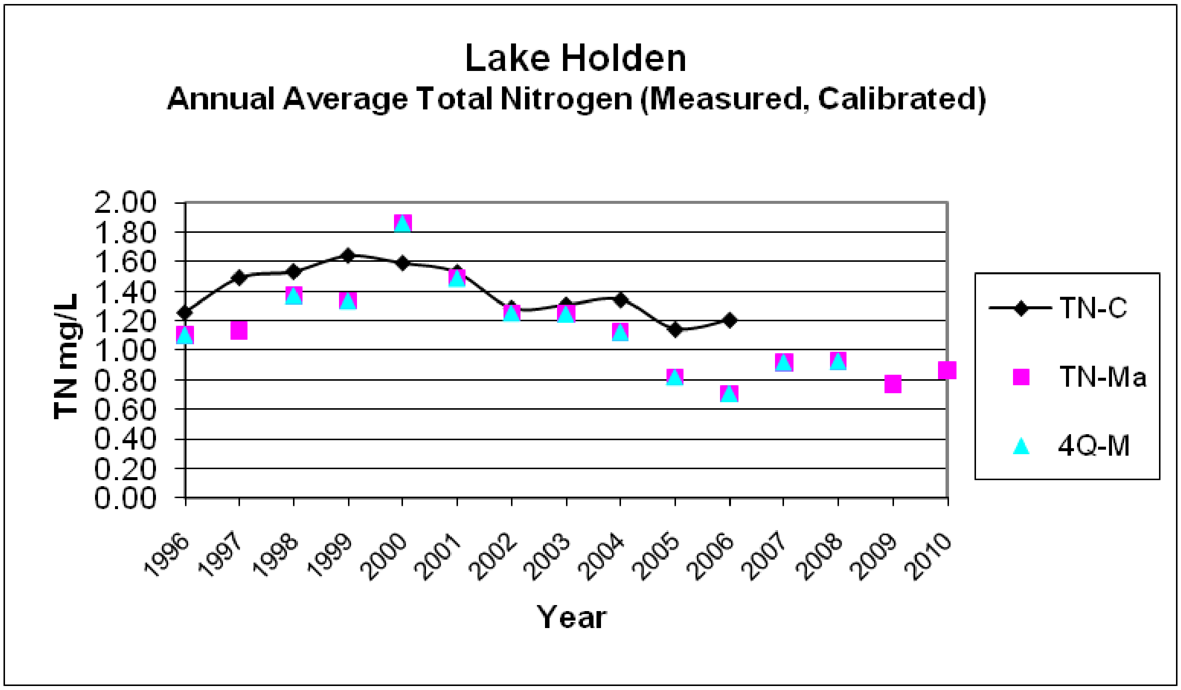

Figure 5.10. **Lake Holden Annual Average TN Measured and Calibration/Validation Results, 1996–2006, with Data Through 2010**

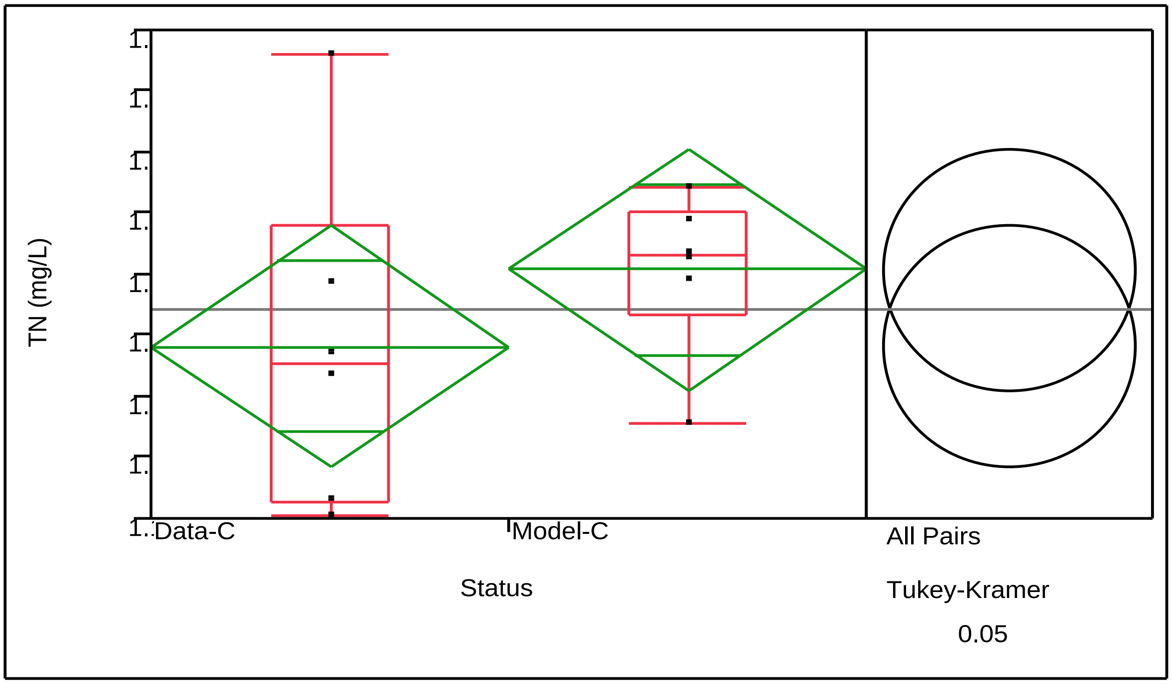

Figure 5.11. Lake Holden Annual Average TN Measured and Calibration Results, 1996–2000

Table 5.9. TN Calibration Annual Means Comparison, 1996–2000

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.22813	0.05

Abs(Dif)-LSD	Model-C	Data-C
Model-C	-0.27878	-0.15282
Data-C	-0.15282	-0.27878

Positive values show pairs of means that are significantly different.

Level		Mean
Model-C	A	1.507
Data-C	A	1.381

Levels not connected by same letter are significantly different.

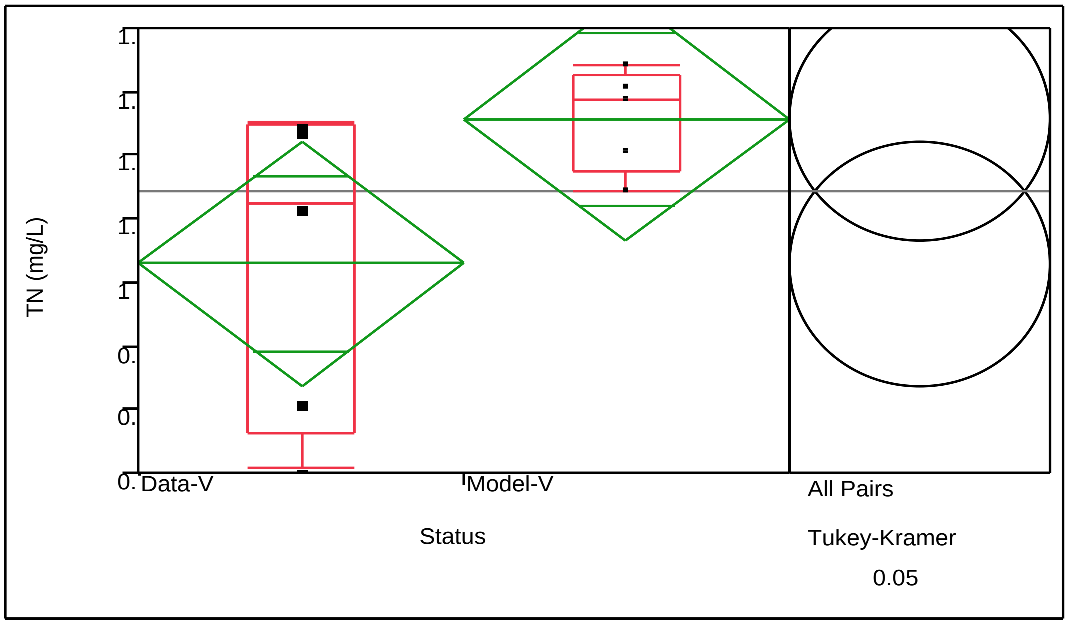

Figure 5.12. Lake Holden Annual Average TN Measured and Validation Results, 2001–06

Table 5.10. TN Validation Annual Means Comparison, 2001–06

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	**Alpha**
2.30598	0.05

Abs(Dif)-LSD	**Model-V**	**Data-V**
Model-V	-0.27329	-0.04507
Data-V	-0.04507	-0.27329

Positive values show pairs of means that are significantly different.

Level		**Mean**
Model-V	A	1.257
Data-V	A	1.029

Levels not connected by same letter are significantly different.

Figure 5.13 depicts the daily average model results against the individual measurements for TP. Overall, the model appears to represent the annual and seasonal patterns in the measured data during the calibration period but only matches the seasonal pattern during the validation period, as the model over predicts TP during the validation period. **Figure 5.14** shows the annual average measured data with the model-predicted annual average across all years. On an annual average basis, the model appears to accurately predict TP during the calibration period but over predicts TP during the validation period.

The calibration results displayed in **Figure 5.15** and **Table 5.11** are based on the same statistical analysis procedures as described for TN. The results show that the model accurately predicts TP during the calibration period and that the annual means are not significantly different at an alpha of 0.05. **Figure 5.16** and **Table 5.12** depict the results for the validation period from 2001 to 2006. Based on the response of the lake to BMPs during the validation period, it was not expected that the annual means would be similar, and they are not. The model over predicts TP by a significant amount during the period from 2001 to 2006. Considering all of the results, the model was determined to be suitably calibrated to the 5-year period from 1996 through 2000, and the TMDL is based on this time frame.

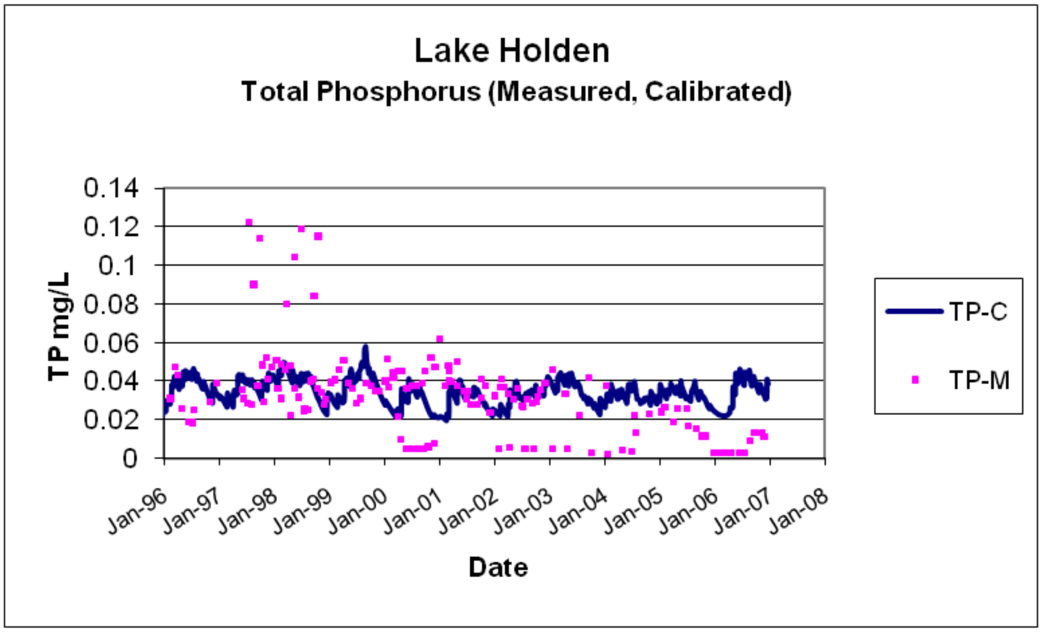

Figure 5.13. Lake Holden Daily TP Measured Data and Calibration/Validation Results, 1996–2006

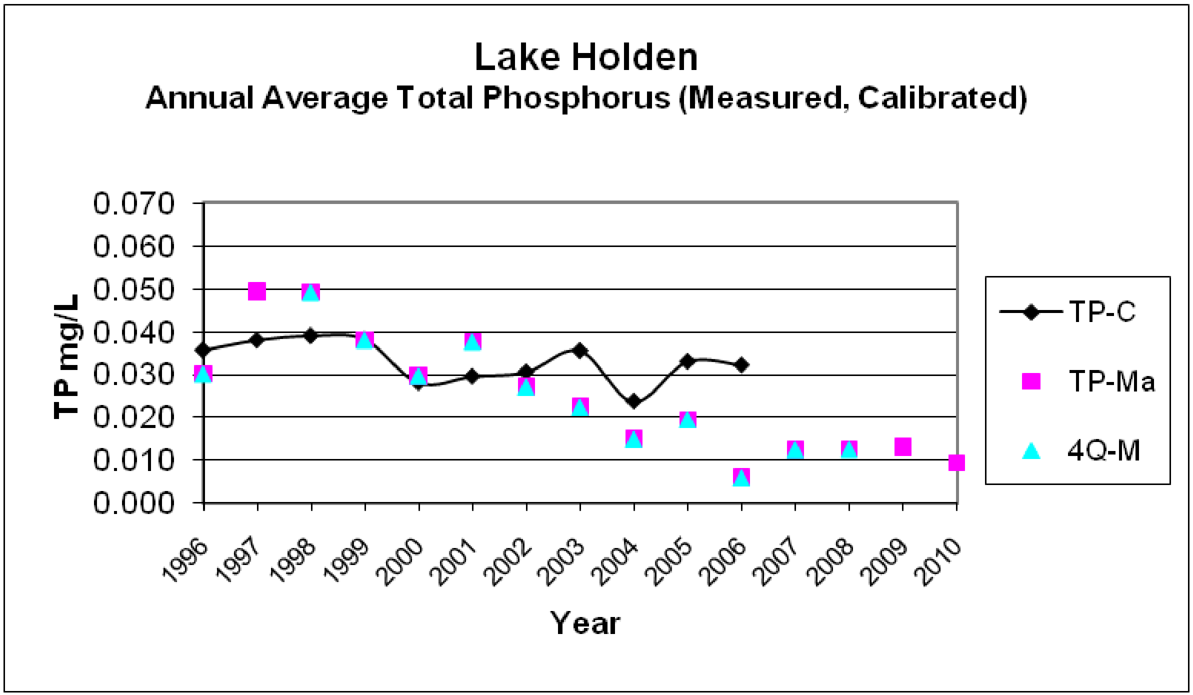

Figure 5.14. **Lake Holden Annual Average TP Measured Data and Calibration/Validation Results, 1996–2006, with Data Through 2010**

