# Carver County Burandt Lake Excess Nutrients TMDL Report Final


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CARVER COUNTY

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# EPA TMDL Summary Sheet

| | | TMDL Page # |
|---|---|---|
| **Water body ID** | Burandt Lake: HUC: 07020012<br>Lake ID 10-0084 | 1 |
| **Location** | City of Waconia in Carver County, Minnesota, located in the Minnesota River Basin | 2- 5 |
| **303(d) Listing Information** | The water body listed above was added to the 303(d) list in 2004 because of excess nutrient concentrations impairing aquatic recreation. MPCA prioritized this TMDL to start in 2006 and be completed by 2007. | 1 |
| **Impairment / TMDL Pollutant(s) of Concern** | Excess Nutrients | 1 |
| **Impaired Beneficial Use(s)** | Aquatic recreation (swimming) | 1 |
| **Applicable Water Quality Standards/ Numeric Targets** | The MPCA has established numerical thresholds based on ecoregions for determination of Minnesota lakes as either impaired or unimpaired. The protected beneficial use for all lakes is aquatic recreation (swimming). Burandt Lake, according to the MPCA definition, is considered a deep lake in the North Central Hardwood Forest (NCHF) ecoregion. Therefore, the NCHF ecoregion deep lake standard of 40µg/L will be set as the goal for Burandt Lake. | 19-20 |
| **Loading Capacity (expressed as daily load)** | The loading capacity is the total maximum daily load. The critical condition is the summer growing season. The loading capacity is set forth in Table 6.1. | 34 |

| | | |
|---|---|---|
| **Total Maximum Daily Load** | The phosphorus Total Maximum Daily Load for Burandt Lake is 0.88 kg/day (average precipitation year). | 34 |

| **Wasteload Allocation** | **Source** | **Permit #** | **Individual WLA** | |
|---|---|---|---|---|
| | Permitted Storm water | City of Waconia MS400232 * Carver County MS400070 * | Wasteload Allocations allocated to the permit holders as set forth in Tables 6.1. WLAs are based on 2030 urban boundaries and road rights-of-way. | 35-36 |
| **Load Allocation** | **Source** | | **Individual LA** | |
| | Atmospheric Load | | Load Allocation includes atmospheric, internal load and watershed area that will not be within urban boundaries according to 2030 Comprehensive Plans.<br><br>See Table 6.1. | 34-36 |
| | Rural Watershed | | | |
| | Internal Load | | | |
| **Margin of Safety** | The margin of safety is implicit due to the conservative assumptions of the model and the proposed iterative nutrient reduction strategy with monitoring. | | | 40-41 |

| | | |
|---|---|---|
| **Seasonal Variation** | Seasonal variation is accounted for by developing targets for the summer critical period where the frequency and severity of nuisance algal growth is greatest. Although the critical period is the summer, lakes are not sensitive to short-term changes but rather respond to long term changes in annual load. | 40 |
| **Reasonable Assurance** | Reasonable assurance is provided by the County Board which acts as the "governing body" of the Carver County Water Resource Management Area (CCWRMA) for surface water management in which this lake is located. The purpose of establishing the CCWRMA is to fulfill the County's water management responsibilities under Minnesota Statute and Rule. The County Land and Water Services Division is responsible for administration of the water plan and coordinating implementation. Other departments and agencies will be called upon to perform water management duties that fall within their area of responsibility. For areas regulated under the NPDES program, and Minnesota's General Permit requires MS4s to amend their Storm Water Pollution Prevention Plans and NPDES permits within 18 months after adoption of a TMDL to set forth a plan to meet the TMDL wasteload allocation. | Section 8 Beginning on pg 45 |
| **Monitoring** | Carver County Land and Water Services periodically monitors this lake and will continue to do so through the implementation period. Also, additional monitoring will be conducted during and following implementation. | 48 |
| **Implementa-tion** | This TMDL sets forth an implementation framework and general load reduction strategies that will be expanded and refined through the development of an Implementation Plan. | Section 9 Beginning on pg 49 |
| **Public Participation** | The County has utilized stakeholder meetings, citizen surveys, workshops and permanent citizen advisory committees to gather input from the public and help guide implementation activities. | Section 7 Beginning on pg 42 |

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## TABLES

**FIGURES**

**APPENDICIES**

## EXECUTIVE SUMMARY

Burandt Lake is a deep, 92-acre lake located 0.5 miles west of Waconia in Carver County, Minnesota (about 25 miles southwest of Minneapolis). The lake has a 7,823-acre (excluding Burandt Lake) watershed that can be divided into three sub watersheds. First, the area of land draining directly to Burandt Lake consists of 246 acres (excluding Burandt Lake) that are primarily developed into residential and commercial areas. Next, flowing in from the northeast is the largest sub watershed, the Lake Waconia (3,080 acres) sub watershed, which is 7,147 acres (including Lake Waconia) of agricultural and residential land. Finally, the Scheuble Lake (16 acres) sub watershed flowing in from the west is 430 acres (including Scheuble Lake) of primarily agricultural lands. Part of the City of Waconia is within the watershed.

**Burandt Lake at a Glance**

**HUC** 07020012
**Lake ID**: # 10-0084
**Recreational uses:** Considered light/moderate by most surveyed, included fishing, boating, jet skiing, and swimming.
**Year Listed:** 2004
**Drainage basin**: Minnesota River
**Impaired by:** Excess nutrients (phosphorus)
**Total Phosphorus (1999 – 2001, 2004, 2005 summer mean):** 56-98 ug/l
**Total Phosphorus (2005 summer mean):** 56 ug/l (16 samples)
**Phosphorus standard:** 40 ug/l
**Lake area:** 92 acres
**Mean/Maximum depth:** 10 ft/24 ft.
**Total drainage area:** 7,823 acres (excluding Burandt lake)
**Sources of phosphorus:**
- **External**: Stormwater runoff from developed and agricultural areas, failing or direct-discharge septic systems, degraded wetlands.
- **Internal:** Anoxic sediments, seasonal turnover, mixing by wind and boat propellers, aquatic plant senescence.

Burandt Lake has been identified for impairment of aquatic recreation (swimming) due to excess nutrients (phosphorus). As a result, it has been placed on the list of Minnesota impaired waters. Because of the exceedance, Carver County conducted a Total Maximum Daily Load (TMDL) study. A TMDL is defined as the maximum quantity of a pollutant that a water body can receive, and continue to meet water quality standards for designated beneficial uses.

Water quality data collected from 1999-2005 revealed that Burandt Lake has average total phosphorus concentrations ranging from 56 to 98 micrograms per liter (ug/l). Nutrient reductions for Burandt Lake are set for phosphorus because it is the limiting nutrient for aquatic plant and algal growth. While phosphorus is an essential nutrient, it is considered a pollutant when it stimulates excessive growth of aquatic plants or algae.

Based on the federal Clean Water Act, waters that do not meet water quality standards are "impaired." The Clean Water Act requires states to develop a cleanup plan for each impairment that affects a water body. The cleanup plan and the process used to create it is a Total Maximum Daily Load (TMDL).

A TMDL must identify all sources of the pollutant that is causing a water body to violate standards. The TMDL also determines the amount by which each source must reduce its contribution to ensure that a water body meets applicable water quality standards.

The phosphorus load to Burandt Lake over the 2005 season (42.18 inches of precipitation) was determined to be 687 kilograms per year (kg/yr), The Burandt Lake loading capacity was 1.19kg/day (2005 study). Of this total, external sources have been determined to contribute approximately 457 kg annually, which includes runoff from precipitation and precipitation itself. The remaining 230 kg of phosphorus is from nutrient recycling within the lake.

Prior to 1970, a sewage treatment plant discharged directly to Burandt Lake. During the course of the TMDL study staff were unable to recover information about the treatment plant, although during discharge there are accounts of severe algal blooms and depletion of oxygen resulting in winterkills. Since the elimination of the discharge, winterkills have been less frequent and water quality has improved.

The water quality goal is 40 micrograms per liter (ug/l) for the mean total phosphorus concentration during the summer growing season (June 1 – September 30). This goal is equal to the state phosphorus standard for deep lakes in the North Central Hardwood Forest Ecoregion.

Because the assimilative capacity of a water body varies with the water load and, ultimately, precipitation, the TMDL was set for an average year (29.11 inches of precipitation), and the implementation plan also considers wet and dry years. The critical condition for Burandt Lake is the summer growing season when the frequency and severity of nuisance algal growth are greatest. Although the critical period is the summer, lakes primarily respond to long term changes in annual load.

**The TMDL for Burandt Lake is 0.88 kg/day, which is equivalent to 321 kg/yr.**

Results indicate the phosphorus loading into and within Burandt Lake must be reduced by 32 to 66%, depending on yearly precipitation, to achieve the water quality goal of 40 ug/l.

To reach the reduction goals, Carver County will rely largely on its current Water Management Plan. Implementation goals not covered in the Water management Plan will be identified and amended. A final implementation plan that further refines watershed loads will be developed within a year of the final approval of the TMDL by the U.S. Environmental Protection Agency (EPA). Regular bi-weekly monitoring of Burandt Lake from April-October of each year will continue as identified in the Water Plan. However, after implementation of nutrient reduction strategies, a stepped-up approach of monitoring will be conducted.

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurances, including a thorough knowledge of the ability to implement BMPs, as well as the overall effectiveness of the BMPs. Carver County is positioned to implement the TMDL and ultimately achieve water quality standards.

The County has utilized stakeholder meetings, citizen surveys, workshops, permanent citizen advisory committees, and personal meetings with the City of Waconia and the City of Waconia consultants to gather input for the study and to help guide implementation activities. The use of this public participation structure will aid in the development of this and other TMDLs in the County.

The City of Waconia is a permitted Municipal Separate Storm Sewer System (MS4) under the EPA's stormwater program. MS4s are regulated through state-issued permits and must create and implement stormwater pollution-prevention programs (SWPPPs). The SWPPP for Waconia will need to include nutrient loading to Burandt Lake.

Because of the uncertainties involved in the development of the TMDL, and the success of management strategies used to reduce pollution, it is necessary to use an "adaptive management" approach to implementation. This approach involves continual evaluation and monitoring of implementation actions taken to reduce pollution over a period of several years.

# 1.0 Introduction

## 1.1 PURPOSE

The goal of this TMDL is to quantify the pollutant reductions needed to meet the water quality standards for nutrients in Burandt Lake. The Burandt Lake nutrient TMDL is being established in accordance with section 303(d) of the Clean Water Act, because the State of Minnesota has determined waters in Burandt Lake exceed the State established standards for nutrients.

## 1.2 PROBLEM IDENTIFICATION

Burandt Lake has been monitored (April 15-Oct 1) for total phosphorus, chlorophyll-a and Secchi transparency in 1999, 2000, 2001, 2004 and 2005. The lake has been monitored by Carver County Environmental Services as part of the Water Management Plan, the Metropolitan Council Environmental Services Citizens Assisted Monitoring Program (CAMP) and the Minnesota Pollution Control Agency's (MPCA) Citizen Lake Monitoring Program (CLMP). Burandt Lake was identified for impairment of aquatic recreation (swimming) due to excess nutrients and placed on the State of Minnesota's 303(d) list of impaired waters in 2004. The lake was listed as a result of mean summer phosphorus values that exceeded the 40µg/L phosphorus standard for Class 2 recreational waters. In order to be listed, the MPCA will only consider the most recent 10 year period of water quality data and requires that there are more than 12 observations of total phosphorus, chl-a, and Secchi transparency.

**Table 1.1 Impaired Waterbody.**

| Lake | HUC # | DNR Lake # | Affected Use | Pollutant or Stressor |
|---|---|---|---|---|
| Burandt Lake | 07020012 | 10-0084 | Swimming | Excess Nutrients |

# 2.0 Watershed and Lake Characterization

## 2.1 LAKE MORPHOMETRY

Burandt Lake is located in the North Central Hardwood Forest (NCHF) ecoregion, in the City of Waconia in Carver County, Minnesota (Figure 2.1). Table 2.1 summarizes the lake morphometry and Figure 2.1 shows the basic bathymetry of Burandt Lake. Although groundwater likely enters the lake, the majority of inflow comes from Lake Waconia in addition to runoff from the direct watershed and seasonal inflow from Scheuble Lake.

**Table 2.1 Burandt Lake morphometric characteristics.**

| Parameter | Burandt Lake |
|---|---|
| Lake Surface Area (ac) | 92 |
| Average Depth (ft) | 9.7 |
| Maximum Depth (ft) | 24 |
| Volume (ac-ft) | 892 |
| Residence Time (days) | 55-73 |
| Littoral Area (ac) | 66 (72%) |
| Watershed drainage area (acres)[1] | 8,483 |
| Direct Watershed (excluding lake) (ac)[1] | 246 |
| Lake: Watershed drainage area ratio | 1:85 |

