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for the Comfort Lake-Forest Lake Watershed District
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# Comfort Lake-Forest Lake Watershed District
# Six Lakes Total Maximum Daily Load Study

March 2010

water | ecology | community

EOR

wq-iw6-03e

**TMDL Summary Table**

| EPA/MPCA Required Elements | Summary | | | TMDL Page # |
|---|---|---|---|---|
| **Location** | The six lakes are in the St. Croix River Drainage Basin and are located in Chisago and Washington Counties. | | | 5 |
| **303(d) Listing Information** | • The six waterbodies addressed are Moody Lake, Bone Lake, School Lake, Little Comfort Lake, Shields Lake and Comfort Lake.<br>• A summary of the waterbody name, description and ID#, impaired beneficial use, impairment, priority ranking and original listing year is given in Table 1 on page 3. | | | 3 |
| **Applicable Water Quality Standards/ Numeric Targets** | List all applicable WQS/Targets with source citations. If the TMDL is based on a target other than a numeric water quality criterion, a description of the process used to derive the target must be included in the submittal. | | | 21 |
| **Loading Capacity (expressed as daily load)** | The Loading Capacity is different for each of the six lakes and is summarized in Table 25 on page 57. | | | 58, 59 |
| **Wasteload Allocation** | Portion of the loading capacity allocated to existing and future point sources: | | | |
| | **Source** | **Permit #** | **Individual WLA** | |
| | City of Forest Lake MS4, Construction and Industrial Stormwater, future regulated MS4s | MS400262, various, not yet permitted | See Tables 27, 29, 32, 35, 37, 41 | 61 |
| | Large Septic | MN0050474, MN0067466 | See Tables 32, 35 | 65, 67 |
| | Reserve Capacity? (and related discussion in report) | NA | NA | 63 |
| **Load Allocation** | Identify the portion of the loading capacity allocated to existing and future nonpoint sources and to natural background if possible [40 CFR §130.2(g)].<br>***Total LA = X/day, for each pollutant*** | | | |
| | **Source** | **LA** | | |
| | Watershed Runoff | See Tables 27, 29, 32, 35, 37, 41 | | 62 |
| | Internal/Atmospheric | See Tables 27, 29, 32, 35, 37, 41 | | 62 |
| | Natural Background? | NA | | NA |

| | | |
|---|---|---|
| **Margin of Safety** | An implicit MOS was incorporated into this TMDL by using conservative assumptions. These were used to account for an inherently imperfect understanding of the lake system and to ultimately ensure that the nutrient reduction strategy is protective of the water quality standard. | 60 |
| **TMDL Summary Table Continued** | | |
| **Seasonal Variation** | Symptoms of nutrient enrichment normally are the most severe during the summer months; the nutrient standards set by the MPCA were set with this seasonal variability in mind. This is the case for all six of these lakes. | 71 |
| **Reasonable Assurance** | ***Summarize Reasonable Assurance***<br><br>Reasonable assurances include Municipal Ordinances and New CLFLWD Rules, CLFLWD Capital Improvement Plan, TMDLs, and the NPDES MS4 Program. | 80 |
| **Monitoring** | ***Monitoring Plan included?***<br><br>A monitoring plan is included | 72 |
| **Implementation** | ***1. Implementation Strategy included?***<br>An implementation strategy is included<br><br>***2. Cost estimate included?***<br>Cost estimates are included in the implementation plan | 74 |
| **Public Participation** | The work plan had a total of six meetings proposed during the course of the study. Four of those meetings have occurred, with the fifth and sixth reserved for a stakeholder meeting regarding TMDL allocations and a public meeting after the draft TMDL report and implementation plan have been through preliminary MPCA and EPA review.<br>Stakeholder meetings were held on:<br>• March 28, 2007<br>• June 21, 2007<br>• July 25, 2007<br>• January 7, 2008<br>• April 8, 2009 | 82 |

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# Executive Summary

This Total Maximum Daily Load (TMDL) study addresses eutrophication impairments for Moody Lake, Bone Lake, School Lake, Shields Lake and Comfort Lake. The study also addresses a potential eutrophication impairment for Little Comfort Lake.

The drainage through this system of lakes flows from Moody Lake to Bone Lake to School Lake to Little Comfort Lake to Comfort Lake. Shields Lake flows into the un-impaired Forest Lake which flows to Comfort Lake. Thus, the Comfort Lake watershed includes the watershed of each of the other lakes.

The Comfort Lake-Forest Lake Watershed District (CLFLWD) completed a water quality modeling initiative for the entire watershed district with a focus on the lakes that are used recreationally. This initiative resulted in the report: *Watershed and Lake Water Quality Modeling Investigation for the Development of a Watershed Capital Improvement Plan* (CLFLWD, 2007), which includes detailed information on lake water quality and provides a plan for capital improvements to improve water quality to state standards and to the water quality goals set by the watershed district. The *Water Quality Modeling Investigation (CLFLWD, 2007)* report provides the basis for much of the information presented in this TMDL report.

This report presents the TMDLs broken out into wasteload allocation and load allocation for each of the six lakes included in the study.

## Lake St. Croix TMDL

The CLFLWD “Six Lakes” TMDL will not only address impairments in the CLFLWD’s watershed, but also work to reduce phosphorus loadings to the Sunrise River and ultimately Lake St. Croix. The Lake St. Croix TMDL development is to be based primarily on the report *Nutrient and Suspended-Sediment Concentrations and Loads, and Benthic-Invertebrate Data for Tributaries to the St. Croix River, Wisconsin and Minnesota, 1997–99* (USGS, 2003), which examined the sub-watershed phosphorus and sediment loadings to Lake St. Croix. In this report, the Sunrise River watershed was identified as the largest contributor on the Minnesota side of the basin. The CLFLWD is a sub-watershed within the Sunrise River Watershed, and thus any reductions seen within this TMDL will benefit the lakes in this TMDL, the Sunrise River, and Lake St. Croix.

The St. Croix Basin Team, which is made of individuals from federal, state, and local governments in Minnesota and Wisconsin as well as local organizations, has established an agreement to reduce phosphorus and sediment loadings to Lake St. Croix by 20%. Therefore any work done within the St. Croix River basin to reduce phosphorus, like this TMDL, will aid in achieving the 20% reduction goal. This TMDL will reduce the amount of TP coming out of the watershed (out of Comfort Lake) from 1418 lb/yr to 1262 lb/yr or an 11% reduction.

In addition, a number of potential stream impairments have been identified for the streams connecting the lakes within the Comfort Lake-Forest Lake Watershed District. The potential impairment listings include three sites for turbidity and six sites for dissolved oxygen and E. coli.

It is not immediately apparent whether or not the lake impairments are the cause of any of these potential stream impairments. Investigation on these potential stream impairments may be completed through the Sunrise River TMDL.

# 1. Background and Pollutant Sources

## 1A. 303(D) LISTINGS

**Table 1. Impaired Waters Listing**

| *Lake name:* | **Moody Lake** | **Bone Lake** | **School Lake** | **Shields Lake** | **Comfort Lake** |
|---|---|---|---|---|---|
| *DNR ID#:* | 13-0023-00 | 82-0054-00 | 13-0057-00 | 82-0162-00 | 13-0053-00 |
| *Hydrologic Unit Code:* | 07030005 | 07030005 | 07030005 | 07030005 | 07030005 |
| *Pollutant or stressor:* | Nutrient/ Eutrophication Biological Indicators | Nutrient/ Eutrophication Biological Indicators | Nutrient/ Eutrophication Biological Indicators | Nutrient/ Eutrophication Biological Indicators | Nutrient/ Eutrophication Biological Indicators |
| *Impairment:* | Aquatic recreation | Aquatic recreation | Aquatic recreation | Aquatic recreation | Aquatic recreation |
| *Year first listed:* | 2008 | 2004 | 2008 | 2006 | 2002 |
| *Target start/completion (reflects the priority ranking):* | 2008/2009 | 2008/2009 | 2008/2009 | 2008/2009 | 2008/2009 |
| *CALM category:* | 5C: Impaired by one pollutant and no TMDL study plan is approved by EPA | 5B: Impaired by multiple pollutants and at least one TMDL study plan is approved by EPA | 5C: Impaired by one pollutant and no TMDL study plan is approved by EPA | 5C: Impaired by one pollutant and no TMDL study plan is approved by EPA | 5B: Impaired by multiple pollutants and at least one TMDL study plan is approved by EPA |

Little Comfort Lake, located downstream of School Lake and adjacent to Comfort Lake, is included in this report even though it is not currently listed as impaired because recent water quality monitoring indicates that Little Comfort Lake will likely be listed as impaired for nutrients in the future. While the lake exceeded impairment thresholds, it lacked sufficient data to be listed by the Minnesota Pollution Control Agency (MPCA) in 2008 and 2010. However, the lake will continue to be monitored with anticipated listing in 2012.

## 1B. BACKGROUND

The Comfort Lake-Forest Lake Watershed District completed a water quality modeling initiative for the entire watershed district with a focus on the lakes that are used recreationally. This initiative resulted in the report: *Watershed and Lake Water Quality Modeling Investigation for the Development of a Watershed Capital Improvement Plan* (CLFLWD, 2007) (called *Water Quality Modeling Investigation* throughout the remainder of the report), which includes detailed information on lake water quality and provides a plan for capital improvements to improve water quality to state standards and to the water quality goals set by the watershed district. The *Water Quality Modeling Investigation (CLFLWD, 2007)* report provides the basis for much of the information presented in this TMDL report. Therefore, additional details on the modeling, background information, and planned watershed district projects are available in that report. Revisions made to the water quality model presented in the *Water Quality Modeling*

*Investigation (CLFLWD, 2007)* for the purposes of this TMDL are discussed in this TMDL report.

**Drainage Pattern**

The drainage through this system of lakes flows from Moody Lake to Bone Lake to School Lake to Little Comfort Lake to Comfort Lake. Shields Lake flows into the un-impaired (for eutrophication) Forest Lake which flows to Comfort Lake. Thus, the Comfort Lake watershed includes the watershed of each of the other lakes as well as drainage flow from the City of Forest Lake and the City of Wyoming. Forest Lake is impaired for mercury (Hg) and a state-wide TMDL has been completed to address that impairment. Forest Lake is also listed as impaired for PCBs.

Figure 1 displays arrows indicating the general drainage direction of the major lakes and displays the drainage region boundaries encompassing the land areas that drain to the major lakes. Areas listed in Table 2 show the total area contributing to the lake, including the lake itself, but excluding land area contributing to an upstream impaired lake. For example, the full drainage area to Bone Lake is the sum of the drainage to Moody and Bone Lake.

To differentiate between the City of Forest Lake and the lake itself, throughout this report all references to the city will be stated as “City of Forest Lake” and all references to the lake will be stated as “Forest Lake.”

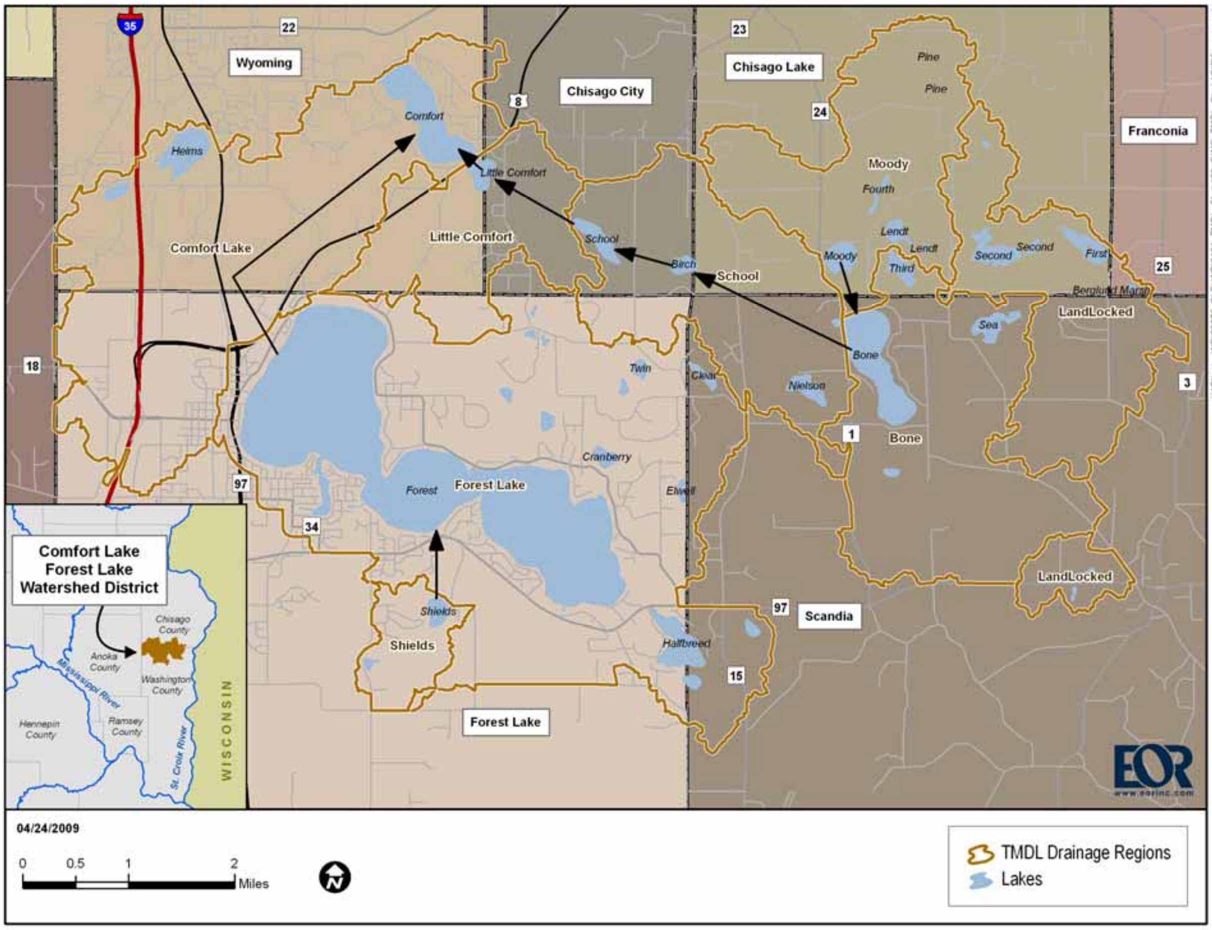



**Figure 1. Location Map**

**Table 2. Municipalities within Lake Watersheds.**

Areas listed are the total area contributing to the lake, including the lake itself, but excluding land area contributing to an upstream impaired lake.

| Lake | Municipality | Area (ac) |
|---|---|---|
| Moody | Chisago Lake Twp. | 2,281 |
| | City of Scandia | 34 |
| Bone | Chisago Lake Twp. | 155 |
| | City of Scandia | 3,116 |
| School | Chisago Lake Twp. | 600 |
| | City of Forest Lake | 270 |
| | City of Scandia | 1,003 |
| | City of Chisago City | 813 |
| Little Comfort | City of Wyoming | 799 |
| | City of Forest Lake | 218 |
| | City of Chisago City | 720 |
| Shields | City of Forest Lake | 538 |
| Comfort | City of Wyoming | 3,431 |
| | City of Forest Lake | 9,663 |
| | City of Chisago City | 192 |
| | City of Scandia | 999 |

## Lake and Watershed Description

### *Moody Lake*

The Moody Lake watershed is located in the northeast portion of the CLFLWD in southern Chisago County and northern Washington County and is a sub-watershed of the Sunrise River and St. Croix River Watersheds. This area lies entirely within the North Central Hardwood Forest Ecoregion. Moody Lake is located in Chisago Lake Township and the watershed is located within two municipalities (Figure 1, Table 2) and two counties (Chisago and Washington).

Moody Lake is 34 acres in surface area, with a 2,315-acre watershed, a 68:1 ratio of watershed to lake surface area. The two main tributaries to Moody Lake enter the lake from the north. One tributary is an outlet from Lendt Lake and the watershed to the north and the other tributary drains the watershed to the northwest. Moody Lake has about 12 parcels along its lakeshore and no public boat access. It is currently used for recreation and for watering of livestock. A bathymetric map of the lake is shown in Figure 2. Table 3 provides a summary comparison of the characteristics of the six lakes in this TMDL.

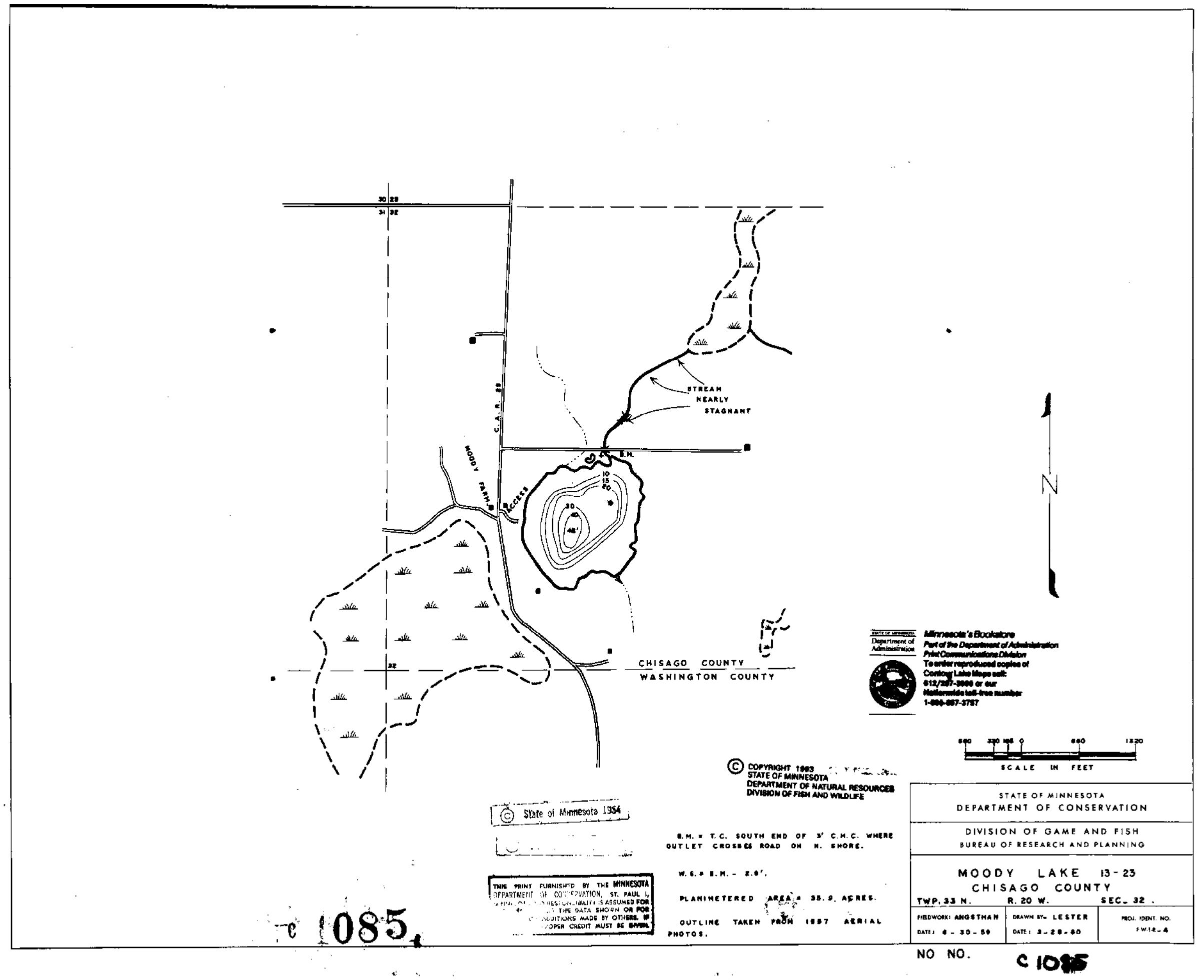



**Figure 2. Moody Lake Bathymetric Map**

*Bone Lake*

Bone Lake is located just downstream of Moody Lake in the east central portion of the CLFLWD. The watershed is located within Washington and Chisago Counties and includes the Moody Lake watershed. Bone Lake is located in the City of Scandia, and its watershed is located in Scandia and Chisago Lake Township (Figure 1, Table 2).

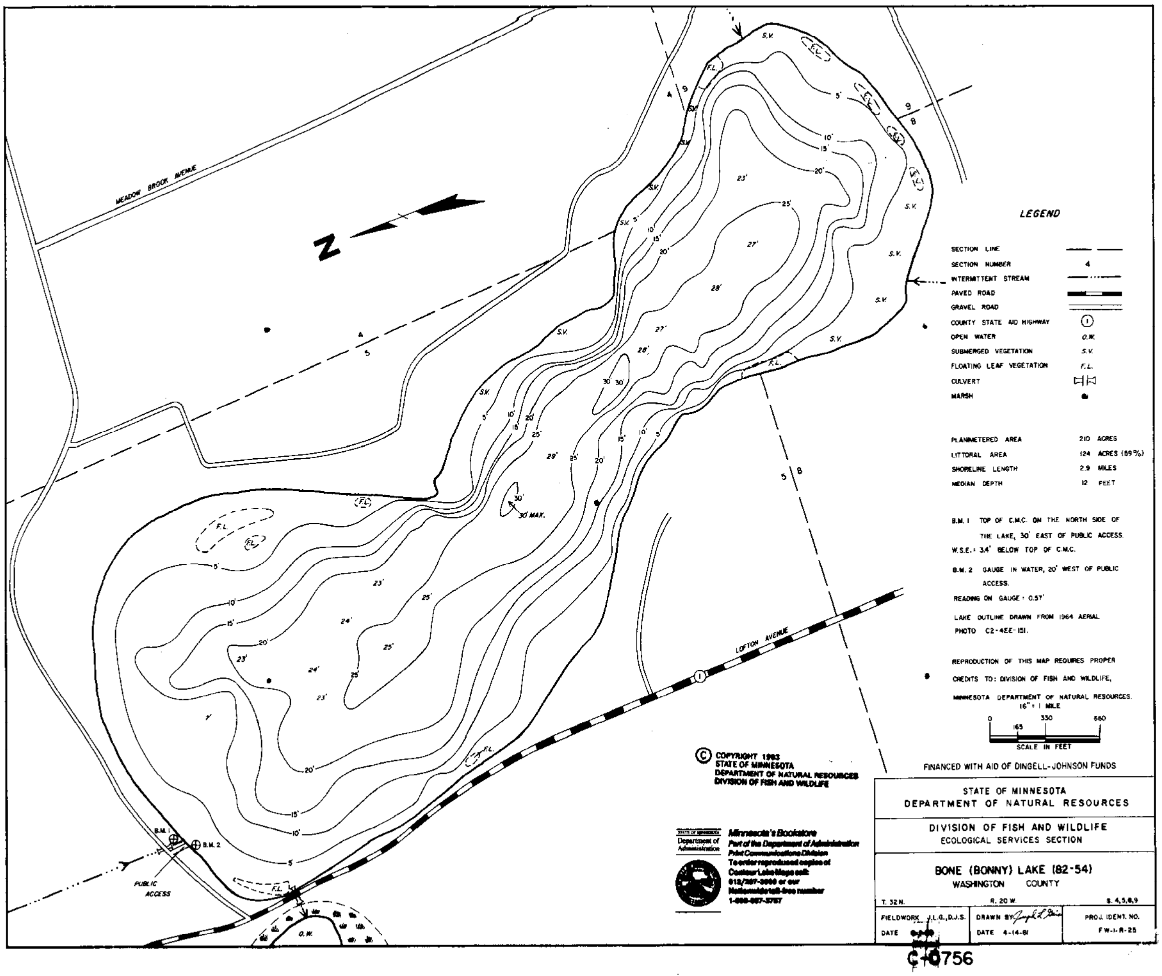



**Figure 3. Bone Lake Bathymetric Map**

Bone Lake has a surface area of 204 acres and a watershed area of 5,586 acres for a ratio of watershed to lake area of about 27:1. There are seven lakes within the Bone Lake watershed. The main tributaries to Bone Lake are drainage from Moody Lake entering at the northwest side of Bone Lake, drainage from Third Lake entering at the northeast side of Bone Lake, and drainage from the east and southeast portions of the watershed entering Bone Lake at the southeast side. Drainage also enters at the southern end of the lake. Bone Lake has a public boat landing and is used recreationally for swimming, fishing, and motorized and non-motorized boating. A bathymetric map of the lake is shown in Figure 3. Table 3 provides a summary comparison of the characteristics of the six lakes in this TMDL.

### *School Lake*

School Lake is located downstream of Bone Lake and Birch Lake in the north central portion of the CLFLWD. The School Lake watershed is located within Washington and Chisago Counties and includes the Bone Lake and Moody Lake watersheds. School Lake is located in Wyoming Township, and its watershed is located in Wyoming Township, the City of Scandia and Chisago Lake Township (Figure 1, Table 2).

School Lake has a surface area of 49 acres and a total watershed area of 8,272 acres for a ratio of watershed to lake area of about 169:1. There are 10 lakes within the School Lake watershed. The main tributaries to School Lake are drainage from Birch Lake and the local northern portion of the watershed entering at the east side of School Lake. School Lake has about 10 lakeshore owners and no public boat access. A bathymetric map of the lake is shown in Figure 4. Table 3 provides a summary comparison of the characteristics of the six lakes in this TMDL.

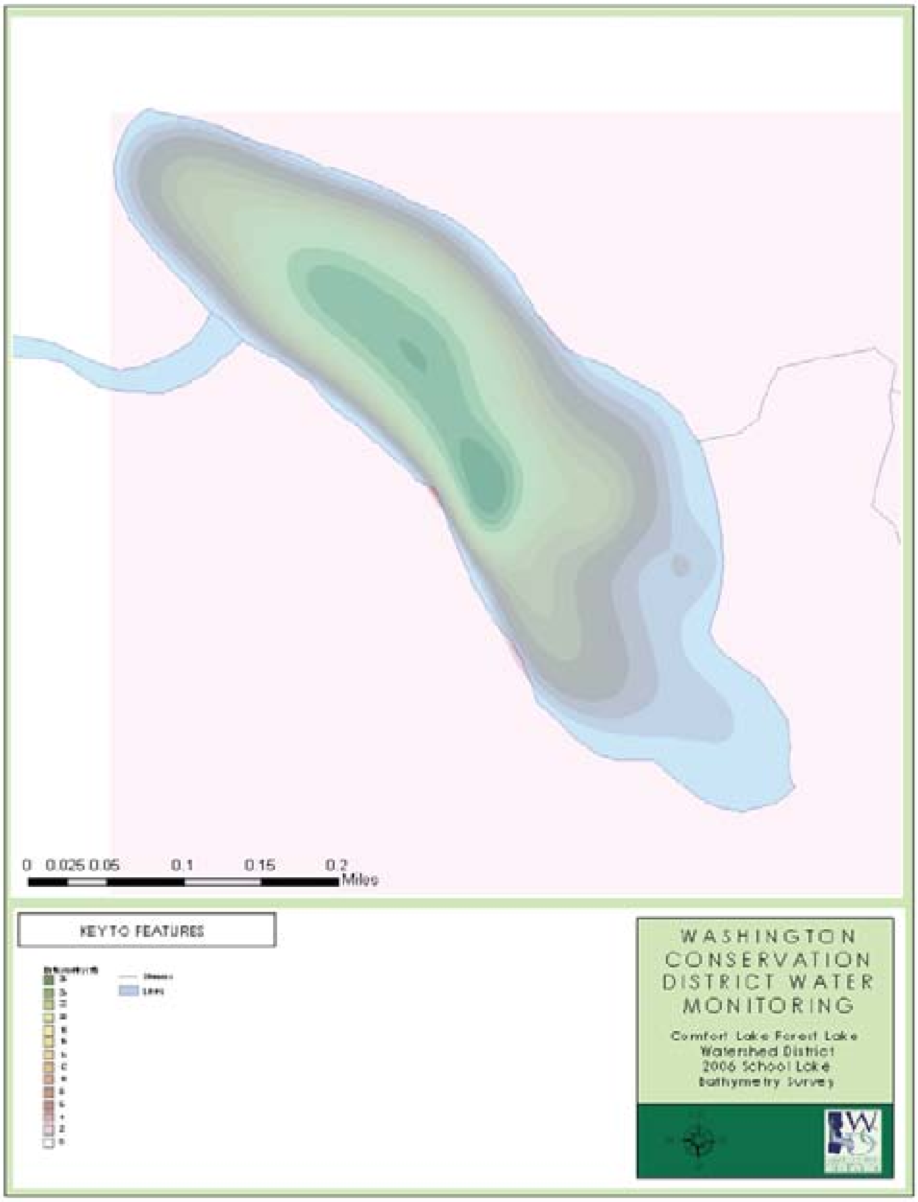



**Figure 4. School Lake Bathymetric Map**

*Little Comfort Lake*

Little Comfort Lake is located downstream of School Lake in the north central portion of the CLFLWD. The Little Comfort Lake watershed is located within Washington and Chisago Counties and includes the School Lake, Bone Lake and Moody Lake watersheds. Little Comfort Lake is located in Chisago City and Wyoming Township, and its watershed is located in Chisago City, Wyoming Township, the City of Scandia and Chisago Lake Township (Figure 1, Table 2).

Little Comfort Lake has a surface area of 35 acres and a total watershed area of 10,009 acres for a ratio of watershed to lake area of about 286:1. There are eleven lakes within the Little Comfort Lake watershed. The only tributary to Little Comfort Lake is drainage from School Lake entering at the east end of the lake. Little Comfort Lake has about 22 lakeshore parcels and no public boat launch. It is used for fishing, swimming, boating, and other recreational activities. A bathymetric map of the lake is shown in Figure 6. Table 3 provides a summary comparison of the characteristics of the six lakes in this TMDL.

### *Shields Lake*

Shields Lake is located in the south central portion of the CLFLWD. The Shields Lake watershed is located within the City of Forest Lake in Washington County and Shields Lake itself is also located in the City of Forest Lake (Figure 1, Table 2). Shields Lake is a shallow lake with a surface area of 27 acres and a total watershed area of 538 acres for a ratio of watershed to lake area of about 20:1. The main tributary to Shields Lake is drainage from the southern portion of its watershed entering the lake at the south side. Shields Lake drains to Forest Lake. A bathymetric map of the lake is shown in Figure 5. Table 3 provides a summary comparison of the characteristics of the six lakes in this TMDL.

Shields Lake has been the focus of a number of past lake improvement efforts including aeration, fish stocking, fish barrier installation, and alum treatment. The lake’s current management includes an aeration system and a fish barrier on the outflow stream to Forest Lake. In 2007, trumpeter swans were noted to be nesting on the lake. Shields Lake has a fishing pier but no public boat launch. It is used primarily for fishing.