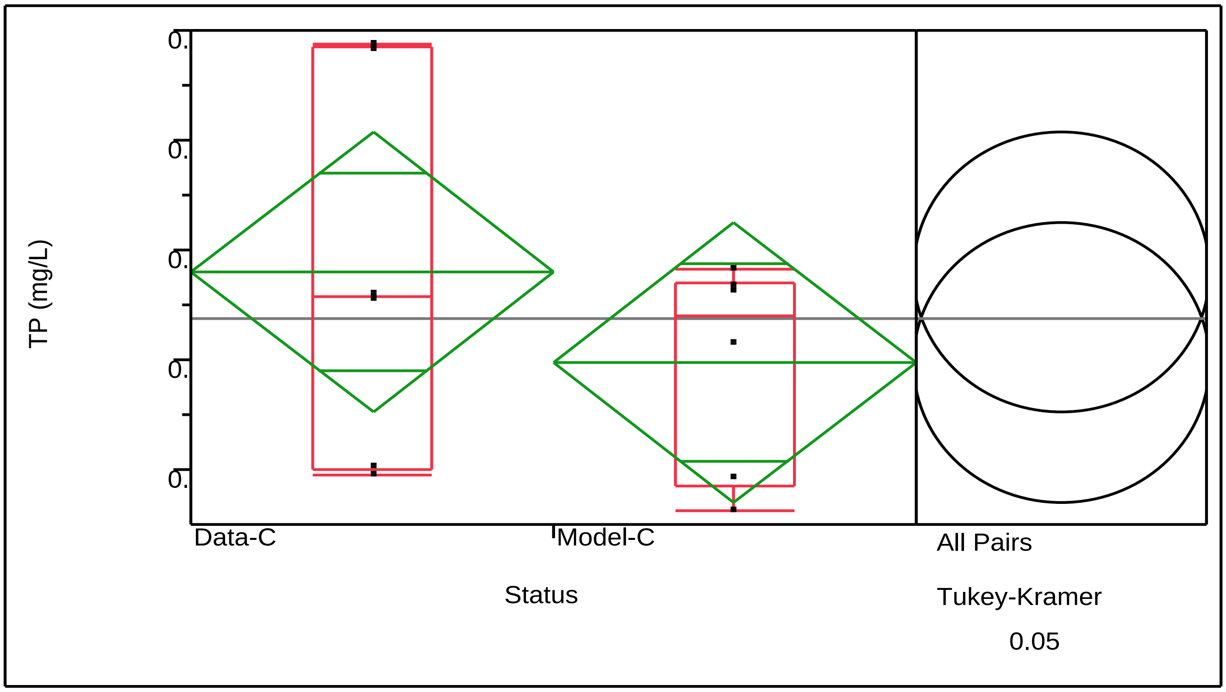

Figure 5.15. **Lake Holden TP Measured Data and Model Results Calibration, 1996–2000**

Table 5.11. TP Calibration Means Comparison, 1996–2000

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.22813	0.05

Abs(Dif)-LSD	Data-C	Model-C
Data-C	-0.00903	-0.00487
Model-C	-0.00487	-0.00903

Positive values show pairs of means that are significantly different.

Level		Mean
Data-C	A	0.0390
Model-C	A	0.0348

Levels not connected by same letter are significantly different.

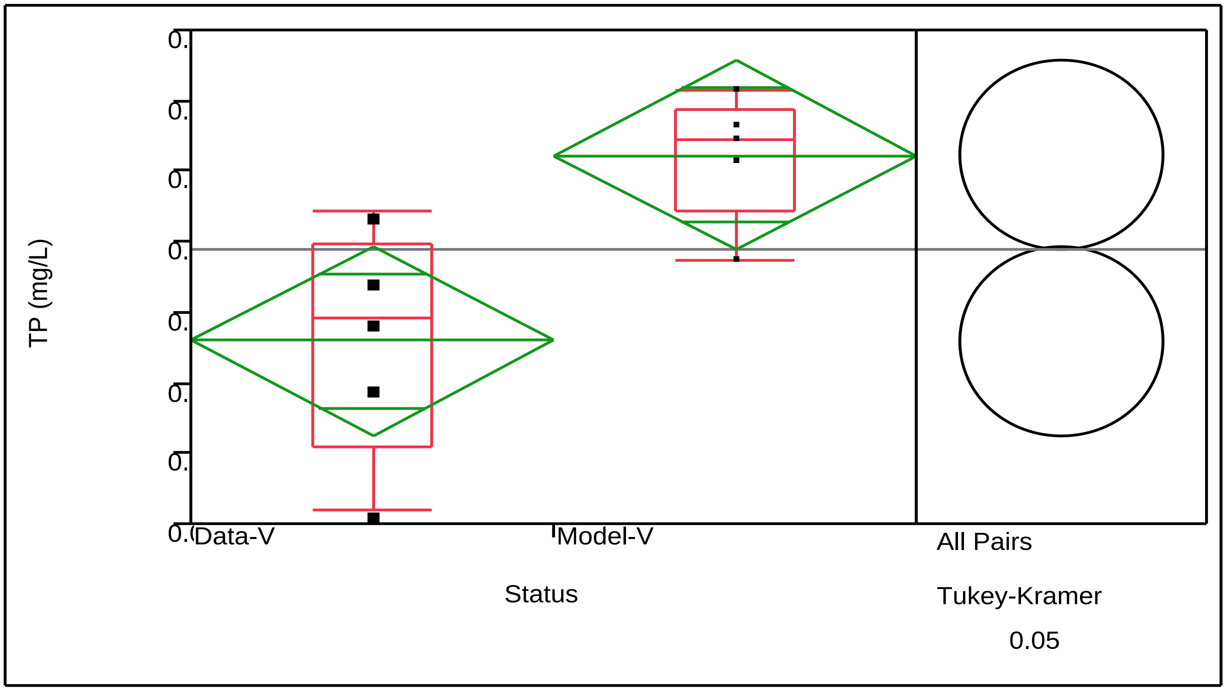

Figure 5.16. Lake Holden TP Measured Data and Model Results Validation, 2001–06

Table 5.12. TP Validation Means Comparison, 2001–06

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	**Alpha**
2.30598	0.05

Abs(Dif)-LSD	**Model-V**	**Data-V**
Model-V	-0.00951	0.003578
Data-V	0.003578	-0.00951

Positive values show pairs of means that are significantly different.

Level			**Mean**
Model-V	A		0.03108
Data-V		B	0.01799

Levels not connected by same letter are significantly different.

Figure 5.17 depicts the daily average model results against the individual measurements for chl*a*. Overall, the model appears to represent annual and seasonal patterns in the measured data during the calibration period but only the seasonal patterns during the validation period, as it over predicts chl*a* during the validation period. **Figure 5.18** shows the annual average measured data with the model-predicted annual average across all years. On an annual average basis, the model appears to accurately predict chl*a* during the calibration period but significantly over predicts chl*a* during the validation period, as the lake responded to BMPs that could not be accurately represented as a time-series in the model.

The calibration results displayed in **Figure 5.19** and **Table 5.13** are based on the same statistical analysis procedures used for TN. The results show that the model accurately predicts chl*a* during the calibration period and that the annual means are not significantly different at an alpha of 0.05. **Figure 5.20** and **Table 5.14** depict the results for the validation period from 2001 to 2006. Based on the response of the lake to BMPs during the validation period, it was not expected the annual means would be similar, and they are not. The model over predicts chl*a* by a significant amount during the period from 2001 to 2006. Considering all of the results, the model was determined to be suitably calibrated to the five-year period from 1996 through 2000, and the TMDL is based on this time frame.

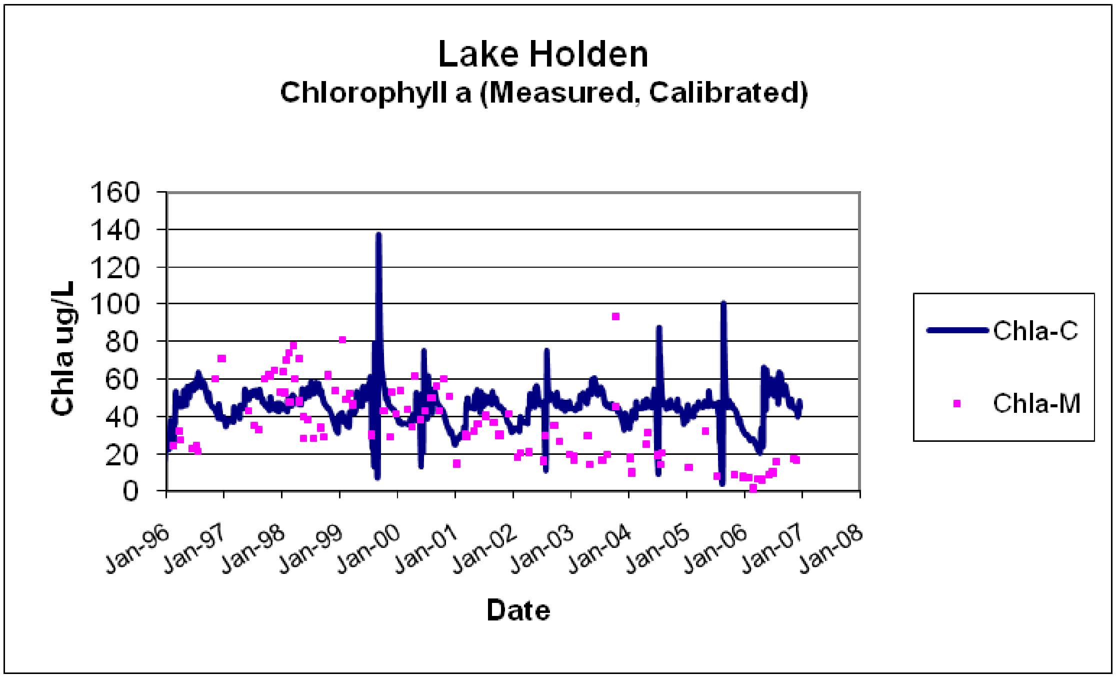

Figure 5.17. **Lake Holden Daily Chl*a* Measured Data and Calibration/Validation Results, 1996–2006**

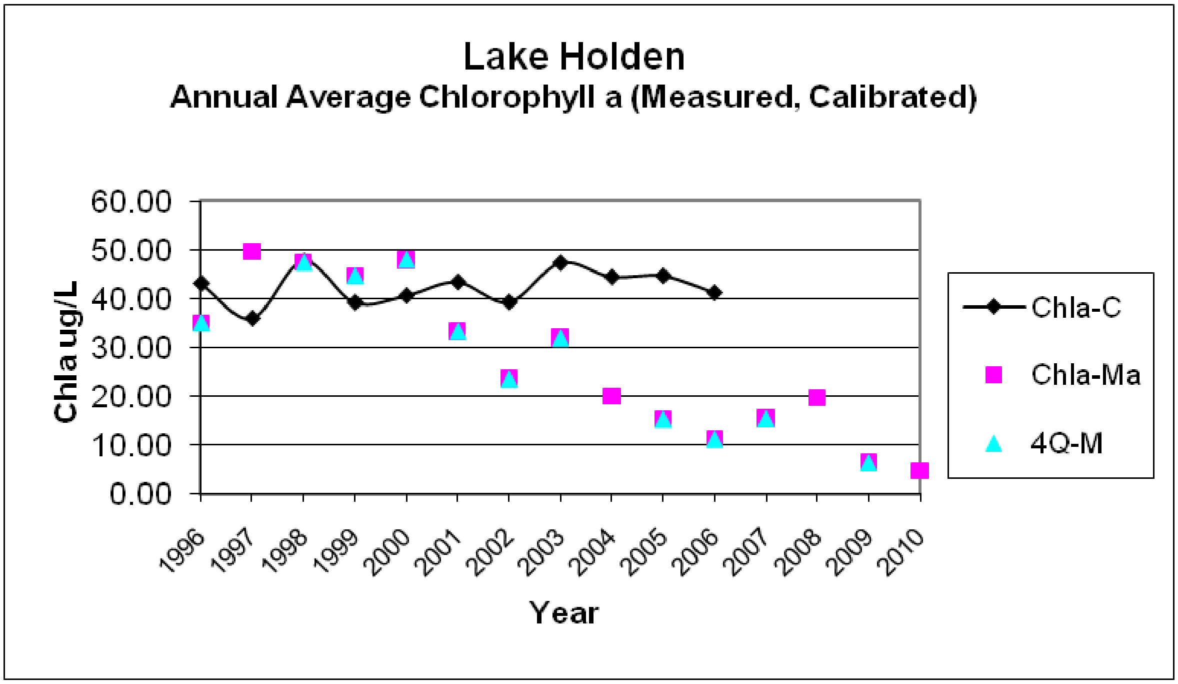

Figure 5.18. **Lake Holden Annual Average Chl*a* Measured Data and Calibration/Validation Results, 1996–2006, with Data Through 2010**

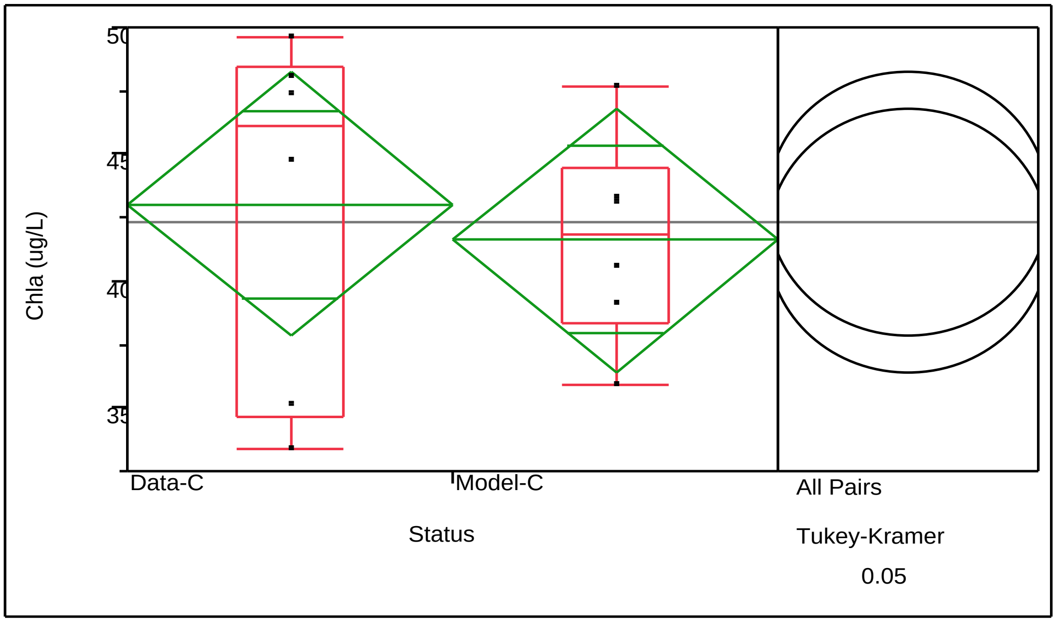

Figure 5.19. Lake Holden Average Chl*a* Measured Data and Calibration Results, 1996–2000

Table 5.13. Chl*a* Calibration Means Comparison, 1996–2000

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	**Alpha**
2.22813	0.05

Abs(Dif)-LSD	**Data-C**	**Model-C**
Data-C	-7.37491	-5.94561
Model-C	-5.94561	-7.37491

Positive values show pairs of means that are significantly different.