1 Excluding Burandt Lake Acreage.

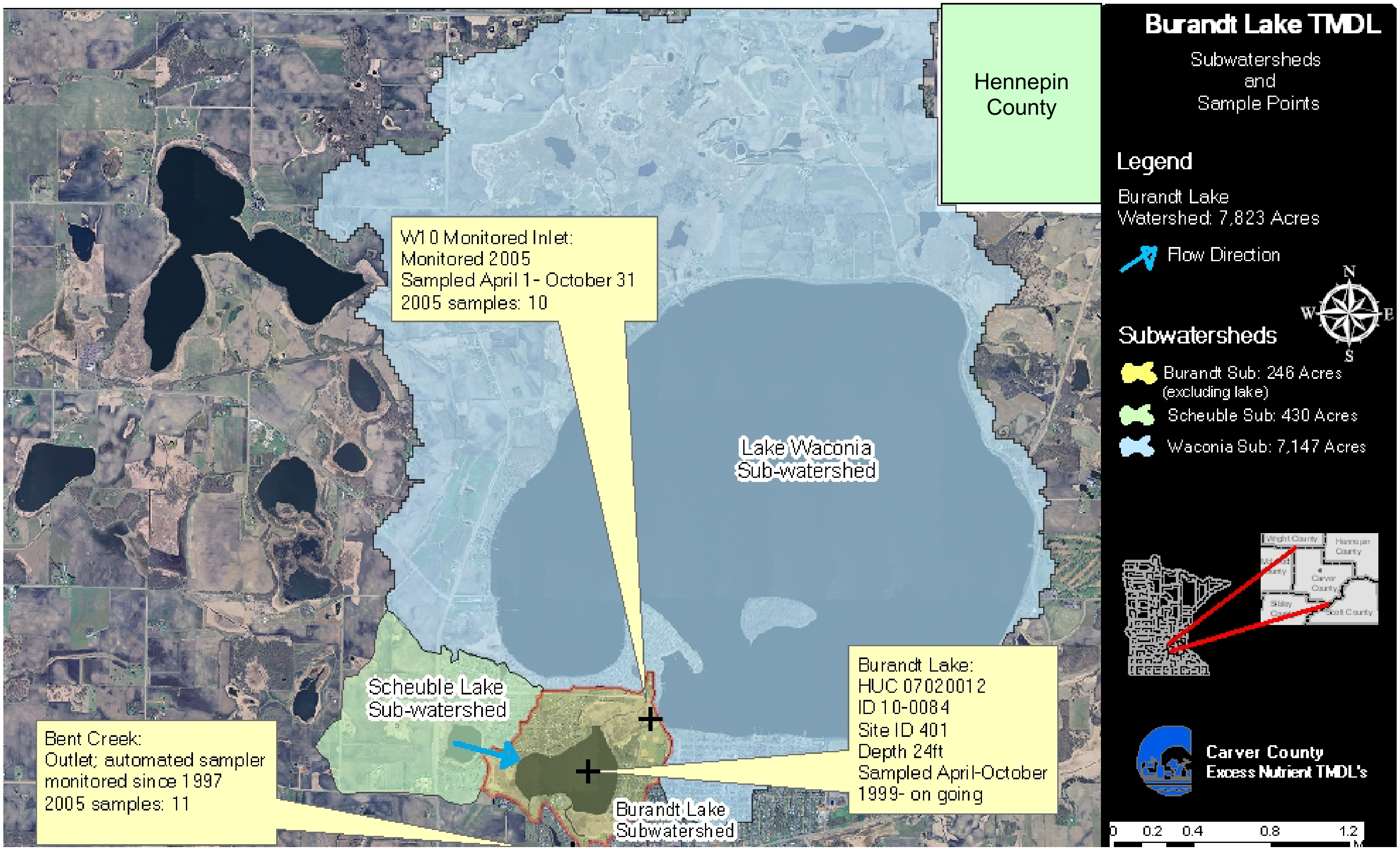



**Figure 2.1**. Map of Burandt Lake watershed, sub-watersheds and sample points.

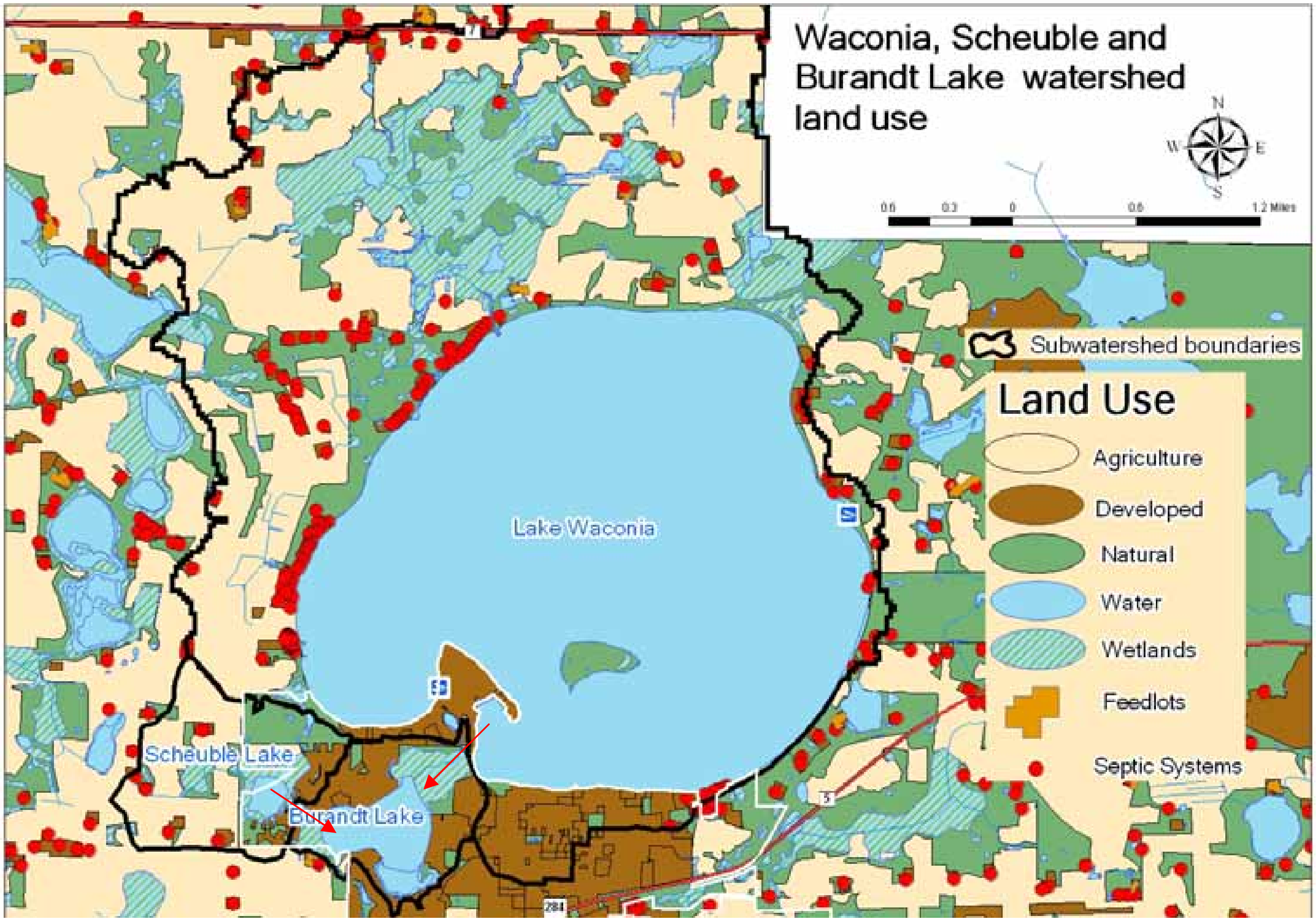



**Figure 2.2**. Burandt Lake watershed land use and watershed size in relation to Burandt Lake (2000).

## 2.2 WATERSHED DESCRIPTION

The entire Burandt Lake watershed consists of 7,823 acres of land which can be divided into three subwatershed areas (figure 2.2). The direct watershed, the area that drains directly to Burandt Lake without first passing through another lake, is 246 acres excluding the lake. The two indirect watersheds consist of 7,147 acres of land draining from Lake Waconia, and another 430 acres flowing from Scheuble Lake (watershed area includes the lakes). The drainage areas contain portions of the City of Waconia. Burandt Lake discharges into Carver Creek (Carver Creek Watershed) which flows southeast into the Minnesota River.

**Table 2.2.** DNR protected waters in the Burandt Lake watershed.

| Waterbody | DNR Number | Classification[1] | 303(d) List |
|---|---|---|---|
| Waconia Lake | 10-0059 | Deep Lake | No |
| Scheuble Lake | 10-0085 | Wetland | N/A |

**1** Surface water classification according to MCPA February 2006 document; Factors for differentiating among lakes, shallow lakes and wetlands.

### 2.2.1 Watershed Land Use

The Burandt Lake direct watershed is primarily developed into residential areas (figure 2.2, table 2.3). There are approximately 305 parcels in the direct watershed, and roughly 46 of these homes have lake frontage. All of the homes are on city sewer line. According to 2000 feedlot inventory data, there is one feedlot with approximately 18 animal units remaining in the southwestern portion of the watershed. According to GIS elevation data and land observation, the majority of the pasture area conveys flow to the outlet of the lake; thus any nutrient input by the animals does not influence water quality in Burandt Lake. Furthermore, the remaining agricultural land in the direct watershed is planned to be converted into residential development according to City of Waconia 2030 Comprehensive Plans. Thus, by the year 2030, the City of Waconia will expand to cover the entire direct watershed.

Land use in the indirect watersheds of the lakes that flow into Burandt Lake influence its water quality. Land use in Scheuble and Lake Waconia watersheds is presented in table 2.3 below. There are approximately 320 homes within the Scheuble Lake watershed; six of the parcels on the western fringe remain on subsurface septic treatment systems (SSTS). In the Waconia Lake watershed, there are approximately 883 homes -- 155 of them have SSTS according to records -- and 2000 feedlot inventories indicate there are nine feedlots with approximately 888 animal units in the northwestern agricultural areas of the Waconia Lake watershed. The City of Waconia will continue to expand into both watersheds; and along with the expansion will come continued development.

**Table 2.3. Current land use (2000) in the Burandt Lake drainage area.**

| Land use | Burandt Lake Direct[1] | | Scheuble Lake | | Lake Waconia | |
|---|---|---|---|---|---|---|
| | Acres | Percent | Acres | Percent | Acres | Percent |
| Agriculture | 3 | 1% | 225 | 52% | 2197 | 28% |
| Developed | 134 | 55% | 50 | 12% | 719 | 9% |
| Natural | 28 | 11% | 89 | 20% | 786 | 10% |
| Wetland | 80 | 33% | 50 | 12% | 955 | 12% |
| Water | 1 | 0% | 16 | 4% | 3150 | 41% |
| TOTAL | 246 | 100% | 430 | 100% | 7807 | 100% |

1 land use in the Burandt Lake watershed depicts all land draining to the lake without first passing through another lake. The acres of water in this subwatershed do not include that of Burandt Lake itself.

## 2.3 HISTORY IN THE WATERSHED

Prior to 1970, a sewage treatment plant discharged directly to Burandt Lake. We were unable to recover information about the treatment plant, although there are accounts of severe algal blooms and depletion of oxygen resulting in winterkills. Since the elimination of the discharge, winterkills have been less frequent and water quality has improved.

## 2.4 RECREATIONAL USES

There is no public access to Burandt Lake nor is there any planned in the near future, so recreation is limited to those owning lakeshore properties. During the lake monitoring periods, Carver County staff witnessed several lakeshore properties with jet skis and large motorized boats such as pontoons and skiing boats. A public survey was sent to landowners within .25 miles of the lake to gain knowledge of the uses of Burandt Lake. Recreational activity was considered by most (93%) to be light to moderate and includes fishing-- the most popular recreational activity on the lake -- followed by boating, jet skiing, and swimming. Other uses include wildlife observation, canoeing, sailing and kayaking. While there appears to be plenty of recreation on the lake, 65% of respondents indicated that their perception of the lake was that swimming is slightly impaired, and some respondents indicated that there were no possible uses (i.e. swimming or boating) for the lake.

## 2.5 FISHERIES

Historical and present fisheries surveys conducted by the MNDNR in conjunction with County Staff on Burandt Lake provide insight into the fish community in the lake. The fish population has been sampled periodically since 1976, with the most recent sample taking place in 2006.

The fish population survey conducted in 2006 was somewhat similar to past surveys in that small pan fish were indicated to be present in above-average numbers. Pan fish populations such as black crappies and bluegill sunfish were very abundant, with yellow perch and pumpkin seed sunfish also present. Predatory fish included small numbers of northern pike and walleye. Similar to past surveys, black bullheads were present well above average numbers for lakes of this class. There was one carp captured, however, neither of the methods utilized for assessing fish populations are effective at capturing carp. Other fish present in average numbers included freshwater drum, golden shiner, largemouth bass, and yellow bullhead.

Pan fish populations in Burandt Lake periodically increase due to open niches caused by low predator populations, and decreased immigration from Lake Waconia during low water levels. High levels of pan fish in the lake, coupled with low predator populations and limited fishing pressure, enable black crappies to become overabundant and stunted in the lake until winterkill conditions or stress related disease reduce numbers (MN DNR Fisheries 1991). This may be the path that current pan fish populations are following.

Abundance of Black Bullhead in Burandt Lake can play a role in the changes in water quality from year to year. Bottom-dwelling fish like bullheads can mix sediments and nutrients into the water column in shallow areas of the lake. They also excrete large quantities of urine and fecal matter, increasing the nutrients available (Cooke et al 2001).

## 2.6 WINTERKILLS

Winterkills occur when snow covers the top layer of ice, inhibiting photosynthesis from happening underneath. This, coupled with high sediment oxygen demand, leads to the depletion of dissolved oxygen, resulting in winterkill. According to MN DNR, fish population estimates of the lake are representative of an occasional winterkill lake. In fact, known winterkills have taken place during the winters of 1935-36, 1948-49, 1950-51, 1954-55, 1959-60, 1975-76, 1978-79, and 1990-91. Since the termination of the sewage treatment plant discharge (see section 2.3), winterkills have been less frequent.

## 2.7 AQUATIC PLANTS

### 2.7.1 Introduction

Aquatic plants are beneficial to lake ecosystems, providing spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments. However, in excess they limit recreational activities, such as boating and swimming, as well as aesthetic appreciation.

Excess nutrients in lakes can lead to invasive plants and exotics taking over a lake. Some exotics can lead to special problems in lakes. For example, eurasian watermilfoil can reduce plant biodiversity in a lake because it grows in great densities and out-competes native species. Ultimately, this can lead to a shift in the fish community because these high densities favor pan fish over larger game fish. Species such as curlyleaf pondweed can cause very specific problems by changing the dynamics of internal phosphorous loading. All in all, there is a delicate balance between the aquatic plant communities and water quality in any lake ecosystem.

### 2.7.2 Littoral Zone

The littoral zone is defined as that portion of the lake that is less than 15 feet in depth, and it's where the majority of aquatic plants are found. The littoral zone of the lake also provides the essential spawning habitat for most warm water fishes (e.g. bass, walleye, and pan fish). Burandt Lake is over 70 percent littoral and much of the benthic environment is sandy. Under best conditions, Burandt Lake could support a healthy, diverse aquatic plant community over much of the lake.

### 2.7.3 Aquatic Plants

Carver County staff conducted a simplified spring macrophyte survey on June 15th. Ten sample points were inspected with macrophyte type, depth, and abundance recorded.

During the macrophyte survey, a total of two floating leaf, five submergant, and one emergent species were documented in up to seven feet of water (Figure 2.5). Eurasian watermilfoil (*Myriophyllum spicatum)* was dominant throughout the lake. Dense stands of watermilfoil could be seen along the shoreline in all portions of the lake. Curly leaf pondweed (*Potomogeton crispus)* is currently found in sparse-to-moderate density throughout the lake. Cattail (*Typha sp.)* was found in small stands between homes and along the lakeshore where there are no homes at lakes edge. It is important to note that, at the time of the survey, the lake was being chemically treated for aquatic plants. At this point, Burandt Lake does support an abundant aquatic plant community; however, the majority of species present are non-native and invasive.

According to a survey distributed to landowners in the Burandt Lake watershed, 47 percent of users responding indicated that aquatic plants interfered with lake use. It was indicated that 21 percent of these people use some form of aquatic plant control. Seventy-five percent of plant control is accomplished by use of chemical control, while the remaining controls were manual or automatic plant removal.

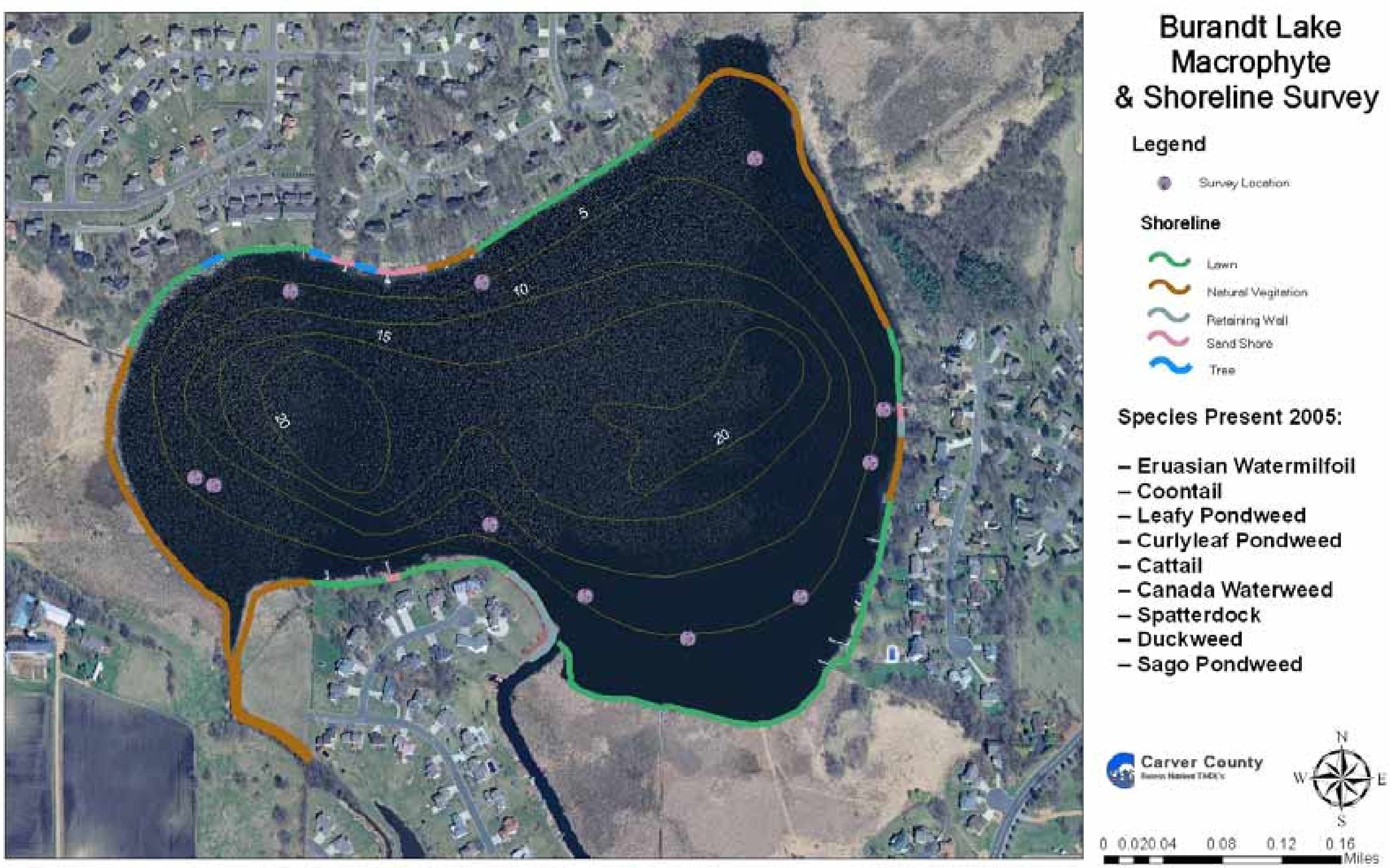



**Figure 2.3**. Burandt Lake Macrophyte survey points and Shoreline Survey Results

## 2.8 SHORELINE HABITAT AND CONDITIONS

The shoreline areas are defined as the areas adjacent to the lake edge with hydrophytic vegetation and water up to 1.5 feet deep, or a water table within 1.5 feet from the surface. Natural shorelines provide water quality treatment, wildlife habitat, and increased biodiversity of plants and aquatic organisms. Natural shoreline areas also provide important habitat to fisheries, including spawning areas and refuge, as well as aesthetic values.