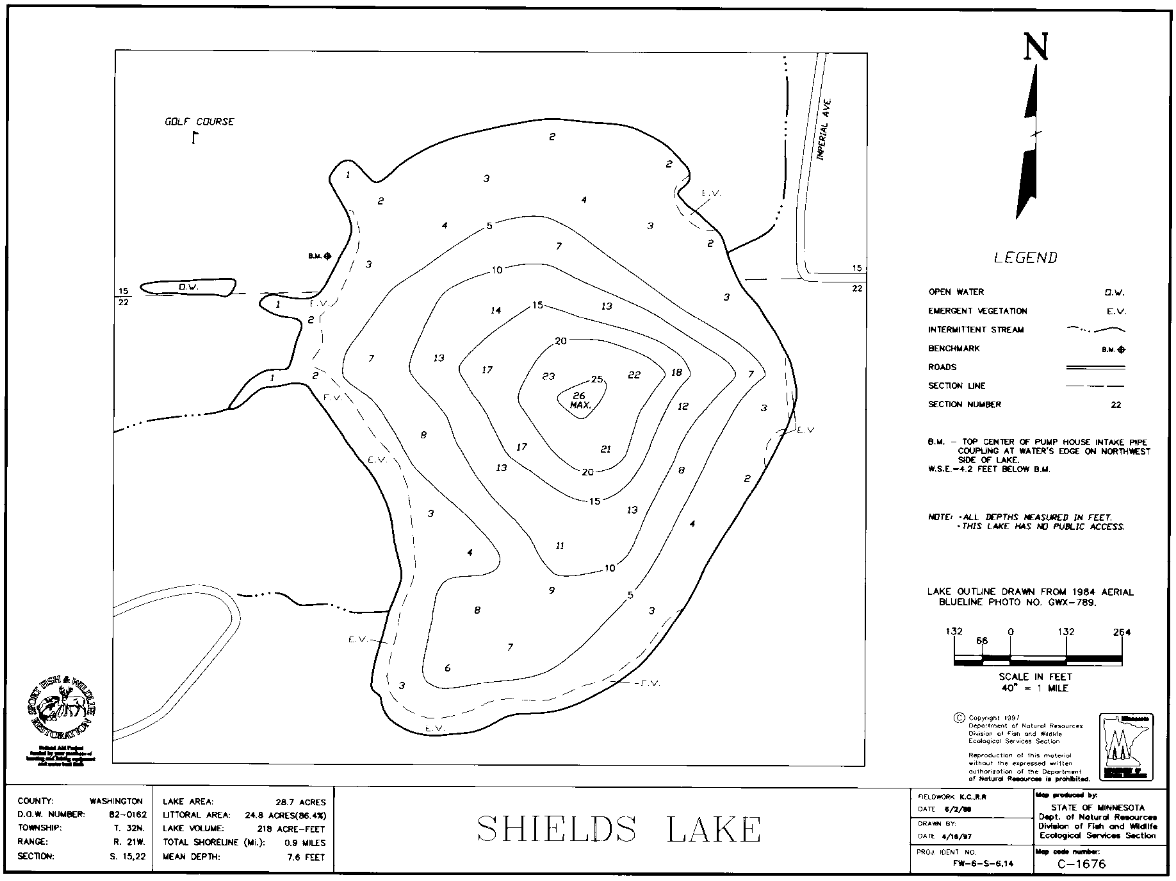



**Figure 5. Shields Lake Bathymetric Map**

*Comfort Lake*

Comfort Lake is located downstream of Little Comfort Lake and Forest Lake in the northwest portion of the CLFLWD. Comfort Lake is the outlet to the entire Comfort Lake-Forest Lake Watershed District. Therefore, its watershed is located within Washington and Chisago Counties and includes all other lakes in the District. Comfort Lake is located in the City of Wyoming (Figure 1, Table 2).

Comfort Lake has a surface area of 218 acres and a total watershed area of 24,832 acres for a ratio of watershed to lake area of about 111:1. The main tributaries to Comfort Lake are drainage from Little Comfort Lake entering at the southeast end of the lake and drainage from Forest Lake and the former Judicial Ditch 1 entering at the west side of the lake through Shallow Pond, a large wetland. Comfort Lake has a public boat landing and is used recreationally for swimming, fishing, and motorized and non-motorized boating. A bathymetric map of the lake is shown in Figure 6. Table 3 provides a summary comparison of the characteristics of the six lakes in this TMDL.

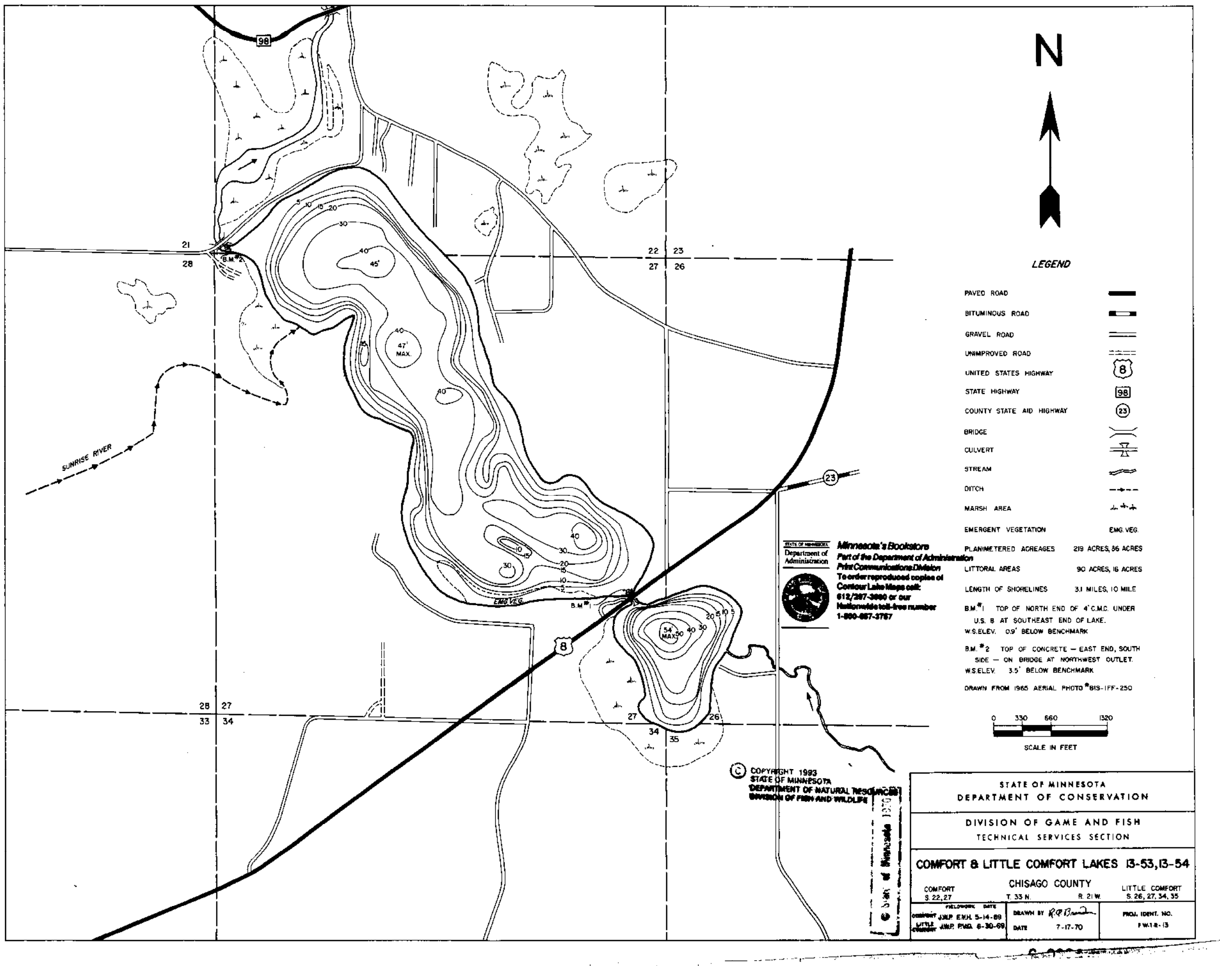



**Figure 6. Comfort and Little Comfort Lake Bathymetric Map**

**Table 3. Lake Characteristics Summary**

| Characteristic | Moody | Bone | School | Little Comfort | Shields | Comfort |
|---|---|---|---|---|---|---|
| Lake total surface area (ac) | 34 | 204 | 49 | 35 | 27 | 218 |
| Percent lake littoral surface area | 61% | 58% | 66% | 49% | 87% | 41% |
| Lake volume (ac-ft) | 470 | 2,470 | 530 | 650 | 203 | 4,200 |
| Mean depth (ft) | 14 | 13 | 11 | 18 | 7.4 | 19 |
| Maximum depth (ft) | 48 | 32 | 26 | 54 | 26 | 47 |
| Drainage area (ac) | 2,315 | 5,586 | 8,272 | 10,009 | 538 | 24,832 |
| Watershed area : lake area | 68:1 | 27:1 | 169:1 | 286:1 | 20:1 | 111:1 |

### Permitted Sources

*Municipal Separate Storm Sewer Systems (MS4)*

The Stormwater Program for Municipal Separate Storm Sewer Systems (MS4s) is designed to reduce the amount of sediment and pollution that enters surface and groundwater from storm sewer systems to the maximum extent practicable (MEP). These stormwater discharges are regulated through the use of National Pollutant Discharge Elimination System (NPDES) / State Disposal System (SDS) permits issued by the MPCA. The EPA has given the MPCA this NPDES permitting authority. Through this permit, the owner or operator is required to develop a stormwater pollution prevention program (SWPPP) that incorporates best management practices (BMPs) applicable to their MS4. The cities within the CLFLWD that are covered under MS4 permits are part of the EPA's Storm Water Phase II Rule, which extended coverage to certain "small" MS4s. These small MS4s include communities with a population of over 10,000 and communities with a population of 5,000 or greater that discharge or have the potential to discharge to an impaired water.

The City of Forest Lake, with a population of over 10,000, is the only municipality in the watershed currently covered under the Phase II MS4 permit (Figure 7). The City of Wyoming estimates their current population to be over 5,000 now that much of the former Wyoming Township has become part of the City of Wyoming. Therefore, the City of Wyoming is expected to soon require coverage under a Phase II MS4 permit. Based on the estimated 2020 populations of the City of Scandia and the City of Chisago City, these municipalities are expected to require Phase II MS4 permit coverage at or before 2020 when their populations reach 5,000 (see also population section below). Based on future updated de-centennial Census data, additional communities may come under coverage of the Phase II MS4 General Permit. At the time that permit coverage is required, discharges to impaired waters will be required to be addressed and a transfer or loading from a LA to a WLA will occur.

Transportation-related MS4s require coverage under NPDES MS4 permits when the facility is within the urbanized area. The urbanized area does not extend into any of the watersheds. See Section 6B for information on transportation-related MS4s and wasteload allocations.

*Point Sources*

Two large sewage treatment systems exist within the watershed, one for the Liberty Ponds residential development and one for The Preserve at Birch Lake residential development (Figure 7). Both of these systems are Large Septic Treatment Systems (LSTS) which do not have a surface discharge, but instead infiltrate through a drainfield. These systems are permitted through the use of National Pollutant Discharge Elimination System (NPDES) / State Disposal System (SDS) permits issued by the MPCA for systems of greater than 10,000 gallons per day. The loads from the two systems are estimated as summarized in Section 4B of this report.

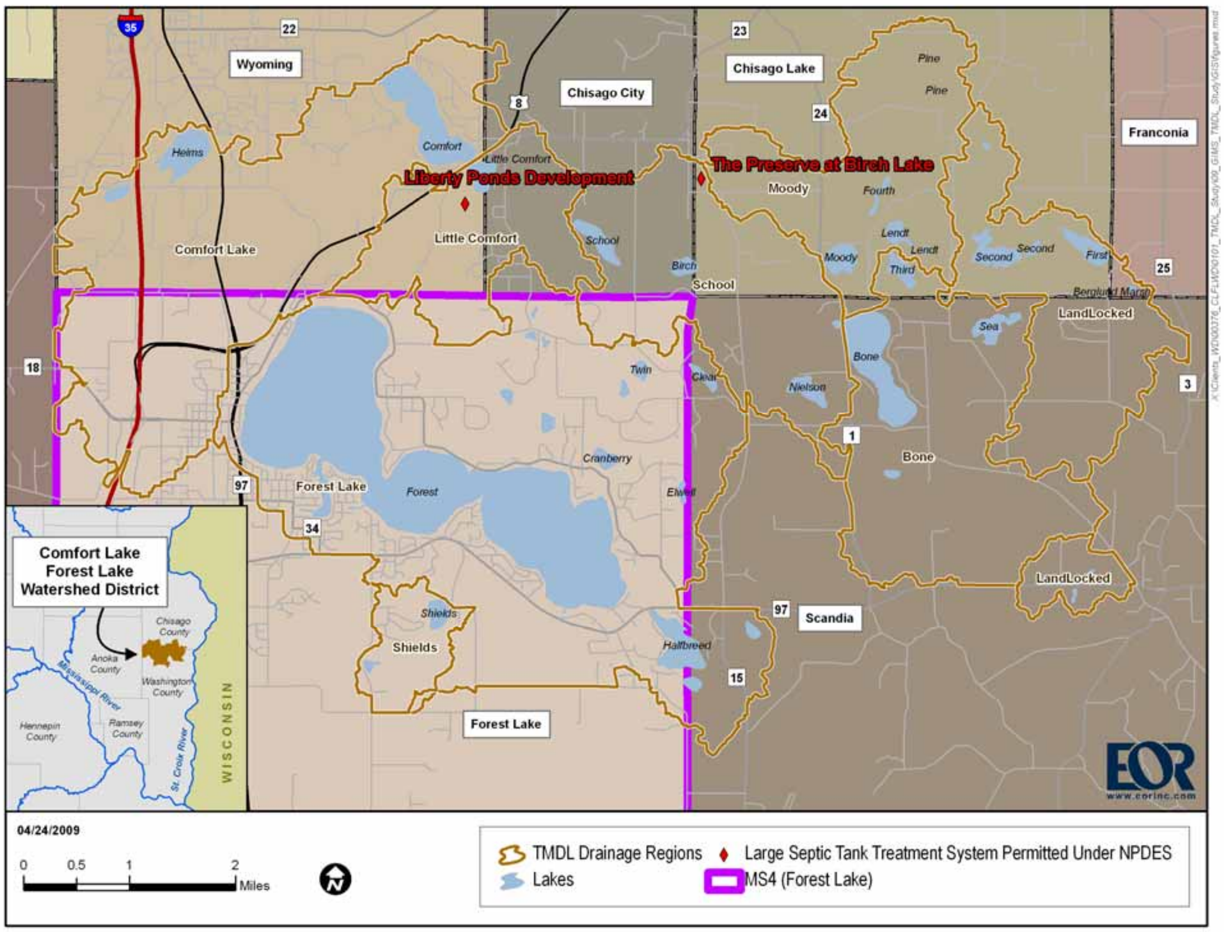



**Figure 7. Permits in the Lake Watersheds**

*Construction and Industrial Stormwater*

The NPDES Construction Stormwater permit program is designed to reduce the impact on water bodies of soil disturbance resulting from construction activities. Site owners and construction operators must develop a stormwater pollution prevention plan (SWPPP) outlining how stormwater will be controlled during and after construction. Permits are required for sites disturbing one acre of soil or more, site disturbing less than one acre that are part of a larger development plan, and sites that are determined by the MPCA to pose a risk to water resources. Washington and Chisago Counties combined have had an average of 0.38% of the total land area under NPDES Construction Stormwater permits each year over the past four years. As discussed further in the implementation section of this report, construction stormwater activities are in compliance with the TMDL if they properly comply with the NPDES Construction General Permit or applicable local requirements if they are more restrictive.

The NPDES Industrial Stormwater Program is designed to reduce water resource pollution from stormwater runoff from industrial facilities. Facility owners must develop a SWPPP outlining the BMPs that will be used to control stormwater runoff from the site. No permitted industrial facilities are present in the watersheds of this study.

## Land Use

The land uses in the CLFLWD were classified in the Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation (CLFLWD, 2007)* as cropland, forest, golf course, grassland, sand and gravel, high-, low-, and medium-density development, wetlands, and other. For the full CLFLWD the land use is primarily wetlands (24%), cropland (21%), medium-density development (18%), forest (14%), and grassland (12%) (Figure 8). The dominant land uses for each of the lakes' individual drainage areas are generally cropland, wetlands, grasslands, and forest (Table 4).

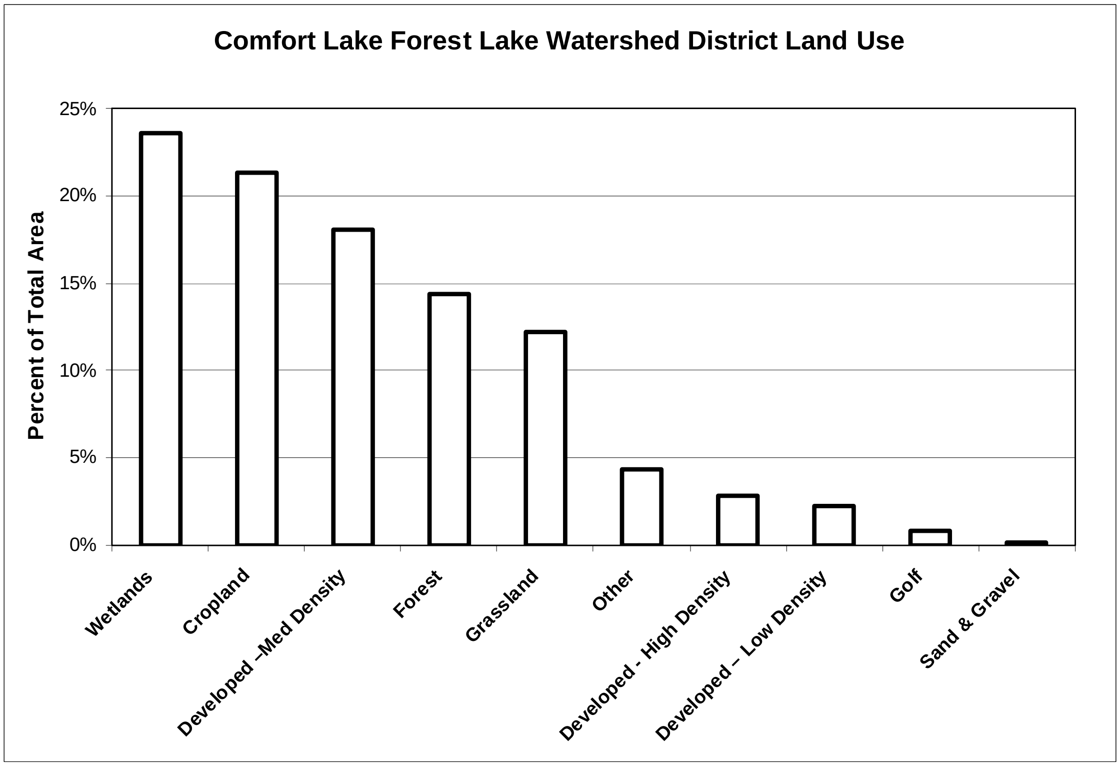



**Figure 8. Land Use**

**Table 4. Lake Watershed Land Use Summary**

| Land Use | Moody | Bone | School | Little Comfort | Shields | Comfort |
|---|---|---|---|---|---|---|
| Cropland | 33% | 39% | 30% | 27% | 20% | 21% |
| Forest | 15% | 13% | 18% | 18% | 13% | 14% |
| Golf Course | 0% | 0% | 0% | 0% | 17% | 1% |
| Grassland | 18% | 16% | 17% | 18% | 15% | 12% |
| Sand & Gravel | 0% | 0% | 0% | 0% | 0% | 0% |
| Developed - High Density | 0% | 0% | 0% | 0% | 0% | 3% |
| Developed - Medium Density | 4% | 7% | 5% | 6% | 14% | 18% |
| Developed - Low Density | 3% | 2% | 3% | 3% | 2% | 2% |
| Wetlands | 26% | 20% | 25% | 25% | 15% | 24% |
| Other | 0% | 3% | 3% | 3% | 2% | 4% |

### Population

Current and future population estimates are available for municipalities in Washington County through the Metropolitan Council. Similar detailed estimates are available for the municipalities in Chisago County through the Minnesota State Demographic Center. Population is expected to increase fairly significantly throughout the watersheds (Table 5).

**Table 5. 2000, 2020 and 2030 Populations by Municipality**

| County | City or Township | Population | | | | |
|---|---|---|---|---|---|---|
| | | 2000[++] | 2020 | 2030 | % Change 2000 to 2020 | % Change 2000 to 2030 |
| Chisago[+] | City of Chisago City | 2,622 | 5,695 | 6,392 | 117% | 144% |
| Chisago[+] | Chisago Lakes Twp. | 3,276 | 4,685 | 5,156 | 43% | 57% |
| Chisago[+] | City of Wyoming | 3,048 | 5,642 | 6,600 | 85% | 117% |
| Chisago[+] | Wyoming Twp.** | 4,379 | 5,460 | 6,501 | 25% | 48% |
| Washington* | City of Forest Lake | 14,440 | 27,800 | 34,200 | 93% | 137% |
| Washington* | City of Scandia | 3,692 | 5,000 | 5,400 | 35% | 46% |

*Data from the Metropolitan Council's 2030 Regional Development Framework - Revised Forecasts, January 3, 2007.
[+] Data from Minnesota State Demographic Center, October 2007
** Wyoming Township is now part of Chisago City and Wyoming, with the majority of the population of Wyoming Township now part of the City of Wyoming.
[++] 2000 population is taken from the 2000 US Census.

### Wildlife Resources

The Comfort Lake-Forest Lake Watershed District contains many of the types of birds, amphibians, reptiles, and mammals typical of wetland and upland areas in this portion of the North Central Hardwood Forests ecoregion. Wood ducks, mallards, and giant Canada geese are common along with wild turkey and white-tailed deer. Bald eagles and red-shouldered hawks can also occur in the area. Threatened mussel species have been identified outside of the Comfort Lake-Forest Lake Watershed District on the Sunrise River downstream of the Kost Dam (Davis and Miller, 1996). Blanding's turtles, a state-listed threatened species, have been observed in the District. The northwest portion of the District, near Comfort Lake, is designated by the DNR as a Blanding's Turtle Priority Area. Trumpeter swans, a state-listed threatened species, nested on Shields Lake in 2007. Lake sturgeon, a state-listed fish species of special concern, have been documented within Comfort Lake.

In addition, a 2008 search of the Minnesota Natural Heritage Information System: Rare Features Database by the MDNR, revealed additional rare species or significant natural features which are known to occur within a one-mile radius of the Comfort Lake-Forest Lake Watershed District. The results of the search revealed numerous plant species including: waterwillow (*Decodon verticillatus*), tuberclad reinorchid (*Platanthera flava var. herbiola*), cross-leaved milkwort (*Polygala cruciata*), american ginseng (*Panax quinquefolius*), tooth-cup (*Rotala ramsior*), halbred-leaved tearthumb (*Polygonum arifolium*), and autumn fimbristylis (*Fimbristylis* *autumnalis*); a bog copper butterfly (*Lyncaena epixanthe michiganensis*); a couple snakes including: eastern hognose snake (*Heterodon platirhinos*) and eastern fox snake (*Elaphe vulpine*); and the sandhill crane (*Grus Canadensis*) (Appendix K of CLFLWD, 2008).

### Groundwater

The Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation (CLFLWD, 2007)* states:

> "Exchange between the lakes and groundwater was included in the watershed loading and lake response models to:
>
> 1) Balance water budgets regionally (i.e., across the whole watershed) between recharge areas in the eastern portion of the watershed and discharge areas in the west. The **regional** exchanges of groundwater have both recharge and discharge zones that have a net zero effect in the CLFLWD.
>
> 2) Represent losses to groundwater in landlocked basins (which have no natural or active surface overflow). This **local** interaction is how landlocked subwatersheds contribute to downstream receiving waters.
>
> The regional groundwater recharge is water **leaving** a waterbody **to** groundwater. This removes water volumes and phosphorus loads from their respective budgets. The total load is calculated using the volume defined in the water budget and phosphorus concentrations predicted in the lake response model.
>
> In contrast, regional groundwater discharge is water **entering** a waterbody **from** groundwater. This adds water volumes and phosphorus loads to their respective budgets. The total load is calculated using the volume defined in the water budget and the MPCA's median phosphorus concentration of 56 ug/L for surficial quaternary aquifers.
>
> The groundwater attributed to landlocked "upstream lakes" represents water leaving a landlocked lake (e.g. Sea Lake, Nielson Lake, Elwell Lake, Sylvan Lake, and Clear Lake) by way of groundwater and entering the next down-gradient lake via regional groundwater flows. This total load is calculated using the groundwater volume defined in the water budget and the MPCA's median phosphorus concentration of 56 ug/L for surficial quaternary aquifers. More detail on estimating these volumes are presented in the water budget, Appendix C" of *Water Quality Modeling Investigation* attached as Appendix A.

Additional information on groundwater loads to the six lakes is summarized in Section 4G of this report.

## 1C. Pollutant of Concern

### Role of Phosphorus in Lakes

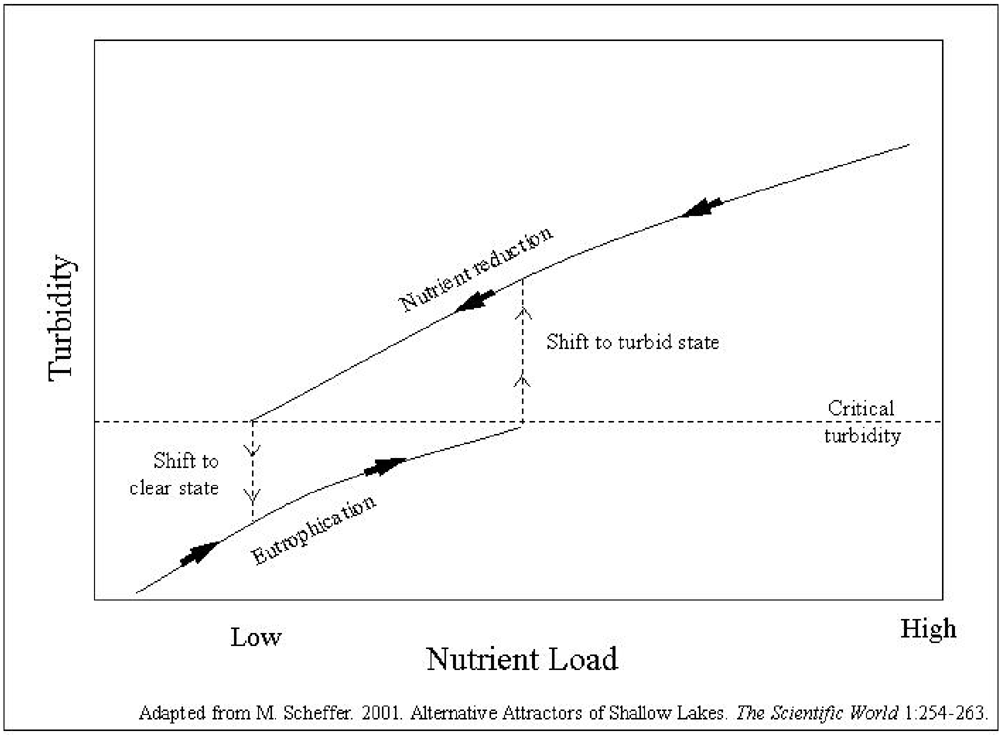
Total phosphorus (TP) is generally the limiting factor controlling primary production in freshwater lakes in Minnesota. It is the nutrient of focus for this TMDL, and is sometimes referred to as the causal factor. As phosphorus concentrations increase, primary production also increases, as measured by higher chlorophyll-*a* concentrations. Chlorophyll-*a* concentrations are used as a proxy to measure the concentration of algae within the water column. Higher concentrations of chlorophyll tends to correlate with lower water transparency because of the abundance of algae in the water column. Both chlorophyll-*a* and Secchi transparency are referred to as response factors, since they indicate the ecological response of a lake to excessive phosphorus input. There is often a positive relationship between TP and chlorophyll-*a* in a lake. Similarly, a negative relationship is often apparent between TP and Secchi depth.

### Role of Phosphorus in Shallow Lakes

The relationship between phosphorus concentration and the response factors (chlorophyll and transparency) is often different in shallow lakes as compared to deeper lakes. In deeper lakes, primary productivity is often controlled by physical and chemical factors such as light availability, temperature, and nutrient concentrations. The biological components of the lakes (such as microbes, algae, macrophytes, zooplankton and other invertebrates, and fish) are distributed throughout the lake, along the shoreline, and on the bottom sediments. In shallow lakes, the biological components are concentrated into less volume and exert a stronger influence on the ecological interactions within the lake. There is a more dense biological community at the bottom of shallow lakes than in deeper lakes because oxygen is replenished in the bottom waters and light can often penetrate to the bottom. These biological components can control the relationship between phosphorus and the response factors.

The result of this impact of biological components on the ecological interactions is that shallow lakes normally exhibit one of two alternative ecologically stable states (Figure 9): the turbid, phytoplankton-dominated state, and the clear, macrophyte (plant)-dominated state. The clear state is the most preferred, since phytoplankton communities (composed mostly of algae) are held in check by diverse and healthy zooplankton and fish communities. Fewer nutrients are released from the sediments in this state. The roots of the macrophytes stabilize the sediments, lessening the amount of sediment stirred up by the wind. Periodic winter fish kills are desirable to control the population of bottom feeders such as carp and bullheads that stir up bottom sediments and exacerbate internal loading. These bottom feeders also tend to forage in the bottom sediments and release nutrients into the water column through excretion.

Nutrient reduction in a shallow lake does not lead to a linear improvement in water quality (indicated by turbidity in Figure 9). As external nutrient loads are decreased in a lake in the turbid state, slight improvements in water quality may at first occur. At some point, a further decrease in nutrient loads will cause the lake to abruptly shift from the turbid state to the clear state. The general pattern in Figure 9 is often referred to as “hysteresis”, meaning that when forces are applied to a system, it does not necessarily return completely to its original state, nor does it follow the same trajectory on the way back.



Adapted from M. Scheffer. 2001. Alternative Attractors of Shallow Lakes. *The Scientific World* 1:254-263.

**Figure 9. Alternative Stable States in Shallow Lakes**

The biological response of the lake to phosphorus inputs will depend on the state that the lake is in. For example, if the lake is in the clear state, the macrophytes may be able to assimilate the phosphorus instead of algae performing that role. However, if enough stressors are present in the lake, increased phosphorus inputs may lead to a shift to the turbid state with an increase in algal density and decreased transparency. The two main categories of stressors that can shift the lake to the turbid state are:

- Disturbance to the macrophyte community, for example from wind, benthivorous (bottom-feeding) fish, boat motors, or light availability (influenced by algal density or water depth)
- A decrease in zooplankton grazer density, which allows unchecked growth of sestonic (suspended) algae. These changes in zooplankton density could be caused by an increase in predation, either directly by an increase in planktivorous fish that feed on zooplankton, or indirectly through a decrease in piscivorous fish that feed on the planktivorous fish.