Level		**Mean**
Data-C	A	43.03
Model-C	A	41.61

Levels not connected by same letter are significantly different.

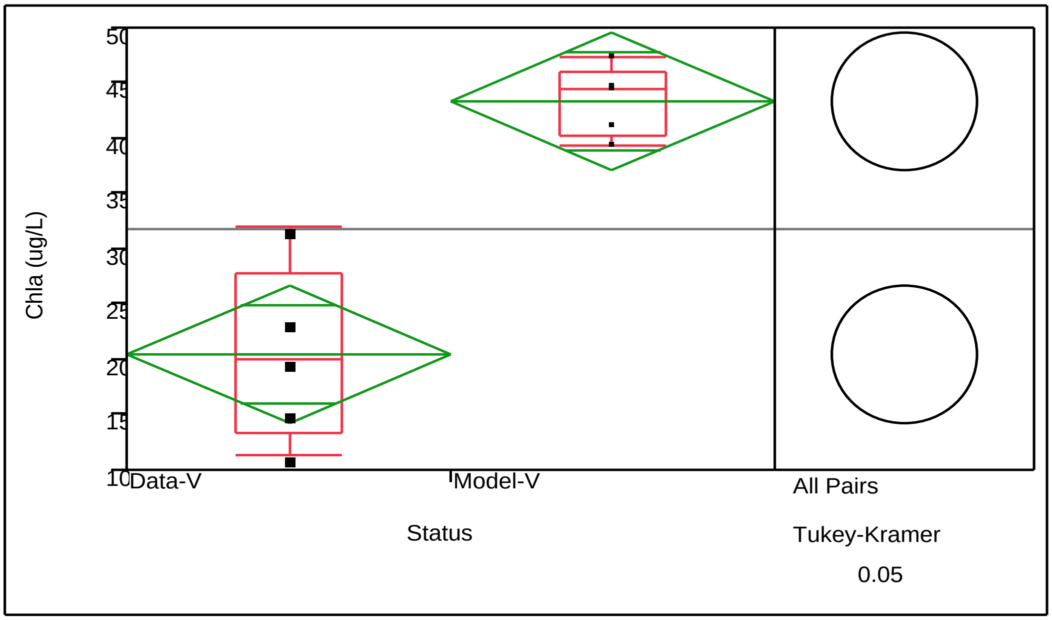

Figure 5.20. **Lake Holden Average Chl*a* Measured Data and Validation Results, 2001–06**

Table 5.14. **Chl*a* Validation Means Comparison, 2001–06**

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	**Alpha**
2.30598	0.05

Abs(Dif)-LSD	**Model-V**	**Data-V**
Model-V	-8.82662	14.06007
Data-V	14.06007	-8.82662

Positive values show pairs of means that are significantly different.

Level			**Mean**
Model-V	A		43.33
Data-V		B	20.44

Levels not connected by same letter are significantly different.

Figure 5.21 shows the annual average TSI measured data with the model-predicted annual average across all years. On an annual average basis, the model appears to accurately predict TSI during the calibration period but significantly over predicts TSI during the validation period, as the lake responded to BMPs that could not be accurately represented as a time-series in the model. The calibration results displayed in **Figure 5.22** and **Table 5.15** are based on the same statistical analysis procedures described for TN. The results show that the model accurately predicts TSI during the calibration period and that the annual means are not significantly different at an alpha of 0.05. **Figure 5.23** and **Table 5.16** depict the results for the validation period from 2001 to 2006. Based on the response of the lake to BMPs during the validation period, it was not expected the annual means would be similar, and they are not. The model is over predicting TSI by a significant amount during the period from 2001 to 2006. Considering all of the results, the model was determined to be suitably calibrated to the 5-year period from 1996 through 2000, and the TMDL is based on this time frame.

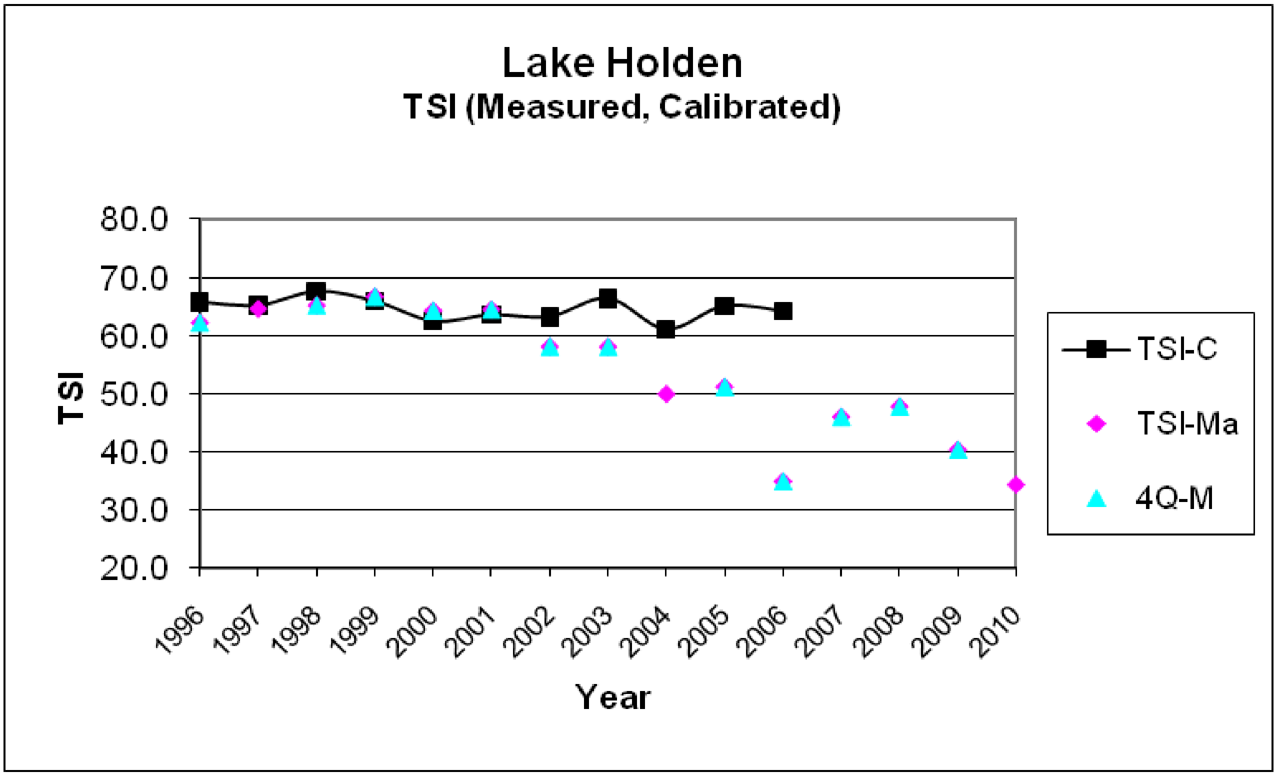

Figure 5.21. Lake Holden Annual Average TSI Measured Data and Calibration/Validation Results (1996–2006) with Data Through 2010

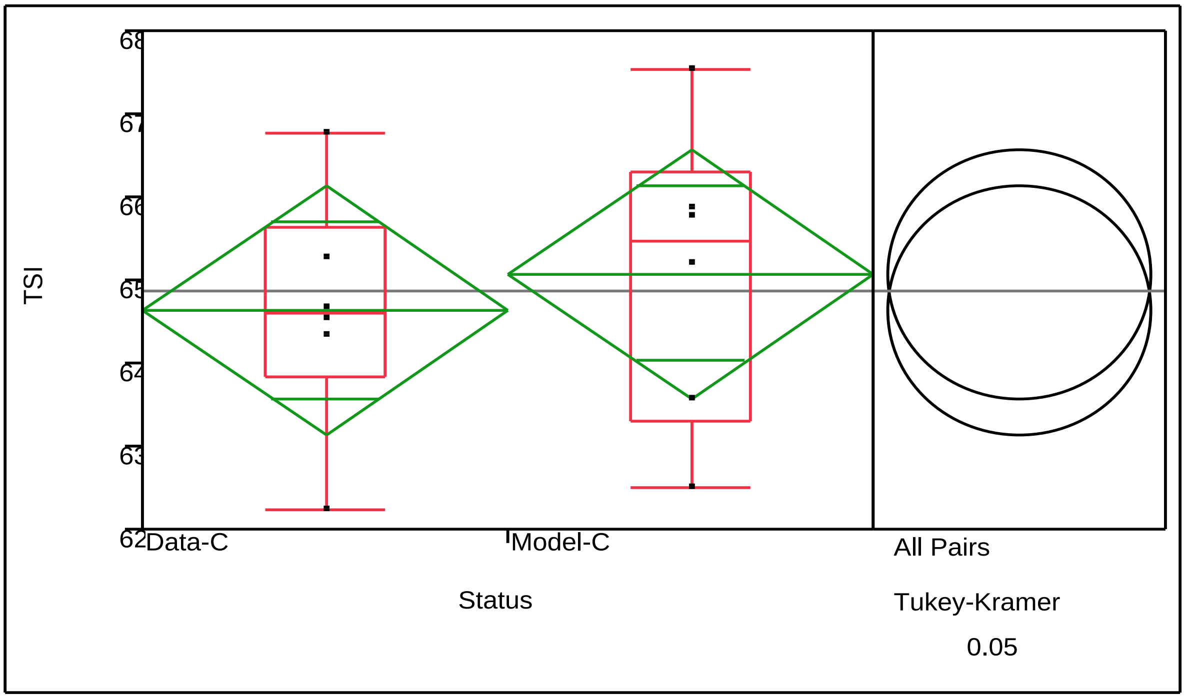

Figure 5.22. Lake Holden Annual Average TSI Measured Data and Calibration Results, 1996–2000

Table 5.15. TSI Calibration Annual Means Comparison, 1996– 2000

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.22813	0.05

Abs(Dif)-LSD	Model-C	Data-C
Model-C	-2.10634	-1.66734
Data-C	-1.66734	-2.10634

Positive values show pairs of means that are significantly different.

Level		Mean
Model-C	A	65.07
Data-C	A	64.63

Levels not connected by same letter are significantly different.

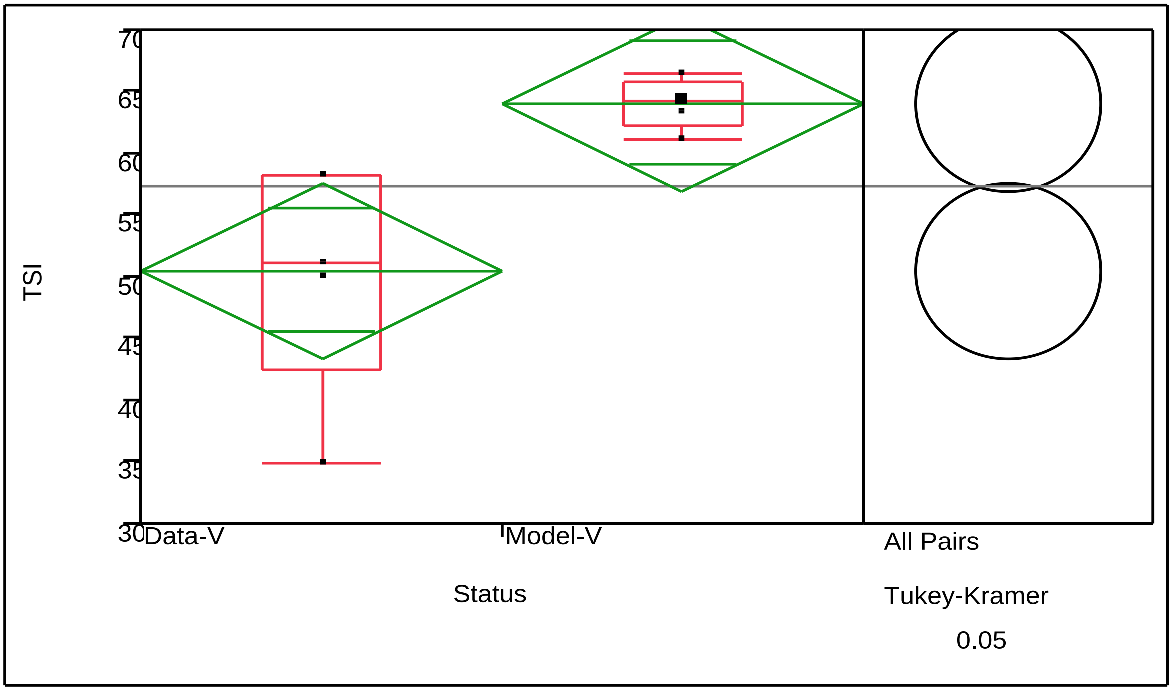

Figure 5.23. Lake Holden Annual Average TSI Measured Data and Validation Results, 2001–06

Table 5.16. TSI Validation Annual Means Comparison, 1996– 2000

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	**Alpha**
2.30598	0.05

Abs(Dif)-LSD	**Model-V**	**Data-V**
Model-V	-10.0008	3.559403
Data-V	3.559403	-10.0008

Positive values show pairs of means that are significantly different.

Level			**Mean**
Model-V	A		64.01
Data-V		B	50.45

Levels not connected by same letter are significantly different.

5.1.3 Background Conditions

HSPF was used to describe and evaluate the “natural land use background condition” for the Lake Holden watershed. The background condition is important in that it sets a “floor” below which concentrations will not be reduced in the lake. For this simulation, all current land uses were 'reassigned' to a mixture of forest and wetland. The current condition was maintained for all waterbody physical characteristics. From this point forward, the natural land use background is referred to as "background." Under the background condition, the lake is considered P-limited with an average TN/TP ratio of 295. Based on the background model run results for the calibrated period (1996 to 2000), the predevelopment lake should have had annual average TP concentrations ranging from 0.003 to 0.007 mg/L, with a long-term average of 0.005 mg/L. The predevelopment annual average TN concentrations ranged between 1.01 and 1.35 mg/L, with a long-term average of 1.17 mg/L. The predevelopment annual average chl*a* ranged from 2.51 to 7.69 µg/L, with an average of 4.3 µg/L. The resulting annual average TSI values ranged between 17.5 and 34.7, with a long-term average of 23.8.

5.2 Selection of the TMDL Target

The Department is relying on the evaluation of site-specific data and information, Best Professional Judgment (BPJ), and information in the EPA Technical Support Document (TSD) (EPA 2009b) and DEP TSD 2009 to develop the TMDL target. The lake data demonstrate that Lake Holden has shown steady and significant improvements in water quality after 2000. The Department's evaluation of the data is in agreement with statements in ERD (2004) that the period inclusive of 1996 to 2000 represents reasonably consistent water quality. Additionally, as the model is well calibrated to the period from 1996 to 2000 but not representative of the period from 2001 to 2006, the results from the calibration period were used to develop the TMDL.