Carver County staff conducted a shoreline survey in June 2005 by utilizing a Trimble GPS unit and an ArcPad program. Staff circumnavigated the shoreline, mapped and recorded shoreline type such as lawn, natural vegetation, retaining wall, and sand shore (Figure 2.6). Forty-nine percent of the shoreline was considered "natural vegetation", 43 % is mowed turf to the waters edge, 4 % sand shore, and the remaining 4 % contains a retaining wall. The "unnatural" portions of the shoreline may pose water quality issues by allowing for surface water runoff and bank erosion.

Vegetated shorelines provide numerous benefits to both lakeshore owners and lake users, including improved water quality, increased biodiversity, important habitat for both aquatic and terrestrial animals, and stabilizing erosion resulting in reduced maintenance of the shoreline. Identifying projects where natural shoreline habitats can be restored or protected will enhance the overall lake ecosystem.

## 2.9 WATER QUALITY

Burandt Lake has been monitored (April 15-Oct 1) periodically for total phosphorus, chlorophyll-a and Secchi transparency since 1999. The lake has been monitored by Carver County Environmental Services as part of the Water Management Plan, the Metropolitan Council Environmental Services Citizens Assisted Monitoring Program (CAMP) and the Minnesota Pollution Control Agency's (MPCA) Citizen Lake Monitoring Program (CLMP). In 2005, Carver County Land and Water Services conducted a more intensive water quality evaluation to better understand nutrient loading in the watershed. The following is a description of the water quality data results, focusing most closely on 2005 (See Appendix D for 2002 and 2005 data).

### 2.9.1 Data Collection Methodology

<u>Carver County Environmental Services</u>

Carver County and its Water Plan act to coordinate monitoring of County lakes and streams. Monitoring of lakes and streams follows the Water Plan management goal of creating and maintaining a comprehensive, accurate assessment of surface water quality trends over the long term. In order to establish baseline water quality, Carver County set up a network of sampling sites in the 1990s. In addition to staff sampling efforts, Carver County promotes volunteer monitoring efforts in an attempt to broaden the public's awareness and expand our monitoring network.

Lake Monitoring: Carver County staff and volunteers follow the lake monitoring techniques set up by the Metropolitan Council Environmental Services (MCES) for the Citizens Assisted Monitoring Program (CAMP). This program includes bi-weekly in-lake samples that are analyzed for total phosphorus, chlorophyll-a, and total Kjeldahl nitrogen, in addition to a Secchi depth measurement and a user perception survey. Monitoring takes place from April to October of each year. All records and observations are sent to the MPCA, and entered into the U.S. Environmental Protection Agency's STORET program.

Stream Monitoring: In the case of this TMDL, Carver County Staff utilized grab sample techniques to collect water quality data. Carver County staff follows techniques set up by the MCES. The sampling protocols are outlined in the 2003 MCES Quality Assurance Program Plan (QAPP). This program includes bi-weekly grab samples, in addition to samples collected during precipitation events. Samples are analyzed for total phosphorus, total suspended solids, nitrate-nitrite, ammonia, volatile suspended solids, turbidity, dissolved phosphorus, alkalinity, COD. All records and observations are sent to the MPCA and entered into the U.S. Environmental Protection Agency's STORET program.

Minnesota Pollution Control Agency (MPCA)
Burandt Lake has periodically been monitored by the MPCA Citizen Lake Monitoring Program (CLMP). The CLMP is similar to the Metropolitan Council's CAMP program and employs the help of citizen volunteers who live on or near the lake to take measurements. The CLMP program has been in existence since 1973. All records and observations are sent to the MPCA and entered into the U.S. Environmental Protection Agency's STORET program.

### 2.9.2 Tributary Monitoring

Water quality was monitored in 2005 at inlet W10 (see Figure 2.1 for map or Table 2.4 for data), which flows into Burandt Lake from Lake Waconia. W10 is located approximately 0.8 miles above the actual entry of the inlet into Burandt Lake and 0.08 miles below the outlet of Lake Waconia. Thus, W10 accounts for inflow from the entire 7,147 acres draining out of the Lake Waconia watershed. Consequently, a rather large portion of the land that contributes to the inflow of water into Burandt Lake is captured at this location. The inlet from Scheuble Lake was not monitored because of low flow conditions throughout the majority of the sampling season. Observation has told us that spring high flow is the only period where this inlet contributes to inflow into Burandt Lake. In addition, it was decided at the beginning of the TMDL process by the MPCA and County staff that it was not necessary to monitor all inlets into the lake, with the idea that the unmonitored inlet information could be accurately estimated by the models used to develop the TMDL.

Water quality was monitored with a handheld electronic meter in the field, and chemical analyses were performed by the Metropolitan Council Laboratory in St. Paul, MN. Temperature, transparency, and dissolved oxygen were measured in the field. Flow was also monitored during water quality sampling events utilizing a hand-held SonTec Flow Tracker. However, stage was not monitored continuously to develop a daily discharge record.

Grab samples and flow were collected from April 1st to September 30th to target an array of flow conditions. All grab samples that were collected are shown below. Monitoring conducted at W10 suggests that water moving into Burandt Lake from Lake Waconia has similar phosphorus concentrations to that of Lake Waconia. In addition, a minimal fraction of phosphorus flowing into Burandt Lake is orthophosphorus, the most readily available form of phosphorus for plants and algae. Observation and knowledge of Lake Waconia suggests that the lake supplies a large percentage (~80%) of water inflow into Burandt Lake; thus the water moving into Burandt Lake from Lake Waconia has a positive effect on Burandt Lake water quality.

**Table. 2.4. W10 phosphorus concentrations (µg/L) collected by grab samples over the summer growing season.**

| Date | W 10 TP (µg/L) | W10 OP(µg/L) | Date | Flow (cfs) |
|---|---|---|---|---|
| 4/13/2005 | 43 | 6 | 4/3/2005 | 15 |
| 4/21/2005 | 21 | <5 | 4/20/2005 | 21 |
| 5/5/2005 | 26 | <5 | 4/27/2005 | 16 |
| 6/1/2005 | 33 | <5 | 5/5/2005 | 15 |
| 6/14/2005 | 31 | <5 | 6/3/2005 | 15 |
| 6/28/2005 | 14 | <5 | 6/15/2005 | 20 |
| 7/13/2005 | 37 | <5 | 7/14/2005 | 13 |
| 8/10/2005 | 65 | <5 | 8/15/2005 | 3 |
| 9/13/2005 | 48 | 29 | 9/26/2005 | 3 |
| 10/6/2005 | 36 | <5 | -- | -- |

| | Summer Average TP µg/L | Range TP µg/L | Number |
|---|---|---|---|
| **W 10** | 35 | 14-65 | 6 |
| **Lake Waconia** | 34 | 11-58 | 10 |

The increase in total phosphorus at W10 late in the growing season corresponds with seasonal turn-over in Lake Waconia, and a period of minimal water movement through the inlet. The thermocline in Lake Waconia began to disappear in mid-July, which corresponds with the increase in total phosphorus at W10 beginning with the 7/13 sample. As the thermocline disappears, phosphorus moves from the hypolimnion to the surface waters, and the phosphorus rich water is mixed throughout the water column.

Even though the phosphorus levels at W10 do increase following Lake Waconia turnover, there was very little movement of water at the time. As such, the higher concentrations do not have an effect on Burandt Lake water quality.

In addition to data gathered at the inlet, there is an automated water quality monitoring station located approximately one mile downstream of the Burandt Lake outlet (Bent Cr.; Figure 2.1). Continuous flow and water quality data have been collected at this site since 1997. While this site captures outflow form Burandt Lake, it also captures runoff from a large area of impervious surface located below the lake outlet. Total phosphorus concentrations at the site are typically above the expected average concentration, 90µg/L, for streams in the NCHF ecoregion, (2005 growing season average 125 µg/L; range 48-312 µg/L). The data collected at this site is, and can be, used for comparison to lake model output; however the data will be better utilized during the implementation phase of the TMDL to aid in determining actual phosphorus reductions.

### 2.9.3 Temperature and Dissolved Oxygen

2005 Burandt Lake profiles demonstrated weak stratification conditions over the summer growing season, coupled with periodic anoxia below the thermocline. A weak thermocline was established near four meters early in the season, although the thermocline fluctuated anywhere from three to six meters throughout the summer. Fluctuation of the thermocline suggests that the lake is transitionally dimictic, and the water column completely mixes in the spring and fall of each year. While temperature may drive stratification, dissolved oxygen has a larger impact on water quality. The cool water trapped below the thermocline may become anoxic, thereby affecting sediment biogeochemistry. Dissolved oxygen is depleted in the hypolimnion during the summer, and can extend from the bottom up to three meters below the surface of the water. Fluctuations of the anoxic areas are caused by the mixing events that take place over the summer and during seasonal turn-over. The loss of oxygen below the thermocline results in a significant accumulation of phosphorus in the deeper areas of the lake. During partial or whole lake mixing events, phosphorus accumulated below the thermocline is mixed into the growing zone of the lake, which adds to eutrophic conditions.

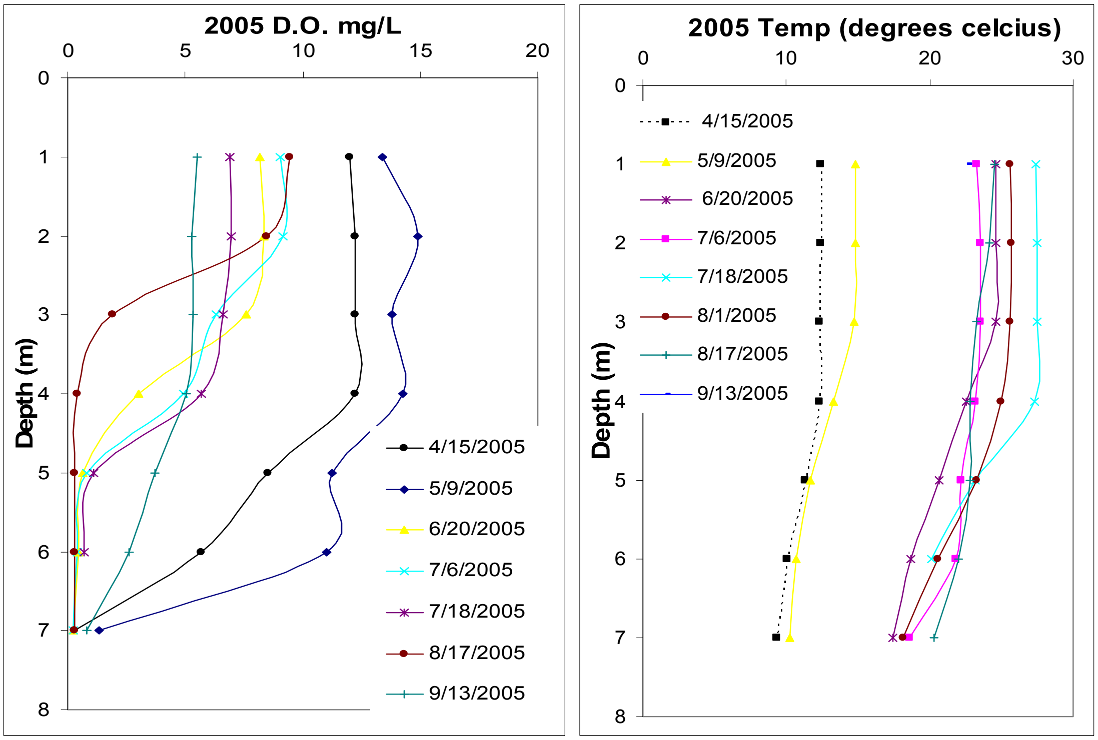



**Figure 2.4 Burandt Lake 2005 dissolved oxygen (mg/L) and temperature (degrees Celsius) profiles.**

### 2.9.4 Phosphorus, Chlorophyll-a, and Secchi Depth

#### 2.9.4.1 Current Water Quality

Monitoring conducted over the past ten years has depicted in-lake conditions which are eutrophic. Total phosphorus, chlorophyll-a, total kjeldahl nitrogen and Secchi depth data collected over the last ten years are presented in table 2.5 below. Ten years ago, the growing season mean total phosphorus was over two times greater than the applicable standard (40µg/L). Over time, total phosphorus has been reduced to a little over one time greater than the applicable standard. Average nitrogen concentrations have remained below 2000 µg/L, the level at which it begins to have a negative effect on water quality.

**Table 2.5. Growing season (June 1 –September 30) lake water quality for Burandt Lake (data obtained from STORET ).**

| Year (number samples) | Total Phosphorus Concentration (µg/L) | Chlorophyll-a Concentration (µg/L) | Secchi disk transparency (meters) | Total Kjeldahl Nitrogen (mg/L) |
|---|---|---|---|---|
| 1999 (5) | 98 | 29 | 0.8 | 1.67 |
| 2000 (7) | 66 | 40 | 1.0 | 1.56 |
| 2001 (9) | 71 | 45 | 0.8 | 1.72 |
| 2004 (10) | 58 | 21 | 1.4 | 1.22 |
| 2005 (16) | 56 | 20 | 1.4 | 1.20 |

Burandt Lake was most intensively monitored in 2005. Therefore, the following discussion of Burandt Lake water quality focuses on the 2005 data.

### 2.9.4.2 Phosphorus

Phosphorus was measured to determine the availability of nutrients for algal and aquatic plant production. Total phosphorus is a measure of all the phosphorus in the water, while orthophosphorus measures the most readily available form of phosphorus to grow plants and algae. The 2005 total phosphorus concentrations in Burandt Lake ranged from 26 to102 µg/L with a growing season average of 56µg/L.