This complexity in the relationships among the biological communities in shallow lakes leads to less certainty in predicting the in-lake water quality of a shallow lake based on the phosphorus load to the lake. The relationships between external phosphorus load and in-lake phosphorus concentration, chlorophyll-*a* concentration, and transparency are less predictable than in deeper lakes, and therefore lake response models are less accurate.

Another implication of the alternative stable states in shallow lakes is that different management approaches are used for shallow lake restoration than those used for restoration of deeper lakes. Shallow lake restoration often focuses on restoring the macrophyte and zooplankton communities to the lake.

Shields Lake is the only shallow lake in this group of six lakes. It exhibits the characteristics of a shallow lake in the tendency to mix throughout the growing season and the estimated high internal load. According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 ft, or if the littoral zone (area where depth is less than 15 ft) covers at least 80% of the lake's surface area. The littoral area of Shields Lake is 87% of the lake's total surface area; the lake is therefore considered shallow by the MPCA definition.

# 2. Applicable Water Quality Standards and Numeric Water Quality Targets

## 2A. Designated Uses

All of the lakes included in this study are classified under Minnesota Rule 7050.0430 as Class 2B, 3B, 4A, 4B, 5, and 6 waters. The most protective of these classes is Class 2 waters, which are protected for aquatic life and recreation. MN Rules Chapter 7050.0140 Water Use Classification for Waters of the State reads:

> Subp. 3. Class 2 waters, aquatic life and recreation. Aquatic life and recreation includes all waters of the state which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes, and where quality control is or may be necessary to protect aquatic or terrestrial life or their habitats, or the public health, safety, or welfare.
>
> Subp. 4. Class 3 waters, industrial consumption.
> Industrial consumption includes all waters of the state that are or may be used as a source of supply for industrial process or cooling water, or any other industrial or commercial purposes, and for which quality control is or may be necessary to protect the public health, safety, or welfare.
>
> Subp. 5. Class 4 waters, agriculture and wildlife.
> Agriculture and wildlife includes all waters of the state that are or may be used for any agricultural purposes, including stock watering and irrigation, or by waterfowl or other wildlife and for which quality control is or may be necessary to protect terrestrial life and its habitat or the public health, safety, or welfare.
>
> Subp. 6. Class 5 waters, aesthetic enjoyment and navigation.
> Aesthetic enjoyment and navigation includes all waters of the state that are or may be used for any form of water transportation or navigation or fire prevention and for which quality control is or may be necessary to protect the public health, safety, or welfare.
>
> Subp. 7. Class 6 waters, other uses and protection of border waters.
> Other uses includes all waters of the state that serve or may serve the uses in subparts 2 to 6 or any other beneficial uses not listed in this part, including without limitation any such uses in this or any other state, province, or nation of any waters flowing through or originating in this state, and for which quality control is or may be necessary for the declared purposes in this part, to conform with the requirements of the legally constituted state or national agencies having jurisdiction over such waters, or for any other considerations the agency may deem proper.

## 2B. Water Quality Standards

Water quality standards are established to protect the designated uses of the state's waters. Amendments to Minnesota's Rule 7050.0222, approved by the EPA in May 2008, include eutrophication standards for lakes (Table 6). Numerical standards are given in Minnesota's Rule 7050.0222 Subp. 4 with narrative standards in Minnesota's Rule 7050.0222 Subp. 4a. Eutrophication standards were developed for lakes in general, and for shallow lakes in particular. Standards are less stringent for shallow lakes, due to higher rates of internal loading in shallow lakes and different ecological characteristics.

To be listed as impaired, the monitoring data must show that the standards for both TP (the causal factor) and either chlorophyll-*a* or Secchi depth (the response factors) were violated. If a lake is impaired with respect to only one of these criteria, it may be placed on a review list; a weight of evidence approach is then used to determine if these lakes will be listed as impaired. For more details regarding the listing process, see the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment* (MPCA, 2007).

Moody, Bone, School, and Comfort lakes were listed as impaired waters based on the general eutrophication standards. Little Comfort is expected to be listed as an impaired water based on the general eutrophication standards in the near future as indicated by recently collected lake water quality monitoring data. Shields Lake was evaluated as a shallow lake because the littoral area is 87% of the lake's total surface area which fits the MPCA definition of a shallow lake.

**Table 6. MN Eutrophication Standards, North Central Hardwood Forests Ecoregion**

| Parameter | Eutrophication Standard. General | Eutrophication Standard, Shallow Lakes |
|---|---|---|
| TP (µg/l) | TP < 40 | TP < 60 |
| Chlorophyll-*a* (µg/l) | Chl-a < 14 | Chl-a < 20 |
| Secchi depth (m) | SD > 1.4 | SD > 1.0 |

# 3. Impairment Assessment

## 3A. Background

Lake characteristics for the six study lakes are discussed in Section 1B of this report and are summarized in Table 3. Assessment of each lake's impairment is given in Sections 3B through 3G.

## 3B. Moody Lake

In-lake monitoring data for Moody Lake are available from 2005 to 2007. These three years were used to calculate the water quality data means (Table 7). Moody Lake is hypereutrophic, with relatively higher TP compared to chlorophyll concentrations and transparency, as indicated by the Trophic State Index (TSI) values (Table 7).

**Table 7. Surface Water Quality, Moody Lake, 2005 - 2007**

| | Growing Season Mean (June – September) | Trophic State Index |
|---|---|---|
| TP (µg/L) | 167 | 78 |
| Chl-a(µg/L) | 61 | 71 |
| Secchi depth (m) | 0.67 | 66 |

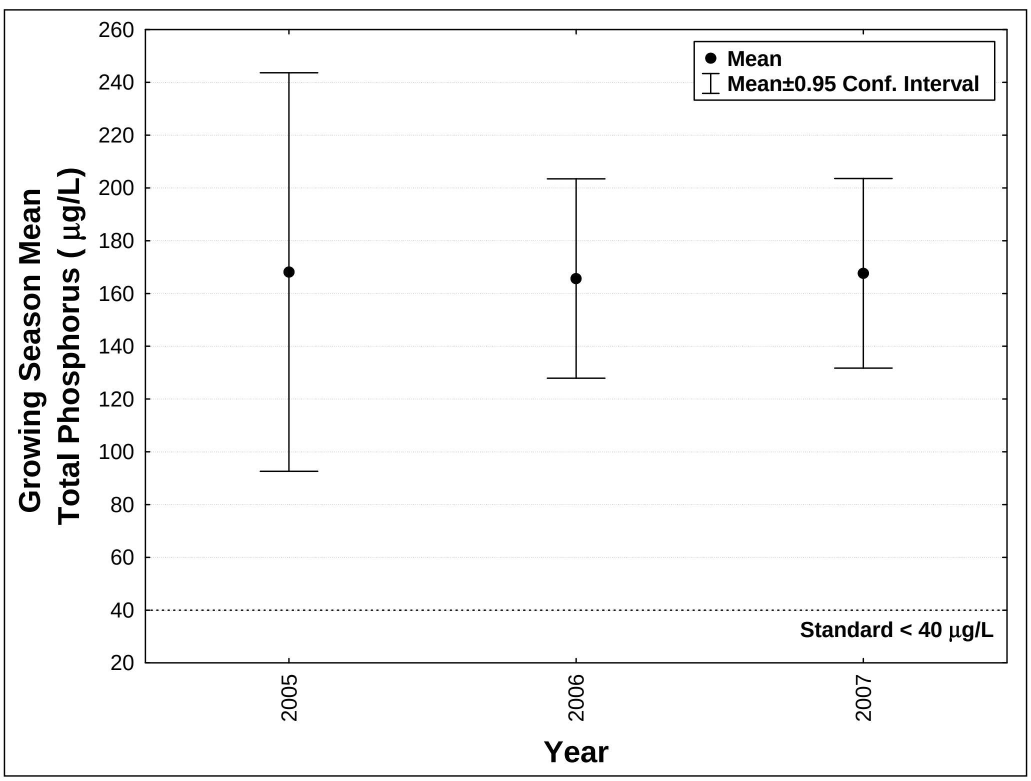



**Figure 10. Total Phosphorus Monitoring Data, Moody Lake**

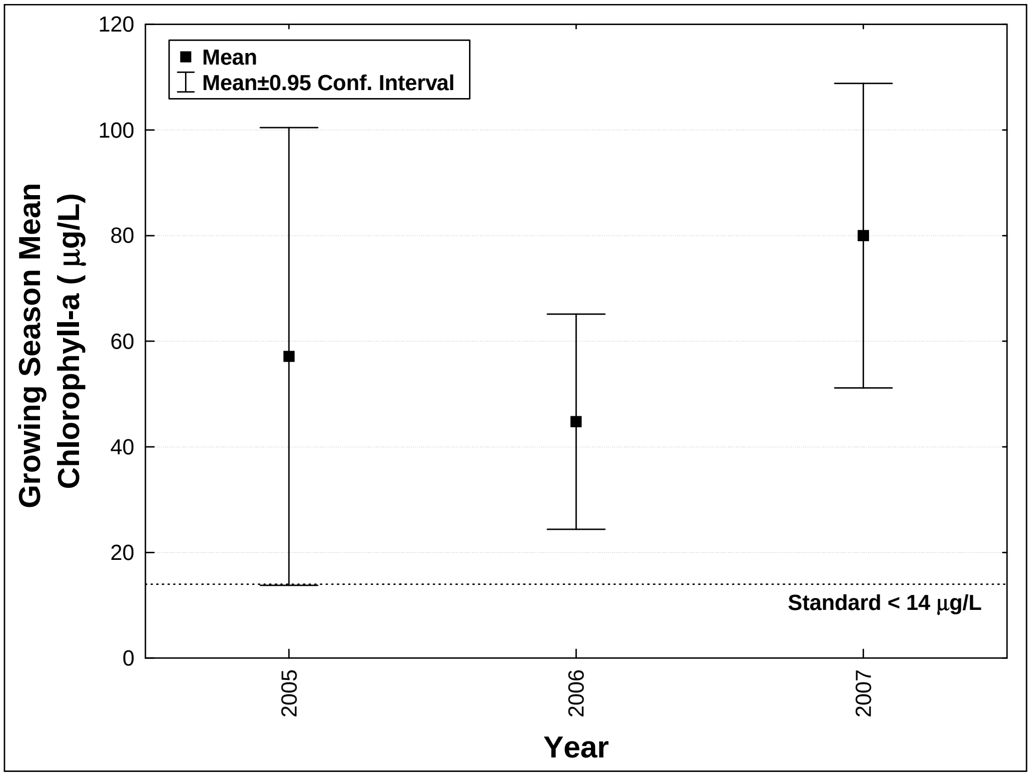



**Figure 11. Mean Chlorophyll-a Monitoring Data, Moody Lake**

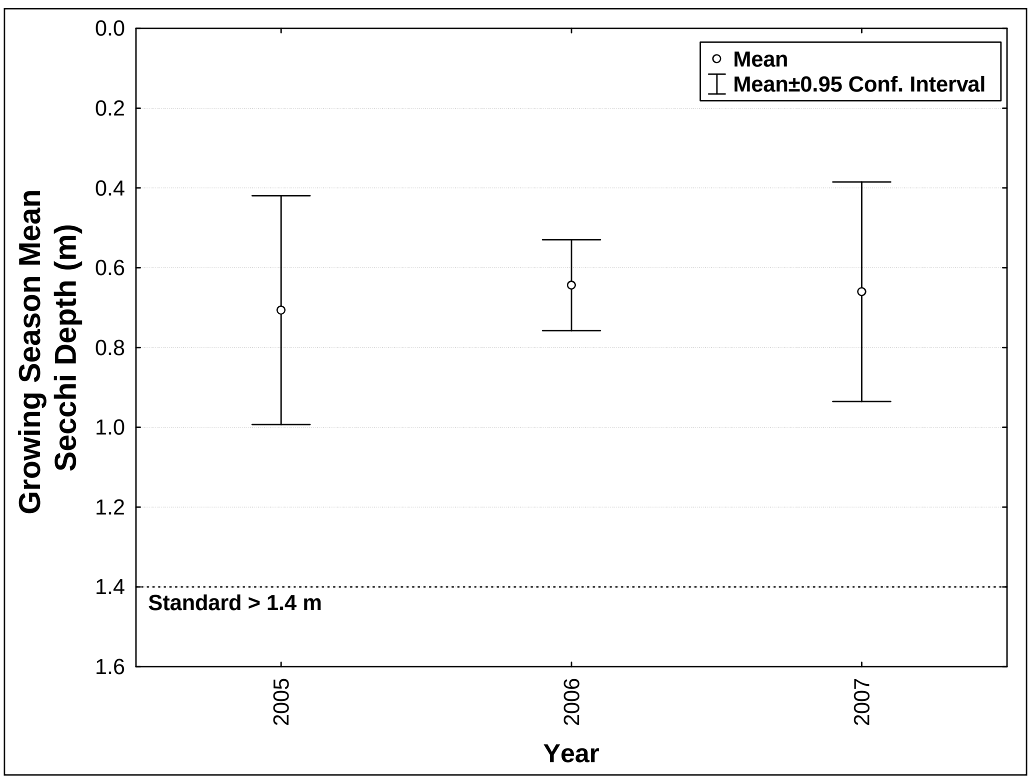



**Figure 12. Secchi Depth Monitoring Data, Moody Lake**

Water quality in Moody Lake generally worsens in June and July (Figures 13 – 15). In the three years with available monitoring data, 2005 through 2007, phosphorus and chlorophyll dramatically increased in early June and decreased in late July and early August. This cycle is likely caused by curly-leaf pondweed, which typically dies off in mid-June to early-July, releasing phosphorus into the water column.

The Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation* (CLFLWD, 2007) identifies the following key observations based on District macrophyte and zooplankton surveys and DNR fish surveys:

- "Panfish population declined dramatically from 1989 to 1998 survey.
- Very high numbers of black bullheads were collected in most recent survey; winter kill may have occurred.
- Macrophyte community diversity is very low, few desirable submergent species are present.
- Curly-leaf pondweed is abundant in the lake, found in both spring and fall surveys in 2006."

Without a more recent fisheries survey, it is difficult to determine the influence of the panfish community on water quality. A high panfish density can overgraze zooplankton, allowing algae concentrations to increase. The high numbers of bullhead and the abundance of curly-leaf pondweed likely contribute to the internal loading in Moody Lake.

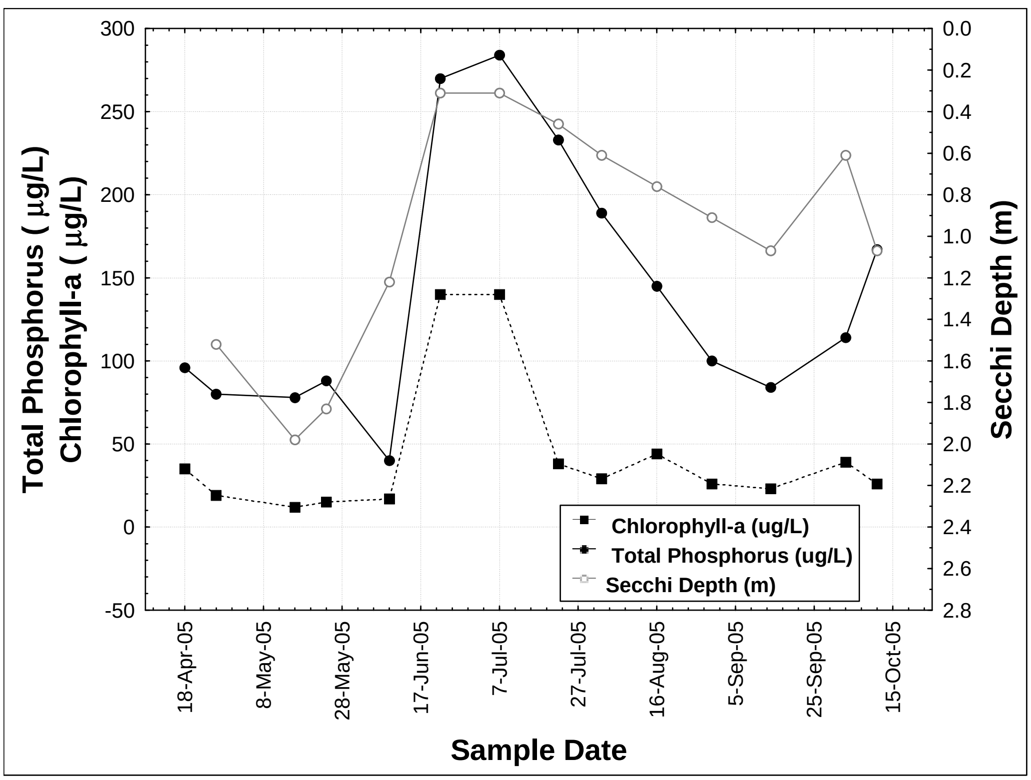



**Figure 13. 2005 Seasonal Water Quality Patterns, Moody Lake**

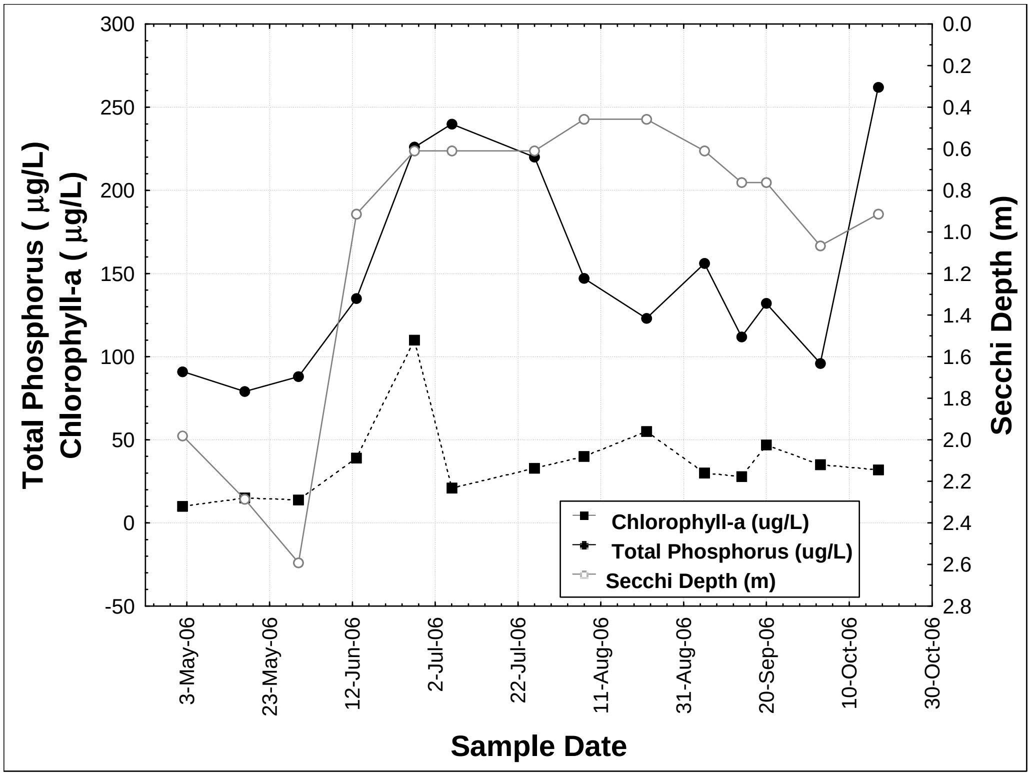



**Figure 14. 2006 Seasonal Water Quality Patterns, Moody Lake**

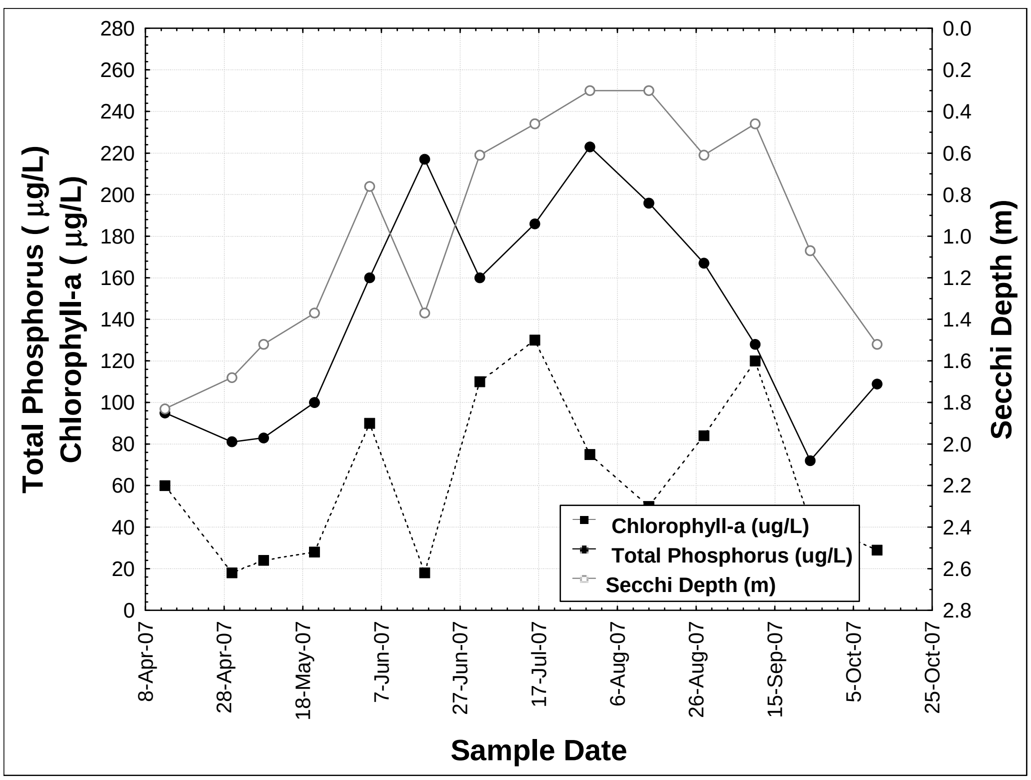



**Figure 15. 2007 Seasonal Water Quality Patterns, Moody Lake**

## 3C. BONE LAKE

In-lake monitoring data are available periodically from 1986 to 2007 for Bone Lake, and for all seven seasons from 2001 through 2007. All available data from the past 10 years (1997-2007) were used to calculate the water quality data means (Table 8); the lake was monitored for nine seasons within the last ten-year period.

Bone Lake is a eutrophic lake, with somewhat higher chlorophyll concentrations compared to transparency, as indicated by the TSI values (Table 8), and slightly better TP. Monitoring data from the 1980s through today suggest that the water quality of the lake has been fairly consistent (Figure 15 through Figure 17).

**Table 8. Surface Water Quality, Bone Lake, 1997 - 2007**

| | Growing Season Mean (June – September) | Trophic State Index |
|---|---|---|
| TP (µg/L) | 61 | 61 |
| Chl-a (µg/L) | 65 | 65 |
| Secchi depth (m) | 1.3 | 56 |

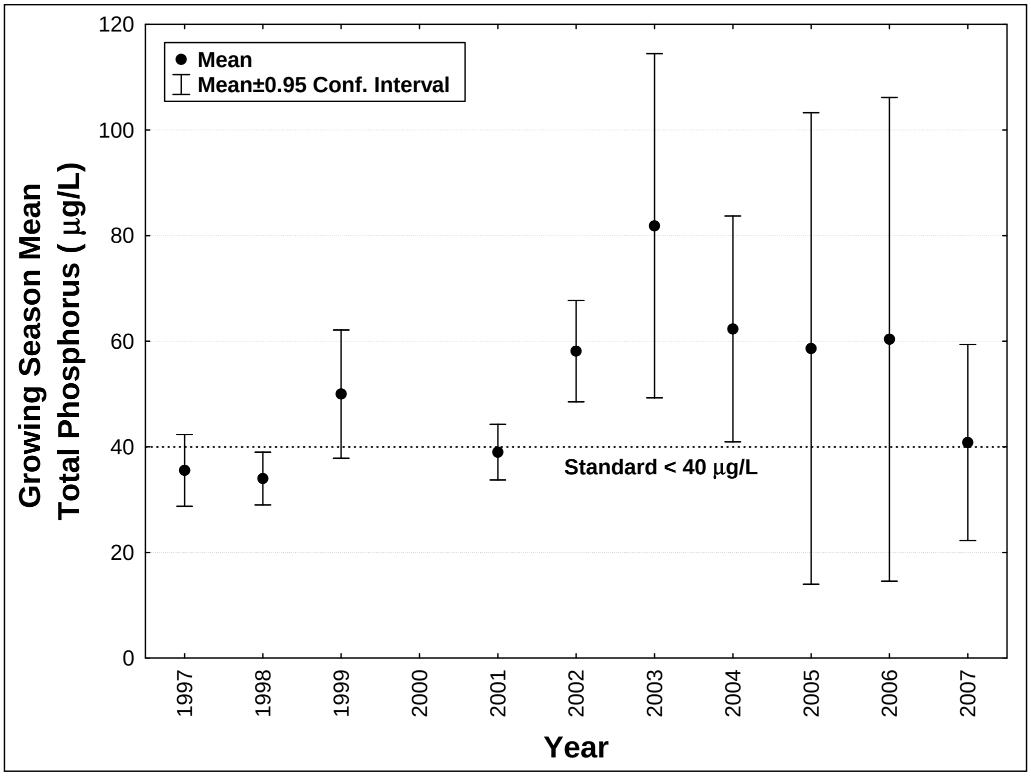



**Figure 16. Total Phosphorus Monitoring Data, Bone Lake**

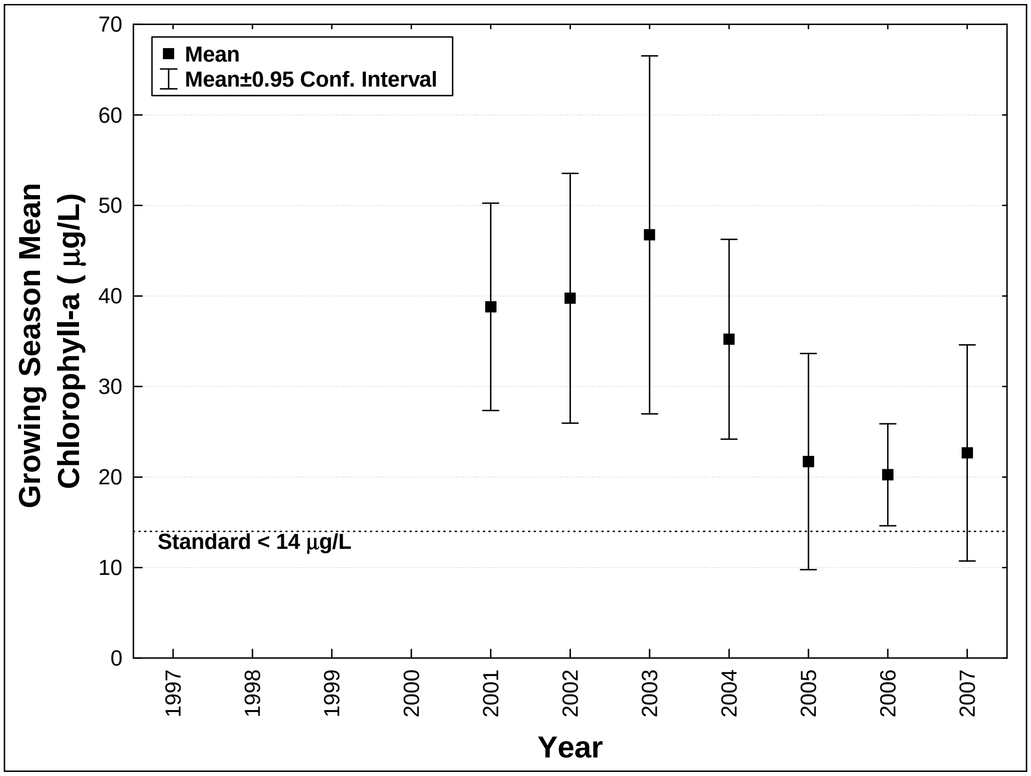



**Figure 17. Mean Chlorophyll-a Monitoring Data, Bone Lake**

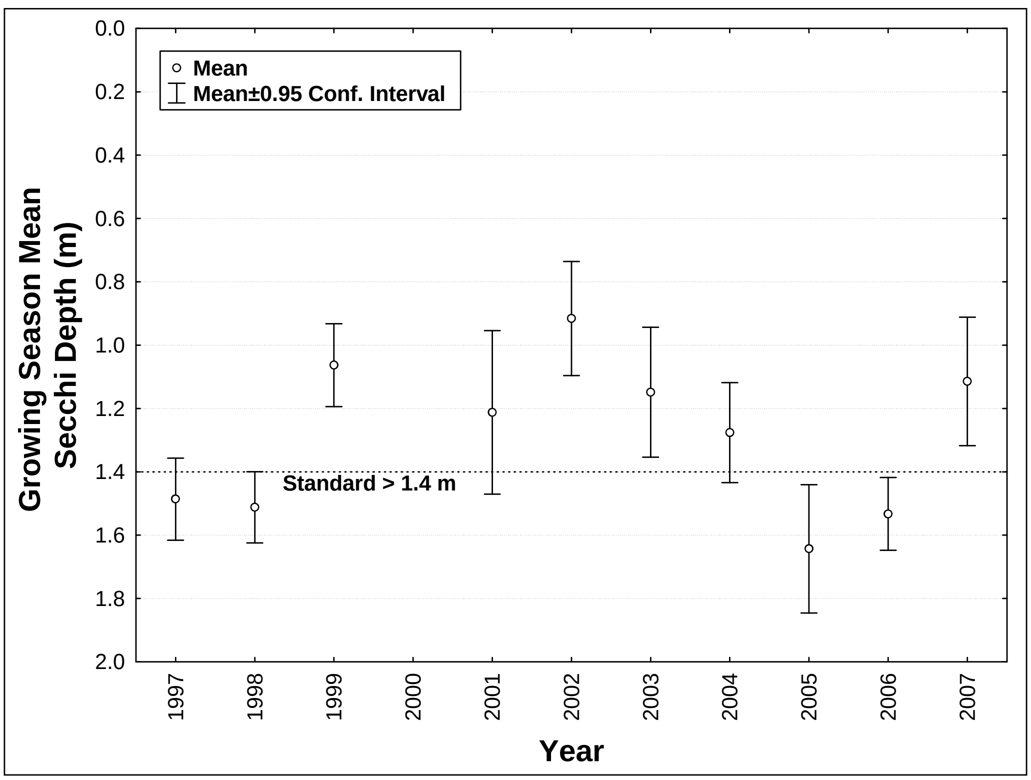



**Figure 18. Secchi Depth Monitoring Data, Bone Lake**

TP in Bone Lake fluctuates somewhat throughout the growing season, with high spikes in phosphorus occurring in June in 2005 and 2007 and in September in 2006 (Figure 18, Figure 19, Figure 20). The high TP in June was likely due to senescence of curly-leaf pondweed, and the high TP in September of 2006 occurred during the fall turnover event.