Carlson and Simpson (1996) noted that trophic state is not synonymous with the concept of water quality. While trophic state is an absolute scale that describes the biological condition of a waterbody, water quality is used to describe the condition of a waterbody in relation to human needs or values, relative to the use of the water and the expectations of the user. Water quality targets for TMDL development are created to protect the designated uses of waterbodies. In the case of Florida lakes, the designated uses are for the protection of healthy, well-balanced populations of fish and wildlife, and for recreation in and on the water. TMDL targets must provide protection for these sometimes competing interests.

The TMDL target for Lake Holden with average color less than 40 PCU and alkalinity greater than 20 mg/L (average from 1989 to 2010 of 59.4 mg/L) is based on an extensive literature review and analysis of data summarized in the TSD (EPA 2009b) and DEP draft TSD 2009. The EPA found that correlations between nitrogen/phosphorus and biological response parameters in the different types of lakes in Florida were specific, significant, and documentable and, when considered in combination with additional lines of evidence, support a stressor-response approach to criteria development for Florida's lakes. The EPA's results show a significant relationship between concentrations of nitrogen and phosphorus in lakes and algal growth. The agency proposed the use of chl*a* concentration as an indicator of a healthy biological condition, supportive of natural balanced populations of aquatic flora and fauna in each of the classes of Florida's lakes. The EPA has found that a stressor-response approach to estimate the relationship between nitrogen/phosphorus concentrations and a response measure that is either directly or indirectly related to the designated use (in this case, chl*a* as a measure of attaining a balanced natural population of aquatic flora and fauna) can be used to determine the concentrations of nutrients that support the designated use.

The DEP TSD summarizes several lines of evidence that can be used to establish TMDL targets for nutrients in low-color lakes (color less than 40 PCU) with average alkalinity greater than 20 mg/L. These lines of evidence include the following:

- *Paleolimnological studies, where prehuman disturbance chla values are inferred from an analysis of diatom communities in deep sediment cores.*
- *Expert elicitation, or BPJ, for the determination of protective TSI or chla values.*
- *Fisheries responses to chla or TSI levels, dependent upon the type of fisheries, which are in turn adapted to associated DO conditions (i.e., cold-water versus warm-water fisheries).*
- *Associating lake user visual perceptions (for swimming and aesthetics) with simultaneously measured chla.*
- *Setting the criterion to maintain the existing condition (protection strategy).*

Paleolimnological studies conducted in Florida lakes with a color less than 40 PCU and alkalinity greater than 20 mg/L suggest that the average chl*a* in these lakes would naturally range between 14 and 20 µg/L. Expert opinions based on BPJ suggest TMDL targets that would protect against excessive eutrophication, expressed as annual or summertime averages, ranging from 20 to 33 µg/L of chl*a*.

Reviews of information from other states on fisheries end points for TMDL development were conducted. For example, Virginia analyzed the effect of chl*a* levels on the health of fisheries and concluded that summer average chl*a* concentrations of 35 to 60 µg/L in warm-water lakes were protective of fish health (Gregory 2007). Texas conducted a study of lake user perceptions that indicated that in reservoirs, chl*a* levels below approximately 20 to 25 µg/L still support full-immersion recreational uses, as well as aesthetics (Glass 2006). Alabama's approach to establishing lake or reservoir chl*a* targets is designed to "maintain the existing condition" (Macindoe 2006), with the targets for specific lakes or reservoirs ranging from 5 to 27 µg/L.

The Department is also currently investigating fish community composition data collected from Florida lakes by the Florida Fish and Wildlife Conservation Commission (FWC) for comparison with chl*a* data. The results of initial analyses do not yield a notable response signal in the data and thus do not currently further inform the determination of chl*a* targets.

After reviewing these multiple lines of evidence, considering the competing designated uses for Lake Holden (color less than 40 PCU and alkalinity greater than 20 mg/L), and using BPJ, the Department recommends using a concentration near the lower end of the range suggested by the paleolimnological studies. For Lake Holden, this is an annual average chl*a* TMDL target no greater than 14 µg/L. This concentration should be fully protective of designated uses. The HSPF model was used to determine the concentrations of TN and TP that would result in an in-lake annual average chl*a* concentration less than 14 µg/L.

5.3 Development of the TMDL and Hierarchy 1 Interpretation of Narrative Nutrient Criterion

Once the target cchl*a* concentration of 14.0 µg/L was established, HSPF was rerun for existing conditions with decreasing loads for upstream inflows from the watershed (loads from direct rainfall on the lake, forest, and wetlands were not reduced) and internal flux (based on a proportional reduction to the watershed load) until the model predictions for chl*a* were below the target concentration of 14 µg/L. The TMDLs for Lake Holden were then expressed as the TN and TP watershed loads required to restore the lake and the resulting in-lake chl*a* concentration. Furthermore, when Paragraph 62-302.531(2)(a), F.A.C., becomes effective, these nutrient TMDLs will constitute site-specific numeric interpretations of the narrative nutrient criterion set forth in Paragraph 62-302.530(47)(b), F.A.C.

The TMDLs were achieved in the model through reductions in current loadings from anthropogenic land uses (commercial/industrial, residential, and agricultural) and internal (benthic flux) loadings to the lake of 82% for TP and 40% for TN. While the restored lake will be P-limited, reductions in TN were also required in the model, as otherwise TN increased in the lake as TP was reduced, and this had an effect on nutrient cycling within the model. The 82% TP reduction in only the anthropogenic sources is equivalent to a 74% reduction in total loading from all watershed sources (the loads from benthic release and rainfall directly on the lake's surface were not tabulated as watershed loads).

It should be noted that the model does not always produce smooth, gradual changes of cchl*a* in response to reductions in nutrient loading; rather, changes are often in the range of 1 to 2 µg/L. This commonly results in TMDL concentrations less than the target concentration and, in these cases, adds to the margin of safety.

As discussed previously, the TMDL is based on reductions in the watershed TP load during the period from 1996 to 2000, as shown in **Table 5.17** and summarized in **Table 5.18**.

Table 5.17. Calibrated Model TP Loadings, 1996–2000

Year	Baseflow TP (lbs)	Interflow TP (lbs)	Runoff TP (lbs)	Rainfall TP (lbs)	Sediment Release TP (lbs)	Total Inflow TP (lbs)	Settling TP (lbs)	Outflow TP (lbs)
Average 1996–2000	42	15	505	48	548	1,158	-1,063	-117

Table 5.18. TP TMDL Watershed Loads Based on Years 1996 to 2000

- = Empty cell/no data
[1] TMDL based on watershed loadings. Watershed load does not include load from benthic flux or rainfall. Percent reductions rounded up.

Year (1996–2000)	Baseflow TP (lbs/yr)	Interflow TP (lbs/yr)	Runoff TP (lbs/yr)	Total Inflow from Watershed TP (lbs/yr)[1]
Existing	42	15	505	562
TMDL	42	15	91	148
% reduction	0%	0%	-	74%

The TP TMDL is expressed as the total allowable watershed load to the lake (148 lbs/yr) and a 74% reduction from the existing total watershed load (562 lbs/yr). The Department notes that the TMDL will not require any reductions from natural land uses within the watershed. These reductions resulted in average (1996 to 2000) lake concentrations of 0.009 mg/L for TP, 1.46 mg/L for TN, and 12.1 µg/L for chl*a*, and a TSI of 40. The data indicate that TN has been below the TMDL condition since 2001 and that chl*a* was below the target in 2006, 2009, and 2010. TP was below the TMDL condition in 2006 (the year after the whole-lake treatment) and slightly above (but decreasing slightly each year) since. The TSI achieved the target condition of 40 in 2006, 2009, and 2010 (not a complete year).

Table 5.17 shows the 1996 to 2000 average TP loading from ***all sources*** (including benthic flux and direct rainfall on the lake) of 1,158 lbs/yr. **Table 5.18** depicts the existing watershed load of 562 lbs/yr and the total allowable watershed loading (TMDL) of 148 lbs/yr (0.40 lbs/day) from ***all watershed sources***. The 74% reduction applied to the total watershed load will be applied to both the load allocation (LA) and stormwater wasteload allocation (MS4) components of the TMDL.

The goal of the TMDL is to maintain the lake long-term average cchl*a* below 14 µg/L, with an equivalent TSI of 40 or less, with strong TP limitation. Combinations of cchl*a* and TP concentrations in the lake other than those derived from the model results could still result in a TSI of 40 and successful restoration of the lake. The modeled in-lake concentrations (based on watershed loadings and model in-lake processes) have resulted in just one possible combination. Maintaining the long-term annual average loadings for TP established in this TMDL should result in attaining the TMDL target condition in the lake. Additionally, it should be noted that the estimated load from pre-1992 (ERD 1992) of 1,741.6 lbs/yr was reduced by the implementation of BMPs in the period from 1996 to 2000 to 1,158 lbs/yr, a reduction of 33.5% in total watershed load, and that additional reductions in loading have occurred after 2000.

Figure 5.24 shows the relationship in TSI for the model calibrated, background, and TMDL condition. **Table 5.19**, depicts the TN loads from various sources for the TMDL condition. **Table 5.20**, depicts the TMDL for Cchla.

5.4 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 the assimilative capacity does not lend itself very well to short-term assessments; (2) the Department is generally more concerned with the net change in overall primary productivity in the segment, 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.

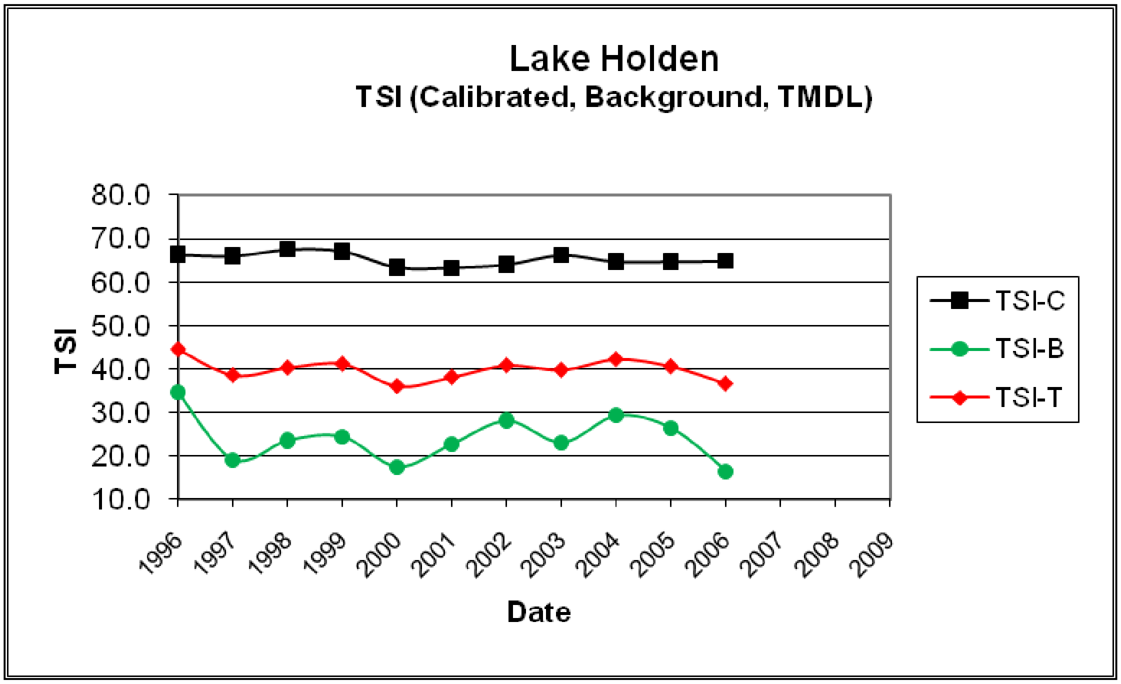

Figure 5.24. TSI for the Calibrated Model, Background, and TMDL Condition

Table 5.19. TN Watershed Loads Based on Years 1996 to 2000

[1] TMDL for nonlimiting nutrient TN based on highest annual average runoff load during the model calibration scenario period from 1996 to 2000. Watershed load does not include load from benthic flux or rainfall. Percent reductions rounded up.

Year (1996–2000)	Baseflow TN (lbs/yr)	Interflow TN (lbs/yr)	Runoff TN (lbs/yr)	Total Inflow from Watershed TN (lbs/yr)[1]
Existing	1,036	210	9,280	10,526
TMDL	1,036	210	5,099	6,345
% reduction	0%	0%	0%	40%

Table 5.20. Chl*a* TMDL Based on Nutrient TMDLs, 1996–2000

Year (1996–2000)	Chl*a* (µg/L)
Existing	45.28
TMDL	12.1
% reduction	73.2%

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:

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

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 "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 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 LA and NPDES stormwater WLA are expressed as a percent reduction in the stormwater loading from these areas. The TMDL is the site-specific numeric interpretation of the narrative nutrient criterion pursuant to Paragraph 62-302.531(2)(a), F.A.C. The TMDL for Lake Holden 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**).

Additionally, as noted in **Chapters 2** and **5,** the pre-1992 TP load of 1,741.6 lbs/yr (ERD 1992) was reduced by the implementation of BMPs in the period from 1996 to 2000 to 1,158 lbs/yr, a reduction of 33.5% in total watershed load, and that additional reductions in loading have occurred since 2000. All of the measured data and ERD studies support the conclusion that the implementation of BMPs in the Lake Holden watershed has significantly improved water quality. Given that the initial effects of the BMPs were not immediately apparent in lake water quality, the in-lake effects of the continued implementation of BMPs since 2000 may not yet be fully realized in the lake data.

Table 6.1. Lake Holden TMDL Load Allocations

NA = Not applicable
[1] Allowable load from all watershed sources.
The TMDL daily load for TP is 0.40 lbs/day.
These reductions resulted in long-term average lake concentrations of 0.009 mg/L for TP, 1.46 mg/L for TN, and 12.1 µg/L for chl*a*, with an average TN/TP ratio of 53.1.

WBID	Parameter	WLA for Wastewater (lbs/yr)	WLA for Stormwater (% reduction)	LA (% reduction)	MOS	TMDL (lbs/yr)[1]
3168H	TP	NA	74%	74%	Implicit	148
3168H	TN	NA	0%	0%	Implicit	10,526

6.2 Load Allocation

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 74% reduction in the total nonpoint source watershed loadings of TP from 1996 to 2000. 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 anthropogenic sources may be greater. It should be noted that the LA may include loading from stormwater discharges regulated by the Department and the SJRWMD that are not part of the NPDES Stormwater Program (see **Appendix A**).

6.3 Wasteload Allocation

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 Holden watershed that discharge surface water within the watershed. Therefore, the $WLA_{wastewater}$ for the Lake Holden TMDL is not applicable because no wastewater or industrial wastewater NPDES facilities discharge directly to the lake.