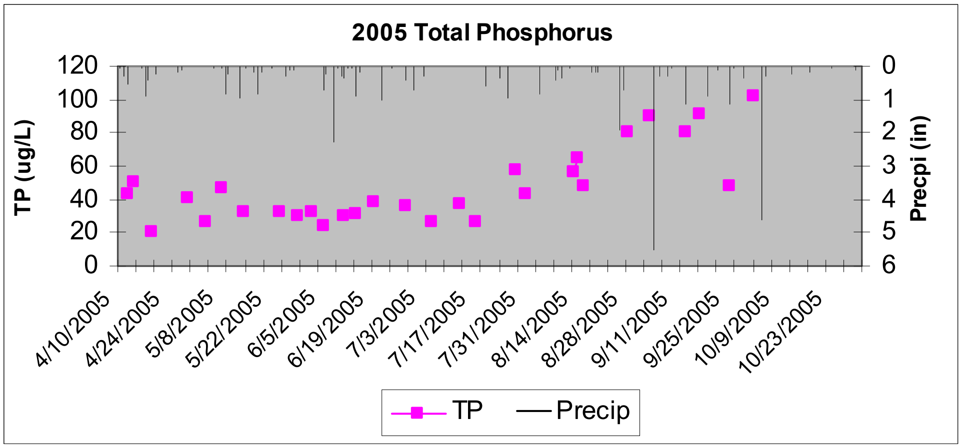
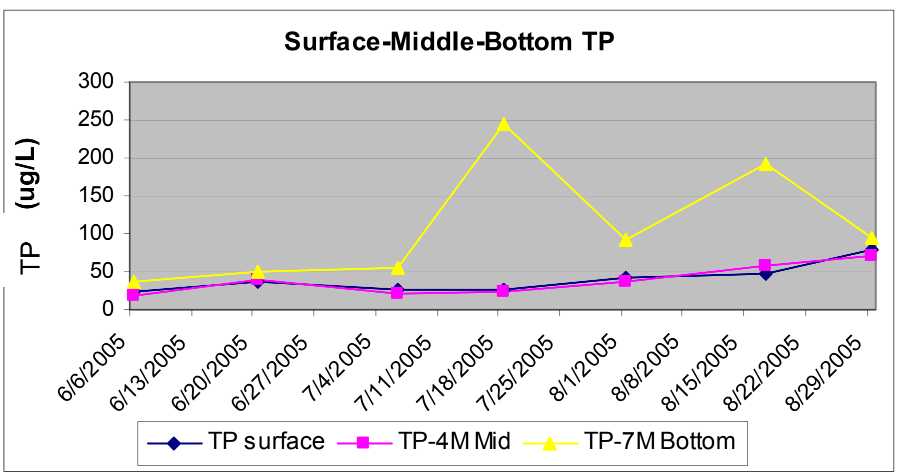



**Figure 2.5. Burandt Lake surface total phosphorus concentrations during the 2005 summer sampling season.**



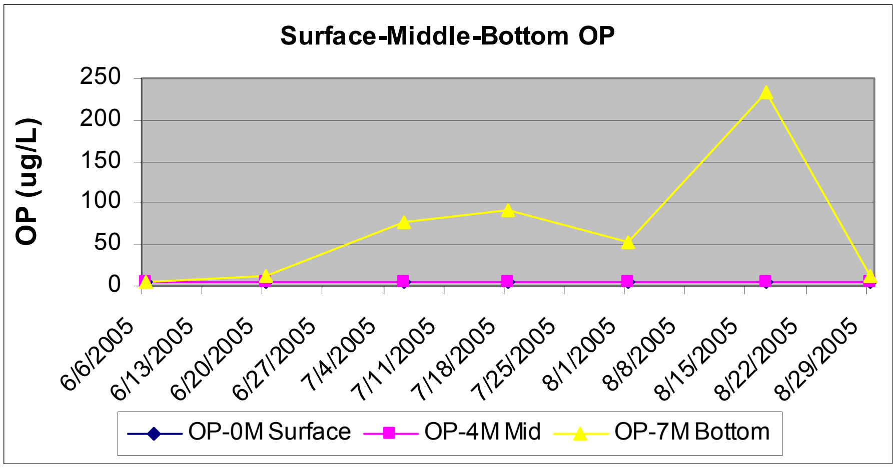



**Figure 2.6. Burandt Lake surface, middle and bottom total phosphorus and orthophosphorus concentrations during the 2005 summer sampling season. Note: Surface OP mimics the middle depth OP.**

Total phosphorus and orthophosphorus were similar in the surface and mid depth samples both increasing throughout the summer (figure 2.6). Total phosphorus and orthophosphorus in hypolimnetic samples were similar to surface samples early in the summer, but began to differentiate in late June when the lake began to form a stronger thermal stratification. The increasing trends of phosphorus in the hypolimnion suggest internal phosphorus release from the lake sediments. In addition, a majority of the phosphorus is orthophosphorus, further indicating the release of phosphorus from internal sources. In early August, phosphorus in the hypolimnion decreased to near surface values and, in late August, epilimnetic and hyplimnetic phosphorus were similar. Both instances indicted periods when mixing events of the water column occurred; first, a mid-season partial mixing of the water column; the latter, complete fall turn-over. When the water column is mixed, phosphorus in the cool, dense hypolinimon is released and made available for algal production.

Note that orthophsophorus concentrations on 7/6 and 8/17/05 exceed that of total phosphorus concentrations. According to the Metropolitian Council Laboratory, this type of result could be due to inaccuracies in field procedures used to collect the sample or laboratory analysis procedures. However, the lab does feel confident that the results can be interpreted as having equal total and orthophosphorus concentrations.

The instances above aid in explaining the increase in surface water total phosphorus, which began in late June (figure 2.5, 2.6). However, hypolimnetic release is not the sole cause of the increase. First, the lake has a large littoral area. Since this area is probably too shallow to thermally stratify, anoxic sediments can release phosphorus over the entire summer season. Next, there is some phosphorus released by the senesce of curlyleaf pondweed in late June/early July. Finally, there were two precipitation events over five inches in September and October, which caused runoff from stormwater in the direct watershed. The effects of all of these instances is magnified late in the season because water inflow from Lake Waconia is diminished, thereby decreasing its positive flushing effect on Burandt Lake. Past years have demonstrated a similar increase in phosphorus over the summer (appendix A).

Lake Waconia outlet flow is not regulated. Flow from Lake Waconia into Burandt Lake is diminished late in the season due to lower water levels in Lake Waconia. Precipitation events late in the summer are typically not enough to elevate Lake Waconia to the point that it overflows at the outlet. Thus, the Burandt Lake response to precipitation late in the season is thought to be a result of runoff form the direct watershed.

#### 2.9.4.3 Chlorophyll-a and Secchi depth

Chlorophyll-a is a good estimator of algal biomass. In addition, Secchi depth aids in the prediction of algal production by measuring the clarity of lake water. Chlorophyll-a concentrations remain fairly low throughout early summer, and increase beginning in August. Chlorphyll-a concentrations generally track with changes in total phosphorus concentrations, and Secchi depth generally corresponds with chlorophyll-a concentrations. All readings remained greater than 1 meter prior to the increase in chlorophyll-a in August. The results suggest that algal growth responds to inputs of phosphorus, which is seen late in the summer when the phosphorus rich water in the hypolimnion is mixed with the epilimnion.

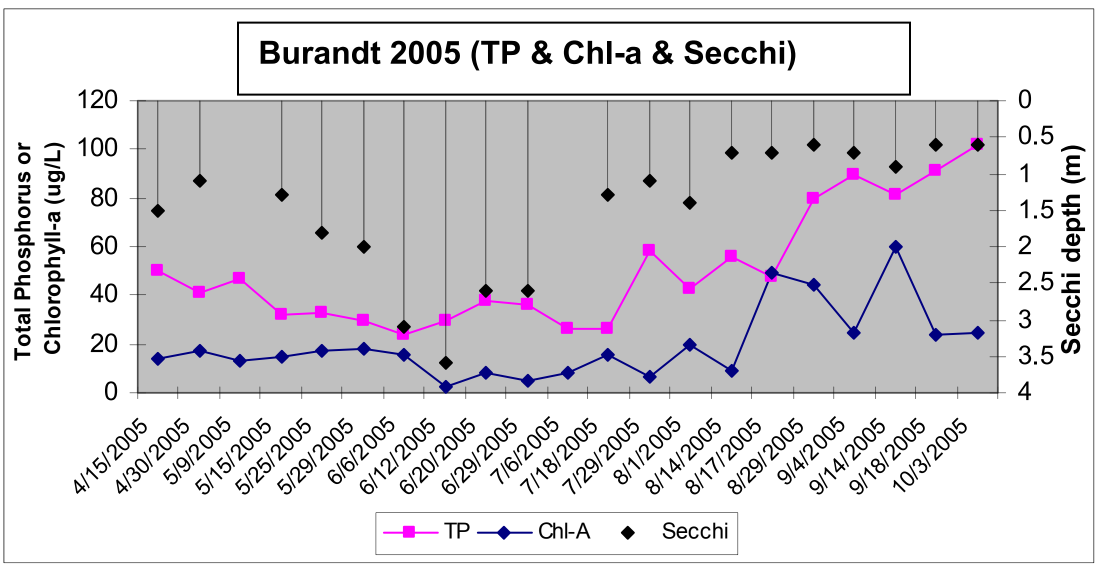



**Figure 2.7. Total phosphorus, chlorophyll-a, and Secchi depth for the summer 2005 growing season.**

#### 2.9.4.4 Historical Water Quality

The earliest record of water quality in Burandt Lake was recorded in 1999 by the CLMP. The parameters measured were recorded to be poorer than that of current water quality. Since the shutdown of the sewage treatment plant prior to 1970, Burandt Lake has continued to see a subtle downward shift in total phosphorus and total kejdahl nitrogen, and increased Secchi depths. A study conducted on internal loading in shallow lakes by G. Dennis Cooke (1995) indicates that following the diversion of external loading, the internal load will eventually decline. However, the time required may be very long.

### 2.9.5 Conclusions

Burandt Lake has historically demonstrated eutrophic conditions, although there has been a continual improvement in water quality since 1999. Currently, Burandt Lake has water quality at or near MPCA standards during a majority of the summer, at which time Lake Waconia provides nearly all of the inflow into the lake. Evidence suggests that internal loading of phosphorus plays a major factor in Burandt Lake water quality. Anoxic sediments rich in phosphorus are released into the epilimnion throughout the growing season due to partial water column mixing events. In addition, phosphorus can be released in littoral areas by wind mixing, rough fish rooting, curly leaf pondweed senescence, and boat propeller disturbance. External sources also play a role in phosphorus loading. Inflow from the Scheuble Lake watershed moves into Burandt Lake during spring runoff. However, evidence suggests that flow is minimal during spring runoff, and non-existent over the summer season. External loading also occurs during high precipitation events, which spur stormwater flow from impervious areas and the direct watershed. The effects of all phosphorus sources are magnified at times when flow from Lake Waconia is diminished, thereby eliminating its positive flushing effect.

# 3.0 Target Identification and Determination of Endpoints

## 3.1 MINNESOTA WATER QUALITY STANDARDS AND ENDPOINTS

The MPCA has established numerical thresholds based on ecoregions for determination of Minnesota lakes as either impaired or unimpaired. The protected beneficial use for all lakes is aquatic recreation (swimming). Table 3.1 outlines the MPCA water quality goals (MPCA 2005). These goals were used to determine that Burandt Lake should be placed on the 303(d) list of impaired waters in Minnesota. For more information on the MPCA's current and proposed water quality goals, go to the MPCA Web site at: http://www.pca.state.mn.us/water/tmdl/index.html#publications and click on: 2006 Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment.

**Table 3.1. MPCA goals for protecting swimming use (North Central Hardwood Forests Ecoregion) (MPCA 2005) as compared to 2005 Burandt Lake summer means.**

| Impairment Designation | Total Phosphorus (µg/L) | Chlorophyll-a (µg/L) | Secchi Depth (m) |
|---|---|---|---|
| Full Use | <40 | <15 | $\geq$1.6 |
| Review | 40 – 45 | NA | NA |
| Impaired | >45 | >18 | <1.1 |
| **Burandt Lake 2005** | **56** | **20** | **1.4** |

However, a water quality standards rules revision is currently in progress. The new rules provide for nutrient cycling differences between shallow and deep lakes, resulting in more appropriate standards for Minnesota lakes. The proposed numerical standards are provided in Table 3.2.

**Table 3.2. Proposed MPCA goals for protecting Class 2B waters. Values are summer averages (June 1 through September 30) (MPCA 2005).**

| Parameters | Ecoregions | | | |
|---|---|---|---|---|
| | North Central Hardwood Forest | | Western Corn Belt Plains | |
| | Shallow[1] | Deep | Shallow[1] | Deep |
| **Phosphorus Concentration (µg/L)** | 60 | 40 | 90 | 65 |
| **Chlorophyll-a Concentration (µg/L)** | 20 | 13 | 30 | 22 |
| **Secchi disk transparency (meters)** | >1 | >1.5 | >0.7 | >0.9 |

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

Determining appropriate goals and endpoints for lakes is an essential part of the TMDL process. In this case, Burandt Lake, according to the MPCA definition, is considered a deep lake in the North Central Hardwood Forest (NCHF) ecoregion. Therefore, the NCHF ecoregion deep lake standard of 40 µg/L will be set as the goal for Burandt Lake.

## 3.2 PRE-EUROPEAN SETTLEMENT CONDITIONS

Another consideration when evaluating nutrient loads-to-lakes is the natural background load. Ultimately, the background load represents the load the lake would be expected to receive under natural, undisturbed conditions. This load can be determined using ecoregion pre-European settlement nutrient concentrations, as determined by diatom fossil reconstruction. Diatom inferred total phosphorus concentrations are presented in Table 3.3 for both the North Central Hardwood Forest and Western Cornbelt Plains (WCBP) ecoregions.

**Table 3.3. Pre-European settlement total phosphorus concentrations based on water quality reconstructions from fossil diatoms (MPCA 2002).**

| Parameters | Ecoregions | | | |
|---|---|---|---|---|
| | North Central Hardwood Forest | | Western Corn Belt Plains | |
| | Shallow[1] (75th Percentile) | Deep (75th Percentile) | Shallow[1] (75th Percentile) | Deep (75th Percentile) |
| **Total Phosphorus Concentration (µg/L)** | 47 | 26 | 89 | 56 |

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

Based on the diatom fossils, pre-settlement concentrations were approximately 26 µg/L for deep lakes in the NCHF ecoregion. Presumably, these are the undisturbed or best conditions for Burandt Lake. The predicted pre-European settlement phosphorus concentrations (NCHF deep lakes) were used to determine the background or natural load for Burandt Lake.

Another benchmark that may be useful in determining goals and load reductions for Burandt Lake is expected stream concentrations under natural or undisturbed conditions. Table 3.4 provides data from minimally impacted streams in the NCHF ecoregion.

**Table 3.4. Interquartile range of summer mean total phosphorus concentrations for minimally impacted streams in the North Central Hardwood Forest Ecoregion of Minnesota (MPCA 2005).**

| **Region** | **Total Phosphorus (µg/L)** | | |
|---|---|---|---|
| | **25$^{th}$ Percentile** | **50$^{th}$ Percentile** | **75$^{th}$ Percentile** |
| NCHF | 60 | 90 | 150 |

As we explore load-reduction scenarios, these benchmarks can be used to assess what constitutes reasonable concentrations for streams within the watershed. The data collected from minimally-impacted streams serves as one source for comparison.

## 3.3 MINNESOTA NON-DEGRADITION POLICY

An important aspect of water quality standards in Minnesota is the non-degradation policy. The fundamental concept of non-degradation is the protection of water bodies already meeting State water quality standards (MPCA 2006).
A more thorough discussion of Minnesota's non-degradation policy can be found in MPCA's "Guidance Manual for Assessing the Quality of Minnesota Surface Waters" (MPCA 2005). This TMDL is prepared within the State of Minnesota's non-degradation policy.

# 4.0 Phosphorus Source Assessment

## 4.1 INTRODUCTION

A key component to developing a TMDL is to understand the sources of nutrients in a lake. This section provides a brief description of the potential phosphorus sources in the direct watershed and indirect watersheds.

**Table 4.1 Identified potential phosphorus sources to Burandt Lake; listed in no particular order.**

| Identified Phosphorus Sources |
|---|
| Septic Systems (SSTS) |
| Atmospheric Deposition |
| Internal Phosphorus Release |
| Urban/Development Runoff |
| Agricultural Runoff |
| Animal Waste |
| Surface Water Exchange |

### 4.1.1 Subsurface Sewage Treatment Systems (SSTS)

Failing or direct discharge SSTS can be a significant source of phosphorus to surface waters. While there are no SSTS located in the direct discharge area of Burandt Lake, there are several SSTS remaining in the indirect subwatersheds. It is difficult to predict the exact contributions from the SSTS because they first drain to another lake, thus SSTS will not be accounted for directly in the TMDL. However, we do recognize the potential for phosphorus loading from SSTS, particularly direct discharge systems. This source will be addressed during implementation.

### 4.1.2 Atmospheric Deposition

Precipitation contains phosphorus that can ultimately end up in the lakes as a result of direct input on the lake surface or as a part of stormwater runoff from the watershed. Although atmospheric inputs must be accounted for in development of a nutrient budget, direct inputs to the lake surface are impossible to control and are consequently considered part of the background load.

### 4.1.3 Internal Phosphorus Release

Burandt Lake is transitionally dimictic and completely mixes in the spring and fall of each year. Lake data indicates that there are increasing trends of phosphorus and orthophosphorus concentrations in the hypolimnion over the summer, which suggests internal phosphorus release from the lake sediments. In addition, knowledge of the lake tells us that high levels of phosphorus are likely present in the lake sediments due to the historic (pre 1970) point source discharge from the City of Waconia sewage treatment plant.

Internal phosphorus loading from lakes has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult in lakes that completely or partially mix several times throughout the year. Furthermore, there is inadequate understanding of the longevity and mechanisms of internal loading resulting from diverted effluent, as is the case with the Waconia Sewage Treatment Plant. Internal loading in some lakes following the diversion of external loading is expected to last over 30 years (Welch & Cooke 1995).