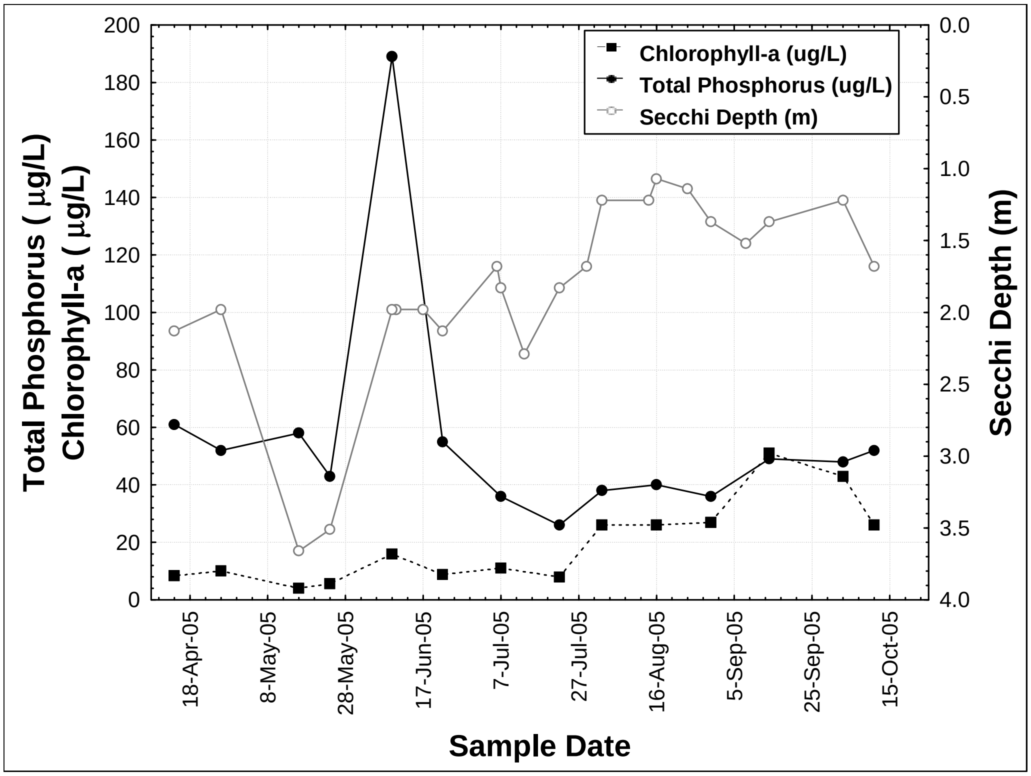



**Figure 19. 2005 Seasonal Water Quality Patterns, Bone Lake**

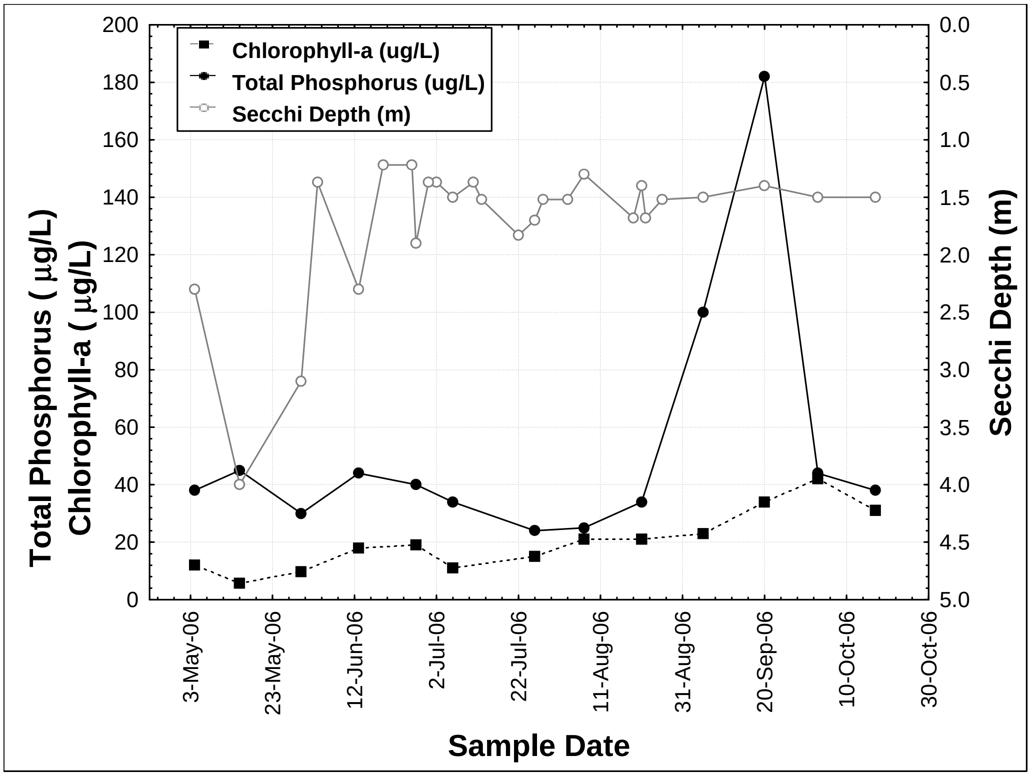



**Figure 20. 2006 Seasonal Water Quality Patterns, Bone Lake**

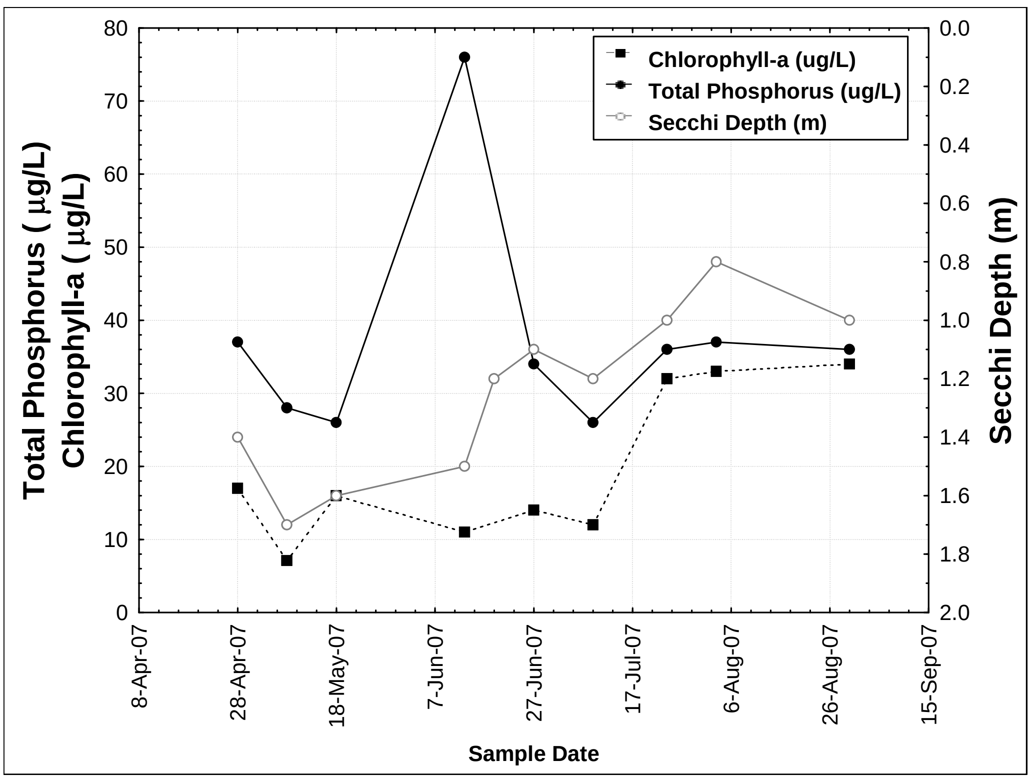



**Figure 21. 2007 Seasonal Water Quality Patterns, Bone Lake**

The Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation* (CLFLWD, 2007) identifies the following key observations based on District macrophyte and zooplankton surveys and DNR fish surveys:

- "Biomass was evenly distributed among panfish, top predator and rough fish groups in last survey.
- Carp present in the lake are large, averaging approximately 8 pounds in last survey
- Exotic species curly-leaf pondweed and Eurasian water milfoil are present in lake.
- Some desirable submergent species exist but they are not abundant."

## 3D. School Lake

In-lake monitoring data are available for 2005 to 2007 for School Lake. Data available from the three available years were used to calculate the water quality data means (Table 9). School Lake is a eutrophic lake, with somewhat better transparency compared to the fairly consistent TP and chlorophyll concentrations (Table 9).

**Table 9. Surface Water Quality, School Lake, 2005 – 2007**

| | Growing Season Mean (June – September) | Trophic State Index |
|---|---|---|
| TP (µg/L) | 67 | 65 |
| Chl-a (µg/L) | 39 | 67 |
| Secchi depth (m) | 1.2 | 58 |

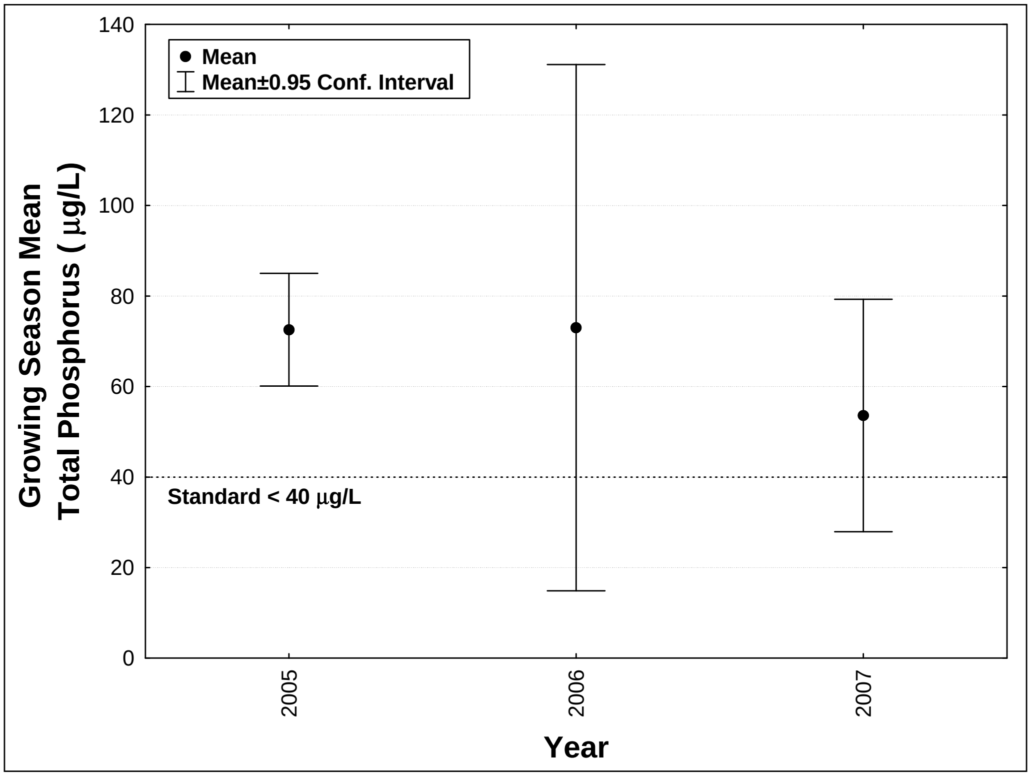



**Figure 22. Total Phosphorus Monitoring Data, School Lake**

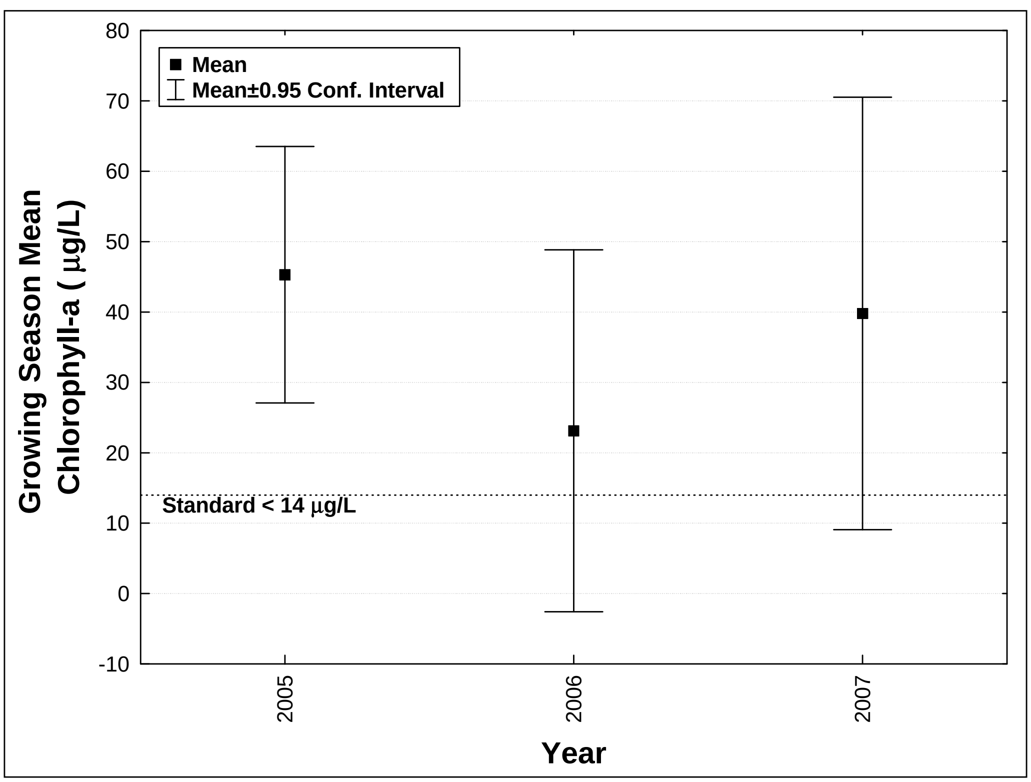



**Figure 23. Mean Chlorophyll-a Monitoring Data, School Lake**

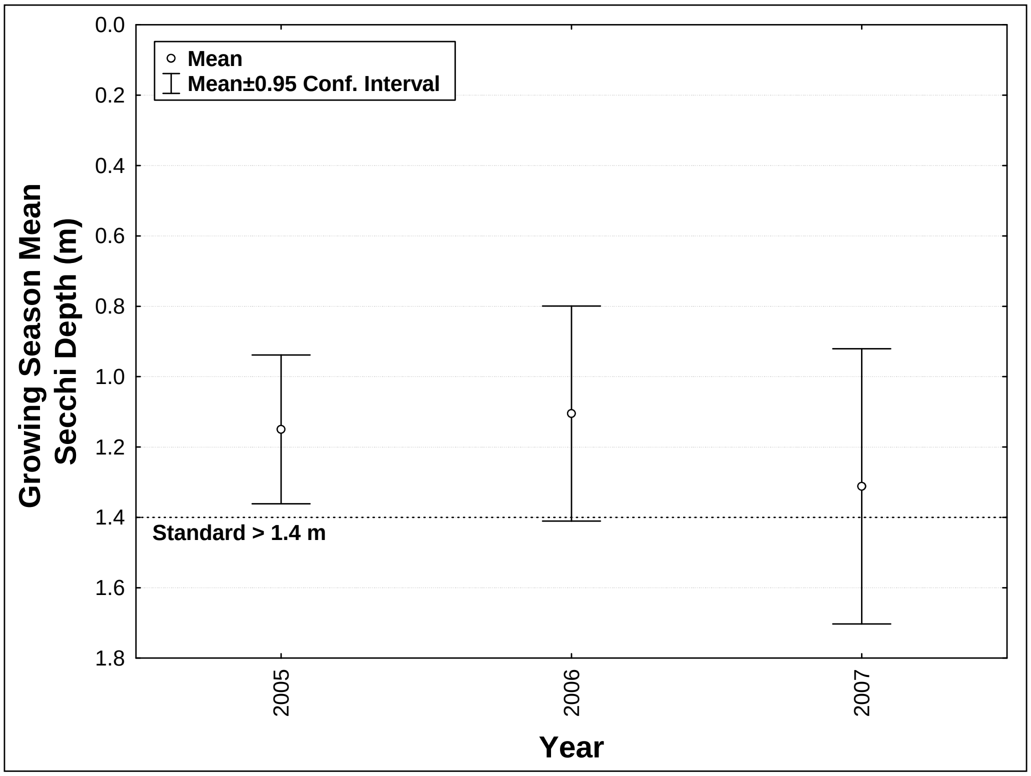



**Figure 24. Secchi Depth Monitoring Data, School Lake**

TP in School Lake fluctuates throughout the growing season, with an increase in July in 2006. Transparency worsens somewhat throughout the growing season (Figure 24, Figure 25, and Figure 26.)

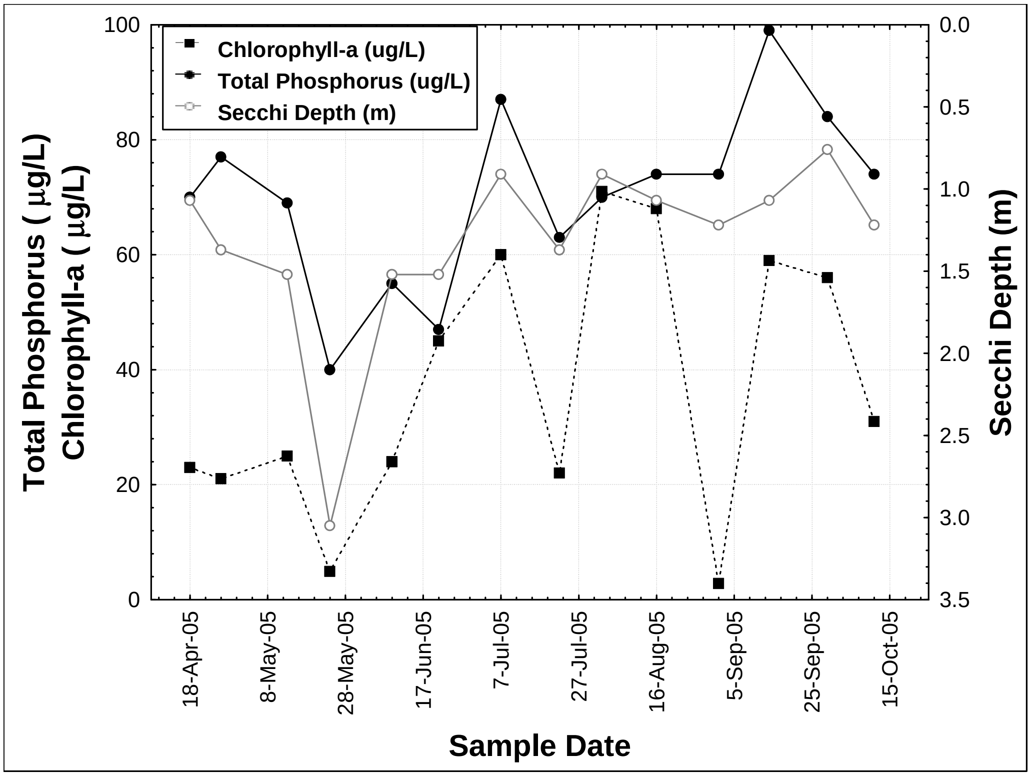



**Figure 25. 2005 Seasonal Water Quality Patterns, School Lake**

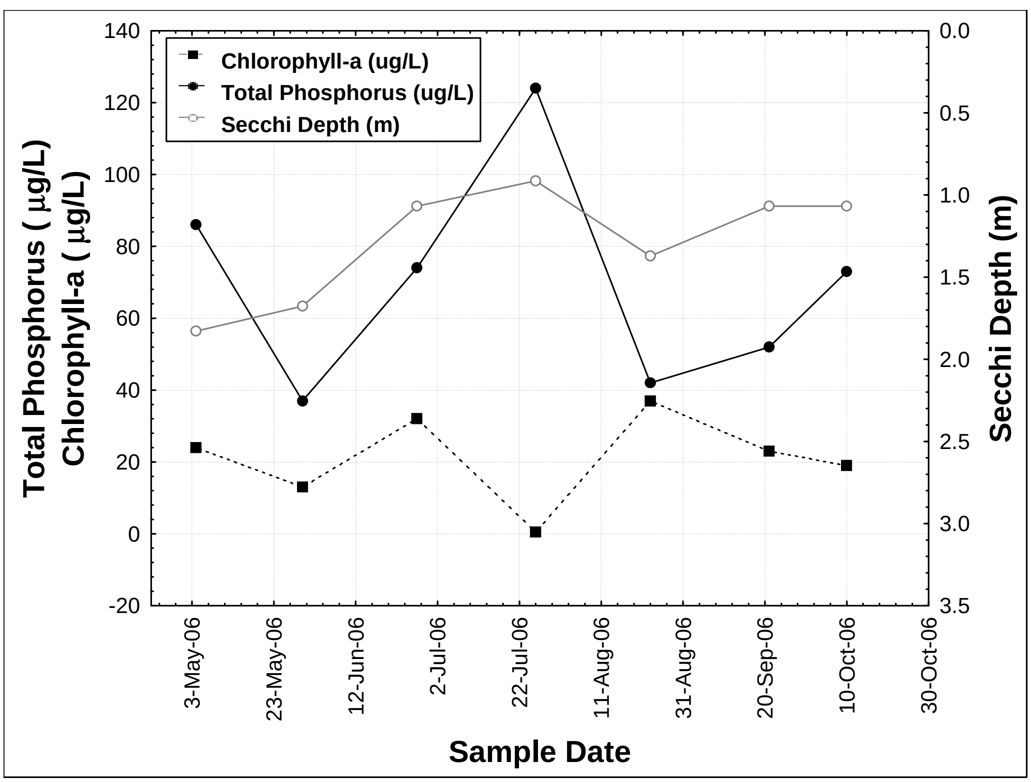



**Figure 26. 2006 Seasonal Water Quality Patterns, School Lake**

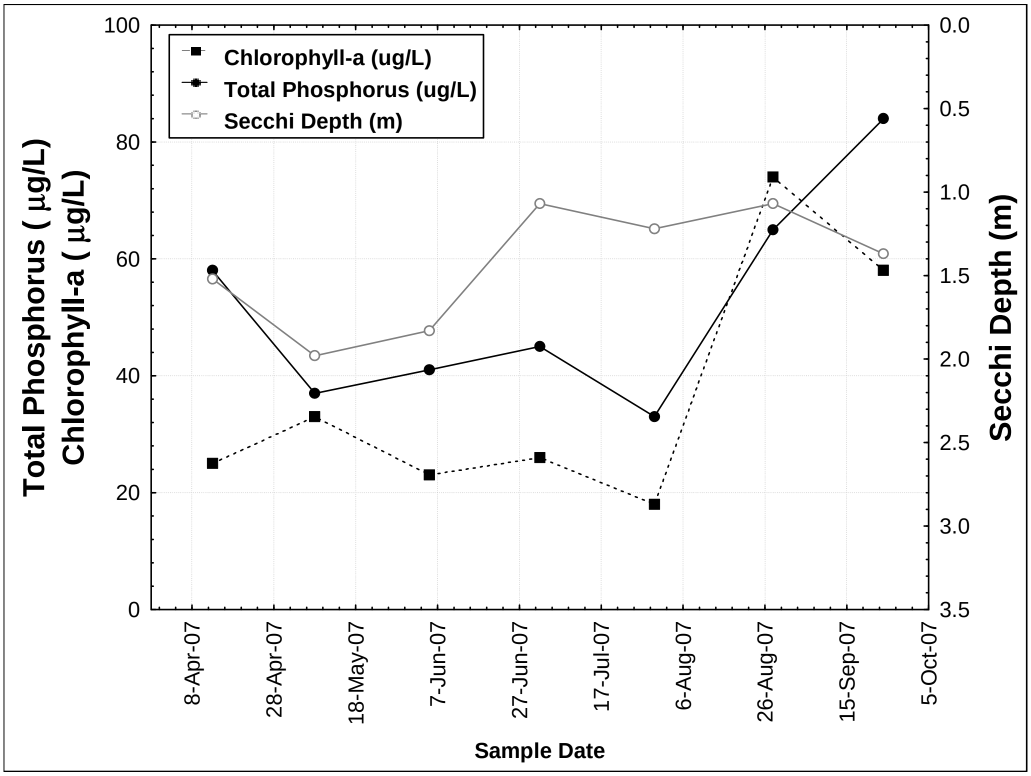



**Figure 27. 2007 Seasonal Water Quality Patterns, School Lake**

The 2008 macrophyte survey for School Lake indicated the presence of curly-leaf pondweed throughout the lake in the June survey with the highest density present along the northern shore (Figure 27). In addition, a diversity of other macrophytes were present in the lake (Table 10). The increases in total phosphorus in the lake in June and July likely represent the impact of the die-off of curly-leaf pondweed on the lake's phosphorus concentrations. Fish population data are not available for School Lake.

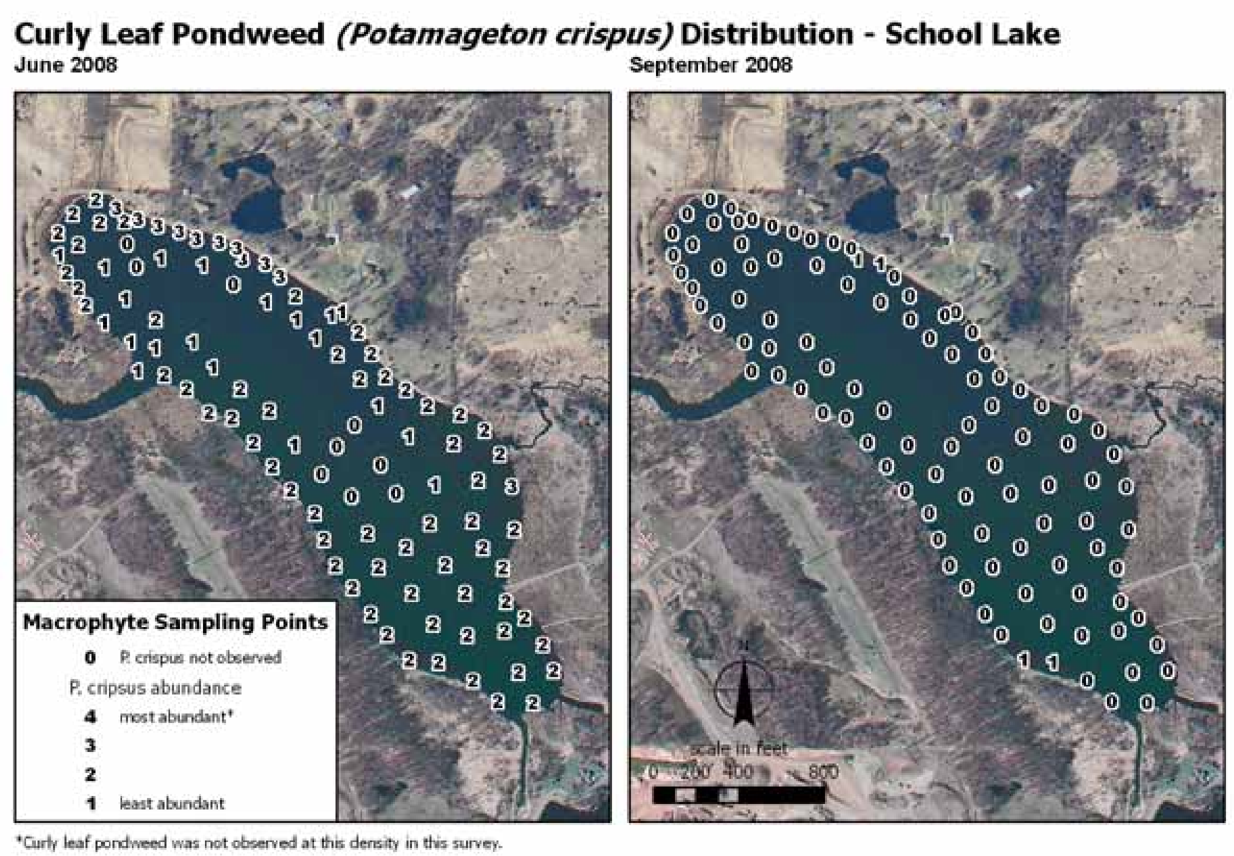



**Figure 28. Distribution and Density of Curly-leaf Pondweed in School Lake**

**Table 10. Plant Species observed during 2008 Summer and Fall Macrophyte Surveys.**

| | **School Lake** | |
|---|---|---|
| **Species** | Summer | Fall |
| *Ceratophyllum demersum* | ✓ | ✓ |
| *Nuphar* sp. | ✓ | ✓ |
| *Nymphaea* sp. | ✓ | ✓ |
| *Potamogeton crispus* | ✓ | ✓ |
| *Potamogeton pectinatus* | ✓ | ✓ |
| *Potamogeton zosteriformas* | ✓ | ✓ |
| *Sagittaria latifolia** | ✓ | ✓ |
| *Scirpus* sp.* | ✓ | ✓ |
| *Typha angustifolia** | ✓ | ✓ |
| *Observed along shoreline. | | |

## 3E. LITTLE COMFORT LAKE

In-lake monitoring data are available for Little Comfort Lake for the years 1994 and 2006 – 2007. Data available from 2006 and 2007 were used to calculate the water quality data means (Table 11). Little Comfort Lake is a eutrophic lake based on TP, with higher TP compared to chlorophyll concentrations and transparency (Table 11).