6.3.2 NPDES Stormwater Discharges

The stormwater collection systems in the Lake Holden watershed, which are owned and operated by the city of Orlando, are covered by NPDES Phase I MS4 Permit Number FLS000014. The collection system for the Florida Department of Transportation District 5 is covered by NPDES Permit Number FLR04E024. The collection systems for the Florida Turnpike are covered by NPDES Permit Number FLR04E049. The collection systems for Orange County are covered by Phase 1-C NPDES Permit Number FLS000011. The wasteload allocation for stormwater discharges is a 74% reduction in total watershed loading from 1996 to 2000 for TP, which is the required percent reduction in stormwater nonpoint sources.

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

6.4 Margin of Safety

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, Section 303[d][1][c]). Considerable uncertainty is usually inherent in estimating nutrient loading from nonpoint sources, as well as predicting water quality response. The effectiveness of management activities (*e.g.,* stormwater management plans) in reducing loading is also subject to uncertainty.

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings.

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department 2001a), an implicit MOS was used in the development of the Lake Holden TMDL because the TMDL was based on the use of conservative decisions associated with a number of the modeling assumptions. For example, numerous BMPs were implemented during the modeling period from 1996 to 2000, with only the alum injection BMP accounted for in the watershed loadings.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 TMDL Implementation

Following the adoption of this TMDL by rule, the Department will determine the best course of action regarding its implementation. Depending upon the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. Basin Management Action Plans 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.

If the Department determines that a BMAP is needed to support the implementation of this TMDL, a 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.

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.

However, in some basins, and for some parameters, particularly those with fecal coliform impairments, the development of a BMAP using the process described above will not be the most efficient way to restore a waterbody, such that it meets its designated uses. Why? Because fecal coliform impairments result from the cumulative effects of a multitude of potential sources, both natural and anthropogenic. Addressing these problems requires good old fashioned detective work that is best done by those in the area. There are a multitude of assessment tools that are available to assist local governments and interested stakeholders in this detective work. The tools range from the simple – such as Walk the WBIDs and GIS mapping - to the complex.

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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 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: Measured Data and CDM Report (2008) for the Lake Holden 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), available upon request (~100 megabytes on disk).

The CDM report (2008) and all data used in the Lake Holden TMDL report are available upon request. Please contact the individual listed below to obtain this information.

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Florida Department of Environmental Protection
Water Quality Evaluation and TMDL Program
Watershed Evaluation and TMDL Section
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Appendix C: HSPF Water Quality Calibration Values for Lake Holden

- = Empty cell/no data

Water Temperature

HSPF Variable	Lake Holden
CFSAEX	0.50
KATRAD	9.37
KCOND	6.12
KEVAP	2.24

TSS

HSPF Variable	Lake Holden
KSAND	6
EXPSND	1.5
W	1.0E-05
TAUCD	0.02
TAUCS	0.32
M	1.2
W	1.6E-06
TAUCD	0.02
TAUCS	0.46
M	1.2

DO and Oxygen Demand

HSPF Variable	Lake Holden
KBOD20	0.0012
TCBOD	1.037
KODSET	0
BENOD	4.6
TCBEN	1.037
REAKT (2)	-
REAKT (3)	-
EXPRED	-
EXPREV	-
TCGINV	1.047

NUTRX Module

HSPF Variable	Lake Holden
KTAM20	0.002
TCNIT	1.07
BRTAM	0.02
BRPO4	0.032

PLANK Module

HSPF Variable	Lake Holden
RATCLP	4.0
NONREF	1.00
ALNPR	0.75
EXTB	0.23
MALGR	0.161
CMMLT	0.033
CMMN	0.045
CMMNP	0.028
CMMP	0.015
TALGRH	95
TALGRL	43
TALGRM	70
ALR20	0.0015
ALDH	0.0027
ALDL	0.0014
CLALDH	45
PHYSET	0.180
REFSET	0.00018
CVBO	1.31
CVBPC	106
CVBPN	10
BPCNTC	49

Appendix D: Raw Data for Lake Holden

Remark Codes:
+ = TN calculated from component parts (NO2+3 + ammonia + organic).
& = Cchl*a* result reported was less than the detection limit of 1.0 µg/L and assigned a value of 1.0 µg/L
A = Value is arithmetic mean of two or more determinations.
I = Value is between the method detection limit and practical quantitation limit.
J = Value is estimated.
Q = Sample held beyond holding time.
T = Value is less than the method detection limit for information only.
U = Compound analyzed but not detected.
Highlighted data shown with an asterisk and in boldface type were removed by request of data providers and were not used for calibration or verification purposes.

Uncorrected Chl*a* (2/17/1993–6/30/1998)
Corrected Chl*a* (7/14/1998 forward)

Year	Month	Day	Unit	Result
1993	2	17	µg/L	45.8
1993	2	17	µg/L	51.0
1993	6	22	µg/L	47.9
1993	6	22	µg/L	43.8
1993	8	25	µg/L	32.3
1993	8	25	µg/L	42.6
1994	3	16	µg/L	36.8
1994	3	16	µg/L	36.2
1994	6	13	µg/L	39.2
1994	6	13	µg/L	32.6
1994	9	19	µg/L	51.4
1994	9	19	µg/L	59.2
1994	11	21	µg/L	51.9
1994	11	21	µg/L	50.8
1995	3	11	µg/L	34.0
1995	3	11	µg/L	32.7
1995	6	12	µg/L	13.1
1995	6	12	µg/L	12.4
1995	7	26	µg/L	38.0
1995	7	26	µg/L	35.0
1995	7	26	µg/L	40.0
1995	8	22	µg/L	38.0
1995	8	22	µg/L	40.0
1995	8	22	µg/L	37.0
1995	10	2	µg/L	40.1

Year	Month	Day	Unit	Result
1995	10	2	µg/L	42.8
1995	11	27	µg/L	43.0
1995	11	27	µg/L	61.0
1995	11	27	µg/L	61.0
1996	2	28	µg/L	24.2
1996	2	28	µg/L	24.6
1996	4	3	µg/L	32.6
1996	4	3	µg/L	31.7
1996	4	16	µg/L	27.0
1996	4	16	µg/L	30.0
1996	4	16	µg/L	26.0
1996*	**6**	**24**	**µg/L**	**1.0**
1996	6	24	µg/L	22.7
1996	7	23	µg/L	27.0
1996	7	23	µg/L	22.0
1996	7	30	µg/L	22.0
1996	7	30	µg/L	20.0
1996	7	30	µg/L	22.0
1996	11	20	µg/L	59.7
1996	11	20	µg/L	60.9
1996	12	30	µg/L	72.7
1996	12	30	µg/L	68.9
1997	6	21	µg/L	51.0
1997	6	21	µg/L	44.0
1997	6	21	µg/L	34.0
1997	7	23	µg/L	38.0
1997	7	23	µg/L	31.0
1997	7	23	µg/L	36.0
1997	8	22	µg/L	34.0
1997	8	22	µg/L	31.0
1997	8	22	µg/L	33.0
1997	9	29	µg/L	62.0
1997	9	29	µg/L	52.0
1997	9	29	µg/L	66.0
1997	10	28	µg/L	42.0

Year	Month	Day	Unit	Result
1997	10	28	µg/L	73.0
1997	10	28	µg/L	71.0
1997	11	29	µg/L	73.0
1997	11	29	µg/L	73.0
1997	11	29	µg/L	48.0
1998	1	2	µg/L	51.0
1998	1	2	µg/L	54.0
1998	1	2	µg/L	54.0
1998	1	21	µg/L	63.6
1998	1	31	µg/L	55.0
1998	1	31	µg/L	49.0
1998	1	31	µg/L	54.0
1998	2	9	µg/L	70.0
1998	3	1	µg/L	75.0
1998	3	1	µg/L	79.0
1998	3	1	µg/L	67.0
1998	3	4	µg/L	47.8
1998	3	31	µg/L	80.0
1998	3	31	µg/L	76.0
1998	3	31	µg/L	77.0
1998	4	8	µg/L	60.3
1998	4	30	µg/L	75.0
1998	4	30	µg/L	66.0
1998	4	30	µg/L	72.0
1998	5	6	µg/L	48.0
1998	5	31	µg/L	40.0
1998	5	31	µg/L	38.0
1998	5	31	µg/L	41.0
1998	6	3	µg/L	27.9
1998	6	30	µg/L	42.0
1998	6	30	µg/L	36.0
1998	6	30	µg/L	37.0
1998*	**7**	**14**	**µg/L**	**1.0**
1998	8	6	µg/L	28.3
1998	9	14	µg/L	34.0

Year	Month	Day	Unit	Result
1998	10	7	µg/L	29.0
1998	11	4	µg/L	62.0
1998	12	17	µg/L	54.0
1999	1	29	µg/L	78.0
1999	1	29	µg/L	83.0
1999	1	29	µg/L	81.0
1999	2	23	µg/L	53.0
1999	2	23	µg/L	52.0
1999	2	23	µg/L	43.0
1999	3	18	µg/L	52.0
1999	3	18	µg/L	52.0
1999	3	18	µg/L	52.0
1999	4	7	µg/L	46.5
1999*	**5**	**6**	**µg/L**	**179.8**
1999	8	5	µg/L	30.1
1999	10	19	µg/L	42.8
1999	11	29	µg/L	29.0
1999	12	9	µg/L	53.0
2000	1	6	µg/L	41.7
2000	1	6	µg/L	41.7
2000	2	2	µg/L	52.6
2000	2	2	µg/L	55.1
2000	3	16	µg/L	44.7
2000	3	16	µg/L	42.6
2000	4	13	µg/L	60.6
2000	4	13	µg/L	8.6
2000	5	5	µg/L	62.2
2000	5	5	µg/L	61.2
2000	6	6	µg/L	38.8
2000	6	6	µg/L	37.7
2000	7	6	µg/L	44.8
2000	7	6	µg/L	41.2
2000	8	15	µg/L	49.9
2000	9	14	µg/L	58.5
2000	9	14	µg/L	53.5

Year	Month	Day	Unit	Result
2000	10	5	µg/L	42.9
2000	11	2	µg/L	59.1
2000	11	2	µg/L	61.4
2000	12	11	µg/L	43.7
2000	12	11	µg/L	57.2
2001	1	22	µg/L	12.7
2001	1	22	µg/L	16.7
2001	3	15	µg/L	28.0
2001	3	15	µg/L	33.6
2001	3	22	µg/L	25.8
2001	3	22	µg/L	32.9
2001	5	10	µg/L	26.1
2001	5	10	µg/L	38.2
2001	6	4	µg/L	43.2
2001	6	4	µg/L	29.0
2001	7	24	µg/L	40.6
2001	7	24	µg/L	39.8
2001	9	12	µg/L	36.1
2001	9	12	µg/L	37.6
2001	10	18	µg/L	27.6
2001	10	18	µg/L	32.8
2001	12	17	µg/L	42.5
2001	12	17	µg/L	40.1
2002	2	13	µg/L	18.7
2002	2	13	µg/L	17.9
2002	2	28	µg/L	22.1
2002	2	28	µg/L	19.2
2002	4	24	µg/L	22.0
2002	4	24	µg/L	19.7
2002	7	25	µg/L	16.1
2002	7	25	µg/L	16.4
2002	8	5	µg/L	30.1
2002	8	5	µg/L	29.1
2002	10	1	µg/L	41.0
2002	10	1	µg/L	29.8

Year	Month	Day	Unit	Result
2002	11	1	µg/L	25.4
2002	11	1	µg/L	27.7
2003	1	7	µg/L	18.7
2003	1	7	µg/L	20.8
2003	2	3	µg/L	16.1
2003	2	3	µg/L	21.2
2003	2	4	µg/L	15.3
2003	2	4	µg/L	18.7
2003	4	29	µg/L	22.2
2003	4	29	µg/L	37.1
2003	5	12	µg/L	7.4
2003	5	12	µg/L	20.7
2003	7	29	µg/L	17.3
2003	7	29	µg/L	15.8
2003	8	28	µg/L	19.9
2003	10	21	µg/L	37.2
2003	10	21	µg/L	53.2
2003	10	23	µg/L	94.1
2003	10	23	µg/L	93.0
2004	1	22	µg/L	17.2
2004	1	22	µg/L	18.2
2004	2	4	µg/L	4.1
2004	2	4	µg/L	15.8
2004	5	4	µg/L	26.7
2004	5	4	µg/L	23.8
2004	5	11	µg/L	30.8
2004	5	11	µg/L	31.9
2004	7	13	µg/L	20.3
2004	7	13	µg/L	18.2
2004	7	29	µg/L	12.5
2004	7	29	µg/L	16.5
2004	8	9	µg/L	24.9
2004	8	9	µg/L	16.0
2005	1	27	µg/L	11.7
2005	1	27	µg/L	13.9

Year	Month	Day	Unit	Result
2005	5	10	µg/L	31.5
2005	5	10	µg/L	32.6
2005	7	21	µg/L	6.2
2005	7	21	µg/L	9.4
2005	11	10	µg/L	9.0
2005	11	10	µg/L	8.5
2006	1	5	µg/L	7.6
2006	1	5	µg/L	7.6
2006	2	6	µg/L	6.8
2006	2	6	µg/L	7.2
2006*	**2**	**6**	**µg/L**	**1.0**
2006*	**3**	**6**	**µg/L**	**1.0**
2006	3	6	µg/L	1.4
2006*	**3**	**6**	**µg/L**	**1.0**
2006	4	5	µg/L	6.6
2006	4	5	µg/L	7.0
2006	5	3	µg/L	5.7
2006	5	3	µg/L	6.5
2006*	**5**	**3**	**µg/L**	**1.0**
2006	6	21	µg/L	8.4
2006	6	21	µg/L	9.1
2006*	**6**	**21**	**µg/L**	**1.0**
2006	7	10	µg/L	10.2
2006	7	10	µg/L	9.8
2006	8	2	µg/L	16.8
2006	8	2	µg/L	14.5
2006*	**8**	**2**	**µg/L**	**1.0**
2006*	**9**	**7**	**µg/L**	**1.0**
2006*	**11**	**21**	**µg/L**	**1.0**
2006	11	21	µg/L	18.8
2006	11	21	µg/L	16.3
2006	12	6	µg/L	17.6
2006	12	6	µg/L	15.0
2006*	**12**	**6**	**µg/L**	**1.0**
2007	1	4	µg/L	20.0

Year	Month	Day	Unit	Result
2007*	**1**	**4**	**µg/L**	**1.0**
2007	1	16	µg/L	11.8
2007	2	21	µg/L	17.1
2007	2	21	µg/L	15.5
2007	3	7	µg/L	9.8
2007*	**3**	**7**	**µg/L**	**1.0**
2007	3	7	µg/L	11.0
2007	4	4	µg/L	17.7
2007*	**4**	**4**	**µg/L**	**1.0**
2007	4	4	µg/L	17.7
2007	4	24	µg/L	7.6
2007	4	24	µg/L	4.1
2007	7	19	µg/L	6.0
2007	7	19	µg/L	4.6
2007	8	7	µg/L	20.0
2007	8	7	µg/L	18.2
2007	9	6	µg/L	27.1
2007	9	6	µg/L	23.1
2007	10	3	µg/L	21.9
2007	10	3	µg/L	22.3
2007	10	23	µg/L	20.0
2007	10	23	µg/L	18.2
2007	11	19	µg/L	21.6
2007	11	19	µg/L	18.8
2007	12	5	µg/L	20.2
2007	12	5	µg/L	20.6
2007	12	18	µg/L	26.0
2008	1	8	µg/L	14.9
2008	1	8	µg/L	13.7
2008	7	8	µg/L	13.6
2008	7	8	µg/L	12.4
2008	10	7	µg/L	31.6
2008	10	7	µg/L	31.6
2009	1	8	µg/L	7.1
2009	1	8	µg/L	2.8