### 4.1.4 Urban /Development Runoff

Stormwater runoff is one of the largest sources of phosphorus to Burandt Lake. As a result, storm sewer systems transport of urban runoff to Burandt Lake is quite efficient. Other materials are transported to the water bodies include grass clippings, fertilizers, leaves, car wash wastewater, and animal waste. All of these materials contain phosphorous that impairs local water quality. Some of the material may add to increased internal loading through the breakdown of organics and subsequent release from the sediments. The addition of organic material into Burandt Lake increases the sediment oxygen demand, further exacerbating the duration and intensity of sediment phosphorous release from lake sediments. Consequently, monitoring stormwater runoff is another important tool in determining water quality in urban and urbanizing watersheds such as Burandt Lake. Note: As of January 1, 2005 all fertilizers containing phosphorus were banned from use on lawns in Minnesota. The only exceptions to this ruling are when establishing new lawns, or a soil test shows the need for phosphorus.

### 4.1.5 Agricultural Runoff

Agricultural runoff can supply a significant phosphorus load to surface waters by transporting eroded soil particles and excess fertilizers. A very minimal portion of the direct drainage into Burandt Lake is in agriculture, and all agricultural land use in this area will become urban according to 2030 projections. Large portions of the indirect subwatersheds remain in agricultural conditions with no plans for future development. Runoff and erosion from these fields can contribute to watershed phosphorus loads to Burandt Lake.

### 4.1.6 Animal Waste

Animal agriculture can have a large affect on water quality, especially nutrients. Animal waste, which contains large amounts of both phosphorus and nitrogen, is often applied to agricultural fields as fertilizer. In fact, a regional Minnesota study suggests that the applied manure represents a 74% greater amount of phosphorus than the amounts recommended by the University of Minnesota (Mulla et al. 2001). This can average an extra 35 pounds per acre of phosphorus which will ultimately be available for runoff. Additionally, runoff from feedlots and manure applications can transport animal waste high in phosphorus to surface waters.

There are no feedlots within the Burandt Lake direct watershed, however, there is one feedlot near the south watershed boundary with approximately 18 animal units. These animals do have the opportunity to periodically roam into the watershed boundaries. However, measures are taken to prevent animals and their waste in this feedlot from entering Burandt Lake. There are presently no feedlots present in the Scheuble Lake watershed and several present in the Lake Waconia subwatershed. Records do not indicate that animal waste is spread onto the agricultural fields in the indirect subwatersheds. Thus, animal waste was not accounted for directly in the development of the TMDL. As such, runoff from animal waste will play a minimal role in managing phosphorus loading to Burandt Lake

### 4.1.7 Surface Water Exchange

Both Lake Waconia and Scheuble Lakes drain directly into Burandt Lake. Consequently, water and potential nutrients flow out of the lakes and into Burandt Lake. All exchange of phosphorus was assumed to occur through advective exchange (water moving through). Burandt Lake receives nearly its entire water budget, approximately 80%, from Lake Waconia suggesting that the water quality of Lake Waconia has heavy influence on the water quality of Burandt Lake. The water quality in Lake Waconia to this point is within State standards with a growing season average of 34µg/L (n=10). Estimates suggest that Scheuble Lake inflow accounts for approximately 5% of the inflow into Burandt Lake during periods of high flow, particularly in the spring. The last time data was collected on Scheuble Lake was in 1999, and results indicated that the average phosphorus was 215µg/L (N=2). Accordingly, Lake Waconia flushes good quality water through Burandt Lake, while Scheuble Lake likely contributes to the nutrient budget early in the season.

### 4.1.8 Wetlands

The correlation between wetlands and water quality is that wetlands act as a sink for nutrients such as phosphorous. However, wetlands can become contaminated with agricultural and/or urban runoff, thus becoming another source of excess phosphorus that may end up in the lake. There are approximately 80 acres of wetlands in the direct drainage area and another 875 acres of wetlands in the contributing or indirect watersheds. No data has been collected regarding the phosphorus concentrations in the wetlands. As indicated above, these wetlands do have the potential to contribute to the phosphorus loading into Burandt Lake, and are estimated and accounted for by modeling as described in sections 5.2.3.

# 5.0 Linking Water Quality Targets and Sources

## 5.1 MODELING INTRODUCTION

A detailed nutrient budget can be a useful tool for identifying management options and their potential effects on water quality. Additionally, lake response models can be developed to understand how different lake variables respond to changes in nutrient loads. With this information, managers can make educated decisions about how to allocate restoration dollars and efforts, as well as predict the resultant effect of such efforts.

## 5.2 SELECTION OF MODELS AND TOOLS

Modeling was completed using two independent platforms including a Reckhow-Simpson spreadsheet and the BATHTUB V6.1 (Walker 1999) model. The Reckhow-Simpson was used to develop watershed hydraulics and runoff volumes through calibration to collected data. The BATHTUB Model was calibrated utilizing monitored data and watershed output from the Reckhow-Simpson Model as described in the following sections.

These models where selected because they are excellent at prediction of water quality when limited monitoring data is available. The Reckhow-Simpson spreadsheet model was selected to estimate water and phosphorus loads for each of the sub-watersheds because there is no data regarding phosphorus export from the Burandt Lake subwatersheds. A detailed description of the Reckhow-Simpson model can be found in section 5.3. Outputs from the Reckhow-Simpson model were then utilized as input into the BATHTUB model. For Burandt Lake, because data was insufficient to develop a dynamic model, the two-dimensional steady state model, BATHTUB (Walker, 1996), was chosen to predict lake response to nutrient loading.

## 5.3 RECKHOW-SIMPSON MODEL

The Reckhow-Simpson Model was used for estimating water and phosphorus loads for unmonitored subwatersheds. The model relies on phosphorus export coefficients and land use area to estimate water and phosphorus loading. This model can be used to estimate the relative phosphorus contribution of each land-use category within the watershed. Output from the Reckhow-Simpson model was used to calibrate the BATHTUB model.

The Reckhow-Simpson model was used to derive nutrient load information for use as input into the BATHTUB model. The Reckhow-Simpson Model was utilized because it can predict water and phosphorus loads to the lake when limited monitoring data is available. The model estimates the loads for the watershed of concern by entering detailed land use area information derived from GIS about each subwatershed within the study area. Land use information and phosphorus export rates are then converted into a range of predicted phosphorus concentrations. As such, the model allows for three possibilities of phosphorus export to the lake; low, average, and high. Using a model that predicts a potential range of phosphorus loading can help to determine potential phosphorus loads in a variety of conditions. Development of the Reckhow-Simpson model is detailed below in sections 5.3.1 and 5.3.2.

### 5.3.1 Watershed Hydrology

Watershed runoff was estimated using runoff coefficients assuming average watershed slopes of less than 2% (Ward And Elliott 1995). Runoff coefficients used are presented in Table 5.1.

**Table 5.1. Runoff coefficients used to estimate runoff from the Burandt Lake Watershed.**

| Land Use | Watershed runoff coefficients |
|---|---|
| Developed | 0.25 |
| Natural | 0.07 |
| Water | 1 |
| Agriculture | 0.23 |
| Wetland | 1 |

Runoff coefficients were developed by applying literature values to the entire 52,923 acre Carver Creek watershed, and then adjusting the values to better predict monitored annual runoff volumes. Actual watershed runoff was monitored at Carver Creek site CA 1.7, which is monitored continuously by the Metropolitan Council Environmental Services Watershed Outlet Monitoring Program (WOMP). Predicted and monitored annual runoff volumes are presented in Table 5.2. Monitored runoff was very low in 2000 due to both the low precipitation (25.39 inches) and the timing of precipitation. Most of the precipitation occurred mid-summer at which time vegetation was present and absorbed the majority of rainfall. Most years had a runoff difference of less than 20% and were deemed to be reasonable to apply to the Burandt Lake watershed.

**Table 5.2. Predicted (runoff coefficient) and monitored annual runoff for the Carver Creek Watershed (52,923 acres).**

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|
| **Predicted Runoff (ac-ft)** | 25,109 | 23,739 | 21,208 | 24,316 | 30,413 | 19,655 | 2,5061 | 35,241 |
| **Monitored Runoff (Ac-ft)** | 26,680 | 23,190 | 3,772 | 28,451 | 38,155 | 17,489 | 20,965 | 28,704 |
| **Percent Difference** | -6% | 2% | 82% | -17% | -25% | 11% | 20% | 19% |

### 5.3.2 Land Use Load

Land use loads were based on GIS files provided by the Carver County GIS Department. Land use loading rates were applied to the watershed land use (Table 5.3) to initially estimate watershed phosphorus loads. Conservative phosphorus export coefficients were selected based on values that best represented conditions in the Burandt Lake watershed, as well as experience from other watersheds in central Minnesota. Additionally, values were compared to concentrations used in other similar lake studies (MPCA 2005).

**Table 5.3 Phosphorus loading rates used to predict watershed runoff concentrations.**

| | Total Phosphorus Loading Rate (kgP/ha/yr) | | | Total Phosphorus Concentration[1] (µg/L) | | |
|---|---|---|---|---|---|---|
| Loading Rates (kg/ha) | Low | Average | High | Low | Average | High |
| Developed | 0.3 | 0.4 | 0.6 | 135.2 | 216.3 | 324.5 |
| Forest | 0.01 | 0.04 | 0.08 | 19.3 | 77.3 | 154.5 |
| Agriculture | 0.2 | 0.5 | 1.3 | 117.6 | 293.9 | 587.8 |
| Wetland | 0.2 | 0.3 | 0.4 | 27.0 | 40.6 | 54.1 |

[1]Based on average precipitation (29 inches).

Using a model that predicts a potential range of phosphorus loading can help to determine potential phosphorus loads in a variety of conditions. Actual phosphorus loading rates likely fall somewhere between the low end and high end of the estimated loading rates. When considering loading rates for the developed areas, it was assumed that no best management practices (BMP's) were in place within the watersheds.

## 5.4 PHOSPHORUS BUDGET COMPONENTS

### 5.4.1 Internal Load

Based on the knowledge described in section 4.1.3, internal load terms for 2000 and 2005 were determined based on a residual process utilizing the BATHTUB model. After accounting for and entering land use and nutrient loads corresponding to the segment and tributaries using a 1.0 $mg/m^2/day$ of internal loading, the model was run. Predicted and observed values were evaluated. At this point, if the in-lake predicted phosphorus values remained below that of the observed, additional internal loading was added until the predicted and observed nutrients were within 10 percent of each other. This process suggests that the internal load is the load remaining after all external sources have been accounted for. The final internal loading terms were entered at 1.7 and 2 $mg/m^2/day$ for 2005 and 2000 respectively.

To further backup internal loading rates, several journal articles on internal loading in lakes with similar structure were studied, and similar internal loading rates were discovered. Welch and Cooke indicate that typical internal load phosphorus release rates for both stratified and unstratified eutrophic lakes range from 2 to 5 $mg/m^2/day$[1] (1995).

### 5.4.2 Atmospheric Load

Atmospheric loading rates were set at a rate of 20 $kg/km^2/yr$ based on conversations with the MPCA and literature values.

### 5.4.3 Surface Water Exchange

To effectively determine phosphorus loading from Lake Waconia and Scheuble Lake, independent BATHTUB models were set up and calibrated in a similar fashion to Burandt Lake. As such, 2000 and 2005 models for Scheuble Lake were calibrated utilizing the observed 1999 data (215µg/L TP) and the Reckhow-Simpson spreadsheet was utilized to determine phosphorus and water runoff from the watershed. The Waconia Lake model was calibrated using the summer average of the monitored data equaling 30µg/L TP for both 2000 and 2005. Because monitoring at W10 depicted the quality of the water moving out of Lake Waconia, the actual average growing season concentration was used as the input in the Burandt Lake model. Output was then entered into the

Burandt Lake model as tributaries (table 5.4). To improve the confidence of the Scheuble Lake model, monitoring should occur in Scheuble Lake as part of the implementation of the TMDL.

**Table 5.4. BATHTUB model outputs for Scheuble Lake and Lake Waconia.**

| Year | Lake | Watershed Area ($km^2$) | P Concentration (µg/L) | Outflow (hm3/yr) |
|---|---|---|---|---|
| 2005 | Scheuble | 1.35 | 232 | 0.6 |
| | Waconia | 16.8 | 37[1] | 8 |
| | | | | |
| 2000 | Scheuble | 1.35 | 232 | 0.3 |
| | Waconia | 16.8 | 37 | 3.7 |

1 average growing season average at W10

### 5.4.4 Tributary or Watershed Load

The tributary load from stormwater runoff from the watershed was developed using the Reckhow-Simpson Model calibrated to the actual runoff volumes for Carver Creek. For development of the loads, we used the low estimated phosphorus concentration because it best represents monitored conditions in the watershed.

## 5.5 MODEL VALIDATION AND BENCHMARK PHOSPHORUS BUDGET

### 5.5.1 BATHTUB Model

The BATHTUB model was set up to simulate Burandt Lake's nutrient response. BATHTUB is a standard modeling tool and is widely used for eutrophication assessments in Minnesota and elsewhere. Details on the BATHTUB model can be found in Walker (1999) and at the USACE web site:
http://www.wes.army.mil/el/elmodels/index.html#wqmodels.

The BATHTUB model for Burandt Lake was calibrated and validated using data for the years 2000 and 2005 (Appendices B and C). Monitored lake and subwatershed data were used to calibrate the model. For unmonitored portions of the lake's watershed, the Reckhow-Simpson model was used to estimate P loads. The selection of model options in BATHTUB was based on past experience in modeling lakes in Minnesota. We chose the Canfield-Bachmann model for natural lakes to predict in-lake total phosphorus concentrations. The model option selected for chlorophyll-*a* was the empirical relationship between chlorophyll-*a* and P, N, light, and temperature. Secchi depth was predicted using the empirical relationship between Secchi depth and chlorophyll-*a* and turbidity. Model coefficients available in the model for calibration or adjustment were left at the default values except for the Secchi/chlorophyll-*a* slope, which was decreased from 0.025 to 0.015 based on the relationship from Minnesota Lakes.

Following calibration and validation, the 2005 version of the BATHTUB model was then used to simulate current and possible future conditions (Appendix C).

### 5.5.2 Model Validation

Results from the 2000 (dry year) and 2005 (wet year) are presented as the predicted and observed values and a coefficient of variation (standard error of the mean). Here we will focus on the primary indicators of trophic status: total phosphorus, chlorophyll-a, and Secchi depth. Predicted phosphorus concentrations best reflected the observed values only after the internal loading was accounted for, suggesting that internal loading is a critical component to water quality in Burandt Lake.

**Table 5.5. Observed and predicted in-lake water quality for Burandt Lake in 2000 and 2005 (growing season).**

| Year | Variable | Predicted | | Observed | | Number Samples |
|---|---|---|---|---|---|---|
| | | Mean | CV | Mean | CV | N[1] |
| 2005 (42.18 inches) | Total Phosphorus (µg/L) | 55.0 | 0.14 | 56.0 | 0.46 | 16 |
| | Chlorophyll-a (µg/L) | 24.2 | 0.29 | 20.4 | 0.83 | 16 |
| | Secchi Depth (meters) | 1.3 | 0.19 | 1.4 | 0.70 | 16 |
| | | | | | | |
| 2000 (25.39 inches) | Total Phosphorus (µg/L) | 68.7 | 0.19 | 71.1 | 0.33 | 7 |
| | Chlorophyll-a (µg/L) | 31.2 | 0.31 | 44.8 | 0.64 | 7 |
| | Secchi Depth (meters) | 1.0 | 0.19 | 0.8 | 0.25 | 7 |

1 Number of samples for summer growing season (June 1- September 31)

The model represents reasonable agreement in both 2000 and 2005. Differences are considered to be reasonable, and well within the error term associated with the Canfield-Bachmann, chlorophyll-a, and Secchi response models.

### 5.5.3 Benchmark Phosphorous Budget

One of the key aspects of developing TMDLs is an estimate of the nutrient budget for the lake in question. Monitoring data from 2005 and modeling were used to estimate the current sources of phosphorus to Burandt Lake. Nutrient and water budgets are presented in table 5.6. This budget does not account for any groundwater exchange; and it is assumed that the lake acts as both a groundwater discharge and recharge area so the net affect on the water or nutrient budgets is very small.