**Table 11. Surface Water Quality, Little Comfort Lake, 2006 and 2007**

| | Growing Season Mean (June – September) | Trophic State Index |
|---|---|---|
| TP (µg/L) | 63 | 64 |
| Chl-a (µg/L) | 17 | 58 |
| Secchi depth (m) | 1.4 | 56 |

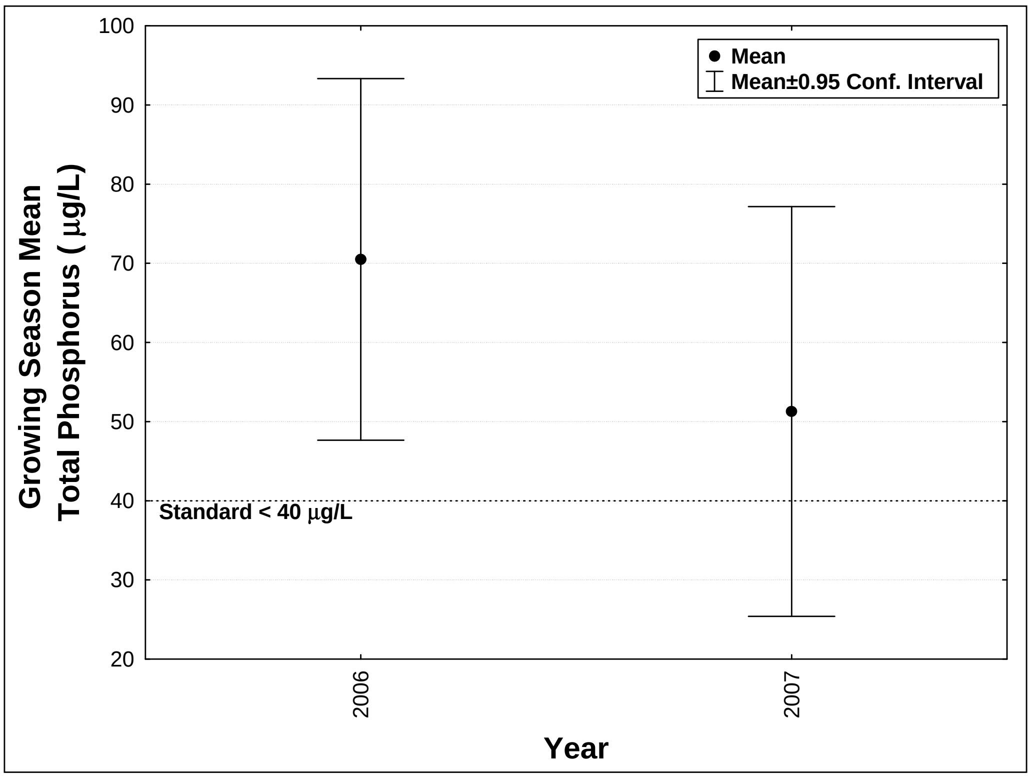



**Figure 29. Total Phosphorus Monitoring Data, Little Comfort Lake**

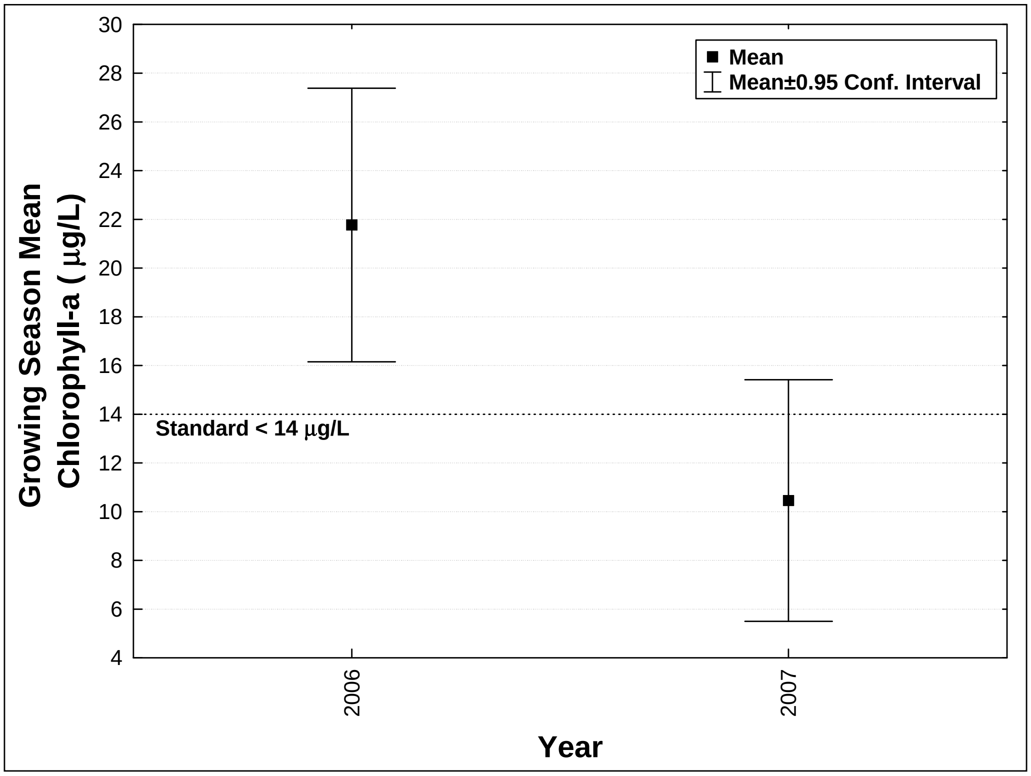



**Figure 30. Mean Chlorophyll-a Monitoring Data, Little Comfort Lake**

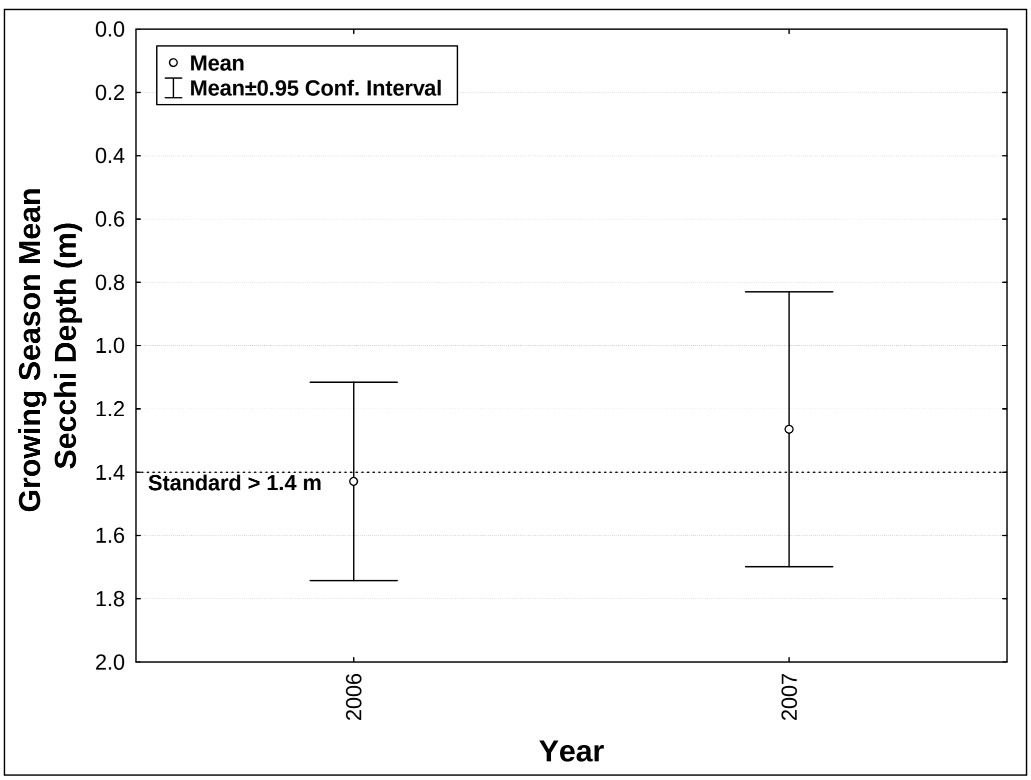



**Figure 31. Secchi Depth Monitoring Data, Little Comfort Lake**

TP in Little Comfort Lake fluctuated somewhat throughout the 2006 growing season (Figure 31). In 2007, a phosphorus spike was observed in June, which could correspond to die off of curly-leaf pondweed (Figure 32).

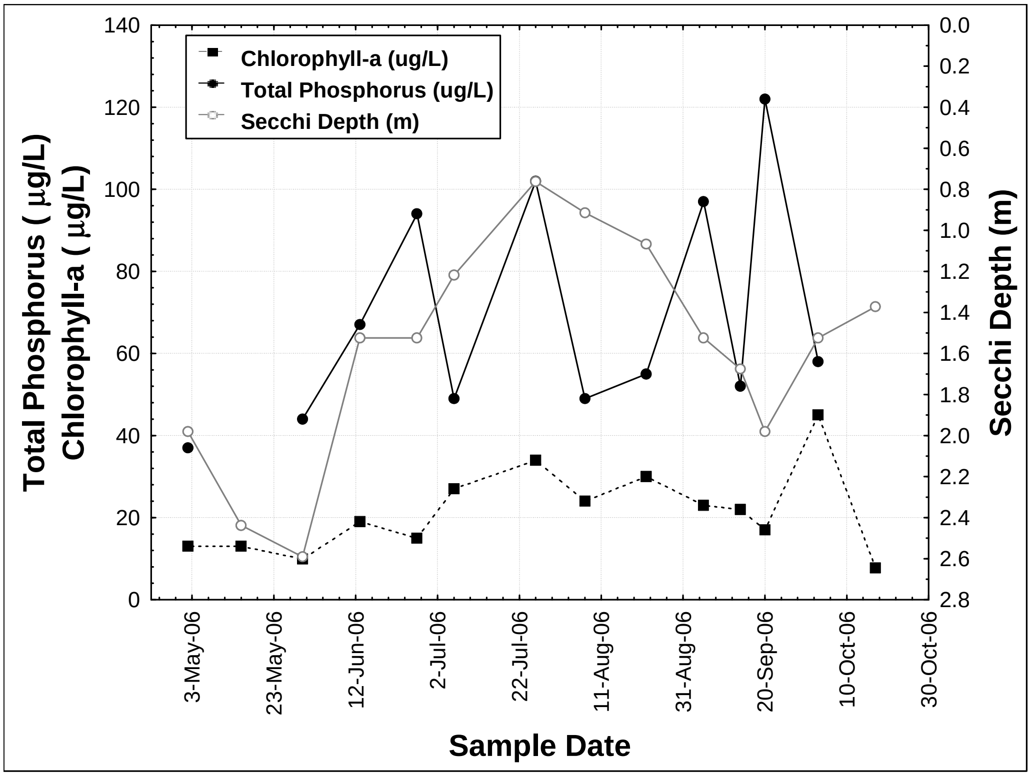



**Figure 32. 2006 Seasonal Water Quality Patterns, Little Comfort Lake**

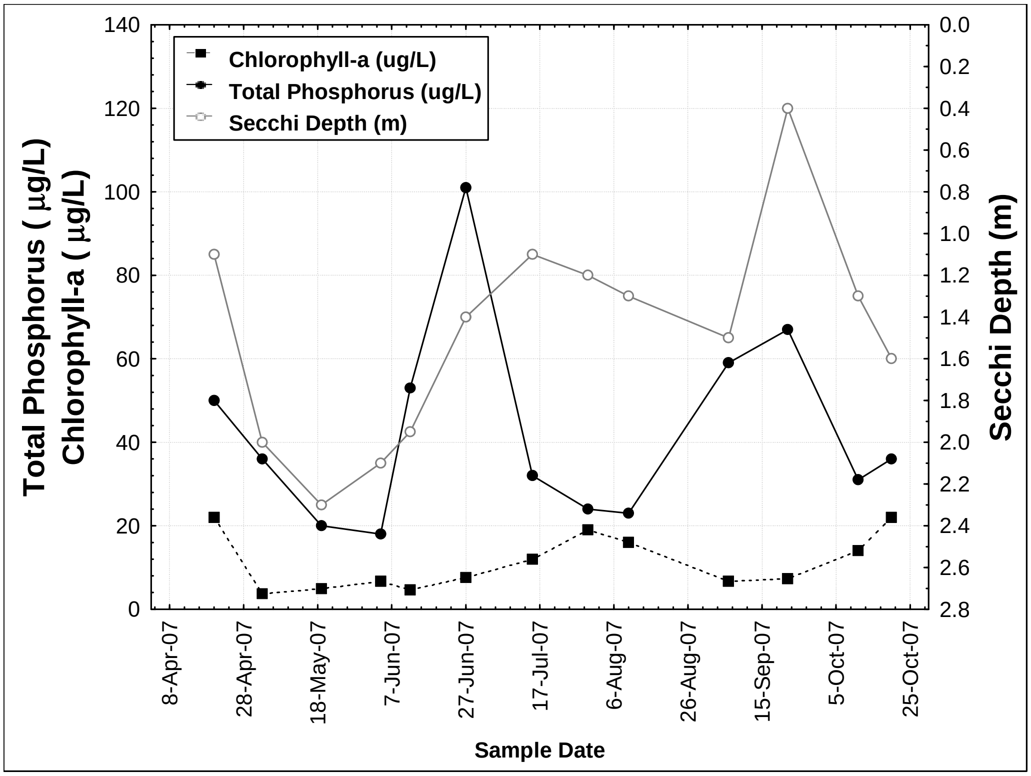



**Figure 33. 2007 Seasonal Water Quality Patterns, Little Comfort Lake**

The Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation* (CLFLWD, 2007) identifies the following key observations based on District macrophyte and zooplankton surveys and DNR fish surveys:

- "Panfish and top predators comprise the majority of biomass.
- Rough fish population has remained stable across surveys.
- Overall plant community diversity is low.
- Lake is dominated by dense stands of curly-leaf pondweed and coontail."

## 3F. Shields Lake

In-lake monitoring data are available for Shields Lake from 1990 to 2007. Data available from the past ten years were used to calculate the water quality data means (Table 12).

Shields Lake is a hypereutrophic lake based on TP, with higher TP concentrations compared to chlorophyll and transparency, as indicated by the TSI values (Table 12). Historical monitoring data suggest that the water quality of the lake has remained fairly consistent through the period of record, however transparency seems to show a trend of poorer transparency in recent years (Figure 33, Figure 34, Figure 35). Despite the high phosphorus and chlorophyll-a concentrations, the lake's transparency has been fairly close to, or better than, the water quality standard for a shallow lake. This high transparency can be due to the fact that different types of algae can influence the transparency in different manners. Good transparency with high chlorophyll is sometimes due to high concentrations of blue-green algae (cyanobacteria). Blue-green algae are often larger in size than other types of algae, and their relatively large size does not affect transparency in the same way that smaller sized algae do.

**Table 12. Surface Water Quality, Shields Lake, 1997 - 2007**

| | Growing Season Mean (June – September) | Trophic State Index |
|---|---|---|
| TP (µg/L) | 234 | 83 |
| Chl-a(µg/L) | 47 | 68 |
| Secchi depth (m) | 1.4 | 55 |

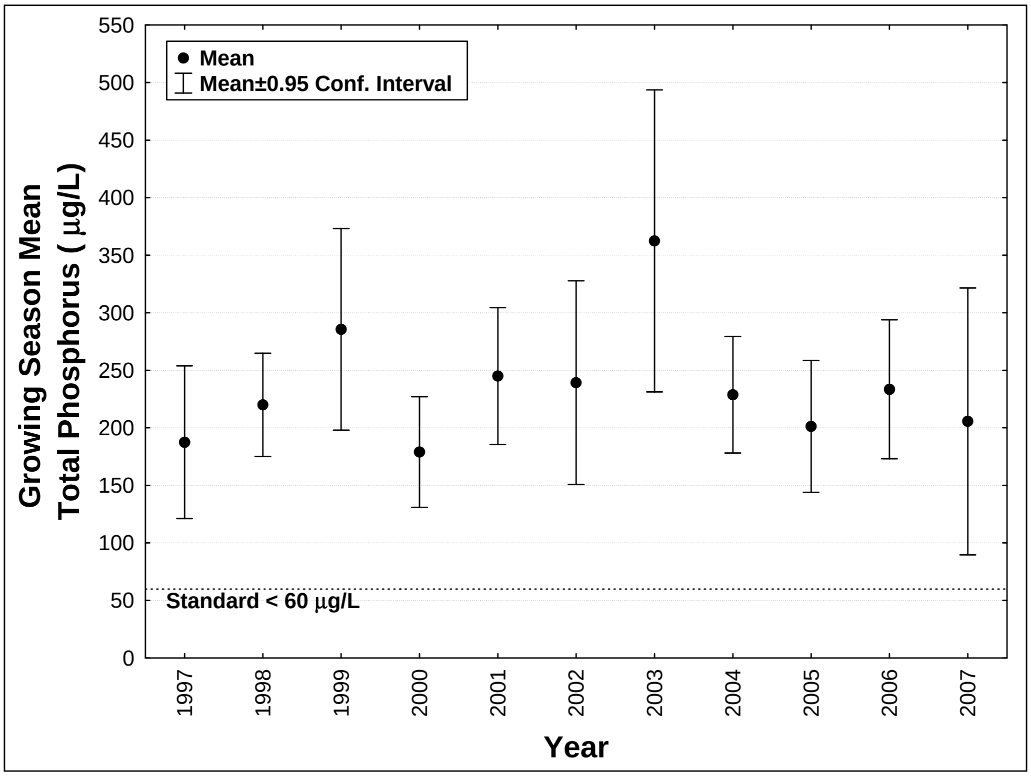



**Figure 34. Total Phosphorus Monitoring Data, Shields Lake**

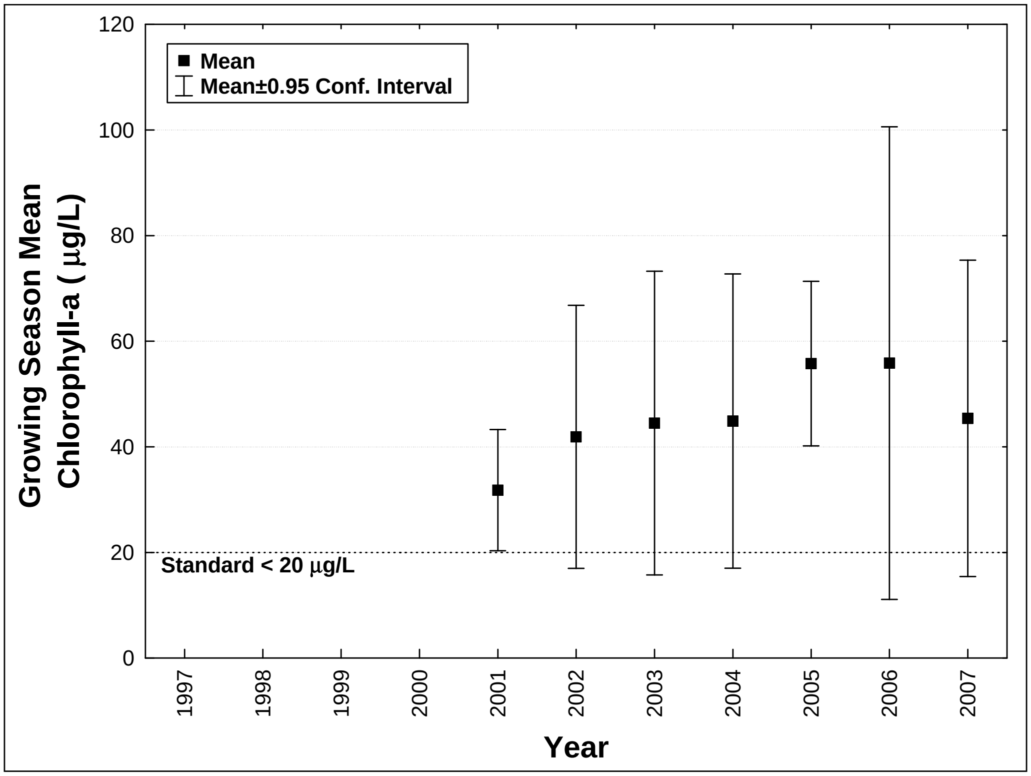



**Figure 35. Mean Chlorophyll-a Monitoring Data, Shields Lake**

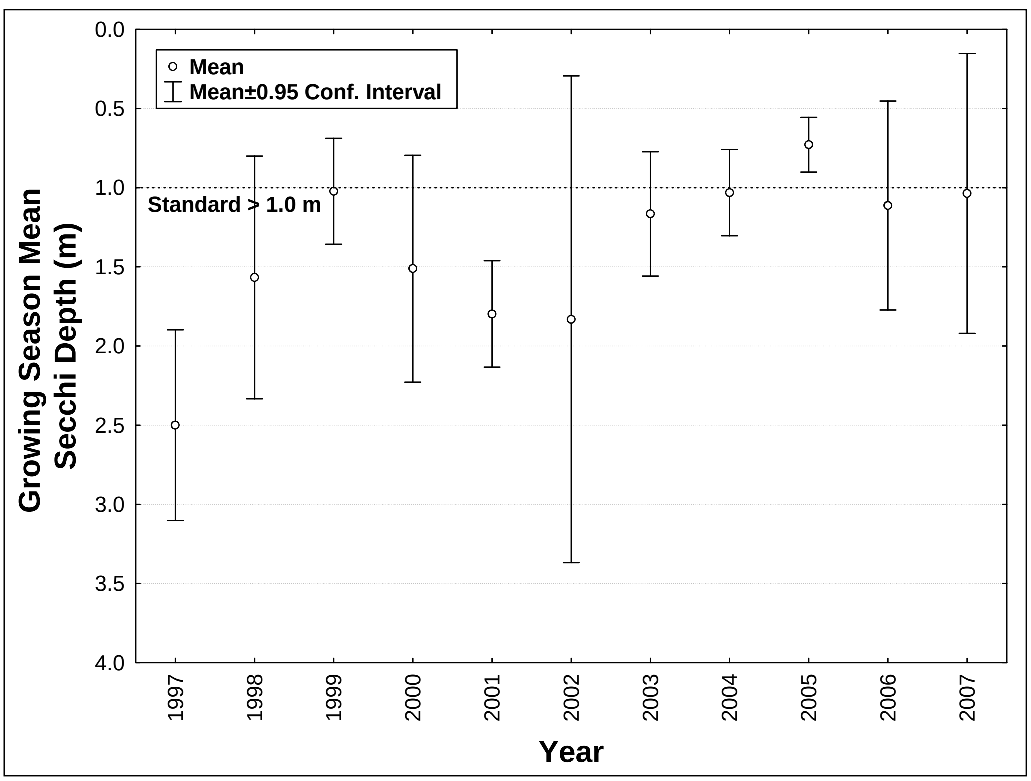



**Figure 36. Secchi Depth Monitoring Data, Shields Lake**

Total phosphorus concentrations in Shields Lake peak in June or July with transparency remaining fairly consistently poor following the TP peak (Figure 36, Figure 37, Figure 38). The phosphorus peak in June or July suggests a curly-leaf pondweed die off.

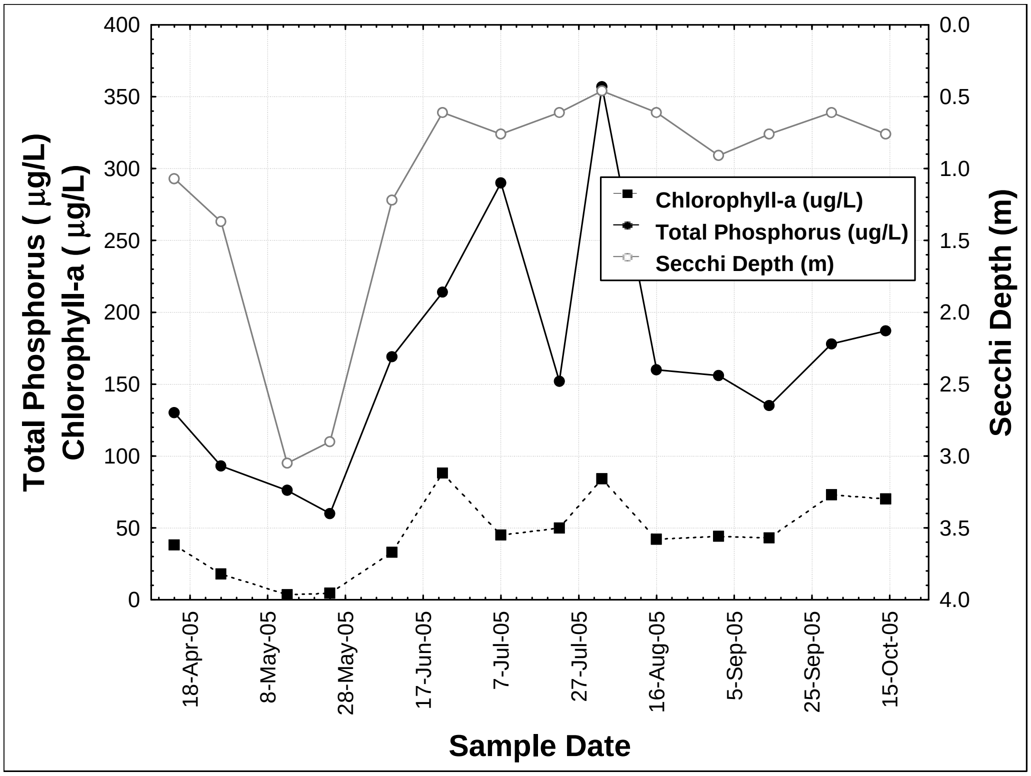



**Figure 37. 2005 Seasonal Water Quality Patterns, Shields Lake**

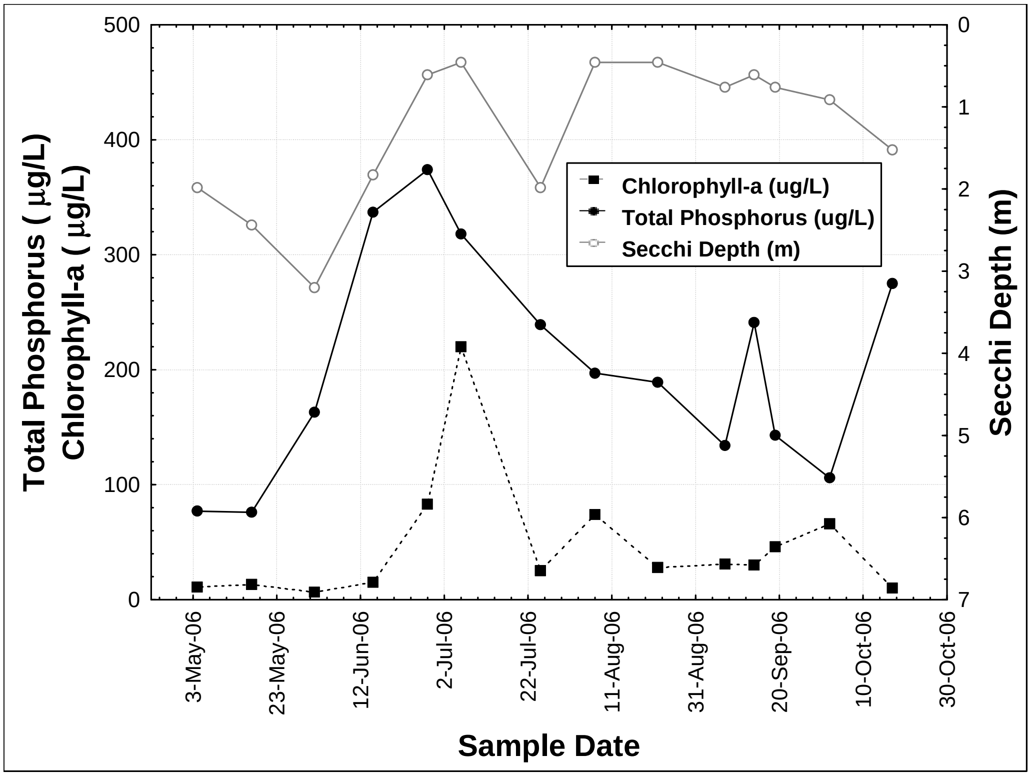



**Figure 38. 2006 Seasonal Water Quality Patterns, Shields Lake**

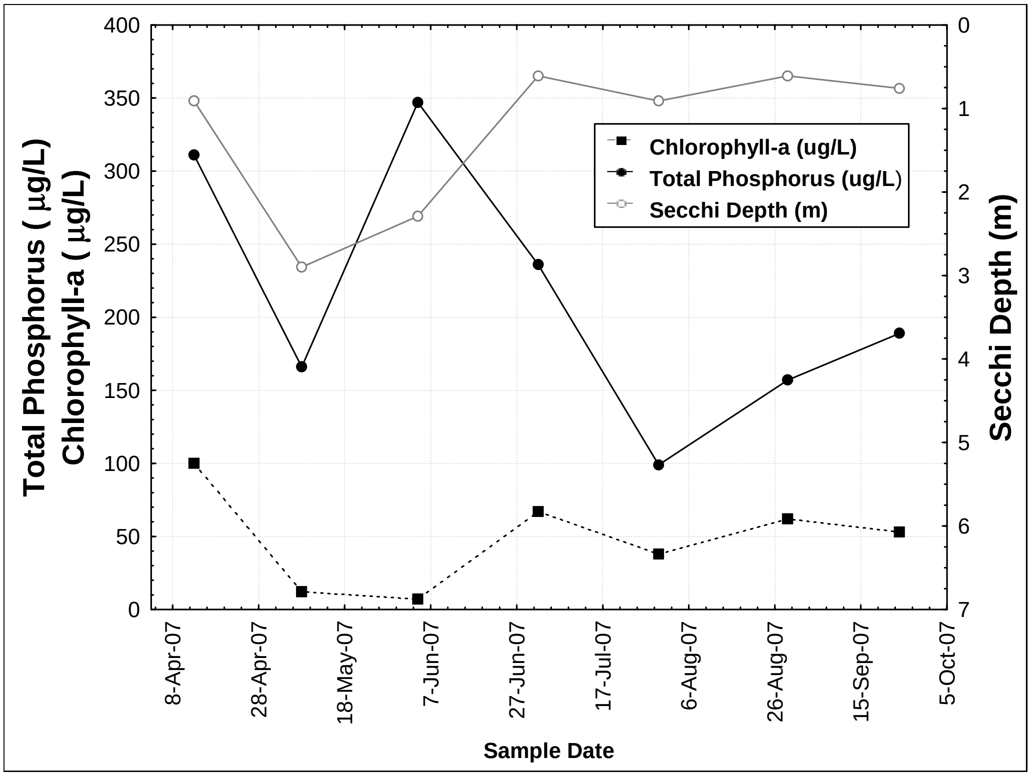



**Figure 39. 2007 Seasonal Water Quality Patterns, Shields Lake**

The Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation* (CLFLWD, 2007) identifies the following key observations based on District macrophyte and zooplankton surveys and DNR fish surveys:

- "Rough fish abundance has decreased due to chemical reclamation of the lake in 1995.
- Top predator and panfish populations have increased since the chemical reclamation.
- Macrophyte community diversity is very low; few submergent or floating leaf species are present.
- Curly-leaf pondweed is prevalent in the lake, abundance increased significantly between 1998 and 2006 surveys.
- Based on the ecological data, Shields Lake appears to be trending toward the turbid water state rather than the competing equilibria for shallow lakes (a clearwater state)."

The recent, 2007, fish survey showed panfish populations 3 times the normal gill net range. A high panfish density can overgraze zooplankton, allowing algae concentrations to increase and clarity to decrease.

## 3G. Comfort Lake

In-lake monitoring data are available periodically from 1989 to 2007, and for all seven seasons from 2001 through 2007. Data available from the past ten years were used to calculate the water quality data means (Table 13).