Year	Month	Day	Unit	Result
2009	4	2	µg/L	3.8
2009	4	2	µg/L	3.3
2009	6	15	µg/L	6.2
2009	6	23	µg/L	5.0
2009	7	7	µg/L	6.0
2009	7	7	µg/L	5.4
2009	9	24	µg/L	8.2
2009	10	6	µg/L	9.4
2009	10	6	µg/L	8.8
2010	1	27	µg/L	5.7
2010	1	27	µg/L	3.9
2010	4	28	µg/L	4.6
2010	4	28	µg/L	4.5
2010	7	7	µg/L	3.6
2010	7	20	µg/L	3.1
2010	7	20	µg/L	2.5
2010	10	11	µg/L	6.8
2010	10	11	µg/L	4.7
2011	7	11	µg/L	2.9
2012	1	19	µg/L	2.2

Total Nitrogen

Year	Month	Day	Date	Result
1993	2	17	mg/L	1.375
1993	2	17	mg/L	1.455
1993	6	22	mg/L	1.448
1993	6	22	mg/L	1.360
1993	8	25	mg/L	1.305
1993	8	25	mg/L	1.465
1994	3	16	mg/L	1.258
1994	3	16	mg/L	1.108
1994	6	13	mg/L	1.335
1994	6	13	mg/L	1.315
1994	9	16	mg/L	1.125
1994	9	19	mg/L	1.255
1994	11	21	mg/L	1.015
1994	11	21	mg/L	1.115
1995	3	13	mg/L	1.015
1995	3	13	mg/L	1.010
1995	6	12	mg/L	0.535
1995	6	12	mg/L	0.325
1995	6	27	mg/L	1.210
1995	7	26	mg/L	0.890
1995	7	26	mg/L	0.860
1995	7	26	mg/L	0.860
1995	8	22	mg/L	1.250
1995	8	22	mg/L	1.000
1995	8	22	mg/L	1.000
1995	9	26	mg/L	1.339
1995	9	26	mg/L	1.210
1995	10	2	mg/L	0.615
1995	11	27	mg/L	1.070
1995	11	27	mg/L	1.270
1995	11	27	mg/L	1.090
1995	11	28	mg/L	1.210
1995	11	28	mg/L	1.510
1995	12	27	mg/L	1.510

Year	Month	Day	Date	Result
1995	12	27	mg/L	1.335
1996	2	28	mg/L	1.015
1996	4	3	mg/L	1.121
1996	4	16	mg/L	0.910
1996	4	16	mg/L	0.910
1996	4	16	mg/L	0.880
1996	5	16	mg/L	1.615
1996	5	16	mg/L	1.615
1996	6	24	mg/L	1.015
1996	6	24	mg/L	1.110
1996	7	24	mg/L	1.115
1996	7	24	mg/L	1.015
1996	7	30	mg/L	0.900
1996	7	30	mg/L	0.890
1996	7	30	mg/L	0.910
1996	11	20	mg/L	1.115
1996	12	30	mg/L	1.421
1996	12	30	mg/L	1.322
1997	6	21	mg/L	1.130
1997	6	21	mg/L	1.070
1997	6	21	mg/L	1.090
1997*	**7**	**1**	**mg/L**	**0.916**
1997	7	23	mg/L	0.990
1997	7	23	mg/L	1.010
1997	7	23	mg/L	1.010
1997*	**8**	**5**	**mg/L**	**4.018**
1997	8	22	mg/L	1.090
1997	8	22	mg/L	0.900
1997	8	22	mg/L	1.140
1997*	**9**	**2**	**mg/L**	**2.615**
1997	9	29	mg/L	1.230
1997	9	29	mg/L	1.310
1997	9	29	mg/L	1.190
1997*	**10**	**9**	**mg/L**	**3.715**
1997	10	28	mg/L	1.110

Year	Month	Day	Date	Result
1997	10	28	mg/L	1.330
1997	10	28	mg/L	1.200
1997*	**11**	**5**	**mg/L**	**1.215**
1997	11	29	mg/L	1.300
1997	11	29	mg/L	1.260
1997	11	29	mg/L	1.370
1997*	**12**	**2**	**mg/L**	**4.232**
1998	1	2	mg/L	1.290
1998	1	2	mg/L	1.280
1998	1	2	mg/L	1.140
1998	1	21	mg/L	1.305
1998	1	31	mg/L	1.330
1998	1	31	mg/L	1.380
1998	1	31	mg/L	1.270
1998	2	9	mg/L	1.305
1998	3	1	mg/L	1.190
1998	3	1	mg/L	1.290
1998	3	1	mg/L	1.130
1998	3	4	mg/L	1.405
1998*	**3**	**4**	**mg/L**	**1.817**
1998	3	31	mg/L	1.590
1998	3	31	mg/L	1.420
1998	3	31	mg/L	1.440
1998	4	8	mg/L	1.805
1998*	**4**	**8**	**mg/L**	**3.015**
1998	4	30	mg/L	1.540
1998	4	30	mg/L	1.370
1998	4	30	mg/L	1.760
1998	5	6	mg/L	1.807
1998*	**5**	**6**	**mg/L**	**1.151**
1998	5	31	mg/L	1.410
1998	5	31	mg/L	1.430
1998	5	31	mg/L	1.380
1998	6	3	mg/L	1.405
1998*	**6**	**3**	**mg/L**	**1.715**

Year	Month	Day	Date	Result
1998	6	30	mg/L	1.320
1998	6	30	mg/L	1.240
1998	6	30	mg/L	1.050
1998	7	14	mg/L	1.305
1998*	**7**	**14**	**mg/L**	**1.816**
1998	7	30	mg/L	1.030
1998	7	30	mg/L	1.120
1998	7	30	mg/L	1.160
1998	8	6	mg/L	1.405
1998*	**8**	**6**	**mg/L**	**1.515**
1998	8	31	mg/L	1.160
1998	8	31	mg/L	1.120
1998	8	31	mg/L	1.150
1998	9	14	mg/L	1.505
1998*	**9**	**14**	**mg/L**	**1.827**
1998	10	1	mg/L	1.290
1998	10	1	mg/L	1.310
1998	10	1	mg/L	1.170
1998	10	7	mg/L	1.405
1998*	**10**	**7**	**mg/L**	**1.515**
1998	10	29	mg/L	1.320
1998	10	29	mg/L	1.340
1998	10	29	mg/L	1.380
1998	11	4	mg/L	1.605
1998*	**11**	**4**	**mg/L**	**1.715**
1998	11	23	mg/L	1.230
1998	11	23	mg/L	1.200
1998	11	23	mg/L	1.300
1998	12	17	mg/L	1.205
1998*	**12**	**17**	**mg/L**	**1.015**
1998	12	20	mg/L	1.310
1998	12	20	mg/L	1.220
1998	12	20	mg/L	1.310
1999	1	29	mg/L	1.110
1999	1	29	mg/L	1.070

Year	Month	Day	Date	Result
1999	1	29	mg/L	1.010
1999	2	23	mg/L	1.400
1999	2	23	mg/L	1.240
1999	2	23	mg/L	1.260
1999	3	18	mg/L	1.480
1999	3	18	mg/L	1.250
1999	3	18	mg/L	1.270
1999	4	22	mg/L	1.540
1999	4	22	mg/L	1.420
1999	4	22	mg/L	1.480
1999	5	20	mg/L	1.320
1999	5	20	mg/L	1.440
1999	5	20	mg/L	1.400
1999	6	18	mg/L	1.080
1999	6	18	mg/L	1.290
1999	6	18	mg/L	1.290
1999	7	12	mg/L	1.170
1999	7	12	mg/L	1.210
1999	7	12	mg/L	1.240
1999	8	9	mg/L	1.250
1999	8	9	mg/L	1.300
1999	8	9	mg/L	1.220
1999	9	20	mg/L	1.560
1999	9	20	mg/L	1.460
1999	9	20	mg/L	1.510
1999	10	18	mg/L	1.490
1999	10	18	mg/L	1.310
1999	10	18	mg/L	1.290
1999	11	15	mg/L	1.460
1999	11	15	mg/L	1.460
1999	11	15	mg/L	1.410
1999	12	15	mg/L	1.520
1999	12	15	mg/L	1.500
1999	12	15	mg/L	1.340
2000	1	23	mg/L	1.600

Year	Month	Day	Date	Result
2000	1	23	mg/L	1.580
2000	1	23	mg/L	1.600
2000	2	2	mg/L	1.700
2000	2	2	mg/L	1.700
2000	2	13	mg/L	1.550
2000	2	13	mg/L	1.510
2000	2	13	mg/L	1.300
2000	3	13	mg/L	1.590
2000	3	13	mg/L	1.930
2000	3	13	mg/L	1.720
2000	3	16	mg/L	1.600
2000	3	16	mg/L	1.700
2000	4	13	mg/L	1.800
2000	4	13	mg/L	1.800
2000	4	19	mg/L	1.700
2000	4	19	mg/L	1.990
2000	4	19	mg/L	1.730
2000	5	5	mg/L	2.100
2000	5	5	mg/L	2.100
2000	5	12	mg/L	1.880
2000	5	12	mg/L	1.910
2000	5	12	mg/L	1.900
2000	6	6	mg/L	1.600
2000	6	6	mg/L	2.200
2000	6	13	mg/L	2.000
2000	6	13	mg/L	2.000
2000	7	6	mg/L	2.100
2000	7	6	mg/L	1.900
2000	7	13	mg/L	1.730
2000	7	13	mg/L	1.670
2000	7	13	mg/L	1.650
2000	8	15	mg/L	2.400
2000	8	15	mg/L	2.000
2000	8	17	mg/L	1.930
2000	8	17	mg/L	1.670

Year	Month	Day	Date	Result
2000	8	17	mg/L	1.810
2000	9	14	mg/L	2.200
2000	9	14	mg/L	2.100
2000	9	21	mg/L	1.820
2000	9	21	mg/L	1.860
2000	9	21	mg/L	1.710
2000	10	5	mg/L	2.100
2000	10	5	mg/L	2.000
2000	10	14	mg/L	1.890
2000	10	14	mg/L	1.950
2000	10	14	mg/L	1.940
2000	11	2	mg/L	1.900
2000	11	2	mg/L	2.200
2000	11	20	mg/L	1.910
2000	11	20	mg/L	1.960
2000	12	11	mg/L	2.000
2000	12	11	mg/L	1.900
2000	12	16	mg/L	1.760
2000	12	16	mg/L	1.830
2001	1	20	mg/L	1.880
2001	1	20	mg/L	1.750
2001	2	24	mg/L	1.460
2001	2	24	mg/L	1.450
2001	3	15	mg/L	1.770
2001	3	15	mg/L	1.760
2001	3	18	mg/L	1.710
2001	3	18	mg/L	1.670
2001	4	4	mg/L	1.470
2001	4	4	mg/L	1.560
2001	5	10	mg/L	1.750
2001	5	10	mg/L	1.830
2001	5	16	mg/L	1.310
2001	5	16	mg/L	1.210
2001	6	24	mg/L	1.510
2001	6	24	mg/L	1.560

Year	Month	Day	Date	Result
2001	7	15	mg/L	1.500
2001	7	15	mg/L	1.680
2001	7	24	mg/L	1.690
2001	7	24	mg/L	1.640
2001	8	13	mg/L	1.350
2001	8	13	mg/L	1.420
2001	9	26	mg/L	1.190
2001	9	26	mg/L	1.210
2001	10	16	mg/L	1.220
2001	10	16	mg/L	1.280
2001	10	16	mg/L	1.330
2001	10	18	mg/L	1.370
2001	10	18	mg/L	1.500
2001	11	19	mg/L	1.080
2001	11	19	mg/L	1.310
2001	11	19	mg/L	1.330
2001	12	17	mg/L	1.210
2001	12	17	mg/L	1.160
2001	12	17	mg/L	0.950
2001	12	17	mg/L	1.200
2001	12	17	mg/L	1.400
2002	1	17	mg/L	1.480
2002	1	17	mg/L	1.120
2002	1	17	mg/L	1.110
2002	2	13	mg/L	1.300
2002	2	13	mg/L	1.300
2002	2	24	mg/L	1.170
2002	2	24	mg/L	1.000
2002	2	24	mg/L	1.140
2002	2	28	mg/L	1.180
2002	2	28	mg/L	1.260
2002	3	23	mg/L	1.220
2002	3	23	mg/L	1.170
2002	3	23	mg/L	1.320
2002	4	19	mg/L	1.370

Year	Month	Day	Date	Result
2002	4	19	mg/L	1.040
2002	4	19	mg/L	1.190
2002	4	24	mg/L	1.500
2002	4	24	mg/L	1.500
2002	5	21	mg/L	1.370
2002	5	21	mg/L	1.540
2002	6	18	mg/L	1.350
2002	6	18	mg/L	1.390
2002	6	18	mg/L	1.280
2002	7	18	mg/L	1.120
2002	7	18	mg/L	1.230
2002	7	18	mg/L	1.270
2002	7	25	mg/L	1.470
2002	7	25	mg/L	1.430
2002	8	5	mg/L	1.400
2002	8	5	mg/L	1.400
2002	8	16	mg/L	1.210
2002	8	16	mg/L	1.240
2002	8	16	mg/L	1.090
2002	9	20	mg/L	1.150
2002	9	20	mg/L	1.170
2002	9	20	mg/L	1.140
2002	10	1	mg/L	1.000
2002	10	1	mg/L	1.300
2002	10	21	mg/L	1.100
2002	10	21	mg/L	1.170
2002	10	21	mg/L	0.990
2002	11	1	mg/L	1.310
2002	11	1	mg/L	1.200
2002	11	15	mg/L	1.080
2002	11	15	mg/L	1.110
2002	11	15	mg/L	1.140
2002	12	16	mg/L	1.020
2002	12	16	mg/L	1.090
2002	12	16	mg/L	1.120