Internal loads are considered to be a substantial source of phosphorus to Burandt Lake contributing approximately 34% of the overall phosphorus load. In fact, if no internal load is accounted for, the water quality in Burandt Lake is similar to that of Lake Waconia. This process is exemplified by the fact that Lake Waconia contributes a substantial portion of water load to Burandt Lake. As such, the phosphorus and water loads flowing into Burandt Lake from Lake Waconia aid in diluting and flushing nutrients out of Burandt Lake. The Lake Waconia watershed contributes 43% of the phosphorus load to Burandt Lake, although the Lake Waconia water quality is within state standards. The Scheuble Lake watershed contributes approximately 18% of the phosphorus load, which is thought to take place early in the season when flows are high. The direct inflow into Burandt Lake is minimal in relation to other sources but does have the potential to contribute during runoff events. Depending on yearly precipitation, the lake retains approximately 23% of the phosphorus load (internal and external). The low nutrient retention of Burandt Lake is due to the high loads of water flowing through Burandt Lake from Lake Waconia.

**Table 5.6. Summary of current total phosphorus and water budget for Burandt Lake based on 2005 data and BATHTUB modeling.**

| **Subwatershed** | **Area $km^2$** | **Water Inflow $hm^3/yr$** | **Estimated TP Load kg/yr** | **Percent of total Load** |
|---|---|---|---|---|
| Lake Waconia Watershed (W10) | 16.8 | 8.0 | 296 | 43% |
| Scheuble Lake Watershed | 1.4 | 0.6 | 126 | 18% |
| Direct Inflow | 1 | 0.5 | 28 | 4% |
| Atmospheric Deposition | | 0.8 | 7 | 1% |
| **Total External** | **19.2** | **9.9** | **457** | **66%** |
| | | | | |
| **Total Internal** | | | **230** | **34%** |
| | | | | |
| **TOTAL P LOADING** | | | **687** | **100%** |
| | | | | **Residence time: ~ 40 days Nutrient Retention: 24.8%** |

## 5.6 CONCLUSIONS

Internal Load

Internal sources of phosphorus have the largest impact on water quality in Burandt Lake. If no internal sources are accounted for, the water quality in the lake would be similar to that of Lake Waconia.

External Load

Because Lake Waconia and Burandt Lake are connected, any phosphorus loading (specifically direct runoff from the Burandt Lake watershed and the Scheuble Lake subwatershed) will decrease the quality of water in Burandt Lake. Thus, areas of focus should include the Scheuble Lake watershed and direct inflow while maintaining, or slightly improving, the water quality from Lake Waconia.

# 6.0 TMDL Allocation

## 6.1 LOAD AND WASTELOAD ALLOCATIONS

Using the Canfield-Bachmann equation, loads and load reductions were calculated for Burandt Lake. Loads in this TMDL are set for phosphorus since this is typically the limiting nutrient for nuisance aquatic plants. The TMDL equation is as follows:

**TMDL = WLA + LA + MOS + RC**

where WLA = wasteload allocation, LA = load allocation, MOS = margin of safety, and RC = reserve capacity.

This TMDL is written to solve the equation for a deep lake in the NCHF ecoregion in the State of Minnesota. Therefore, the lake phosphorus standard will be subject to meet 40µg/L phosphorus as a final goal.

### 6.1.1 Critical Condition

The critical condition for Burandt Lake is the summer growing season. Minnesota lakes typically demonstrate impacts from excessive nutrients during the summer recreation season (June 1 through September 31), including excessive algal blooms and fish kills. Lake goals have focused on summer-mean total phosphorus, Secchi transparency and chlorophyll-a concentrations. Consequently, the lake response models are focused on the summer growing season as the critical condition. Loads are expressed both as annual and daily loads; however, an annual load better represents this TMDL because the growth of phytoplankton and aquatic plants respond to changes in the annual load and not the daily load. The TMDL is based on an average precipitation year (Table 6.1). The selected average precipitation year was 2001.

**Table 6.1. TMDL as set for an average precipitation year (29.11 inches).**

| | TMDL | WLA | LA | MOS | RC |
|---|---|---|---|---|---|
| **kg/yr** | 321 | 48 | 273 | Implicit | 0 |
| **kg/day** | 0.88 | 0.13 | 0.75 | Implicit | 0 |

### 6.1.2 Load Allocations (LAs)

The LA includes atmospheric deposition, internal loading, and watershed runoff outside 2030 urban boundaries (See Appendix E). All three sources are allocated here as a gross load; the reduction approach is outlined in the implementation plan. Atmospheric and internal loading are assumed to remain the same regardless of precipitation levels, although it is likely that the internal load does increase in dry years.

### 6.1.3 Wasteload Allocations (WLAs)

Stormwater discharges that are regulated under NPDES permits and allocations of phosphorus reductions are considered wasteloads, and must be allocated to the permit holders. Current and future discharges regulated by NPDES permits and classified as Municipal Separate Storm Sewer Systems (MS4s) in the Burandt Lake watershed include the City of Waconia and Carver County. As a result, the target phosphorus reductions associated with the MS4s have been designated as WLA. The unique permit numbers assigned to MS4s are as follows;

- City of Waconia- MS400232
- Carver County- MS400070

The WLA is based on urban boundaries projected by the City of Waconia 2030 Comprehensive Plans and road rights-of-way, and is allocated here as a gross load.

The stormwater WLA includes loads from construction and industrial stormwater. Loads from construction and industrial stormwater are considered to be a small percent of the total WLA and are difficult to quantify. Construction storm water activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit for discharges to impaired waters 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. Alternatively, construction storm water activities are considered in compliance if they meet local construction stormwater requirements when the local requirements are more restrictive than requirements of the State General Permit. Industrial storm water activities are considered in compliance with provisions of the TMDL if they obtain an industrial stormwater general permit under the NPDES program and properly select, install and maintain all BMPs required under the permit.

### 6.1.4 Assigning Load and Wasteload Allocations

To develop the appropriate loads in the load and wasteload allocations, conservative estimations and assumptions were used. Atmospheric loading is assumed to remain the same regardless of precipitation and because there are no BMPs to address phosphorus loads from rainfall. The internal load was allocated utilizing the 2005 phosphorus budget, and the assumption that the internal load percentage will decrease as external loads are reduced. In addition, because water quality in Burandt Lake is heavily influenced by that of Lake Waconia, the internal load will be further reduced by the water flowing out of Lake Waconia and into Burandt Lake. The land use load allocated in the LA is the portion of land that is not projected to be within urban boundaries by 2030.

The wasteload allocation includes the entire Burandt Lake watershed and portions of the subwatersheds which flow into the lake including Scheuble and Waconia Lakes. Allocations are based on 2005 phosphorus loads and 2030 urban boundaries. A more thorough discussion of the partitioning of the reductions is laid out in section 9.3. Carver County and the City of Waconia will work cooperatively to meet the phosphorus loads assigned.

Implementation will be conducted using adaptive management principals. It is difficult to predict the nutrient reduction that would occur from implemented strategies because we do not know each pollutant source contribution to Burandt Lake, and many of the strategies affect more than one source. Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL.

## 6.2 RATIONALE FOR LOAD AND WASTELOAD ALLOCATIONS

The TMDL presented here is developed to be protective of aquatic life and aquatic recreation. To aid in understanding the impacts of the phosphorus loads to the lake, we utilized a water quality response model to predict the water quality after load reductions were implemented. Utilization of this approach allows for a better understanding of potential lake conditions under numerous load scenarios. The following sections describe the results from the water quality response modeling.

### 6.2.1 Modeled Historical Loads

Using the Canfield-Bachmann equation, historic loads and load reductions were calculated for Burandt Lake. Historical allowable loads were calculated using the Canfield-Bachmann model to predict the total phosphorus load at that year's conditions that would achieve the State standards. These calculations provide some insight into the assimilative capacity of the lake under different hydrologic conditions, as well as over time. Additionally, these results provide a sense for the level of effort necessary to achieve that TMDL, and whether that TMDL will be protective of the water quality standard.

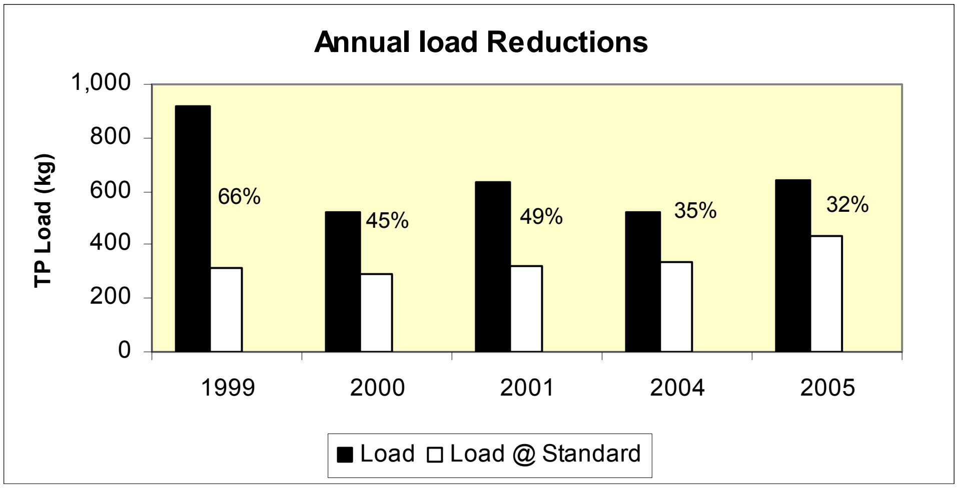



**Figure 6.1. Predicted annual loads for monitored conditions and predicted loads at the standard of 40 µg/L total phosphorus since the onset of regular monitoring. Percentages represent the necessary reduction to meet the standard.**

Based on 1999 through 2005 predicted annual total phosphorus loads, Burandt Lake requires a 32 to 66 % total phosphorus reduction to meet the summer average water quality standard of 40 ug/L total phosphorus (Figure 6.1). Over the last ten years, the lowest and maximum allowable annual phosphorus load that Burandt Lake could receive to meet the standard was 288 kilograms and 436 kilograms of phosphorus respectively.

### 6.2.2 Water Quality Response to Load Reductions

Using the previously described BATHTUB water quality response model, total phosphorus, chlorophyll-a, and Secchi depth were predicted for load reductions in 5% increments. These predicted responses can be used to develop goals for load reductions with an understanding of the overall water quality benefits.

The summary presented here applies reductions to the overall loads including precipitation and internal loading. These reductions help provide an understanding of the response of the lakes for load reductions regardless of their source.

### 6.2.3 Lake Phosphorus Response

The summer average in-lake total phosphorus responses to phosphorus load reductions are presented in Figure 6.2. The two models (wet and dry) years were predicted using a 30-50% reduction in the overall load to meet the NCHF ecoregion State water quality standard. This is similar to the modeling results using the Canfield-Bachmann equation as presented in section 5.2.1. Lake response will be dependent on the effect of external load reductions, and there impacts on internal loading in addition to possible bio-manipulation.

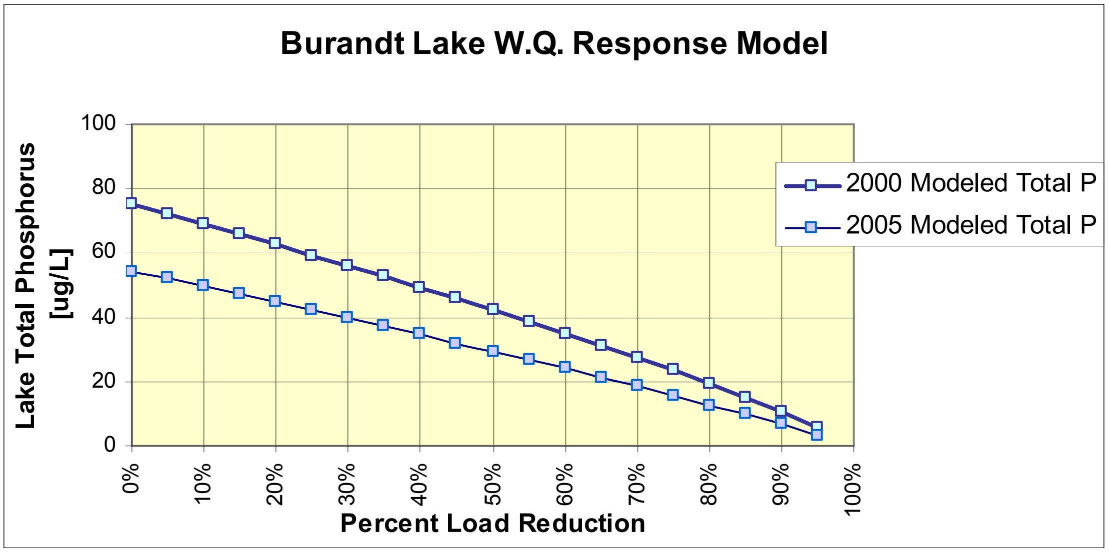



**Figure 6.2. In lake total phosphorus concentrations predicted for total phosphorus load reductions applied to Burandt Lake.**

### 6.2.4 Lake Chlorophyll-a Response

Modeled chlorophyll-a concentrations for each load reduction are presented in Figure 6.3. Chlorophyll-a concentrations do decrease with reductions in total phosphorus. However, based on the results of the model, Burandt Lake would need to reduce phosphorus near the high end (66%) of the TMDL to reach and/or get close to the chlorophyll-a goal for deep lake (13ug/L). This response is often seen in shallow-type lakes with high planktivore populations which graze zooplankton to the point where they are unable to control algae. The lagging chlorophyll response indicates the need for fish/zooplankton biomanipulation. The chlorophyll-a response to phosphorus concentrations will be monitored under adaptive management.

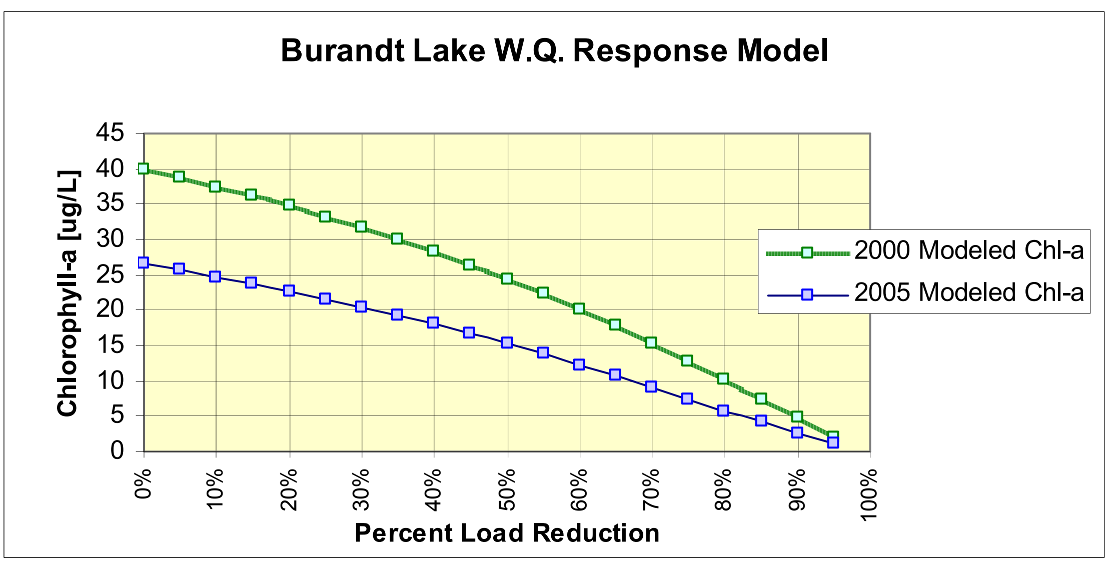


**Figure 6.3. In lake chlorophyll-a concentrations predicted for total phosphorus load reductions applied to Burandt Lake.**

### 6.2.5 Lake Secchi Depth Response

Secchi depth was responsive to the reductions in total phosphorus with the strongest response after a 40% reduction (Figure 6.4). Based on the model, the Secchi depth will surpass the NCHF ecoregion standard of greater than 1.5 feet with 30-50% reductions in total phosphorus. However, the current Secchi depth is close to that of the standard and, therefore, only small reductions in phosphorous would need to be achieved to meet the standard.