Comfort Lake is a slightly eutrophic lake as indicated by the TSI values (Table 13), with TP concentrations that fluctuate around the 40 ug/l standard and transparency that often exceeds the standards. In fact, over the past four years (2004 – 2007), at least two of the lake water quality standards were met in Comfort Lake based on growing season means (Figure 39, Figure 40, Figure 41). Secchi depth monitoring data from the 1980s suggest that the transparency of the lake was better at that time. In 2007, the mean values for all three water quality parameters met the water quality standards. 2007 had little rain during the majority of the growing season and Comfort Lake received little inflow from Forest Lake. The high quality of the lake when there was little external input indicates that internal load is likely not a strong contributor of phosphorus to the lake.

**Table 13. Surface Water Quality, Comfort Lake, 1997 - 2007**

| | Growing Season Mean (June – September) | Trophic State Index |
|---|---|---|
| TP (µg/L) | 37 | 56 |
| Chl-a (µg/L) | 16 | 58 |
| Secchi depth (m) | 1.6 | 53 |

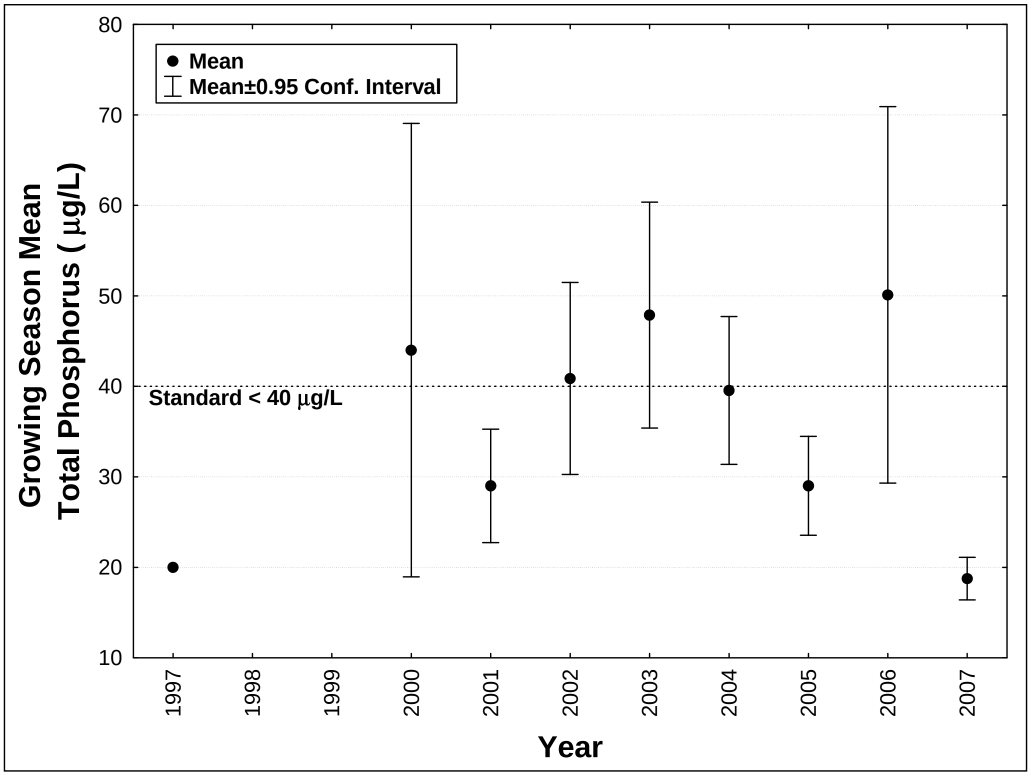



**Figure 40. Total Phosphorus Monitoring Data, Comfort Lake**

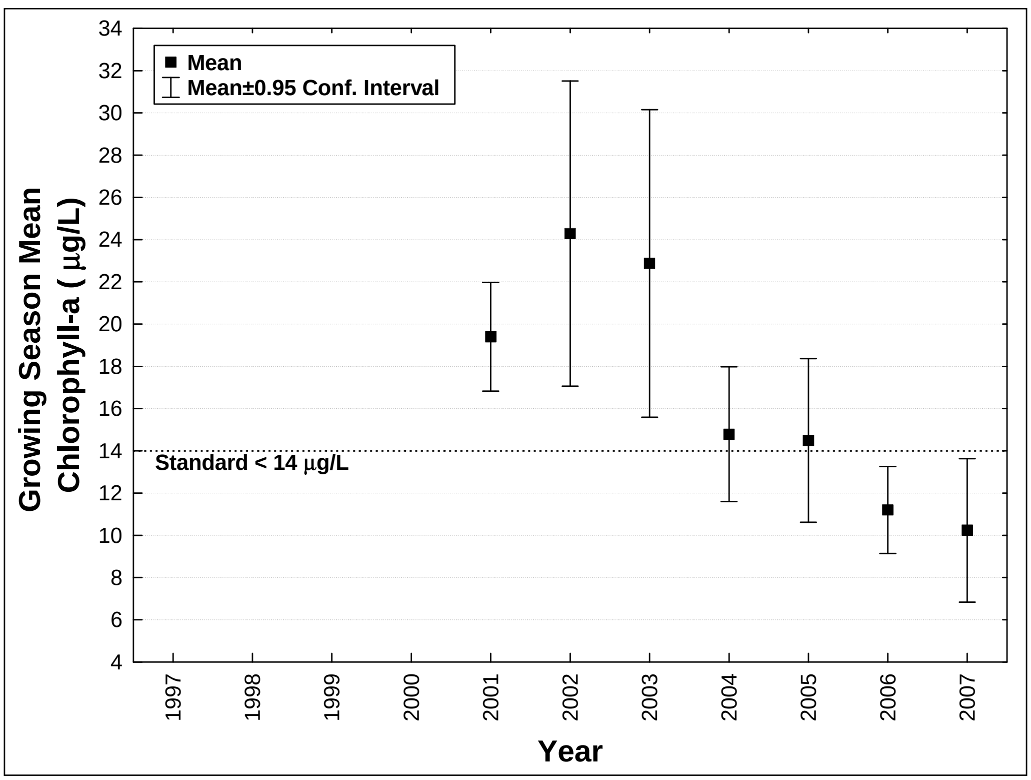



**Figure 41. Mean Chlorophyll-a Monitoring Data, Comfort Lake**

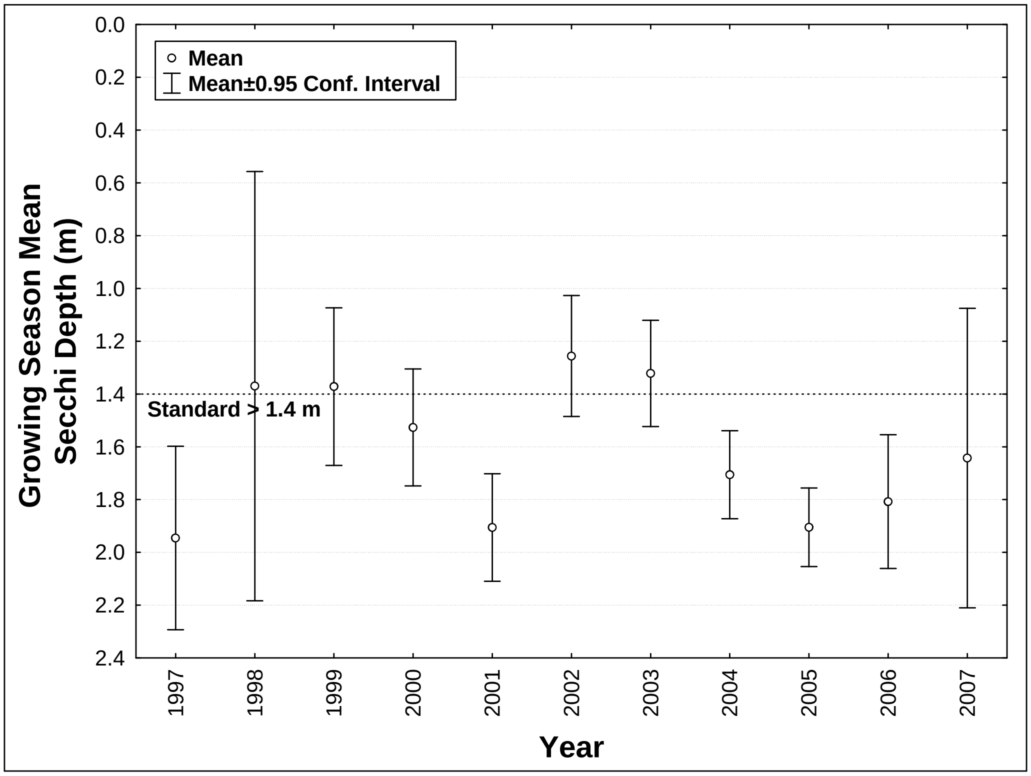



**Figure 42. Secchi Depth Monitoring Data, Comfort Lake**

Comfort Lake does not exhibit June/July spikes in phosphorus concentration that are typical of curly-leaf pondweed impacts despite the known presence of curly-leaf pondweed in the lake. The lake also does not exhibit the August peak in phosphorus concentration that is typical of lakes with high internal load.

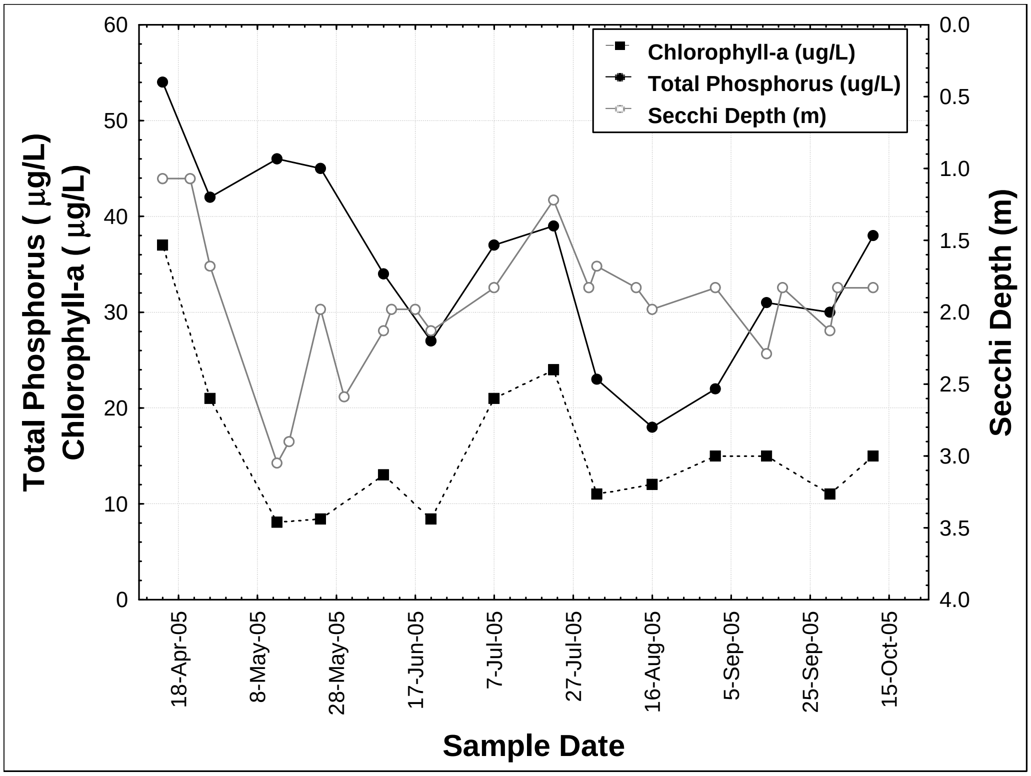



**Figure 43. 2005 Seasonal Water Quality Patterns, Comfort Lake**

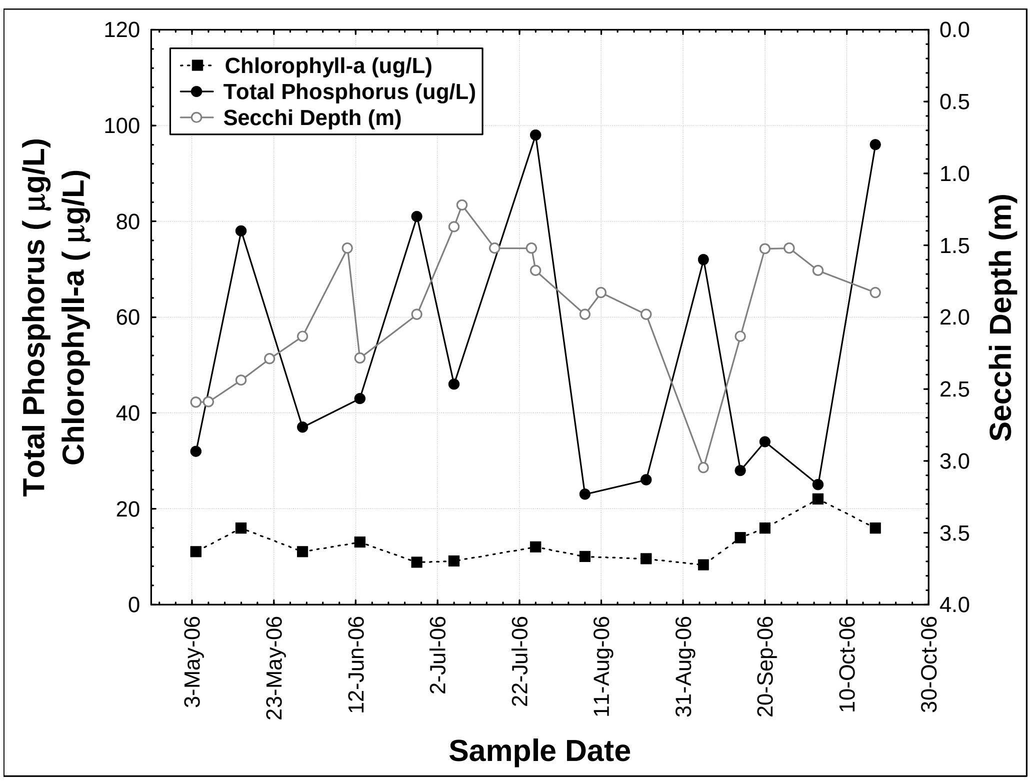



**Figure 44. 2006 Seasonal Water Quality Patterns, Comfort Lake**

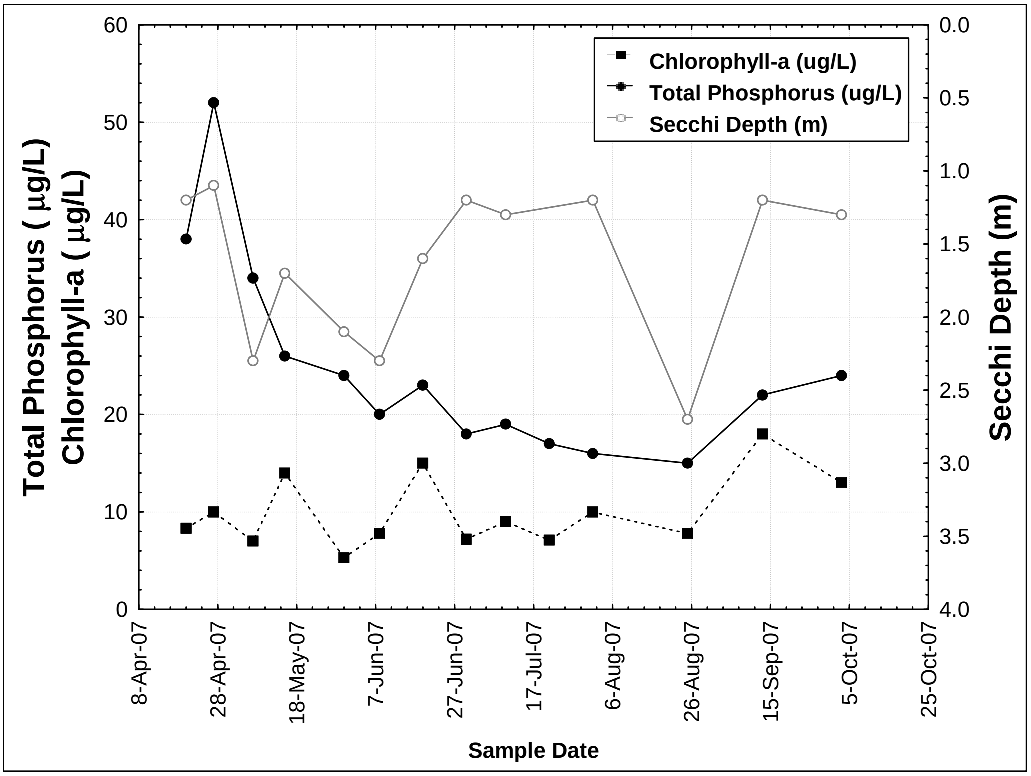



**Figure 45. 2007 Seasonal Water Quality Patterns, Comfort Lake**

The Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation* (CLFLWD, 2007) identifies the following key observations based on District macrophyte and zooplankton surveys and DNR fish surveys:

- "Fish population has remained relatively stable across surveys.
- Rough fish are present but not overly abundant.
- Desirable submergent macrophyte species exist in the lake but abundance is low.
- Exotic species curly pondweed is now prevalent in lake."

# 4. Pollutant Sources

The Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation* (CLFLWD, 2007) provides detailed information on the methods used to study the watershed hydrology, lake phosphorus loading, and lake response (see Section 2 and Appendices C – H of the report). Phosphorus load estimates included non-point source loads based on land use, point source loads, shoreline septic system releases, livestock input, upstream lake input, atmospheric deposition, groundwater exchange, and internal release.

This section of this report summarizes the methods and results presented in the *Water Quality Modeling Investigation* (CLFLWD, 2007). It provides a brief summary of the methods used to estimate the load from each phosphorus source category. Loads were estimated and then used as input into the lake response model.

## 4A. Non-Point Source Loads

Loads from current and future permitted MS4 sources were included in the model as non-point loads. Non-point source phosphorus loads were determined using unit area loading rates (Table 14) based on literature values and using available land cover and land use data. The unit area loads were based primarily on the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA, 2004). Land uses were determined based on a GIS analysis of land cover and land use data. The results of this analysis are shown in Table 15 and Table 16.

**Table 14. Total Phosphorus Unit Area Loads used in Model**

| Land Use | Phosphorus Unit Area Load (lb/ac-yr) |
|---|---|
| Cropland | 0.34 |
| Forest | 0.067 |
| Grassland | 0.15 |
| Developed – High | 1.34 |
| Developed – Med | 1.02 |
| Developed – Low | 0.81 |
| Golf Course | 0.81 |
| Sand & Gravel Mining | 0.0 |
| Wetlands | -0.02 |

**Table 15. Summary of Non-Point Loads for each Lake by Source**

| Land Use | Phosphorus Load (lb/yr) | | | | | |
|---|---|---|---|---|---|---|
| | Moody Lake | Bone Lake | School Lake | Little Comfort Lake | Shields Lake | Comfort Lake |
| Cropland | 238 | 398 | 87 | 122 | 34 | 60 |
| Forest | 20 | 19 | 7 | 20 | 4 | 6 |
| Grassland | 55 | 53 | 22 | 54 | 12 | 12 |
| Developed – High | 0 | 0 | 0 | 0 | 0 | 0 |
| Developed – Med | 94 | 207 | 36 | 145 | 72 | 16 |
| Developed – Low | 52 | 25 | 30 | 41 | 9 | 280 |
| Golf Course | 0 | 0 | 0 | 0 | 72 | 0 |
| Sand & Gravel Mining | 0 | 0 | 0 | 0 | 0 | 0 |
| Wetlands | -10 | -7 | -2 | -9 | -2 | -2 |
| Landlocked | -19 | -26 | -9 | -9 | -15 | -7 |

**Table 16. Non-Point Phosphorus Load Summary**

| Lake | Non-Point Phosphorus Load (pounds/year) |
|---|---|
| Moody Lake | 430 |
| Bone Lake | 669 |
| School Lake | 171 |
| Little Comfort Lake | 364 |
| Shields Lake | 186 |
| Comfort Lake | 372 |

## 4B. POINT SOURCE LOADS

Two point sources exist within the watershed, both are community sewage systems that discharge to the soil at locations removed from any expected direct impact on the lakes. Thus, these loads were modeled as zero.

## 4C. SHORELINE SEPTIC SYSTEM LOADS

Shoreline septic system contributions to the phosphorus load were estimated based on the number of shoreline residences and expected phosphorus contributions per system based on data from the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA, 2004). The assumptions used for shoreline septic system loads were: 2.68 people per residence, 1.83 pounds of phosphorus production per capita per year, and an average of 78% phosphorus retention by the system and soils for an estimated loading rate of 1.08 lb/yr per septic system. The results of this analysis are shown in Table 17.

**Table 17. Shoreline Septic System Phosphorus Load Summary**

| Lake | Estimated Number of Shoreline Septic Systems | Septic System Phosphorus Load (pounds/year) |
|---|---|---|
| Moody Lake | 8 | 9 |
| Bone Lake | 78 | 84 |
| School Lake | 7 | 8 |
| Little Comfort Lake | 15 | 16 |
| Shields Lake | 0 | 0 |
| Comfort Lake | 91 | 98 |

## 4D. LIVESTOCK LOADS

The phosphorus load expected from livestock in the watershed was based on a windshield survey of livestock numbers and locations, production rates of phosphorus (Table 18), and a 4% delivery rate to the lake. Appendix F of *Water Quality Modeling Investigation* (CLFLWD, 2007) includes maps indicating the locations of livestock noted in the windshield survey. The results of this analysis are shown in Table 19.

**Table 18. Livestock Phosphorus Production Rates**

| Animal Unit [AU] | Production Rate of P in Manure [lb/AU-day] | Reference |
|---|---|---|
| Beef Cattle | 0.097 | [c]ASAE D384.2 |
| Beef Calves | 0.055 | ASAE D384.2 |
| Dairy Cattle | 0.17 | ASAE D384.2 |
| Dairy Calves | 0.055 | Assumed AUF = 1.0[a] Beef Calf |
| Horses | 0.029 (sedentary) | ASAE D384.2 |
| Chickens | 0.011 | ASAE D384.2 |
| Sheep | 0.0087[b] | MWPS |
| Goats | 0.0097 | Assumed AUF = 0.1 Mature Beef Cow |
| European Red Deer | 0.0055 | Assumed AUF = 0.1 Beef Calf |
| Llamas | 0.0055 | Assumed AUF = 0.1 Beef Calf |
| Dogs | 0.0000275 | Assumed AUF = 0.0005 Beef Calf |

a) Use MPCA Feedlot Inventory Animal Unit Factor (AUF) to relate published value for Mature Beef Cattle Production Rate of P in Manure.
b) Converted from 0.02 lbs P2O5/day using P2O5=2.29*P (MWPS, 2004)
c) American Society of Agricultural Engineers

**Table 19. Livestock Phosphorus Load Summary**

| Lake | Livestock |
|---|---|

| | Phosphorus Load (pounds/year) |
|---|---|
| Moody Lake | 194 |
| Bone Lake | 77 |
| School Lake | 105 |
| Little Comfort Lake | 22 |
| Shields Lake | 1 |
| Comfort Lake | 0 |

## 4E. UPSTREAM LAKE LOADS

The phosphorus load contributed by upstream lakes was calculated based on water balance estimates of lake outflow and growing season lake total phosphorus concentrations. The results of this analysis are shown in Table 20.

**Table 20. Upstream Lake Phosphorus Load Summary**

| Lake | Upstream Lake Phosphorus Load (pounds/year) |
|---|---|
| Moody Lake | 15 |
| Bone Lake | 215 |
| School Lake | 587 |
| Little Comfort Lake | 475 |
| Shields Lake | 0 |
| Comfort Lake | 2,013 |

## 4F. ATMOSPHERIC DEPOSITION LOADS

Atmospheric deposition loads are based on data from the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA, 2004) and were estimated at 0.13 lb P/ac-yr to include both dry deposition and deposition through precipitation. The results of this analysis are shown in Table 21.

**Table 21. Atmospheric Deposition Phosphorus Load Summary**

| Lake | Atmospheric Deposition Phosphorus Load (pounds/year) |
|---|---|
| Moody Lake | 4 |
| Bone Lake | 27 |
| School Lake | 7 |
| Little Comfort Lake | 5 |
| Shields Lake | 4 |
| Comfort Lake | 29 |

## 4G. GROUNDWATER LOADS

Phosphorus loads due to groundwater input are based on the groundwater input determined through a water balance and the MPCA's median phosphorus concentration of 56 µg/L for surficial quaternary aquifers. See the Groundwater portion of Section 1B of this report for additional information on the groundwater calculations. The results of this analysis are shown in Table 22.

**Table 22. Groundwater Phosphorus Load Summary**

| Lake | Groundwater Phosphorus Load (pounds/year) |
|---|---|
| Moody Lake | 2 |
| Bone Lake | 25 |
| School Lake | 5 |
| Little Comfort Lake | 2 |
| Shields Lake | 3 |
| Comfort Lake | 19 |

## 4H. INTERNAL LOADS

Internal loads were estimated based on sediment cores tested in the U.S. Army Corps of Engineers environmental lab for phosphorus release rates under anoxic conditions. Phosphorus accumulation in the hypolimnion was calculated using measurements of growing season phosphorus. Any internal loading from sediment resuspension from rough fish activity, wind mixing, or boat activity and curly-leaf pondweed senescence are not part of the internal load estimates, but will be addressed in the implementation strategy. The results of this analysis, prior to calibration, are shown in Table 23.

**Table 23. Internal Phosphorus Load Summary**

| Lake | Internal Phosphorus Load (pounds/year) |
|---|---|
| Moody Lake | 490 |
| Bone Lake | 165 |
| School Lake | 46 |
| Little Comfort Lake | 56 |
| Shields Lake | 76 |
| Comfort Lake | 223 |

# 5. Loading Capacity

This section describes the derivation of the TMDL for Moody, Bone, School, Little Comfort, Shields and Comfort lakes. Little Comfort Lake is not listed as impaired at this time, but is expected to be listed after the most recently collected monitoring data, presented in this report, is analyzed.

## 5A. Methods

To estimate the assimilative capacity of the lake, an in-lake water quality model was developed using the Canfield-Bachmann (1981) natural lakes phosphorus sedimentation model. This model is described in more detail in Section 2 and Appendices C – H of the Comfort Lake-Forest Lake Watershed District's *Water Quality Modeling Investigation* (CLFLWD, 2007). A brief summary is provided here. Input data consisted of the estimated lake water balances and phosphorus loads. The model was calibrated to best fit the three years included in the study: 2004 (benchmark), 2003 (wet conditions), and 2006 (dry conditions). The data from 2004 was used as the benchmark year because hydrologic conditions were closest to normal of the three years of data available.

The *Water Quality Modeling Investigation* (CLFLWD, 2007) highlights the following four points regarding the lake response model:

- "Each lake response is modeled using the Canfield-Bachmann (1981) natural lakes phosphorus sedimentation model. It balances the effects of hydraulic loading and discharge through the outlet with phosphorus sedimentation to estimate the growing season in-lake phosphorus concentration.
- Phosphorus – chlorophyll-*a*, and chlorophyll-*a* – Secchi depth relationships were compared to the ecoregion relationships from MNLEAP [Minnesota Lake Eutrophication Analysis Procedure] and either confirmed to fit, or adjusted to fit historic data for each lake.
- Lake response to load reductions was determined for the benchmark year, and corresponding changes in total phosphorus, chlorophyll-*a*, and Secchi depth were plotted against load reduction for each of the study lakes.
- The lake export load was determined from the predicted in-lake phosphorus concentration and water volume. Adjustments to this load were made due to the differences between the growing season average in-lake concentration and the actual discharge concentration that would apply to the annual discharge load."

## 5B. Model Calibration and Validation

The *Water Quality Modeling Investigation* (CLFLWD, 2007) describes the following calibration process for the lake response model (see Section 2 and Appendices C – H of the report):

- "Global adjustments to the UALs to improve fit to monitored annual loads;
- Global adjustments to the percent yield to water bodies from animal unit loads;
- Identification of loading increments – such as differences between the modeled load increases and the increase in load between a lake outlet and the downstream monitored

load – that would indicate unusual conditions such as phosphorus export from an impacted wetland;

- Adjustment of internal loads to match in-lake concentrations where estimates suggested a range of possible loads;
- Finally, the Canfield-Bachmann settling rate was adjusted by a calibration factor in order to improve the fit to the benchmark, wet and dry year conditions."

## 5C. RESULTS

### Existing Conditions

To calibrate the results to best match the observed lake response, some of the inputs required a change the loads estimated as summarized in Section 4 of this report. The calibration changes were needed for Little Comfort, Shields, and Comfort lakes.

For Little Comfort Lake an increase in phosphorus load of 314 lb/yr was needed to calibrate the lake response. This additional load is attributed in the *Water Quality Modeling Investigation* (CLFLWD, 2007) to the wetland between School Lake and Little Comfort Lake. This calibration increment was added to the upstream lakes load for Little Comfort Lake in Table 24.

For Shields Lake an increase in phosphorus load of 837 lb/yr was needed to calibrate the lake response. This additional load is attributed in the *Water Quality Modeling Investigation* (CLFLWD, 2007) to the condition as a turbid shallow lake. This calibration increment was added to the lake internal load for Shields Lake (Table 24).

For Comfort Lake a decrease in phosphorus load of 200 lb/yr was needed to calibrate the lake response. This decreased load is not specifically attributed in the *Water Quality Modeling Investigation* (CLFLWD, 2007) to any one factor but it is indicated that it may reflect short-circuiting or the effect of wetlands. This calibration increment was subtracted from the upstream lakes load for Comfort Lake in Table 24.

Additional data on the breakdown of loads between various non-point sources is available in the District's *Water Quality Modeling Investigation* (CLFLWD, 2007).