Year	Month	Day	Date	Result
2003	1	7	mg/L	1.300
2003	1	7	mg/L	1.300
2003	2	3	mg/L	1.200
2003	2	3	mg/L	1.300
2003	2	4	mg/L	1.330
2003	2	4	mg/L	1.260
2003	4	29	mg/L	1.060
2003	4	29	mg/L	1.180
2003	5	12	mg/L	1.400
2003	5	12	mg/L	1.400
2003	7	29	mg/L	1.150
2003	7	29	mg/L	1.130
2003	8	28	mg/L	1.140
2003	10	2	mg/L	1.404
2003	10	21	mg/L	1.280
2003	10	21	mg/L	1.320
2003	10	23	mg/L	1.130
2003	10	23	mg/L	1.270
2004	1	22	mg/L	1.140
2004	1	22	mg/L	1.080
2004	2	5	mg/L	1.070
2004	2	5	mg/L	1.230
2004	5	4	mg/L	1.300
2004	5	4	mg/L	1.360
2004	5	11	mg/L	1.580
2004	5	11	mg/L	1.140
2004	7	13	mg/L	1.030
2004	7	13	mg/L	1.130
2004	7	29	mg/L	1.220
2004	7	29	mg/L	1.230
2004	8	9	mg/L	1.180
2004	8	9	mg/L	1.240
2004	11	8	mg/L	0.860
2004	11	8	mg/L	0.840
2005	1	27	mg/L	1.070

Year	Month	Day	Date	Result
2005	1	27	mg/L	1.020
2005	2	16	mg/L	0.770
2005	2	16	mg/L	0.750
2005	4	11	mg/L	0.620
2005	4	11	mg/L	0.680
2005	5	10	mg/L	1.290
2005	5	10	mg/L	1.310
2005	7	11	mg/L	1.010
2005	7	11	mg/L	0.960
2005	7	21	mg/L	1.130
2005	7	21	mg/L	1.050
2005	9	15	mg/L	0.601
2005	9	15	mg/L	0.470
2005	10	20	mg/L	0.363
2005	10	20	mg/L	0.353
2005	11	10	mg/L	0.700
2005	11	10	mg/L	0.670
2006	1	5	mg/L	0.760
2006	1	5	mg/L	0.720
2006	2	6	mg/L	0.740
2006	2	6	mg/L	0.810
2006*	**2**	**6**	**mg/L**	**0.020**
2006	3	6	mg/L	0.520
2006	3	6	mg/L	0.540
2006*	**3**	**6**	**mg/L**	**0.020**
2006	4	5	mg/L	0.580
2006	4	5	mg/L	0.630
2006	5	3	mg/L	0.620
2006	5	3	mg/L	0.580
2006*	**5**	**3**	**mg/L**	**0.040**
2006	6	21	mg/L	0.520
2006	6	21	mg/L	0.520
2006*	**6**	**21**	**mg/L**	**0.020**
2006	7	10	mg/L	0.690
2006	7	10	mg/L	0.690

Year	Month	Day	Date	Result
2006	8	2	mg/L	0.760
2006	8	2	mg/L	0.710
2006*	**8**	**2**	**mg/L**	**0.020**
2006	9	7	mg/L	0.920
2006	9	7	mg/L	0.820
2006*	**9**	**7**	**mg/L**	**0.004**
2006	10	4	mg/L	0.760
2006	10	4	mg/L	0.760
2006*	**11**	**21**	**mg/L**	**0.004**
2006	11	21	mg/L	0.880
2006	11	21	mg/L	0.830
2006	12	6	mg/L	0.770
2006	12	6	mg/L	0.820
2006*	**12**	**6**	**mg/L**	**0.004**
2007	1	4	mg/L	0.800
2007*	**1**	**4**	**mg/L**	**0.004**
2007	1	4	mg/L	0.800
2007	1	16	mg/L	0.810
2007	1	16	mg/L	0.870
2007	2	21	mg/L	0.830
2007	2	21	mg/L	0.780
2007	3	7	mg/L	0.795
2007*	**3**	**7**	**mg/L**	**0.004**
2007	3	7	mg/L	0.858
2007	4	24	mg/L	1.150
2007	4	24	mg/L	1.070
2007	5	3	mg/L	0.840
2007*	**5**	**3**	**mg/L**	**0.004**
2007	5	3	mg/L	0.850
2007	6	6	mg/L	0.870
2007*	**6**	**6**	**mg/L**	**0.004**
2007	6	6	mg/L	0.930
2007	7	9	mg/L	0.900
2007*	**7**	**9**	**mg/L**	**0.004**
2007	7	9	mg/L	0.880

Year	Month	Day	Date	Result
2007*	**7**	**9**	**mg/L**	**0.004**
2007	7	19	mg/L	0.940
2007	7	19	mg/L	0.880
2007	8	7	mg/L	0.850
2007	8	7	mg/L	0.790
2007	9	6	mg/L	0.960
2007*	**9**	**6**	**mg/L**	**0.004**
2007	9	6	mg/L	0.910
2007	10	4	mg/L	0.960
2007*	**10**	**4**	**mg/L**	**0.004**
2007	10	4	mg/L	0.930
2007	10	23	mg/L	0.980
2007	10	23	mg/L	1.000
2007	11	19	mg/L	0.720
2007	11	19	mg/L	0.780
2007	12	5	mg/L	1.140
2007	12	5	mg/L	1.020
2007	12	18	mg/L	1.304
2008	1	8	mg/L	1.060
2008	1	8	mg/L	0.890
2008	4	3	mg/L	0.960
2008	4	3	mg/L	0.840
2008	7	8	mg/L	0.810
2008	7	8	mg/L	0.860
2008	10	7	mg/L	0.980
2008	10	7	mg/L	1.010
2009	1	8	mg/L	0.650
2009	1	8	mg/L	1.280
2009	4	2	mg/L	0.780
2009	4	2	mg/L	0.850
2009	6	15	mg/L	0.614
2009	6	23	mg/L	0.615
2009	7	7	mg/L	0.700
2009	7	7	mg/L	0.680
2009	9	24	mg/L	0.641

Year	Month	Day	Date	Result
2010	1	2	mg/L	0.75
2010	1	2	mg/L	0.63
2010	1	2	mg/L	0.69
2010	1	27	mg/L	0.78
2010	1	27	mg/L	0.95
2010	3	7	mg/L	0.54
2010	3	7	mg/L	0.53
2010	3	7	mg/L	0.62
2010	4	11	mg/L	0.54
2010	4	11	mg/L	0.37
2010	4	11	mg/L	0.43
2010	4	28	mg/L	0.73
2010	4	28	mg/L	0.78
2010	5	21	mg/L	0.62
2010	5	21	mg/L	0.43
2010	5	21	mg/L	0.41
2010	6	6	mg/L	0.59
2010	6	6	mg/L	0.39
2010	6	6	mg/L	0.42
2010	7	7	mg/L	0.46
2010	7	11	mg/L	0.45
2010	7	11	mg/L	0.38
2010	7	11	mg/L	0.41
2010	7	20	mg/L	0.70
2010	7	20	mg/L	0.58
2010	8	8	mg/L	0.51
2010	8	8	mg/L	0.44
2010	8	8	mg/L	0.36
2010	9	5	mg/L	0.49
2010	9	5	mg/L	0.40
2010	9	5	mg/L	0.42
2010	10	3	mg/L	0.57
2010	10	3	mg/L	0.48
2010	10	3	mg/L	0.46
2010	10	11	mg/L	0.44

Year	Month	Day	Date	Result
2010	10	11	mg/L	0.44
2010	11	9	mg/L	0.71
2010	11	9	mg/L	0.52
2010	11	9	mg/L	0.53
2010	12	8	mg/L	0.75
2010	12	8	mg/L	0.51
2010	12	8	mg/L	0.56
2011	1	9	mg/L	0.76
2011	1	9	mg/L	0.50
2011	1	9	mg/L	0.54
2011	2	8	mg/L	0.93
2011	2	8	mg/L	0.56
2011	2	8	mg/L	0.54
2011	3	13	mg/L	0.91
2011	3	13	mg/L	0.52
2011	3	13	mg/L	0.61
2011	4	10	mg/L	0.84
2011	4	10	mg/L	0.55
2011	4	10	mg/L	0.51
2011	6	5	mg/L	0.87
2011	6	5	mg/L	0.48
2011	6	5	mg/L	0.55
2011	7	2	mg/L	0.59
2011	7	2	mg/L	0.59
2011	7	2	mg/L	0.38
2011	7	11	mg/L	0.52
2011	7	30	mg/L	0.46
2011	7	30	mg/L	0.45
2011	7	30	mg/L	0.41
2011	9	4	mg/L	0.50
2011	9	4	mg/L	0.40
2011	9	4	mg/L	0.41
2011	10	1	mg/L	0.57
2011	10	1	mg/L	0.48
2011	10	1	mg/L	0.52

Year	Month	Day	Date	Result
2011	11	6	mg/L	0.54
2011	11	6	mg/L	0.48
2011	11	6	mg/L	0.46
2011	12	11	mg/L	0.71
2011	12	11	mg/L	0.55
2011	12	11	mg/L	0.60
2012	1	10	mg/L	0.60
2012	1	10	mg/L	0.51
2012	1	10	mg/L	0.50
2012	1	19	mg/L	0.54

Total Phosphorus

Year	Month	Day	Unit	Result
1993	2	17	mg/L	0.422
1993	2	17	mg/L	0.446
1993	6	22	mg/L	0.431
1993	6	22	mg/L	0.403
1993	8	25	mg/L	0.397
1993	8	25	mg/L	0.446
1994	3	16	mg/L	0.375
1994	3	16	mg/L	0.329
1994	6	13	mg/L	0.397
1994	6	13	mg/L	0.388
1994	9	16	mg/L	0.329
1994	9	19	mg/L	0.369
1994	11	21	mg/L	0.310
1994	11	21	mg/L	0.341
1995	3	13	mg/L	0.083
1995	3	13	mg/L	0.086
1995	6	12	mg/L	0.033
1995	6	12	mg/L	0.096
1995	6	27	mg/L	0.021
1995	7	26	mg/L	0.040
1995	7	26	mg/L	0.033
1995	7	26	mg/L	0.036
1995	8	22	mg/L	0.047
1995	8	22	mg/L	0.032
1995	8	22	mg/L	0.036
1995	9	26	mg/L	0.070
1995	9	26	mg/L	0.026
1995	10	2	mg/L	0.018
1995	11	27	mg/L	0.049
1995	11	27	mg/L	0.051
1995	11	27	mg/L	0.054
1995	11	28	mg/L	0.021
1995	11	28	mg/L	0.054

Year	Month	Day	Unit	Result
1995	12	27	mg/L	0.046
1995	12	27	mg/L	0.046
1996	2	28	mg/L	0.031
1996	4	3	mg/L	0.047
1996	4	16	mg/L	0.042
1996	4	16	mg/L	0.043
1996	4	16	mg/L	0.045
1996	5	16	mg/L	0.025
1996	5	16	mg/L	0.026
1996	6	24	mg/L	0.018
1996	6	24	mg/L	0.020
1996	7	24	mg/L	0.018
1996	7	24	mg/L	0.019
1996	7	30	mg/L	0.029
1996	7	30	mg/L	0.023
1996	7	30	mg/L	0.023
1996	11	20	mg/L	0.029
1996	12	30	mg/L	0.041
1996	12	30	mg/L	0.037
1997	6	21	mg/L	0.032
1997	6	21	mg/L	0.031
1997	6	21	mg/L	0.043
1997	7	1	mg/L	0.031
1997	7	23	mg/L	0.029
1997	7	23	mg/L	0.029
1997	7	23	mg/L	0.027
1997	8	5	mg/L	0.122
1997	8	22	mg/L	0.025
1997	8	22	mg/L	0.022
1997	8	22	mg/L	0.036
1997	9	2	mg/L	0.090
1997	9	29	mg/L	0.031
1997	9	29	mg/L	0.048
1997	9	29	mg/L	0.033
1997	10	9	mg/L	0.114

Year	Month	Day	Unit	Result
1997	10	28	mg/L	0.037
1997	10	28	mg/L	0.049
1997	10	28	mg/L	0.059
1997	11	5	mg/L	0.029
1997	11	29	mg/L	0.044
1997	11	29	mg/L	0.048
1997	11	29	mg/L	0.064
1997	12	2	mg/L	0.041
1998	1	2	mg/L	0.044
1998	1	2	mg/L	0.049
1998	1	2	mg/L	0.048
1998*	**1**	**21**	**mg/L**	**0.005**
1998	1	31	mg/L	0.051
1998	1	31	mg/L	0.052
1998	1	31	mg/L	0.049
1998*	**2**	**9**	**mg/L**	**0.005**
1998	2	9	mg/L	0.036
1998	3	1	mg/L	0.056
1998	3	1	mg/L	0.047
1998	3	1	mg/L	0.043
1998*	**3**	**4**	**mg/L**	**0.005**
1998	3	4	mg/L	0.031
1998	3	31	mg/L	0.038
1998	3	31	mg/L	0.057
1998	3	31	mg/L	0.042
1998*	**4**	**8**	**mg/L**	**0.005**
1998	4	8	mg/L	0.080
1998	4	30	mg/L	0.042
1998	4	30	mg/L	0.041
1998	4	30	mg/L	0.061
1998*	**5**	**6**	**mg/L**	**0.005**
1998	5	6	mg/L	0.022
1998	5	31	mg/L	0.043
1998	5	31	mg/L	0.032

Year	Month	Day	Unit	Result
1998	5	31	mg/L	0.033
1998*	**6**	**3**	**mg/L**	**0.007**
1998	6	3	mg/L	0.104
1998	6	30	mg/L	0.043
1998	6	30	mg/L	0.027
1998	6	30	mg/L	0.025
1998*	**7**	**14**	**mg/L**	**0.005**
1998	7	14	mg/L	0.119
1998	7	30	mg/L	0.032
1998	7	30	mg/L	0.021
1998	7	30	mg/L	0.021
1998*	**8**	**6**	**mg/L**	**0.005**
1998	8	6	mg/L	0.026
1998	8	31	mg/L	0.034
1998	8	31	mg/L	0.018
1998	8	31	mg/L	0.024
1998*	**9**	**14**	**mg/L**	**0.014**
1998	9	14	mg/L	0.040
1998	10	1	mg/L	0.042
1998	10	1	mg/L	0.040
1998	10	1	mg/L	0.041
1998*	**10**	**7**	**mg/L**	**0.007**
1998	10	7	mg/L	0.084
1998	10	29	mg/L	0.035
1998	10	29	mg/L	0.039
1998	10	29	mg/L	0.035
1998*	**11**	**4**	**mg/L**	**0.012**
1998	11	4	mg/L	0.115
1998	11	23	mg/L	0.031
1998	11	23	mg/L	0.032
1998	11	23	mg/L	0.039
1998*	**12**	**17**	**mg/L**	**0.011**
1998	12	17	mg/L	0.028
1998	12	20	mg/L	0.026