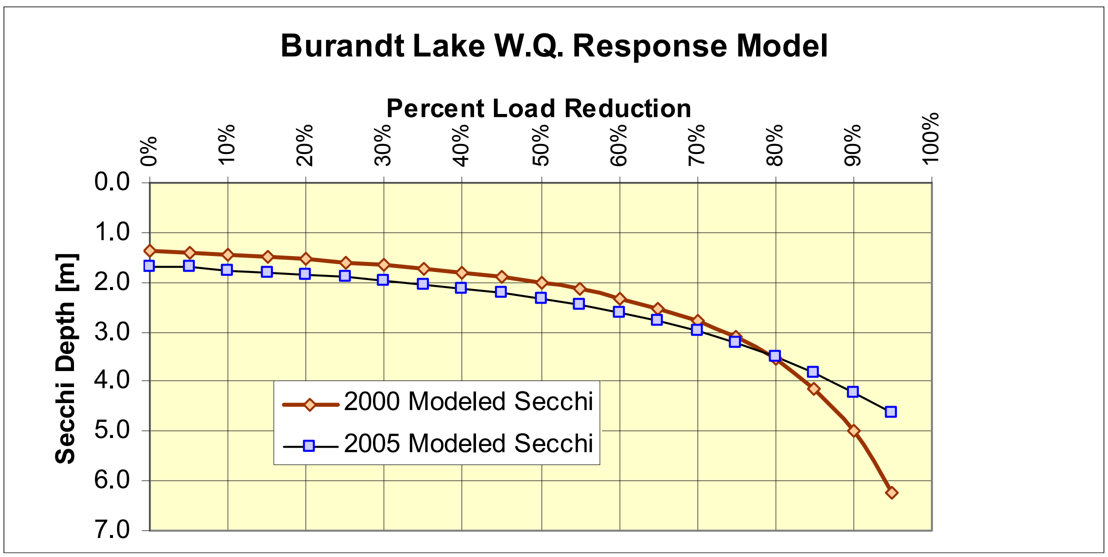



**Figure 6.4. Secchi depth predicted for total phosphorus load reductions applied to Burandt Lake.**

### 6.2.6 Summary

While modeling suggests that this TMDL will be protective of the phosphorus and Secchi water quality standards in Burandt Lake, lake responses do indicate that a larger reduction in phosphorus will be needed to result in meeting standards for chlorophyll-a. This response is the result of a high planktivore population leading to a decreased zooplankton population, which finally results in uncontrolled algae blooms. Secchi and chlorophyll-a response to phosphorus concentrations will be monitored under adaptive management, and we are confident that the TMDL will result in a marked improvement in water quality.

## 6.3 SEASONAL AND ANNUAL VARIATION

Both seasonal and annual variability have been accounted for in this TMDL. Annual variability was accounted for utilizing two modeling years. The years modeled represented a wet year (42.18 inches) and a dry year (25.39 inches). The 30-year normal precipitation is around 28.3 inches. By modeling two extreme years, we can assure that the TMDL will be protective of water quality during any condition in between. Annual variation was also addressed by setting the TMDL for wet, dry and average conditions.

The seasonal variability was accounted for by setting the TMDL for the summer growing season where recreational use is the highest and, more importantly, is the season where problematic algal blooms occur. Lake responses were similar in the two modeled years, suggesting that this TMDL will be protective of the water quality standard in Burandt Lake.

Implementation of this TMDL will be conducted utilizing the principles of adaptive management. The County will continue to monitor the lake to identify improvements and adapt implementation strategies accordingly. Under adaptive management, the County will be able to account for annual variability and adapt implementation to adjust for these differences.

## 6.4 MARGIN OF SAFETY

An implicit margin of safety has been incorporated into this TMDL by using conservative assumptions. Conservative assumptions were utilized 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. Conservative assumptions included utilization of the Canfield-Bachmann model sedimentation rates in the BATHTUB model. The Canfield-Bachmann model does not account for the higher sedimentation rates which are likely in a healthy shallow lake system. While Burandt Lake is not by definition a shallow lake, over 60 percent of the lake is littoral and likely has higher sedimentation rates. Next, no calibration factors were applied to the Canfield-Bachmann model. The sedimentation rates used in the model are low for Minnesota lakes and provides for a margin of safety.

TMDL implementation will be on an iterative basis so that course corrections, based on periodic monitoring and reevaluation, can adjust the strategy to meet the standard. After the first phase of nutrient reduction efforts, reevaluation will identify those activities that need to be strengthened, or other activities that need to be implemented to reach the standards. This type of iterative approach is more cost effective than over-engineering to conservatively inflated margins of safety (Walker 2003).

## 6.5 PROVISIONS FOR FUTURE GROWTH

The current population of the Burandt Lake watershed is 9,892. Development will continue in and surrounding the Burandt Lake watershed (see Section 4.1.4). The City of Waconia is expected to annex land over the coming years. The 2030 Comprehensive Plan suggests the boundaries will expand to cover the entire Burandt Lake direct watershed and portions of the Scheuble and Lake Waconia watersheds. The City of Waconia is currently designated for permit coverage through NPDES Phase II in the portions of the watersheds that are within the city's municipal boundaries. By 2030, Waconia will adjoin the Twin Cities Metro Area and will therefore become a mandatory MS4. When this occurs, Carver County will require permit coverage for conveyances it owns within the Burandt Lake Watershed. Thus, the two entities will be responsible for meeting the required phosphorus loads in that area. In the event that additional stormwater discharges come under permit coverage within the watershed, WLA will be transferred to these new entities based on the process used to set wasteload allocations in the TMDL. Reallocations will be public noticed. MS4s will be notified and will have an opportunity to comment on the reallocation during the public notice period.

Carver County is the Watershed Management Authority in the entire Burandt Lake Watershed including Scheuble and Lake Waconia, and has an adopted Water Management Plan and Water Management Rules. These Rules (Carver County Code – Section 153) apply standards to stormwater runoff on any new development, including phosphorus runoff standards and sediment control standards. These Rules have been in place since 2002 and incorporate NPDES and MS4 standards, as well as more strict requirements for infiltration and filtration of stormwater runoff. It is believed that the continued implementation of these rules will mitigate nutrient runoff from new development.

If needed, the County may require additional phosphorus reduction as the implementation plan for Burandt Lake is completed. County Rules could apply stricter phosphorus reductions (i.e. greater than 60%) in the Burandt lake subwatershed.

## 6.6 RESERVE CAPACITY

Reserve capacity is the amount of new loading that will be allowed under the TMDL in the future. Often, reserve capacity is the reduction of current nutrient loads beyond what is needed to meet water quality goals in order to allow some new inputs. This TMDL was set based on the need for all external sources to meet their phosphorus load equally, based on an average per-acre ratio. As land use continues to change within the watershed, the phosphorus load currently assigned to the land will still apply to the land. Thus, an increase in development can not lead to an increased average phosphorus load, and no reserve capacity is allocated.

# 7.0 Public Participation

## 7.1 INTRODUCTION

The County has an excellent track record with inclusive participation of its citizens, as evidenced through the public participation in completion of the Carver County Water Management Plan, approved in 2001. The County has utilized stakeholder meetings, citizen surveys, workshops and permanent citizen advisory committees to gather input from the public and help guide implementation activities. The use of this public participation structure will aid in the development of this and other TMDLs in the County.

## 7.2 TECHNICAL ADVISORY COMMITTEE

The Water, Environment, & Natural Resource Committee (WENR) was established as a permanent advisory committee. The WENR is operated under the standard procedures of the County for advisory committees. The WENR works with staff to make recommendations to the County Board on matters relating to watershed planning.

The make-up of the WENR is as follows:

1 County Board Member
1 Soil and Water Conservation District Member
5 citizens – (1 appointed from each commissioner district)
1 City of Chanhassen (appointed by city)
1 City of Chaska (appointed by city)
1 City of Waconia (appointed by city)
1 appointment from all other cities (County Board will appoint)
2 township appointments (County Board will appoint– must be on existing township board)
4 other County residents (1 from each physical watershed area – County)

The full WENR committee received updates on the TMDL process from its conception in 2004. At a meeting relating solely to the Burandt Lake TMDL on July 31st 2007, County staff presented the methods of TMDL development and phosphorus loading allocations. The committee was given the opportunity to give input on possible implementation scenarios between Carver County and the City of Waconia. Comments/remarks received included:

- Maybe the County WMO should assume all of the TMDL implementation responsibility.
- Cost sharing should definitely be the implementation approach.
- How is it determined which BMP provides how much load reduction? (limited research available)
- Contribution of other lakes and adjacent wetlands is key.

- Developers and landowners should be expected to contribute. City's plan for lake use should be factored in.
- Other considerations should be rough fish elimination, alum treatments, and city housekeeping (e.g. street sweeping).

As part of the WENR committee, two sub-committees are in place and have held specific discussions on the Excess Nutrients TMDL. These are the Technical sub-committee and the Policy/Finance sub-committee. Sub-committee review meetings relating to Burandt Lake were held on: June 8, 2005, July 13, 2005, and January 30, 2006.

TMDL progress, methods, data results and implementation procedures were presented and analyzed at the WENR meetings mentioned. Committee members commented on carp removal possibilities, sources, internal loading rates, and future monitoring plans. All issues commented on were considered in the development of the Draft TMDL.

## 7.3 PUBLIC SURVEYS/MEETINGS

Stakeholders that would be impacted by the Burandt Lake TMDL were given the opportunity to voice their opinions of the TMDL. Stakeholder involvement involved the following components: public survey; public meeting; and personal meetings with the City of Waconia and the City of Waconia consultants.

The user perception survey was sent out to landowners inquiring upon lake uses and perceptions in July of 2006. Due to the high number of homes within the lake watershed and lack of public access on the lake, only landowners within .25 miles of the lake were sent surveys. Nearly 400 surveys were sent out and 110 surveys were returned. Of the surveys returned, 36 percent were lakeshore owners. Many of the comments were incorporated throughout the TMDL. Below is a list of general comments and concerns respondents had for the lake and thoughts on what may be causing excess nutrients in the lake.

- Should add a public access/boat landing as most of the lake is isolated from general public.
- Lake users would like to be able to swim with out disturbance by milfoil.
- High speed boats/jet skis should be restricted due to noise and sediment disturbance.
- Runoff from fertilizer used in yards (lawns up to lakeshore), storm sewers and streets are causing pollution.
- Eurasian water milfoil is taking over the lake. Also, people kill weeds but don't remove them.
- Runoff from developments and agricultural/farming practices in the watershed are causing high nutrients.
- Sewage, which was discharged by the City of Waconia for years, is now built up in sediments.

A Burandt Lake TMDL open house was held on February 7th, 2008 at the Waconia City Hall for landowners within the Burandt Lake watershed. The open house was well attended with 46 attendees, 9 of whom were staff.

Carver County staff, along with MPCA staff, invited the City of Waconia Planners along with their engineers to a meeting and comment session regarding the WLA to the City as a MS4 in February 2007. City staff were presented with the TMDL development methods and the TMDL allocations.

# 8.0 Reasonable Assurance

## 8.1 INTRODUCTION

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurances, including a thorough knowledge of the ability to implement BMPs, as well as the overall effectiveness of the BMPs. Carver County is positioned to implement the TMDL and ultimately achieve water quality standards.

## 8.2 CARVER COUNTY

The Carver County Board of Commissioners (County Board), acting as the Water Management Authority for the former Bevens Creek (includes Silver Creek), Carver Creek, Chaska Creek, Hazeltine-Bavaria Creek, and South Fork Crow River watershed management organization areas, has established the "Carver County Water Resource Management Area" (CCWRMA). The purpose of establishing the CCWRMA is to fulfill the County's water management responsibilities under Minnesota Statute and Rule. The County chose this structure because it will provide a framework for water resource management as follows:

- Provides a sufficient economic base to operate a viable program.
- Avoids duplication of effort by government agencies.
- Avoids creation of a new bureaucracy by integrating water management into existing County departments and related agencies.
- Establishes a framework for cooperation and coordination of water management efforts among all of the affected governments, agencies, and other interested parties.
- Establishes consistent water resource management goals and standards for at least 80% of the county.

The County Board is the "governing body" of the CCWRMA for surface water management and the entire county for groundwater management. In function and responsibility the County Board is essentially equivalent to a joint powers board or a watershed district board of managers. The Burandt Lake watershed is part of the CCWRMA

The County is uniquely qualified through its zoning and land use powers to implement corrective actions to achieve TMDL goals. The County has stable funding for water management each year, but will likely need assistance for full TMDL implementation in a reasonable time frame, and will continue its baseline-monitoring program. Carver County has established a stable source of funding through a watershed levy in the CCWRMA taxing district (adopted 2001). This levy allows for consistent funding for staff, monitoring, and engineering costs, as well as on the ground projects.

The County has also been very successful in obtaining grant funding from local, state and federal sources due to its organizational structure.

Carver County recognizes the importance of the natural resources within its boundaries, and seeks to manage those resources to attain the following goals:

1. Protect, preserve, and manage natural surface and groundwater storage and retention systems.
2. Effectively and efficiently manage public capital expenditures needed to correct flooding and water quality problems.
3. Identify and plan for means to effectively protect and improve surface and groundwater quality.
4. Establish more uniform local policies and official controls for surface and groundwater management.
5. Prevent erosion of soil into surface water systems.
6. Promote groundwater recharge.
7. Protect and enhance fish and wildlife habitat and water recreational facilities.
8. Secure the other benefits associated with the proper management of surface and ground water.

Water management involves the following County agencies: Carver County Land and Water Services Division; Carver County Extension; and the Carver Soil and Water Conservation District (SWCD). The County Land and Water Services Division is responsible for administration of the water plan and coordinating implementation. Other departments and agencies will be called upon to perform water management duties that fall within their area of responsibility. These responsibilities may change as the need arises. The key entities meet regularly as part of the Joint Agency Meeting (JAM) process to coordinate priorities, activities, and funding.

## 8.3 REGULATORY APPROACH

### 8.3.1 Watershed Rules

Water Management Rules establish standards and specifications for the common elements relating to watershed resource management including: Water Quantity; Water Quality; Natural Resource Protection; Erosion and Sediment Control; Wetland Protection; Shoreland Management; and Floodplain Management. Of particular benefit to nutrient TMDL reduction strategies are the stormwater management and infiltration standards which are required of new development in the CCWRMA. The complete water management rules are contained in the Carver County Code, Section 153.

### 8.3.2 NPDES MS4 Stormwater Permits

MS4s that have been designated by the MCPA for permit coverage under Minn. R. ch. 7090 are required to obtain a NPDES/SDS stormwater permit. The Stormwater Program for MS4s is designed to reduce the amount of sediment and pollution that enters surface and ground water from storm sewer systems to the maximum extent practicable. As part of the permit the city will be required to develop and implement a stormwater pollution prevention program (SWPPP) to reduce the discharge of pollutants from their storm sewer system. The SWPPPs are required to cover six "minimum control measures" to ensure adequate stormwater management and pollution prevention. Measures include:

1) Public education and outreach.
2) Public participation/involvement.
3) Illicit discharge, detection and elimination.
4) Construction site runoff control.
5) Post-construction site runoff control, and
6) Pollution prevention/good housekeeping.

For more information visit the MPCAs Web site:
http://www.pca.state.mn.us/water/stormwater/stormwater-ms4.html.

### 8.3.3 NPDES Permits

The MPCA issues NPDES permits for Point Source discharges into waters of the state. These permits have both general and specific limits on pollutants that are based on water quality standards. Permits regulate discharges with the goals of protecting public health and aquatic life, and assuring that every facility treats wastewater. More information about permits, water quality data, and other MPCA programs can be found on the agency's Web site: http://www.pca.state.mn.us/water.

## 8.4 NONREGULATORY APPROACH

### 8.4.1 Education

The implementation of this Plan relies on three overall categories of activities: Regulation, Incentives, and Education. For most issues, all three means must be part of an implementation program.

The County has taken the approach that regulation is only a supplement to a strong education and incentive based program to create an environment of low risk. Understanding the risk through education can go a long way in preventing problems. In addition, education, in many cases, can be a simpler, less costly and more community-friendly way of achieving goals and policies. Education efforts can provide the framework for more of a "grass roots" community plan implementation, while regulation and incentives traditionally follow a more "top-down" approach. It is recognized, however, that education by itself will not always meet intended goals, has certain limitations, and is characteristically more of a long-term approach. To this end, Carver County created the Environmental Education Coordinator position in 2000. This position has principal responsibility for development and implementation of the water education work plan.