**Table 24. TP Load Source Contributions**

| Load Source | Moody Lake | Bone Lake | School Lake |
|---|---|---|---|

| | [lb/yr] | % of total | [lb/yr] | % of total | [lb/yr] | % of total |
|---|---|---|---|---|---|---|
| Non-Point Source | 430 | 42% | 669 | 54% | 171 | 18% |
| Shoreline Septic System | 9 | 1% | 84 | 7% | 8 | 1% |
| Livestock | 194 | 19% | 77 | 6% | 105 | 11% |
| Upstream Lake | 15 | 2% | 215 | 17% | 587 | 63% |
| Atmospheric Deposition | 4 | 0% | 27 | 2% | 7 | 1% |
| Groundwater | 2 | 0% | 25 | 2% | 5 | 1% |
| Lake Internal Load | 368 | 36% | 132 | 11% | 46 | 5% |
| *Total Inflow Load* | *1023* | *100%* | *1229* | *100%* | *928* | *100%* |

| **Load Source** | **Little Comfort Lake** | | **Shields Lake** | | **Comfort Lake** | |
|---|---|---|---|---|---|---|
| | [lb/yr] | % of total | [lb/yr] | % of total | [lb/yr] | % of total |
| Non-Point Source | 364 | 29% | 186 | 17% | 372 | 15% |
| Shoreline Septic System | 16 | 1% | 0 | 0% | 98 | 4% |
| Livestock | 22 | 2% | 1 | 0% | 0 | 0% |
| Upstream Lake | 789 | 63% | 0 | 0% | 1813 | 74% |
| Atmospheric Deposition | 5 | 0% | 4 | 0% | 29 | 1% |
| Groundwater | 2 | 0% | 3 | 0% | 19 | 1% |
| Lake Internal Load | 56 | 4% | 913 | 82% | 134 | 5% |
| *Total Inflow Load* | *1255* | *100%* | *1107* | *100%* | *2465* | *100%* |

### Assimilative Capacity

A loading scenario based on the benchmark year (2004) was developed for Moody, Bone, School, Little Comfort, and Comfort Lakes to reach the standard of 40 µg/L, and a loading scenario was developed for Shields Lake to reach the standard of 60 µg/L TP (Table 25 and Table 26). These total loads to the lakes represent the assimilative capacity, or TMDL, of each lake. The outflow volume for each lake used in the assimilative capacity determination was 470 ac-ft for Moody Lake, 1,591 ac-ft for Bone Lake, 2,838 ac-ft for School Lake, 3,810 for Little Comfort Lake, 710 ac-ft for Shields Lake, and 12,175 ac-ft for Comfort Lake.

The water quality model presented in the *Water Quality Modeling Investigation* (CLFLWD, 2007) was revised for this TMDL study. The revision changed the way Birch Lake was accounted for in the model. The model originally included Birch Lake as one of the study lakes where improvements are proposed. Therefore, the original assimilative capacity model assumed that Birch Lake was at its water quality goal when discharging to School Lake. The model was revised to assume that Birch Lake discharges to School Lake at its current water quality, since Birch Lake is not listed as an impaired water, due to it being considered a wetland and not a lake.

The assimilative capacity is based on the lake meeting the TP standard, provided that either the chlorophyll-*a* or Secchi standard is also being met. The assimilative capacity will be split up among a load allocation (LA), a waste load allocation (WLA) (if applicable), and a margin of safety (MOS) in Section 6:

$$TMDL = LA + WLA + MOS$$

**Table 25. Existing Loads and Assimilative Capacities**

| Lake | Model Scenario | Total Load to Lake (lb/yr) | Assimilative Capacity (lb/day) |
|---|---|---|---|
| Moody | Existing | 1,023 | -- |
| | Standard (40 µg/L TP) | 144 | 0.395 |
| Bone | Existing | 1,229 | -- |
| | Standard (40 µg/L TP) | 669 | 1.833 |
| School | Existing | 928 | -- |
| | Standard (40 µg/L TP) | 452 | 1.238 |
| Little Comfort | Existing | 1,255 | -- |
| | Standard (40 µg/L TP) | 577 | 1.58 |
| Shields | Existing | 1,107 | -- |
| | Standard (60 µg/L TP) | 195 | 0.534 |
| Comfort | Existing | 2,465 | -- |
| | Standard (40 µg/L TP) | 2,339 | 6.41 |

**Table 26. Predicted In-Lake Water Quality under Observed Conditions and Achievement of Standards, Compared to Actual Standards**

| Lake | Condition | In-Lake Conditions | | |
|---|---|---|---|---|
| | | TP (µg/L) | Chl-a (µg/L) | Secchi (m) |
| Moody | Existing, observed | 167 | 48 | 0.79 |
| | 40 µg/L TP Modeled Scenario | 40 | 7 | 2.2 |
| | State Standard, General | <40 | <14 | >1.4 |
| Bone | Existing, observed | 57 | 35 | 1.24 |
| | 40 µg/L TP Modeled Scenario | 40 | 18 | 1.4 |
| | State Standard, General | <40 | <14 | >1.4 |
| School | Existing, observed | 73 | 39 | 1.13 |
| | 40 µg/L TP Modeled Scenario | 40 | 18 | 1.4 |
| | State Standard, General | <40 | <14 | >1.4 |
| Little Comfort | Existing, observed | 64 | 29 | 1.58 |
| | 40 µg/L TP Modeled Scenario | 40 | 8 | 3 |
| | State Standard, General | <40 | <14 | >1.4 |
| Shields | Existing, observed | 216 | 47 | 1.42 |
| | 60 µg/L TP Modeled Scenario | 60 | 6 | 3.9 |
| | State Standard, Shallow Lakes | <60 | <20 | >1.0 |
| Comfort | Existing, observed | 40 | 19 | 1.74 |
| | 40 µg/L TP Modeled Scenario | 40 | 16 | 1.5 |
| | State Standard, General | <40 | <14 | >1.4 |

## Critical Conditions

Critical conditions in the lakes occur in the summer when TP concentrations peak and clarity is at its worst, often in July and August. Since the standards are based on June through September water quality averages, the standard itself addresses the lake condition during critical conditions. The load reductions are designed so that the lakes will meet the water quality standards over the course of the growing season (June through September).

# 6. TMDL Allocations

The TMDL for each lake was apportioned between the waste load allocation (WLA) and the load allocation (LA). The WLA includes loads from sites currently covered by an NPDES permit: the City of Forest Lake MS4, two large sewage treatment systems, and construction and industrial stormwater sites. The WLA also includes sites expected to be covered by an NPDES permit in the future: City of Scandia MS4, City of Wyoming MS4, and City of Chisago City MS4. The LA includes loads from stormwater runoff that originate in unregulated MS4 communities (Chisago Lake Township), unregulated MS4 portions of permitted MS4 or future permitted MS4 communities (City of Scandia, City of Chisago City, City of Wyoming and City of Forest Lake) livestock loading, internal loading, and atmospheric deposition.

The watershed load (including regulated MS4, future regulated MS4 and unregulated or non-MS4 areas) was divided between the WLA and LA according to the amount of upland area estimated in each category. The upland area was selected to represent the developable area in the watershed; it includes the total watershed area with the lake and wetland area subtracted out. Total area was not used due to the high amount of surface water in some of the watersheds. To calculate TMDL allocations, upstream impaired lakes were assumed to have outflow meeting the phosphorus standard because each of these lake impairments is also addressed through this TMDL.

The WLAs and LAs are presented in terms of phosphorus loading per day. The modeling and load estimates were based on annual loads, and these loads were divided by the number of days in a year (365) to determine the daily loads. These TMDLs are based on the allocated loads (both WLAs and LAs in lbs/day), not on percent reduction. The percent reductions are presented only to provide further information.

## 6A. Margin of Safety

The margin of safety (MOS) is included in the TMDL equation to account for both the inability to precisely describe current water quality conditions and the unknowns in the relationship between the load allocations and the in-lake water quality. A MOS may be either explicitly calculated or implicitly included in the modeling assumptions and approach to calculating the TMDL.

An implicit MOS was incorporated into this TMDL by using conservative assumptions. These were used to account for an inherently imperfect understanding of the lake system and to ultimately ensure that the nutrient reduction strategy is protective of the water quality standard.

- Several years of monitoring data were used for model development, taking into account wet, dry, and benchmark years.
- Conservative modeling assumptions included applying sedimentation rates from the Canfield-Bachmann model that likely under-predict the sedimentation rate for shallow lakes. Zooplankton grazing plays a large role in algal and subsequent phosphorus sedimentation in shallow lakes. However, the Canfield-Bachmann equation does not

account for the expected higher sedimentation rates expected in healthy shallow lake systems.

- Additionally, empirical relationships used to predict chlorophyll-*a* and Secchi transparency are more established for deep lakes and do not account for zooplankton grazing critical to maintaining a clear water state in shallow lakes. Consequently, the models likely under-predict the clarity response of the lake to reduced phosphorus concentrations.

## 6B. Wasteload Allocations

The construction stormwater and industrial stormwater sources were given separate categorical allocation for all six lakes and the regulated MS4s and future regulated MS4s were given individual WLAs for all six lakes studied.

The construction stormwater and industrial stormwater wasteload allocations were calculated based on the estimated area of the watershed under permitted construction activity over the past four years. MPCA data on stormwater permits issued for Chisago and Washington counties was used to determine that, based on total county land area, the average area of the two counties under construction was 0.38% each year. There are currently no industrial facilities permitted for stormwater in the watershed. Because no industrial stormwater sources are present in the watershed and industrial stormwater is likely to be smaller than construction stormwater, the same allocation was used for both construction and industrial stormwater. The WLA for construction stormwater and for industrial stormwater were each set at 0.38% of the TMDL.

The MS4 wasteload was allocated based on the portion of the lake's developable watershed area contained within the estimated regulated portions of the MS4. The developable area was approximated with the upland area, or the total area minus the lakes and wetlands. The boundaries of the regulated portion of the MS4s were estimated by excluding the portions of MS4 communities that are not technically covered under NPDES permits (i.e., areas that are either agricultural or otherwise not projected to be served by stormwater conveyances, such as open space, park and recreation, and rural residential).

As additional data become available after EPA approval of the TMDL, WLAs for individual permitted sources may be modified, provided the overall WLA does not change. Modifications in individual WLAs will be public noticed.

Minnesota Department of Transportation (Mn/DOT) and county roads in the watershed are currently not under permit coverage. No WLA is therefore assigned to them. If, in the future, the U.S. Census Bureau Urban Area extends into the watershed and these roads come under permit coverage, WLA will be shifted from the municipality or township in which the roads occur. In the case of a load transfer, the WLA will be converted to a load per unit area (e.g. lbs/acre) and the resulting WLA for the roads will be based on their areal proportion. This would result in no change in the overall WLA for the lakes. Should this occur, the MPCA's stormwater program will calculate the amount of load to be transferred and notify the affected MS4s of changes in the WLA.

Additional detail on the specific considerations in setting wasteload and load allocations is provided in the lake summaries of sections 6E through 6J.

## 6C. Load Allocation

The LA includes loads from stormwater runoff that originate in unregulated MS4 or non-MS4 communities (Chisago Lake Township), unregulated portions of MS4 and future regulated MS4 communities (City of Forest Lake, City of Wyoming, City of Chisago City, City of Scandia) internal loading, and atmospheric deposition. Although the load designated for each of these sources was estimated separately, they are jointly included as one overall LA.

### Watershed Runoff from Non-MS4 Communities, unregulated portions of MS4s, unregulated MS4s and future MS4s

The City of Scandia, Chisago City, City of Wyoming, and Chisago Lake Township are not currently covered under NPDES MS4 permits. The City of Wyoming estimates their current population to be over 5,000 now that much of Wyoming Township has become part of the City of Wyoming. Therefore, the City of Wyoming is expected to soon require coverage under a Phase II MS4 permit. Based on the estimated 2020 populations of the City of Scandia and the City of Chisago City, these municipalities are expected to require Phase II MS4 permit coverage at or before 2020 when their populations reach 5,000. Wasteload allocations were determined for the estimated future MS4s regulated portions of the City of Wyoming, City of Chisago City, and City of Scandia (see section 6B).

The portion of each municipality that is not estimated to be within the regulated boundaries of an MS4 (i.e., areas that are either agricultural or otherwise not projected to be served by stormwater conveyances, such as open space, park and recreation, and rural residential) is provided with a LA determined based on the developable watershed area. The developable area was approximated with the upland area, or the total area minus the lakes and wetlands. This area includes all upland area within Chisago Lake Township and portions of the City of Wyoming, the City of Forest Lake, the City of Chisago City, and the City of Scandia.

### Upstream Lakes

The allocations assume that upstream impaired lakes discharge at the TMDL water quality. The load to a lake from an upstream impaired water body is allocated as a LA because the loads to the upstream lake were already addressed in the upstream lake's WLAs and LAs. Non-impaired upstream lakes are assumed to discharge at current water quality following the standard for non-degradation. The load to a lake from an upstream non-impaired water body is allocated as a WLA and/or LA based on the contributing drainage area to the lake following the methods stated above for non-MS4 and regulated and unregulated MS4 communities. The allocations for upstream lakes maintain existing loads to ensure non-degradation. The exception to this is Birch Lake, which is not listed as impaired, but has poor enough water quality that the water quality of School Lake downstream cannot attain the standard unless some improvement is also made to the water quality of Birch Lake (see section 6G).

### Internal Loading

The portion of the LA that accounts for internal loading was based on the existing modeled internal load. Where internal load was indicated as a concern in the *Water Quality Modeling Investigation* (CLFLWD, 2007) and a future internal load reduction effort is planned, a 70% reduction in internal load is assumed unless the full reduction is not needed in order to meet the TMDL. This level of reduction was indicated in the *Water Quality Modeling Investigation* (CLFLWD, 2007) as the expected feasible internal load reduction using in-lake alum treatment, curly-leaf pondweed management, and rough fish removal.

### Atmospheric Deposition

The portion of the LA that accounts for atmospheric deposition (both wet and dry) was based on the load estimate in the existing conditions model. It was assumed that atmospheric deposition will remain constant, and that load reductions in atmospheric deposition are not warranted.

### Groundwater

The portion of the LA that accounts for groundwater was based on the load estimated in the existing conditions model. The phosphorus loading from groundwater is not a large source for the lakes and is not a feasible area for reductions under the TMDL. Therefore, the portion of the LA that accounts for groundwater is consistent with existing conditions.

## 6D. Reserve Capacity

Reserve capacity, an allocation for future growth, was not explicitly calculated for this TMDL, but rather was included as part of the WLAs and LAs. The watershed WLAs and LAs were divided according to the amount of upland area in each category, used to approximate the amount of developable area. Therefore each category receives a WLA or LA based on how much it can develop in the future.

## 6E. Moody Lake Allocations

The watershed to Moody Lake does not contain any permitted sources other than potential construction and industrial stormwater permits. In addition, based on expected future land use, no regulated MS4 boundaries are expected to include any of the Moody Lake drainage area (see section 6B). Therefore, the only WLA for Moody Lake is for construction and industrial stormwater. An 86% reduction in phosphorus load is required for Moody Lake to meet the TMDL. In Moody Lake, the internal load reduction will have to be greater than 70% unless the phosphorus load from the watershed is nearly eliminated. The allocations are summarized in Table 27 and information on the percent reduction needed to meet the TMDL allocations is summarized in Table 28.

**Table 27. Moody Lake TP Allocations**

| Source | WLA (lbs/day) | LA (lbs/day) |
|---|---|---|
| Construction (various permits) | 0.0015 | -- |
| Industrial Stormwater (future permits) | 0.0015 | -- |
| Unregulated MS4 portions of City of Scandia, Chisago Lake Township, Internal, Atmospheric, Groundwater | -- | 0.392 |

**Table 28. TP Reduction Needed to Attain Moody Lake TMDL Allocations**

| Source | Current Modeled Load (lbs/day) | % TP Reduction Needed |
|---|---|---|
| Unregulated MS4 portions of Municipalities: Chisago Lake Township | 1.17 | 88% |
| Unregulated MS4 portions of Municipalities: City of Scandia | 0.03 | 82% |
| Livestock | 0.53 | 88% |
| Internal | 1.01 | 88% |
| Atmospheric and Groundwater | 0.02 | 0% |
| Upstream Lakes | 0.04 | 0% |

## 6F. Bone Lake Allocations

Moody Lake drains into Bone Lake. The assumption is made for the Bone Lake allocations that Moody Lake discharges at the water quality goal. This input from Moody Lake is allocated as a LA for Bone Lake, since any WLA for the Moody Lake watershed has been addressed in the Moody Lake WLA. The watershed to Bone Lake does not contain any permitted sources other than potential construction and industrial stormwater permits. In addition, based on expected future land use, no regulated MS4 boundaries are expected to include any of the Bone Lake drainage area (see section 6B). Therefore, the only WLA for Bone Lake is for construction and industrial stormwater. A 70% reduction in internal load is assumed when determining the allocations for Bone Lake. Overall, a 46% reduction in phosphorus load to Bone Lake is required to meet the TMDL. If Moody Lake discharges at the goal phosphorus concentration, it will account for 24% of the total needed reduction in phosphorus load. The allocations are summarized in Table 29 and information on the percent reduction needed to meet the TMDL allocations is summarized in Table 30.

**Table 29. Bone Lake TP Allocations**

| Source | WLA (lbs/day) | LA (lbs/day) |
|---|---|---|
| Construction (various permits) | 0.007 | -- |
| Industrial Stormwater (future permits) | 0.007 | -- |
| Unregulated MS4 portions of City of Scandia, Chisago Lake Township, Internal, Atmospheric, Groundwater, Moody Lake outflow * | -- | 1.819 |

* may include MnDOT and County road authorities

**Table 30. TP Reduction Needed to Attain Bone Lake TMDL Allocations**

| Source | Current Modeled Load (lbs/day) | % TP Reduction Needed |
|---|---|---|
| Unregulated MS4 portions of Municipalities: Chisago Lake Township* | 0.01 | 45% |
| Unregulated MS4 portions of Municipalities: City of Scandia* | 2.06 | 45% |
| Livestock | 0.21 | 0% |
| Internal | 0.36 | 70% |
| Atmospheric and Groundwater | 0.14 | 0% |
| Upstream Lakes: Moody | 0.59 | 64% |

* may include MnDOT and County road authorities

## 6G. School Lake Allocations

Bone Lake drains into School Lake by way of Birch Lake. Bone Lake is impaired and will be addressed by a TMDL. Therefore, the assumption is made for the School Lake allocations that Bone Lake discharges at the water quality goal. This input from Bone Lake is allocated as a LA for School Lake, since any WLA for the Bone Lake watershed has been addressed in the Bone Lake WLA. Since Birch Lake is not listed as an impaired water (it is classified as a wetland), Birch Lake and its drainage area are included as part of the School Lake watershed and are addressed by the School Lake allocation. It should be noted that the existing phosphorus load contributed to School Lake from Birch Lake exceeds the School Lake TMDL, so an assumption of non-degradation or current water quality was not used for Birch Lake. School Lake cannot attain the water quality goal if Birch Lake remains at the current water quality. A load reduction was included for the discharge from Birch Lake to School Lake in order to meet the load reduction required for School Lake.

The watershed to School Lake (downstream of Bone Lake) contains the permitted sources of The Preserve at Birch Lake large sewage treatment system, and potential construction and industrial stormwater permits. While the City of Forest Lake is located within the watershed to School Lake, the regulated portions of the City of Forest Lake MS4 are not expected to extend into the School Lake watershed. The regulated portions of a future MS4 for the City of Chisago City are expected to extend into the School Lake watershed and a WLA is provided based on the percent of the developable area of the watershed it covers and the modeled watershed load (Table 31, see also section 6B). Each permitted source is given a separate WLA. The Preserve at Birch Lake is a large sewage treatment system that discharges to the soil and is therefore given a zero allocation. While the system will certainly discharge phosphorus, it will not discharge phosphorus to a location expected to impact the lake. The allocations assume no reduction in internal load because the School Lake internal load was not identified as a source of concern. Overall, a 51% reduction in phosphorus load to School Lake is required to meet the TMDL. The allocations are summarized in Table 32 and information on the percent reduction needed to meet the TMDL allocations is summarized in Table 32.

**Table 31. Percent of Developable Drainage Area to School Lake, downstream of Bone Lake**

| Municipality | Percent of Upland Drainage Area (%) |
|---|---|

| | Future WLA Land Use | Future LA Land Use |
|---|---|---|
| City of Chisago City | 1% | 26% |
| Chisago Lake Township | 0% | 22% |
| City of Forest Lake | 0% | 12% |
| City of Scandia | 0% | 39% |

**Table 32. School Lake TP Allocations**

| Source | WLA (lbs/day) | LA (lbs/day) |
|---|---|---|
| Construction (various permits) | 0.0045 | -- |
| Industrial Stormwater (future permits) | 0.0045 | -- |
| City of Chisago City MS4: future permit * | 0.003 | -- |
| The Preserve at Birch Lake: MN0050474 | 0.000 | -- |
| Unregulated MS4 portions of City of Scandia, Chisago City, City of Forest Lake, and Chisago Lake Township, Internal, Atmospheric, Groundwater, Bone Lake outflow* | -- | 1.226 |

* may include MnDOT and County road authorities

**Table 33. TP Reduction Needed to Attain School Lake TMDL Allocations**

| Source | Current Modeled Load (lbs/day) | % TP Reduction Needed |
|---|---|---|
| City of Chisago City MS4 * | 0.005 | 60% |
| Unregulated MS4 portions of City of Chisago City* | 0.14 | 77% |
| Unregulated MS4 portions of Municipalities: City of Forest Lake* | 0.06 | 76% |
| Unregulated MS4 portions of Municipalities: Chisago Lake Township* | 0.10 | 74% |
| Unregulated MS4 portions of Municipalities: City of Scandia* | 0.18 | 74% |
| Livestock | 0.29 | 76% |
| Internal | 0.13 | 0% |
| Atmospheric and Groundwater | 0.03 | 0% |
| Upstream Lakes: Bone and Birch | 1.61 | 45% |

* may include MnDOT and County road authorities

## 6H. Little Comfort Lake Allocations

School Lake drains into Little Comfort Lake. Therefore, the assumption is made for the Little Comfort Lake allocations that School Lake discharges at the water quality goal. This input from School Lake is allocated as a LA for Little Comfort Lake, since any WLA for the School Lake watershed has been addressed in the School Lake WLAs.

The watershed to Little Comfort Lake (downstream of School Lake) contains the permitted sources of the City of Forest Lake MS4, the Liberty Ponds large sewage treatment system, potential construction and industrial stormwater permits, and the future permitted MS4s of the City of Chisago City, and the City of Wyoming. Each are given a separate WLA. The Liberty Ponds sewage treatment system discharges to the soil and is therefore given an allocation of zero. While the system will certainly discharge phosphorus, the discharge is to the soil and the phosphorus does not reach the lake. The WLA for each of the current and future regulated MS4 communities is calculated based on the percent of the developable area of the watershed it covers and the modeled watershed load (Table 34, see also section 6B). A 70% reduction in internal load is assumed for Little Comfort Lake in the determination of load allocations. Overall, a 54% reduction in phosphorus load to Little Comfort Lake is required to meet the TMDL. The attainment of TMDL water quality for School Lake provides 78% of the phosphorus load reduction required to meet the TMDL. The allocations are summarized in Table 35 and information on the percent reduction needed to meet the TMDL allocations is summarized in Table 36.

**Table 34. Percent of Developable Drainage Area to Little Comfort Lake, downstream of School Lake**

| Municipality | Percent of Upland Drainage Area (%) | |
|---|---|---|
| | Future WLA Land Use | Future LA Land Use |
| City of Chisago City | 20% | 28% |
| City of Forest Lake | 1% | 7% |
| City of Wyoming | 21% | 23% |

**Table 35. Little Comfort Lake TP Allocations**

| Source | WLA (lbs/day) | LA (lbs/day) |
|---|---|---|
| Construction (various permits) | 0.005 | -- |
| Industrial Stormwater (future permits) | 0.005 | -- |
| City of Forest Lake MS4: MS400262 * | 0.01 | -- |
| City of Chisago City MS4: future permit * | 0.15 | -- |
| City of Wyoming MS4: future permit * | 0.15 | -- |
| Liberty Ponds: MN0067466 | 0.00 | -- |
| Unregulated MS4 portions of City of Forest Lake, City of Chisago City, City of Wyoming, Internal, Atmospheric, Groundwater, School Lake outflow * | -- | 1.26 |

* may include MnDOT and County road authorities

**Table 36. TP Reduction Needed to Attain Little Comfort Lake TMDL Allocations**

| Source | Current Modeled Load (lbs/day) | % TP Reduction Needed |
|---|---|---|
| City of Forest Lake MS4 * | 0.02 | 33% |
| City of Chisago City MS4 * | 0.20 | 24% |
| City of Wyoming MS4 * | 0.24 | 36% |
| Unregulated MS4 portions of City of Forest Lake* | 0.07 | 30% |
| Unregulated MS4 portions of City of Chisago City* | 0.26 | 29% |
| Unregulated MS4 portions of City of Wyoming* | 0.26 | 29% |
| Livestock | 0.06 | 0% |
| Internal | 0.15 | 70% |
| Atmospheric and Groundwater | 0.02 | 0% |
| Upstream Lakes: School Lake | 2.16 | 67% |

* may include MnDOT and County road authorities

## 6I. SHIELDS LAKE ALLOCATIONS

The watershed to Shields Lake contains the permitted sources of the City of Forest Lake MS4 and potential future construction and industrial stormwater permits. The City of Forest Lake covers the entire watershed to Shields Lake. The regulated portions of the City of Forest Lake MS4 are estimated to extend into the 58% of the Shields Lake watershed (see section 6B). Each permitted source is given a separate WLA. The internal load reduction and the watershed load reduction must both be 83% in order to meet the TMDL. The allocations are summarized in Table 37 and information on the percent reduction needed to meet the TMDL allocations is summarized in Table 38.

**Table 37. Shields Lake TP Allocations**

| Source | WLA (lbs/day) | LA (lbs/day) |
|---|---|---|
| Construction (various permits) | 0.002 | -- |
| Industrial Stormwater (future permits) | 0.002 | -- |
| City of Forest Lake MS4: MS400262 | 0.049 | -- |
| Unregulated MS4 portions of City of Forest Lake, Internal, Atmospheric, Groundwater: no permit | -- | 0.481 |

**Table 38. TP Reduction Needed to Attain Shields Lake TMDL Allocations**

| Source | Current Modeled Load (lbs/day) | % TP Reduction Needed |
|---|---|---|
| City of Forest Lake MS4 | 0.30 | 83% |
| Unregulated MS4 portions of City of Forest Lake | 0.21 | 83% |
| Livestock | 0.003 | 0% |
| Internal | 2.50 | 83% |
| Atmospheric and Groundwater | 0.02 | 0% |
| Upstream Lakes: none | 0.00 | 0% |

## 6J. COMFORT LAKE ALLOCATIONS

Little Comfort Lake drains into Comfort Lake. This input from Little Comfort Lake is allocated as a LA for Comfort Lake, since any WLA for the Little Comfort Lake watershed was addressed in the Little Comfort Lake WLAs.

Forest Lake, a large waterbody un-impaired for nutrients, drains into Comfort Lake through the Sunrise River. For Comfort Lake, the allocations for drainage through Forest Lake were calculated as a portion of the outflow load from Forest Lake when the lake is discharging at its current water quality. The outflow load from Forest Lake was allocated based on the equivalent downstream contribution to Comfort Lake. Therefore, the load used to determine allocations was reduced from current water quality to account for the modeled 26% reduction in load expected to occur between the outlet of Forest Lake and Comfort Lake (CLFLWD, 2007). The load was then portioned to WLA and LA based on each municipality’s percentage of Forest Lake’s developable drainage area estimated to be under WLA or LA land uses in the future (Table 39, see also section 6B). This effectively allows loading in the Forest Lake drainage area to remain at existing levels, since Forest Lake itself is not impaired.

**Table 39. Percent of Developable Drainage Area to Forest Lake**

| Municipality | Percent of Upland Drainage Area (%) | |
|---|---|---|
| | Future WLA Land Use | Future LA Land Use |
| City of Chisago City | 0% | 2% |
| City of Forest Lake | 39% | 43% |
| City of Scandia | 0% | 16% |

The watershed to Comfort Lake (including the Forest Lake watershed but downstream of Little Comfort Lake) contains the permitted sources of the City of Forest Lake MS4, future City of Wyoming MS4, future City of Chisago City MS4, and potential construction and industrial stormwater permits. Each are given a separate WLA. The WLA for the City of Forest Lake MS4 and the future MS4s are calculated based on the percent of the developable area of the watershed it covers and the modeled watershed load plus any WLA for drainage from Forest Lake itself (Table 40, see also section 6B).

**Table 40. Percent of Developable Drainage Area to Comfort Lake, downstream of Forest Lake**

| Municipality | Percent of Upland Drainage Area (%) | |
|---|---|---|
| | Future WLA Land Use | Future LA Land Use |
| City of Chisago City | 2% | 0% |
| City of Forest Lake | 26% | 5% |
| City of Wyoming | 43% | 24% |

Overall, a 5% reduction in total load to Comfort Lake is needed to meet the TMDL. All five of the other impaired lakes eventually drain through Comfort Lake. Therefore, the water quality of Comfort Lake is highly dependent on the quality of upstream lakes. In fact, the TMDL for Comfort Lake could be met by ensuring that Little Comfort Lake meets its goal water quality. However, Little Comfort Lake is not currently listed as impaired and its quality depends on the quality of the three impaired lakes upstream of Little Comfort. Because of the relatively small load reduction needed for Comfort Lake and the dependency on the quality of upstream lakes, the assumption of upstream lakes meeting water quality goals was not used for the Comfort Lake allocations. Comfort Lake allocations were made by holding watershed loads to existing levels and assuming some improvement in water quality of Little Comfort Lake, but not the full improvement required by the TMDL. This allocation method provides an additional level of assurance that the TMDL and goal water quality can be met in Comfort Lake. The allocations are summarized in Table 41 and information on the percent reduction needed to meet the TMDL allocations is summarized in Table 42.

**Table 41. Comfort Lake TP Allocations**

| Source: Permit Number | WLA (lbs/day) | LA (lbs/day) |
|---|---|---|
| Construction (various permits) | 0.02 | -- |
| Industrial Stormwater (future permits) | 0.02 | -- |
| City of Forest Lake MS4: MS400262 + | 1.35 | -- |
| City of Wyoming MS4: future permit + | 1.55 | |
| City of Chisago City MS4: future permit + | 0.06 | |
| Unregulated MS4 portions of City of Forest Lake, City of Chisago City, City of Scandia and City of Wyoming, Internal, Atmospheric, Groundwater, Little Comfort Lake outflow: no permit + | -- | 3.41 |

+ May include MnDOT and County road authorities

**Table 42. TP Reduction Needed to Attain Comfort Lake TMDL Allocations**

| Source | Current Modeled Load into Comfort Lake (lbs/day) | % TP Reduction Needed |
|---|---|---|
| City of Forest Lake MS4* + | 1.35 | 0% |
| City of Wyoming MS4 + | 1.55 | 0% |
| City of Chisago City MS4* + | 0.06 | 0% |
| Unregulated MS4 portions of City of Forest Lake* + | 0.55 | 0% |
| Unregulated MS4 portions of City of Scandia* + | 0.01 | 0% |
| Unregulated MS4 portions of City of Wyoming + | 0.86 | 0% |
| Unregulated MS4 portions of City of Chisago City*+ | 0.02 | 0% |
| Livestock | 0.01 | 0% |
| Internal | 0.37 | 0% |
| Atmospheric and Groundwater | 0.13 | 0% |
| Upstream Lakes: Little Comfort | 1.86 | 21% |

* Includes the city's portion of the outflow from Forest Lake. The City of Wyoming does not include any area draining to Forest Lake.
+ May include MnDOT and County road authorities

## 6K. TMDL ALLOCATION SUMMARY

The TMDL and WLAs and LAs are presented in terms of phosphorus loading per day. The modeling was based on annual loads, and these loads were divided by the number of days in a year (365) to determine the daily loads. Table 43 lists the TMDL, total WLA and LA for each of the six lakes included in this study.