Year	Month	Day	Unit	Result
1998	12	20	mg/L	0.029
1998	12	20	mg/L	0.036
1999	1	29	mg/L	0.044
1999	1	29	mg/L	0.036
1999	1	29	mg/L	0.038
1999	2	23	mg/L	0.041
1999	2	23	mg/L	0.039
1999	2	23	mg/L	0.042
1999	3	18	mg/L	0.058
1999	3	18	mg/L	0.041
1999	3	18	mg/L	0.038
1999	4	22	mg/L	0.048
1999	4	22	mg/L	0.045
1999	4	22	mg/L	0.059
1999	5	20	mg/L	0.038
1999	5	20	mg/L	0.044
1999	5	20	mg/L	0.035
1999	6	18	mg/L	0.033
1999	6	18	mg/L	0.044
1999	6	18	mg/L	0.031
1999	7	12	mg/L	0.033
1999	7	12	mg/L	0.027
1999	7	12	mg/L	0.026
1999	8	9	mg/L	0.031
1999	8	9	mg/L	0.027
1999	8	9	mg/L	0.035
1999	9	20	mg/L	0.036
1999	9	20	mg/L	0.036
1999	9	20	mg/L	0.044
1999	10	18	mg/L	0.038
1999	10	18	mg/L	0.037
1999	10	18	mg/L	0.037
1999	11	15	mg/L	0.035
1999	11	15	mg/L	0.038
1999	11	15	mg/L	0.031

Year	Month	Day	Unit	Result
1999	12	15	mg/L	0.033
1999	12	15	mg/L	0.034
1999	12	15	mg/L	0.038
2000	1	23	mg/L	0.036
2000	1	23	mg/L	0.042
2000	1	23	mg/L	0.042
2000	2	2	mg/L	0.056
2000	2	2	mg/L	0.047
2000	2	13	mg/L	0.035
2000	2	13	mg/L	0.038
2000	2	13	mg/L	0.038
2000	3	13	mg/L	0.038
2000	3	13	mg/L	0.051
2000	3	13	mg/L	0.045
2000	3	16	mg/L	0.056
2000	3	16	mg/L	0.028
2000	4	13	mg/L	0.018
2000	4	13	mg/L	0.025
2000	4	19	mg/L	0.053
2000	4	19	mg/L	0.042
2000	4	19	mg/L	0.041
2000	5	5	mg/L	0.010
2000	5	5	mg/L	0.010
2000	5	12	mg/L	0.040
2000	5	12	mg/L	0.054
2000	5	12	mg/L	0.041
2000	6	6	mg/L	0.005
2000	6	6	mg/L	0.005
2000	6	13	mg/L	0.036
2000	6	13	mg/L	0.036
2000	7	6	mg/L	0.005
2000	7	6	mg/L	0.005
2000	7	13	mg/L	0.032
2000	7	13	mg/L	0.048
2000	7	13	mg/L	0.032

Year	Month	Day	Unit	Result
2000	8	15	mg/L	0.005
2000	8	15	mg/L	0.005
2000	8	17	mg/L	0.031
2000	8	17	mg/L	0.044
2000	8	17	mg/L	0.037
2000	9	14	mg/L	0.005
2000	9	14	mg/L	0.005
2000	9	21	mg/L	0.039
2000	9	21	mg/L	0.033
2000	9	21	mg/L	0.045
2000	10	5	mg/L	0.005
2000	10	5	mg/L	0.005
2000	10	14	mg/L	0.041
2000	10	14	mg/L	0.046
2000	10	14	mg/L	0.049
2000	11	2	mg/L	0.006
2000	11	2	mg/L	0.006
2000	11	20	mg/L	0.051
2000	11	20	mg/L	0.053
2000	12	11	mg/L	0.005
2000	12	11	mg/L	0.010
2000	12	16	mg/L	0.051
2000	12	16	mg/L	0.044
2001	1	20	mg/L	0.038
2001	1	20	mg/L	0.086
2001	2	24	mg/L	0.036
2001	2	24	mg/L	0.039
2001	3	15	mg/L	0.046
2001	3	15	mg/L	0.050
2001	3	18	mg/L	0.046
2001	3	18	mg/L	0.045
2001	3	22	mg/L	0.040
2001	3	22	mg/L	0.040
2001	4	4	mg/L	0.038
2001	4	4	mg/L	0.041

Year	Month	Day	Unit	Result
2001	5	10	mg/L	0.050
2001	5	10	mg/L	0.050
2001	5	16	mg/L	0.039
2001	5	16	mg/L	0.036
2001	6	24	mg/L	0.035
2001	6	24	mg/L	0.034
2001	7	15	mg/L	0.030
2001	7	15	mg/L	0.032
2001	7	24	mg/L	0.037
2001	7	24	mg/L	0.033
2001	8	13	mg/L	0.027
2001	8	13	mg/L	0.029
2001	9	26	mg/L	0.029
2001	9	26	mg/L	0.027
2001	10	16	mg/L	0.034
2001	10	16	mg/L	0.030
2001	10	16	mg/L	0.030
2001	10	18	mg/L	0.039
2001	10	18	mg/L	0.043
2001	11	19	mg/L	0.036
2001	11	19	mg/L	0.038
2001	11	19	mg/L	0.038
2001	12	17	mg/L	0.030
2001	12	17	mg/L	0.030
2001	12	17	mg/L	0.043
2001	12	17	mg/L	0.007
2001	12	17	mg/L	0.009
2002	1	17	mg/L	0.027
2002	1	17	mg/L	0.044
2002	1	17	mg/L	0.026
2002	2	13	mg/L	0.005
2002	2	13	mg/L	0.005
2002	2	24	mg/L	0.033
2002	2	24	mg/L	0.046
2002	2	24	mg/L	0.031

Year	Month	Day	Unit	Result
2002	2	28	mg/L	0.043
2002	2	28	mg/L	0.039
2002	3	23	mg/L	0.033
2002	3	23	mg/L	0.045
2002	3	23	mg/L	0.032
2002	4	19	mg/L	0.041
2002	4	19	mg/L	0.031
2002	4	19	mg/L	0.029
2002	4	24	mg/L	0.006
2002	4	24	mg/L	0.005
2002	5	21	mg/L	0.033
2002	5	21	mg/L	0.028
2002	6	18	mg/L	0.032
2002	6	18	mg/L	0.043
2002	6	18	mg/L	0.033
2002	7	18	mg/L	0.026
2002	7	18	mg/L	0.025
2002	7	18	mg/L	0.031
2002	7	25	mg/L	0.030
2002	7	25	mg/L	0.023
2002	8	5	mg/L	0.005
2002	8	5	mg/L	0.005
2002	8	16	mg/L	0.028
2002	8	16	mg/L	0.034
2002	8	16	mg/L	0.029
2002	9	20	mg/L	0.033
2002	9	20	mg/L	0.028
2002	9	20	mg/L	0.025
2002	10	1	mg/L	0.005
2002	10	1	mg/L	0.005
2002	10	21	mg/L	0.029
2002	10	21	mg/L	0.031
2002	10	21	mg/L	0.028
2002	11	1	mg/L	0.032
2002	11	1	mg/L	0.032

Year	Month	Day	Unit	Result
2002	11	15	mg/L	0.039
2002	11	15	mg/L	0.032
2002	11	15	mg/L	0.035
2002	12	16	mg/L	0.037
2002	12	16	mg/L	0.041
2002	12	16	mg/L	0.039
2003	2	3	mg/L	0.005
2003	2	3	mg/L	0.005
2003	2	4	mg/L	0.046
2003	2	4	mg/L	0.046
2003	4	29	mg/L	0.032
2003	4	29	mg/L	0.035
2003	5	12	mg/L	0.005
2003	5	12	mg/L	0.005
2003	7	29	mg/L	0.022
2003	7	29	mg/L	0.023
2003	10	2	mg/L	0.042
2003	10	23	mg/L	0.003
2003	10	23	mg/L	0.003
2004	1	22	mg/L	0.041
2004	1	22	mg/L	0.034
2004	2	5	mg/L	0.002
2004	2	5	mg/L	0.002
2004	5	11	mg/L	0.002
2004	5	11	mg/L	0.006
2004	7	13	mg/L	0.004
2004	7	13	mg/L	0.003
2004	7	29	mg/L	0.023
2004	7	29	mg/L	0.022
2004	8	9	mg/L	0.013
2004	8	9	mg/L	0.013
2004	11	8	mg/L	0.021
2004	11	8	mg/L	0.025
2005	1	27	mg/L	0.024
2005	2	16	mg/L	0.026

Year	Month	Day	Unit	Result
2005	2	16	mg/L	0.027
2005	4	11	mg/L	0.017
2005	4	11	mg/L	0.021
2005	5	10	mg/L	0.024
2005	5	10	mg/L	0.027
2005	7	11	mg/L	0.025
2005	7	11	mg/L	0.026
2005	7	21	mg/L	0.016
2005	7	21	mg/L	0.017
2005	9	15	mg/L	0.017
2005	9	15	mg/L	0.014
2005	10	20	mg/L	0.011
2005	10	20	mg/L	0.012
2005	11	10	mg/L	0.011
2005	11	10	mg/L	0.012
2006	1	5	mg/L	0.003
2006	1	5	mg/L	0.003
2006	2	6	mg/L	0.003
2006	2	6	mg/L	0.003
2006	2	6	mg/L	0.003
2006	3	6	mg/L	0.003
2006	3	6	mg/L	0.003
2006	3	6	mg/L	0.003
2006	4	5	mg/L	0.003
2006	4	5	mg/L	0.003
2006	5	3	mg/L	0.003
2006	5	3	mg/L	0.003
2006	5	3	mg/L	0.003
2006	6	21	mg/L	0.003
2006	6	21	mg/L	0.003
2006	6	21	mg/L	0.003
2006	7	10	mg/L	0.003
2006	7	10	mg/L	0.003
2006	8	2	mg/L	0.003
2006	8	2	mg/L	0.003

Year	Month	Day	Unit	Result
2006	8	2	mg/L	0.003
2006	9	7	mg/L	0.013
2006	9	7	mg/L	0.012
2006	9	7	mg/L	0.003
2006	10	4	mg/L	0.014
2006	10	4	mg/L	0.013
2006	11	21	mg/L	0.002
2006	11	21	mg/L	0.020
2006	11	21	mg/L	0.018
2006	12	6	mg/L	0.015
2006	12	6	mg/L	0.016
2006	12	6	mg/L	0.002
2007	1	4	mg/L	0.016
2007	1	4	mg/L	0.002
2007	1	4	mg/L	0.017
2007	1	16	mg/L	0.014
2007	1	16	mg/L	0.015
2007	4	24	mg/L	0.016
2007	4	24	mg/L	0.015
2007	5	3	mg/L	0.015
2007	5	3	mg/L	0.002
2007	5	3	mg/L	0.017
2007	6	6	mg/L	0.014
2007	6	6	mg/L	0.002
2007	6	6	mg/L	0.013
2007	7	9	mg/L	0.014
2007	7	9	mg/L	0.002
2007	7	9	mg/L	0.017
2007	7	19	mg/L	0.011
2007	7	19	mg/L	0.012
2007	8	7	mg/L	0.008
2007	8	7	mg/L	0.009
2007	9	6	mg/L	0.017
2007	9	6	mg/L	0.002
2007	9	6	mg/L	0.016

Year	Month	Day	Unit	Result
2007	10	4	mg/L	0.016
2007	10	4	mg/L	0.002
2007	10	4	mg/L	0.012
2007	10	23	mg/L	0.016
2007	10	23	mg/L	0.017
2007	11	19	mg/L	0.015
2007	11	19	mg/L	0.016
2007	12	5	mg/L	0.007
2007	12	5	mg/L	0.017
2007	12	18	mg/L	0.017
2008	1	8	mg/L	0.013
2008	1	8	mg/L	0.012
2008	4	3	mg/L	0.010
2008	4	3	mg/L	0.011
2008	7	8	mg/L	0.015
2008	7	8	mg/L	0.013
2008	10	7	mg/L	0.014
2008	10	7	mg/L	0.013
2009	1	8	mg/L	0.008
2009	1	8	mg/L	0.020
2009	4	2	mg/L	0.005
2009	4	2	mg/L	0.006
2009	6	15	mg/L	0.012
2009	6	23	mg/L	0.015
2009	7	7	mg/L	0.012
2009	7	7	mg/L	0.015
2009	9	24	mg/L	0.016
2010	1	2	mg/L	0.018
2010	1	2	mg/L	0.016
2010	1	2	mg/L	0.020
2010	1	27	mg/L	0.012
2010	1	27	mg/L	0.007
2010	3	7	mg/L	0.010
2010	3	7	mg/L	0.008

Year	Month	Day	Unit	Result
2010	3	7	mg/L	0.010
2010	4	11	mg/L	0.021
2010	4	11	mg/L	0.010
2010	4	11	mg/L	0.012
2010	4	28	mg/L	0.009
2010	4	28	mg/L	0.015
2010	5	21	mg/L	0.016
2010	5	21	mg/L	0.015
2010	5	21	mg/L	0.011
2010	6	6	mg/L	0.012
2010	6	6	mg/L	0.008
2010	6	6	mg/L	0.011
2010	7	7	mg/L	0.012
2010	7	11	mg/L	0.007
2010	7	11	mg/L	0.012
2010	7	11	mg/L	0.012
2010	7	20	mg/L	0.006
2010	7	20	mg/L	0.006
2010	8	8	mg/L	0.019
2010	8	8	mg/L	0.009
2010	8	8	mg/L	0.011
2010	9	5	mg/L	0.015
2010	9	5	mg/L	0.010
2010	9	5	mg/L	0.010
2010	10	3	mg/L	0.019
2010	10	3	mg/L	0.011
2010	10	3	mg/L	0.012
2010	10	11	mg/L	0.010
2010	10	11	mg/L	0.003
2010	11	9	mg/L	0.015
2010	11	9	mg/L	0.012
2010	11	9	mg/L	0.013
2010	12	8	mg/L	0.013
2010	12	8	mg/L	0.010

Year	Month	Day	Unit	Result
2010	12	8	mg/L	0.011
2011	1	9	mg/L	0.020
2011	1	9	mg/L	0.009
2011	1	9	mg/L	0.012
2011	2	8	mg/L	0.017
2011	2	8	mg/L	0.007
2011	2	8	mg/L	0.007
2011	3	13	mg/L	0.025
2011	3	13	mg/L	0.011
2011	3	13	mg/L	0.012
2011	4	10	mg/L	0.032
2011	4	10	mg/L	0.007
2011	4	10	mg/L	0.010
2011	6	5	mg/L	0.015
2011	6	5	mg/L	0.008
2011	6	5	mg/L	0.010
2011	7	2	mg/L	0.010
2011	7	2	mg/L	0.010
2011	7	2	mg/L	0.014
2011	7	11	mg/L	0.010
2011	7	30	mg/L	0.022
2011	7	30	mg/L	0.009
2011	7	30	mg/L	0.010
2011	9	4	mg/L	0.023
2011	9	4	mg/L	0.008
2011	9	4	mg/L	0.010
2011	10	1	mg/L	0.023
2011	10	1	mg/L	0.008
2011	10	1	mg/L	0.011
2011	11	6	mg/L	0.011
2011	11	6	mg/L	0.008
2011	11	6	mg/L	0.010
2011	12	11	mg/L	0.014
2011	12	11	mg/L	0.014

Year	Month	Day	Unit	Result
2011	12	11	mg/L	0.012
2012	1	10	mg/L	0.014
2012	1	19	mg/L	0.010