**Table 43. TMDL TP Allocation Summary**

| Lake and Standard | TMDL (lbs/day) | WLA (lbs/day) | LA (lbs/day) |
|---|---|---|---|
| Moody Lake: Eutrophication standard (40 µg/L) | 0.395 | 0.003 | 0.392 |
| Bone Lake: Eutrophication standard (40 µg/L) | 1.833 | 0.014 | 1.819 |
| School Lake: Eutrophication standard (40 µg/L) | 1.238 | 0.012 | 1.226 |
| Little Comfort Lake: Eutrophication standard (40 µg/L) | 1.58 | 0.32 | 1.26 |
| Shields Lake:Eutrophication standard (60 µg/L) | 0.534 | 0.053 | 0.481 |
| Comfort Lake: Eutrophication standard (40 µg/L) | 6.41 | 3.00 | 3.41 |

# 7. Seasonal Variation

In-lake water quality models predict growing season or annual averages of water quality parameters based on growing season or annual loads, and the MPCA's nutrient standards are based on growing season averages. Symptoms of nutrient enrichment normally are the most severe during the summer months; the nutrient standards set by the MPCA were set with this seasonal variability in mind.

This is the case for all six of these lakes; seasonal variation results in critical conditions in the lakes in early or late summer when TP concentrations peak and clarity is at its worst.

# 8. Monitoring Plan

The following monitoring plan lays out the different types of monitoring that will need to be completed in order to track the progress of implementation activities associated with these six lakes, and of associated changes in water quality due to the management practices.

## 8A. In-Lake Monitoring

The CLFLWD has been monitoring all of these lakes except Little Comfort since at least 2005. Consistent monitoring on Little Comfort began in 2006. Details of the CLFLWD monitoring protocol can be found on the CLFLWD website at www.clflwd.org/programs.php, and in the CLFLWD 2007 *Water Monitoring Report*.

Monitoring should occur after implementation activities are initiated in order to evaluate the effectiveness of the BMPs, and should continue throughout the implementation period until water quality standards are attained.

The following parameters should be part of the monitoring plan:

In the deeper lakes, depth profiles of temperature and dissolved oxygen should be taken every two weeks during the growing season at the deepest portion of the lakes.

- Total phosphorus, soluble reactive phosphorus, chlorophyll-a, and transparency should be monitored every two weeks during the growing season.
- Depth profiles of temperature and dissolved oxygen should be taken every two weeks during the growing season at the deepest portion of the lakes.
- After commencement of in-lake curly-leaf pondweed management practices, two macrophyte surveys should be undertaken annually: 1) in the spring, when curly-leaf pondweed is at its peak, and 2) mid-summer, after curly-leaf has died back and native plants and Eurasian watermilfoil are potentially growing. Macrophyte surveys should be conducted every five years in lakes without active management of macrophytes.
- A fish survey should be completed once every five years to obtain data on fish population abundance and size distribution, year class strength as well as to evaluate management activities. Surveys should be conducted following the Manual for Instruction of Lake Survey, Special Publication No. 147 from the Minnesota Department of Natural Resources.

For Little Comfort Lake, to establish the data-set needed to determine impairment:

- Total phosphorus, soluble reactive phosphorus, chlorophyll-a, and transparency should be monitored at least every two weeks during the growing season.
- Depth profiles of temperature and dissolved oxygen should be taken at least every two weeks during the growing season at the deepest portion of the lake.

Additionally for Shields Lake:

- Zooplankton monitoring should be undertaken for a full season every five years in Shields Lake. Monitoring should start in early spring (March or April), when large zooplankton peak; zooplankton community dynamics during this period influence the water quality during the remainder of the growing season.

- At least one year of winter nitrate data should be obtained in Shields Lake. Winter nitrate has been shown to be an indicator of plant species richness in shallow lakes and can provide information on nitrogen loading and the potential for aquatic macrophyte restoration (James et al. 2005). This information can help target future management practices aimed at reducing nitrogen loading to the lake.

# 9. Implementation Strategy

## 9A. Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities will depend on the lake's nutrient balance and opportunities for restoration. In a lake that does not have an excessive internal loading problem, like School Lake and Comfort Lake, the focus will be on reducing external loads. In a lake that does have high internal loading rates, such as Shields Lake, practices to address internal loading will be central to the lake restoration effort. Internal load reduction efforts will be needed for Moody, Bone, Little Comfort, and Shields Lakes.

Although controlling the internal load in Shields Lake will be central to restoring the lake, controlling the external loads is essential in the restoration of a shallow lake. A restoration is less likely to be stable when external nutrient loads are still high (Moss et al. 1996).

As a number of the lakes flow into each other (Moody to Bone to School to Little Comfort to Comfort), improvements in the water quality of upstream lakes are taken into account for the water quality of downstream lakes. Therefore the upstream lakes should be higher priority in overall implementation to ensure that downstream lakes can attain goal water quality. This implementation strategy sets the stage for action by providing the overall approach to the management practices needed to achieve the TMDL.

## 9B. Load Reduction Strategies

The Comfort Lake-Forest Lake Watershed District has developed rules to protect the water quality of these six lakes and other lakes in the watershed through stormwater management, erosion control, shoreline buffers and floodplain management. Many of the municipalities also have standards in these areas and it is expected that the Comfort Lake-Forest Lake Watershed District and municipalities will work together to implement water quality standards and programs.

A number of BMPs are identified in the Comfort Lake-Forest Lake Watershed District's (CLFLWD) *Water Quality Modeling Investigation* (CLFLWD, 2007) that will help to address lake impairments. For most lakes, these planned projects alone are not estimated to provide the full reduction in phosphorus loads needed to attain the goal water quality, so additional efforts will be necessary by municipalities, local and state agencies, local organizations, and individual citizens as appropriate. The CLFLWD's planned BMPs are estimated to provide the phosphorus load reduction required for Bone Lake and Comfort Lake to attain the goal water quality. Additional efforts beyond what is planned by CLFLWD will be needed to attain goal water quality in Moody Lake, School Lake, Little Comfort Lake, and Shields Lake. The CLFLWD's planned BMPs may be implemented as cooperative projects of CLFLWD and municipalities.

The Comfort Lake-Forest Lake Watershed District assists landowners with the voluntary implementation of on-lot water quality improvement projects and Best Management Practices

(BMPs) through their BMP cost-share incentive program. The program provides targeted funding to projects that provide water quality improvements that are not required by ordinance or rule and address runoff from existing infrastructure or erosion from existing problem areas. This program will help to fund smaller-scale, distributed practices throughout the watershed.

A summary of the primary load reduction strategies for each lake is provided below. It is estimated that the implementation strategies outlined will be accomplished within the next twenty years. Adaptive management evaluation will occur every three years during and after that time to allow the revision and refinement of the implementation strategy. Additional implementation efforts may be necessary beyond this twenty year timeframe, especially for Moody Lake, School Lake, Little Comfort Lake, and Shields Lake.

### Moody Lake Strategies

Moody Lake was identified as having a high watershed load and a high internal load. Therefore load reduction strategies for Moody Lake will focus on reducing the watershed load from the agricultural areas surrounding the lake and on managing curly-leaf pondweed, fisheries, and other internal loads. Implementation of planned strategies for Moody Lake are estimated to cost $930,000.

#### *Watershed Load Reduction Implementation Strategies*

Watershed load reduction for Moody Lake will focus on reducing the load from the agricultural areas adjacent to the lake through manure management, livestock management, and implementation of conservation tillage, buffers, and vegetated swales. These reductions will be implemented through interaction of CLFLWD, municipalities, and county and state agencies with landowners interested in voluntary participation in education, cost-share, and targeted project programs. In addition, wetland restoration projects in the Moody Lake watershed have the potential to reduce the phosphorus load to Moody Lake.

#### *Internal Load Reduction Implementation Strategies*

Reducing the internal load in Moody Lake will be a requirement before major improvements can be seen. The internal load reduction efforts will include alum treatment, rough fish management, and curly-leaf pondweed management.

### Bone Lake Strategies

The strongest influences on Bone Lake’s impairment were identified to be a high watershed load and Moody Lake’s input to Bone Lake. Watershed load reduction efforts will focus on reducing the load from cropland and developed areas of the watershed as these were identified as the largest sources. Internal load was identified as an area for improvement with noted rough fish, curly-leaf pondweed, and Eurasian water milfoil populations in the lake. Lakeshore septic systems and livestock are identified as secondary sources of phosphorus to the lake. Reducing the load from these sources will be a secondary focus. Implementation of planned strategies for Bone Lake are estimated to cost $1,717,000.

#### *Watershed Load Reduction Implementation Strategies*

The primary load reduction focus for Bone Lake will be the improvement of water quality in Moody Lake through the efforts identified for Moody Lake above. Within the Bone Lake watershed, watershed load reduction activities will focus on reducing the load from the developed and cropland areas within the watershed through raingardens, buffers, vegetated swales, shoreline restoration, manure management, livestock management, and implementation of conservation tillage. These reductions will be implemented through interaction of CLFLWD, municipalities, and county and state agencies with landowners interested in voluntary participation in education, cost-share, and targeted project programs.

In addition, potential locations for a wetland restoration, a flow diversion, and regional infiltration projects that are estimated to reduce the phosphorus load to Bone Lake have been identified in the lake's watershed.

*Internal Load Reduction Implementation Strategies*
Internal load reduction efforts for Bone Lake will include alum treatment, rough fish management, and curly-leaf pondweed management.

### School Lake Strategies

School Lake is most strongly affected by the upstream load from Birch Lake. The current load to School Lake from Birch Lake is higher than the TMDL for School Lake. Therefore, reducing the phosphorus input to School Lake from Birch Lake will be the primary strategy for meeting the TMDL for School Lake. Reducing the watershed load to School and Birch Lakes from livestock, cropland, and developed areas will be the focus of load reduction strategies. Implementation of planned strategies for School Lake are estimated to cost $700,000.

*Watershed Load Reduction Implementation Strategies*
The primary load reduction focus for School Lake will be the improvement of water quality in Birch Lake. A wetland restoration in the Birch Lake watershed is expected to provide TP load reductions for School Lake by way of Birch Lake.

In addition, watershed load reduction activities for the Birch and School Lake watersheds will include reductions in the load from the agricultural and developed areas within the watershed through raingardens, buffers, vegetated swales, shoreline restoration, manure management, livestock management, and implementation of conservation tillage. These reductions will be implemented through interaction of CLFLWD, municipalities, and county and state agencies with landowners interested in voluntary participation in education, cost-share, and targeted project programs.

*Internal Load Reduction Implementation Strategies*
Internal load reductions do not appear necessary for School Lake. Load reduction efforts will focus on watershed load reductions.

### Little Comfort Lake Strategies

The input from School Lake to Little Comfort Lake is the strongest influence on the water quality of Little Comfort Lake. Upstream water quality improvements will directly benefit Little Comfort Lake. In addition, load reduction efforts will focus on reducing the watershed load from developed and cropland areas and on reducing the internal load to Little Comfort Lake. Implementation of planned strategies for Little Comfort Lake are estimated to cost $444,000.

*Watershed Load Reduction Implementation Strategies*
Within the Little Comfort Lake watershed, watershed load reduction activities will focus on reducing the load from the cropland and developed areas within the watershed through raingardens, buffers, vegetated swales, shoreline restoration, manure management, livestock management, and implementation of conservation tillage. These reductions will be implemented through interaction of CLFLWD, municipalities, and county and state agencies with landowners interested in voluntary participation in education, cost-share, and targeted project programs.

In addition, potential locations for wetland restoration or outlet modifications on School Lake are estimated to reduce the phosphorus load to Little Comfort Lake.

*Internal Load Reduction Implementation Strategies*
Internal load reduction efforts for Little Comfort will include alum treatment, rough fish management, and curly-leaf pondweed management.

**Shields Lake Strategies**

Shields Lake, as a shallow lake, is influenced by phosphorus concentrations in balance with the biological community. Internal load was identified as a large source of phosphorus to Shields Lake and will be the primary focus of load reduction efforts. Implementation of planned strategies for Shields Lake are estimated to cost $380,000.

*Watershed Load Reduction Implementation Strategies*
Watershed load reduction activities within the Shields Lake watershed will focus on reducing the load from the adjacent lands through shoreline restoration and implementation of buffers and vegetated swales. These reductions will be implemented through interaction of CLFLWD, municipalities, and county and state agencies with landowners interested in voluntary participation in education, cost-share, and targeted project programs.

*Internal Load Reduction Implementation Strategies*
Reducing the internal load in Shields Lake will be an important aspect of lake restoration. Internal load reduction efforts will include alum treatment, rough fish management, and curly-leaf pondweed management. In addition, biomanipulation is planned for Shields Lake. Biomanipulation is intended to shift the lake to a clear water state through food web alterations that increase algae consumption and decrease recycling of nutrients within the lake.

**Comfort Lake Strategies**

Comfort Lake is most strongly influenced by inputs from upstream lakes. All of the other lakes in this study eventually drain through Comfort Lake. The water quality in Comfort Lake depends primarily on hydrologic inputs. The more discharge the lake receives from upstream lakes, the poorer the water quality of Comfort Lake. Therefore, upstream water quality improvements will directly benefit Comfort Lake and will be a key focus of the load reduction strategy. The load reduction strategy for Comfort Lake will also include reducing the load to the lake from the developed portion of its watershed. Implementation of planned strategies for Comfort Lake is estimated to cost $4,490,000.

*Watershed Load Reduction Implementation Strategies*

Within the Comfort Lake watershed, watershed load reduction activities will focus on reducing the load from the developed areas within the watershed through raingardens, buffers, vegetated swales, and shoreline restoration. These reductions will be implemented through interaction of CLFLWD, municipalities, and county and state agencies with landowners interested in voluntary participation in education, cost-share, and targeted project programs.

In addition, two wet detention ponds and one potential water quality treatment project are planned in the Comfort Lake watershed to reduce the phosphorus load contributing to the lake.

Another potential strategy that was investigated through this TMDL study was that Shallow Pond, a large wetland upstream of Comfort Lake, was acting as a phosphorus source. Monitoring conducted in 2008 upstream and downstream of Shallow Pond did not support this hypothesis. In fact, the data indicate a 45% reduction in TP load through Shallow Pond and an 83% reduction in TSS load (Appendix B). 2008 may represent an atypical hydrologic year, with flows at higher levels in the first half of the sampling period, falling to almost zero flow in the second half. The resultant pollutant loading for this flow pattern could be substantially different than that resulting from a more typical hydrologic situation. In addition the monitoring did not cover spring snow melt conditions which may have a different interaction with Shallow Pond than low flow conditions observed for much of the monitoring season. Despite these distinctions in the flow pattern through Shallow Pond in 2008, past monitoring data also supports the conclusion that Shallow Pond is not consistently acting as a source of phosphorus (see section 11.2.2.1 of *Water Quality Modeling Investigation* (CLFLWD, 2007)). The data suggest that alterations to Shallow Pond are not a warranted load reduction strategy.

*Internal Load Reduction Implementation Strategies*

Internal load reduction strategies do not appear necessary for Comfort Lake although internal load reductions were recommended in *Water Quality Modeling Investigation* (CLFLWD, 2007). More recent lake water quality monitoring data show that water quality tends to exceed the standard in years with low watershed and upstream lake inputs (see Figure 44 and Appendix B). This suggests that the lake's internal load does not need to be reduced in order for Comfort Lake to meet the water quality standard.

### Construction and Industrial Stormwater Strategies

Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

Industrial stormwater activities are also considered in compliance with provisions of the TMDL if they obtain an Industrial Stormwater General Permit or General Sand and Gravel general permit (MNG49) under the NPDES program and properly select, install, and maintain all BMPs required under the permit, or meet local industrial stormwater requirements if they are more restrictive than requirements of the State General Permit.

## Watershed Protection and Restoration

The goal of the TMDL process is to address the impaired waters and develop a plan to bring them back to achieving water quality standards. However, there is also a need to ensure that un-impaired or un-assessed waters are protected from further degradation and potential listing. One example of the need for protection is Forest Lake. Currently, this lake is not listed as impaired but efforts are needed to ensure the lake does not become impaired; not only for the benefit of Forest Lake but for the benefits of downstream water bodies as well.
The CLFLWD's Watershed Management Plan has developed goals for all of the Lakes and Streams within the watershed. These goals not only set targets for the water bodies in the CLFLWD, but also identify that protection and restoration of the water bodies is necessary. The CLFLWD's Watershed Management Plan which will act as the driver for Protection and Restoration can be found at: http://www.clflwd.org/resources.php

## Adaptive Management Approach

The adaptive management approach to implementation will involve the evaluation of the response of the lake to the implementation of management practices. An evaluation of data on the lake response to implementation will occur every three years after the commencement of implementation actions. The management approach to achieving the goals should be adapted as new information is collected and evaluated.

# 10. Reasonable Assurances

Reasonable assurances must be provided to demonstrate the ability to reach and maintain water quality endpoints.

## 10A. Individual Programs

### Municipal Ordinances and New CLFLWD Rules

The Comfort Lake-Forest Lake Watershed District has developed rules to protect the water quality of the District lakes through stormwater management, erosion control, shoreline buffers and floodplain management. Many of the municipalities also have standards in these areas and it is expected that the Comfort Lake- Forest Lake Watershed District and municipalities will work together to implement water quality standards and programs.

### CLFLWD Capital Improvement Plan

The Comfort Lake-Forest Lake Watershed District has developed a Capital Improvement Program guided by the *Water Quality Modeling Investigation* (CLFLWD, 2007) that identifies a number of specific BMPs and capital projects to help to address phosphorus impairments in the District's lakes.

### TMDLs

This TMDL study concurrently addresses all of the phosphorus impairments in the Comfort Lake watershed. Each impaired lake upstream of each of the lakes in this TMDL study are addressed through this TMDL, therefore providing reasonable assurance that impacts to downstream lakes from upstream impairments will be addressed.

### NPDES MS4 Program

The MS4 permit program is in place only for the City of Forest Lake within the six lakes' watersheds. The majority of municipalities are not currently MS4 communities. However, the City of Wyoming, the City of Chisago City, and the City of Scandia are expected to require an MS4 permit by or before 2020. Each of the current and future MS4 permits are provided with a WLA.

Under the MS4 program, each permitted community must develop a Storm Water Pollution Prevention Program, or SWPPP, that lays out the ways in which the community will actively and effectively manage its stormwater. SWPPPs are required to incorporate the results of any approved TMDLs within their area of jurisdiction, subject to review by the MPCA.

### Shared Education Program

The East Metro Water Resource Education Program partnership provides a comprehensive water resource education and outreach program within the watersheds to each of the lakes addressed by this TMDL study. The Comfort-Lake Forest Lake Watershed District, the City of Forest Lake and the Washington Conservation District are members of the program. The program goal is to reduce non-point source water pollution from storm water runoff and illicit discharges by educating citizens, municipal staff and officials, developers and businesses. The program conducts trainings and provides educational materials through a variety of formats.

#### Soil & Water Conservation District, Natural Resources Conservation Service Programs

The Washington Conservation District and the Chisago Soil and Water Conservation District administer several state and federal funding programs that are available to landowners to implement a variety of agricultural and urban best management practices. The Washington Conservation District currently runs a technical assistance and cost share program for implementation of water quality BMPs (funded by Washington County and the state) and collaborates with the Comfort-Lake Forest Lake Watershed District. The Washington Conservation District and the Chisago Soil and Water Conservation District can also provide technical assistance to landowners. The Natural Resources Conservation Service also provides technical assistance and runs a variety of cost-share programs.

## 10B. SUMMARY

In summary, there are federal, state, watershed, local, and water utility authorities in place to provide a reasonable assurance that the implementation efforts within this TMDL study will go forward.

# 11. Public Participation

Public participation for the CLFLWD Six Lakes TMDL study consisted of several stakeholder input meetings held during development of the water quality modeling and capital improvement program that make up the *Water Quality Modeling Investigation* (CLFLWD, 2007). Minutes from the meetings are available on the CLFLWD website at www.clflwd.org under Resources, Meeting Minutes & Agendas.

The work plan had a total of six meetings proposed during the course of the study. Four of those meetings have occurred, with the fifth and sixth reserved for a stakeholder meeting regarding TMDL allocations and a public meeting after the draft TMDL report and implementation plan have been through preliminary MPCA and EPA review.

Stakeholder meetings were held on:

- March 28, 2007
- June 21, 2007
- July 25, 2007
- January 7, 2008
- April 8, 2009

Attendee organizations at one of more of these meetings included the following:

City of Forest Lake
City of Scandia
City of Chisago City
Wyoming Township
City of Wyoming
Bone Lake Association
Comfort Lake Association
Chisago County
Washington County
Chisago County Soil Water Conservation District
Washington Conservation District
Metropolitan Council
St. Croix Basin Planning Team
MN Department of Natural Resources
Minnesota Pollution Control Agency
Board of Water and Soil Resources
U.S. Army Corps of Engineers
Comfort Lake-Forest Lake Watershed District
Comfort Lake-Forest Lake Watershed District Citizen Advisory Committee
Wenck Associates, Inc.
Emmons & Olivier Resources, Inc.

The schedule called for a public input meeting for comments on the draft review after the MPCA preliminary review and comments are received and addressed. Minutes from stake-holder meetings can be found on the CLFLWD website at www.clflwd.org under Resource, Meeting Minutes & Agendas.

The CLFLWD Six Lakes TMDL was posted on the MPCA's website for public comment and review for a 30-day review period. The review period took place from November 23, 2009 through December 23, 2009. During this time the MPCA received and responded to five comment letters from the public and local entities.

# 12. References

Comfort Lake-Forest Lake Watershed District (CLFLWD). 2007. Watershed and Lake Water Quality Modeling Investigation for the Development of a Watershed Capital Improvement Plan. Prepared by Wenck Associates, Inc.

Comfort Lake-Forest Lake Watershed District (CLFLWD). 2008. Watershed Management Plan. Prepared by Houston Engineering, Inc. Revised by Comfort Lake-Forest Lake Watershed District.

Davis, M and S. Miller. 1996. A Mussel Survey of the Sunrise River. Minnesota Department of Natural Resources, Conservation Biology Research Grants Program, Division of Ecological Services.

James, C., J. Fisher, V. Russell, S. Collings, and B. Moss. 2005. Nitrate availability and hydrophyte species richness in shallow lakes. Freshwater Biology 50: 1049-1063.

Moss, B., J. Madgwick, and G. Phillips. 1996. A guide to the restoration of nutrient-enriched shallow lakes. Environment Agency and Broads Authority.

Minnesota Pollution Control Agency. 2004. Legislative Report: Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared by Barr Engineering. (www.pca.state.mn.us/hot/legislature/reports/phosphorus-report.html)

Minnesota Pollution Control Agency. 2007. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment. Environmental Outcomes Division.

United States Geological Survey. 2003. Nutrient and Suspended-Sediment Concentrations and Loads, and Benthic-Invertebrate Data for Tributaries to the St. Croix River, Wisconsin and Minnesota, 1997–99.

# 13. Abbreviations

| | |
|---|---|
| BMP | Best management practice |
| CALM | Consolidation Listing and Assessment Methodology; part of the TMDL listing process on 303d |
| Chl-a | Chlorophyll-*a* |
| CLFLWD | Comfort Lake-Forest Lake Watershed District |
| DNR | Minnesota Department of Natural Resources |
| EPA | see USEPA |
| LA | Load allocation |
| MEP | Maximum extent practicable |
| µg/L | Micrograms per liter |
| MOS | Margin of safety |
| MPCA | Minnesota Pollution Control Agency |
| MS4 | Municipal separate storm sewer system |
| NPDES | National Pollutant Discharge Elimination System |
| SD | Secchi depth |
| SWPPP | Stormwater pollution prevention program |
| TMDL | Total maximum daily load |
| TP | Total phosphorus |
| TSI | Trophic state index |
| UAL | Unit Area Load |
| USEPA | U.S. Environmental Protection Agency |
| WLA | Waste load allocation |

# 14. Appendices

Appendix A: Watershed and Lake Water Quality Modeling Investigation for the Development of a Watershed Capital Improvement Plan (Water Quality Modeling Investigation) (CLFLWD, 2007) (Available on CLFLWD website: www.clflwd.org)

Appendix B: Shallow Pond TP and TSS Loading Analysis for 2008

Document available in the "Resources" section of the Comfort Lake-Forest Lake Watershed District website: www.clflwd.org links are also provided below.

*Watershed and Lake Water Quality Modeling Investigation for the Development of a Watershed Capital Improvement Plan* (Water Quality Modeling Investigation) (CLFLWD, 2007)

Final Report

Appendices

A: Review of CLFLWD XP-SWMM Model

B: XP-SWMM Model Calibration and Monitoring Station Rating Curves

C: Development of Lake Water Budgets and Lake Water Budget Fgures

D: GIS Analysis of Unit Area Loading Inputs

E: Development of Unit Area Load Export Coefficients

F: Watershed Loading Data Figures

G: Internal Phosphorus Loading

H: Lake Bathymetric Maps

I: Historic Lake Water Quality Data and Technical Memorandum

J: Lake Ecology

K: Combined Watershed Loading and Lake Water Quality Response Model

L: Comfort Lake Investigations

M: Project Screening

N: Preliminary Design Drawings and Supporting Information

O: Cost Estimates and Schedules for Proposed Projects

P: Lake Response Curves Post CIP Implementation

**Date |** April 27, 2009

**To |** Lisa Tilman **Contact info |** ltilman@eorinc.com

**cc |** **Contact info |**

**From |** Kent Brander **Contact info |** kbrander@eorinc.com

**Regarding |** CLFLWD TMDL TP and TSS Loading Analysis Summary

## Overview

An analysis was performed to characterize the functioning of the shallow pond wetland just upstream (west-southwest) of Big Comfort Lake, by calculating the loads of TP and TSS entering the wetland and comparing them to the loads leaving the wetland and entering Big Comfort Lake.

## Data

The following data was used to perform the analysis:

Flow monitoring data:
- Greenway Avenue monitoring site (wetland inflow) 4/14/2008-11/4/2008
- Big Comfort Lake inlet station 4/3/2008-9/24/2008

Water quality monitoring data:
- Greenway Avenue monitoring site 4/2/2008-8/28/2008
- Big Comfort Lake inlet station 4/2/2008-10/20/2008

The water quality sampling data for flow entering the shallow pond wetland is summarized in Table 1. Table 2 contains the same data for flow leaving the wetland and entering Big Comfort Lake.

**Table 1. Wetland Inflow Sampling Data**

| Sampling Date | Total Phosphorus (TP) (mg/L) | Total Suspended Solids (TSS) (mg/L) |
|---|---|---|
| 4/2/2008 | 0.081 | 6 |
| 4/22/2008 | ~0.026 | 5 |
| 4/25/2008 | 0.146 | 97 |
| 5/3/2008 | 0.166 | 103 |
| 5/21/2008 | ~0.047 | 17 |
| 6/12/2008 | 0.173 | 79 |
| 6/23/2008 | 0.056 | 9 |
| 6/28/2008 | 0.523 | 422 |
| 7/31/2008 | 0.090 | 5 |
| 8/28/2008 | 0.229 | 87 |

**Table 2. Comfort Lake Inflow Sampling Data**

| Sampling Date | Total Phosphorus (TP) (mg/L) | Total Suspended Solids (TSS) (mg/L) |
|---|---|---|
| 4/2/2008 | 0.069 | 4 |
| 4/22/2008 | ~0.038 | 4 |
| 4/25/2008 | ~0.047 | 12 |
| 5/5/2008 | 0.058 | 8 |
| 5/21/2008 | 0.067 | 17 |
| 5/27/2008 | 0.081 | 16 |
| 6/6/2008 | 0.097 | 17 |
| 6/12/2008 | 0.087 | 16 |
| 6/23/2008 | 0.066 | 14 |
| 7/31/2008 | 0.050 | 3 |
| 9/15/2008 | 0.060 | 3 |
| 10/20/2008 | ~0.039 | ~1 |

## Analysis

Procedure

Given that the monitoring data was not continuous, the concentrations of TP and TSS occurring between sampling events had to be assumed; for this analysis, they were calculated based on a linear interpolation between adjacent data points. Where the available data indicated an approximate value, the indicated numerical value was used.

For purposes of comparison, the analysis was performed for the period for which flow and water quality data were available for both the wetland inflow and the Big Comfort Lake inflow (4/14/2008-8/28/2008).

Continuous flow data was available in 15-minute time steps for the period of analysis. For each time step, the volume of flow was calculated and then multiplied by the (sampled or interpolated) concentrations of TP and TSS, in order to determine the mass of TP or TSS present in the flow during that time step. The total mass of TP or TSS delivered during the overall sampling period was then calculated by summing the results from all applicable time steps.

Results

The total calculated loads of TP and TSS are shown in Table 3.

**Table 3. Total Loads for Sampling Period**

| Location | Total Phosphorus (TP) | Total Suspended Solids (TSS) |
|---|---|---|
| Greenway Avenue (Wetland Inflow) | 1717 lbs | 978634 lbs |
| Big Comfort Lake (Wetland Outflow) | 939 lbs | 166165 lbs |
| Difference in Load | 778 lbs (45% reduction) | 812469 lbs (83% reduction) |

## Conclusions and Limitations

Based on the available data and using the above-stated assumptions, the shallow pond wetland would appear to be removing phosphorus and total suspended solids with the efficiency indicated in Table 3

(45% and 83% removal, respectively). These values are within the typical range of pollutant removal efficiency for wetlands. However, there are a number of potential complicating factors that must be considered before these results are applied generally.

One concern is that the analyzed sampling period is relatively short, and it occurs in an atypical hydrologic year, with flows at higher levels in the first half of the sampling period, falling to almost zero flow in the second half. The resultant pollutant loading for this flow pattern could be substantially different than that resulting from a more typical hydrologic situation. Also, with the analysis spanning a period of less than 5 months, it does not provide a clear picture of what is occurring on an annual basis.

Also, the nature of the water quality sampling may not provide a full picture of the pollutant loading. Each of the samples essentially represents a “snapshot” of the system, and it was assumed that the pollutant concentration between samples could be computed by linear interpolation. However, in reality, the pattern of pollutant loading is more complicated, and is likely influenced by a number of factors not reflected in the available data. A different pattern of pollutant concentrations would result in a significantly different end result.

## Recommendation

In order to develop a better understanding of the functioning of the wetland, it is recommended that at least one more full year (non-frozen conditions) of monitoring data be collected. If feasible, a greater frequency of sampling (e.g., weekly) would provide substantially more reliable results. It would be especially important to obtain monitoring data during the spring snowmelt. Going through the above analysis with the additional data would make it possible to characterize the wetland functioning with a higher degree of confidence.