Several issues associated with the water plan were identified as having a higher priority for educational efforts. These were identified through discussions with the advisory committees, based on ease of immediate implementation and knowledge of current problem areas and existing programs. The higher priority objectives are not organized in any particular order. The approach to implement the Burandt Lake TMDL will mimic the education strategy of the water plan. Each source reduction strategy will need an educational component, and will be prioritized based on the number of landowners, type of source, and coordination with existing programs.

### 8.4.2 Incentives

Many of the existing programs on which the water management plan relies are incentive-based programs offered through the County and the Carver SWCD. Some examples include: state and federal cost share funds directed at conservation tillage, crop nutrient management, rock inlets, conservation buffers, and low interest loan programs for SSTS upgrades. Reducing nutrient sources will need to rely on a similar strategy of incorporating incentives into implementing practices on the ground. After the approval of the TMDL by the EPA and the County enters the implementation phase, it is anticipated that we will apply for monies to assist landowners in the application of BMPs identified in the Implementation Plan.

## 8.5 MONITORING

Regular bi-weekly monitoring of Burandt Lake from April-October of each year will continue as identified in the Water Plan. However, after implementation of nutrient reduction strategies, a stepped-up approach of monitoring will be conducted. Adaptive management relies on the County conducting additional monitoring as BMPs are implemented in order to determine if the implementation measures are effective, and how effective they are. Additional areas that may need to be monitored include the Scheuble Lake inlet (not monitored during the initial TMDL study), additional sampling at the inlet to the lake, wetland monitoring, sediment samples to further account for internal loading, and land use change. Furthermore, assessment of the stormwater discharge may be monitored to better grasp the nutrient loads caused by runoff from surrounding land. This monitoring will assist in evaluating the success of projects and identify changes needed in management strategies. Revision of management and monitoring strategies will occur as needed.

# 9.0 Implementation

## 9.1 INTRODUCTION

Carver County, through their Water Management Plan, has embraced a basin-wide goal for protecting water quality in the Carver Creek watershed including Burandt Lake. Currently, Carver County has developed detailed action strategies to address several of the issues identified in this TMDL. The Carver SWCD is active in these watersheds and works with landowners to implement best management practices on their land.

This generalized implementation section charts the course Carver County will take to incorporate TMDL results into local management activities as well as the Carver County Water Management Plan. The ultimate goal is to achieve the identified load reductions in the Burandt Lake watershed to meet the State water quality standard, and protect the aquatic recreation beneficial use. The following is an introduction to the implementation practices that may be applied. Within one year of the approval of the Burandt TMDL, a detailed implementation plan will be developed.

## 9.2 THE CARVER COUNTY WATER MANAGEMENT PLAN

To respond to the County's established goals for Natural Resource Management, the Carver County Water Management Plan describes the set of issues requiring implementation action. MN Rule 8410 describes a list of required plan elements. Carver County has determined the following issues to be of higher priority. Items not covered in this plan will be addressed as necessary to accomplish the higher priority goals. Each issue is summarized in the Carver County Water Management Plan, followed by background information, a specific goal, and implementation steps. The issues included in the plan which address nutrient TMDL sources and reductions are:

- SSTS.
- Feedlots.
- Stormwater Management.
- Construction Site Erosion & Sediment Control.
- Land Use Practices for Rural & Urban Areas.
- Water Quality.

## 9.3 ANNUAL LOAD REDUCTIONS

The assimilative capacity of the lake varies with changes in the water load and ultimately precipitation amounts. To address these changes, in addition to the TMDL for average conditions (Table 9.1), appropriate loadings were determined for dry (Table 9.2) and wet (Table 9.3) conditions. For the wet and dry years, the maximum and minimum allowable loads used were calculated using the Canfield-Bachmann equation. The wet and dry year loadings were calculated for the wettest and driest years with data available over the last ten years, 2005 and 2000 respectively. The loadings in Tables 9.2 and 9.3 represent the appropriate maximums for each of these conditions.

**Table 9.1. TMDL as set for an average precipitation year (29.11 inches).**

| | TMDL | WLA | LA | MOS | RC |
|---|---|---|---|---|---|
| **kg/yr** | 321 | 48 | 273 | Implicit | 0 |
| **kg/day** | 0.88 | 0.13 | 0.75 | Implicit | 0 |

**Table 9.2 Target loads for low precipitation year (25.39 inches)**

| | Total Load | Waste Load | Nonpoint Load |
|---|---|---|---|
| **kg/yr** | 288 | 43 | 245 |
| **kg/day** | 0.79 | 0.12 | 0.67 |

**Table 9.3. Target loads for high precipitation year (42.18 inches)**

| | Total Load | Waste Load | Nonpoint Load |
|---|---|---|---|
| **kg/yr** | 436 | 67 | 369 |
| **kg/day** | 1.19 | 0.18 | 1.01 |

For purposes of implementation, the TMDL can be represented as a percent reduction needed by each of the contributing subwatersheds based on our knowledge of the watersheds, the ratio of the phosphorus load that it contributes, and the reduction deemed necessary and reasonable by all stakeholders to meet the TMDL. Table 9.4 shows the estimated percent reduction required by each subwatershed to meet the TMDL, and table 9.5 shows the phosphorus loading targets by subwatershed. The table is based on reductions for the most current conditions, a wet year (2005). Because lakes are uniquely dynamic systems, a dry year may result in increases in internal loading while a wet year may result in increases of runoff from the surrounding land. Thus, actual watershed reductions may vary slightly from year to year.

**Table 9.4. Required subwatershed phosphorus reductions based on 2005 modeling and data.**

| Sub-watershed | TMDL kg/yr | % Reduction |
|---|---|---|
| **Lake Waconia** | -- | 15% |
| **Scheuble Lake** | -- | 50% |
| **Burandt Lake** | -- | 25% |
| **Internal** | | 60% |
| **Total** | **288-436*** | **32-66%**** |

***Dry-wet year range (Tables 9.1-9.3)**
****Range for various years (Figure 6.1)**

**Table 9.5. TMDL phosphorus load targets based on subwatershed required phosphorus reductions.**

| Sub-watershed | TMDL kg/yr | Target Load for Permitted Sources kg/yr | Target Load for Non-permitted Sources kg/yr | MOS kg/yr | RC kg/yr |
|---|---|---|---|---|---|
| **Lake Waconia** | -- | 20 | 232 | Implicit | 0 |
| **Scheuble Lake** | -- | 25 | 38 | Implicit | 0 |
| **Burandt Lake** | -- | 22 | 99* | | 0 |
| **Total** | **436** | **67** | **369** | **Implicit** | **0** |

***Burandt Lake Internal Loading**

## 9.4 SOURCE REDUCTION STRATEGIES

To reach the reduction goals Carver County will rely largely on its current Water Management Plan which identifies the Carver SWCD as the local agency for implementing best management practices. Implementation goals not covered in the Water Management Plan will be identified and included in the implementation plan. A final implementation plan will be developed within a year of the final approval of the TMDL report by the EPA.

It will list the BMPs to be applied in the watershed and the order of importance for which they will be applied. An important aspect of the implementation plan will be the input of both the City of Waconia and the public. The order of which BMPs will be implemented will take into consideration which sources landowners see as top concerns for the lake.

The strategies listed below will be utilized to assist in reducing pollutant loads. It is difficult to predict nutrient reductions that would occur from each strategy. Because of this, monitoring will need to be carried out after the implementation of each strategy and adaptive management will occur. The following is a list of the best management practices as outlined by the Carver County Water Management Plan, and additional strategies as identified by the TMDL study.

### 9.4.1 External Loading Reduction Strategies

**Strategy 1. Urban Development**

Runoff from urban landscapes is potentially a major source of nutrients, particularly phosphorus, entering lakes and streams. One of the largest potential sources of phosphorus to the urban runoff is from phosphorus fertilizer applied to lawns. In addition, household activities generate pollutants that may affect water quality if not properly used and disposed of. There are several cost effective practices landowners can do to reduce or eliminate phosphorus and nutrient loads (also see Section 8.0 Reasonable assurance).

*Goals:*

- *Landscaping to reduce runoff and promote infiltration, such as vegetated swales.*
- *Minimizing the amount of impervious surface.*
- *Using phosphorus-free fertilizer- required by law on January 1st , 2005.*
- *Planting and maintaining grass and natural vegetation to help water quality by soaking up rainfall, reducing runoff, and retaining sediment.*
- *Creating/maintaining buffers of at least 50 feet at waterways, with 100 foot buffers to maximize water quality benefits.*
- *Rain garden installation.*
- *Street sweeping in areas immediately adjacent to the lake.*
- *Removal of leaf litter from lakeshore lawns and streets adjacent to the lake.*

### 9.4.2 Internal Loading Reduction Strategies

**Strategy 1. Rough Fish Management**

Rough fish populations have historically been high in Burandt Lake. Species such as black bullhead and carp increase the mixing of sediments releasing phosphorus into the water column. Implementation plans must include the management of rough fish species by including the following management practices.

*Goals:*

- *Investigate partnership with U of M in research of effective carp removal methods.*
- *Stocking of pan fish to assist in destruction of carp reproduction efforts.*

- *Increased fish surveys and correspondence with MNDNR to monitor the results of management efforts.*
- *Installation of fish barriers paired with intensified efforts for removal of carp.*

**Strategy 2. Aquatic Plant Management**

Macrophyte surveys and monitoring efforts on Burandt Lake indicate that Eurasian water milfoil and curly leaf pondweed are sources of phosphorus within the lake. While Eurasian water milfoil, which out-competes native plants, is the current dominant aquatic plant, curly leaf pondweed can quickly take its place if given the chance. Curly leaf pondweed grows under the ice, but dies back relatively early, releasing nutrients to the water column in summer, possibly leading to algal blooms. For these reasons, it is of importance to control populations of Eurasian water milfoil and curly leaf pondweed.

*Goals:*

- *Manual, chemical or mechanical removal of Eurasian water milfoil and curly leaf pondweed.*
- *Establish a native plant community*

**Strategy 3. Boat Traffic Management**

At high speeds, boat motors can cause disturbance, not only to the aquatic plant community, but to the sediments on the bottom of the lake. The wave action causes the release of phosphorus from the disturbed sediments. No wake zones will aid in controlling the disturbance to sediments.

*Goals:*

- *Establish Restricted Areas to protect aquatic resources.*
- *Enforcement and education of regulations promoting awareness among boaters where slow or no wake zones are ignored.*

**Strategy 4. Alum Treatments**

Aluminum sulfate (Alum) is a chemical addition that forms a non-toxic precipitate with phosphorus. It removes phosphorus from the lake system so that is not available for algal growth and forms a barrier between lake sediments and the water to restrict phosphorus release from the sediments.

*Goals:*

- *Inquire if Alum is a viable option to reduce internal phosphorus loading.*
- *Establish treatment area, dosing amounts and costs needed to treat the lake.*

### Strategy 5. Bio-manipulation

Switching a lake from algae dominated to a clear water state requires a reverse switch which typically consists of bio-manipulation. This process consists of the complete restructuring of the fish community and works best if nutrient levels (both internal and external) are reduced prior to manipulation. Upon removal of fish, zooplankton such as daphnia populations will increase and graze away phytoplankton thereby allowing for clear water. Clear water will then allow for the growth of aquatic plants, return of healthy zooplankton populations, and the return of a more stable clear-water lake.

*Goals:*

- *External nutrient reductions as indicated by implementation plan.*
- *Internal nutrient reductions as indicated by implementation plan.*
- *Manipulation of fish community and reintroduction following zooplankton and aquatic plant establishment.*

The projected cost of installing these practices is expected to range from $400,000 to $980,000. However, these practices and costs will be outlined further in the implementation plan.

# 10.0 Literature Cited

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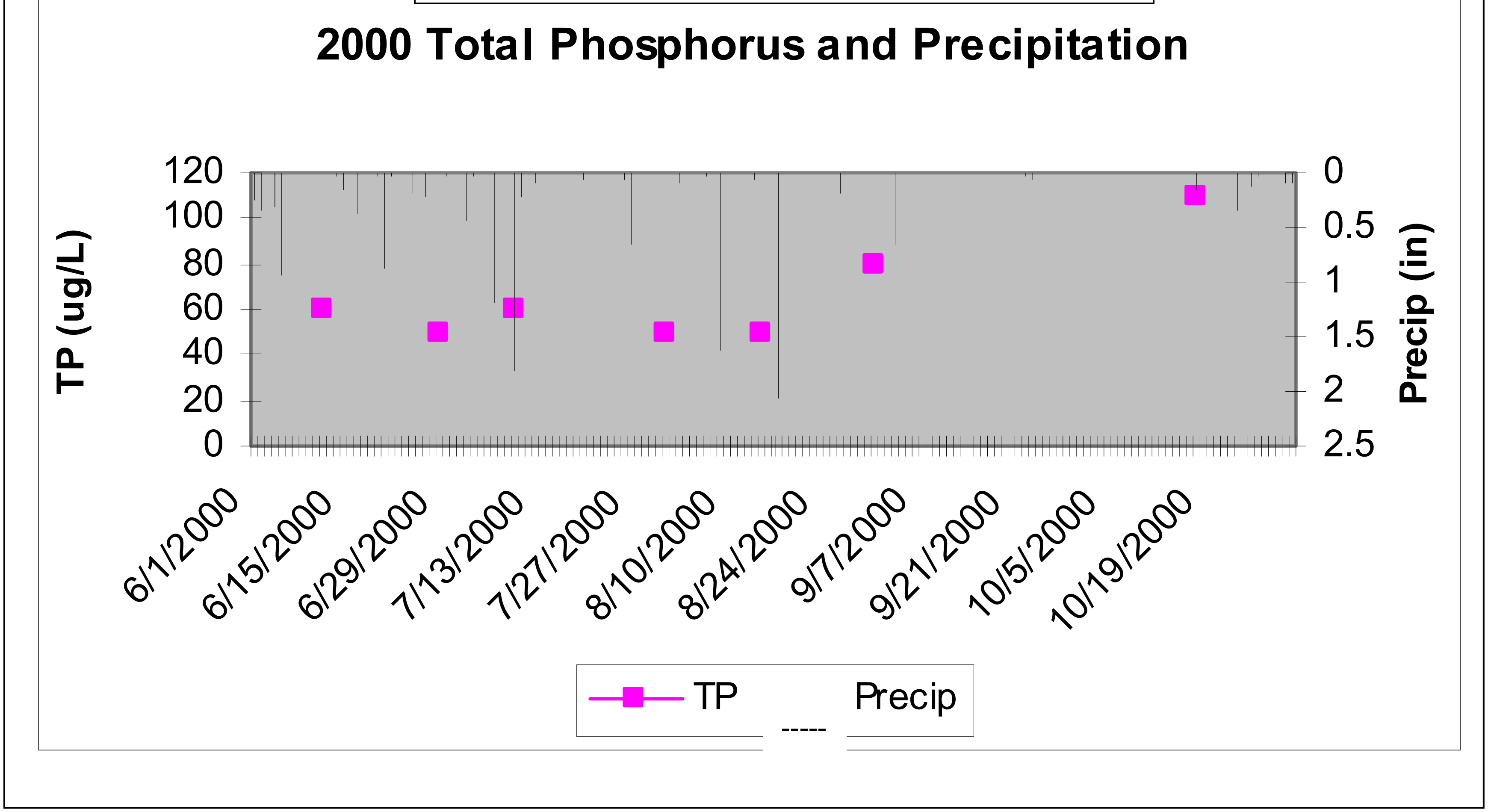
**APPENDIX A:** Burandt Lake 2000 Total Phosphorus and Precipitation plot. – Signifies that a seasonal increase in total phosphorus following turnover is typical. In addition, this plot suggests that the water quality does not respond to watershed runoff due to precipitation




**APPENDIX A**

## APPENDIX B
2000 BATHTUB model inputs & outputs

| Model Coefficients | Mean | CV |
|---|---|---|
| Dispersion Rate | 1.000 | 0.70 |
| Total Phosphorus | 1.000 | 0.45 |
| Total Nitrogen | 1.000 | 0.55 |
| Chl-a Model | 1.000 | 0.26 |
| Secchi Model | 1.000 | 0.10 |
| Organic N Model | 1.000 | 0.12 |
| TP-OP Model | 1.000 | 0.15 |
| HODv Model | 1.000 | 0.15 |
| MODv Model | 1.000 | 0.22 |
| Secchi/Chla Slope (m2/mg) | 0.015 | 0.00 |
| Minimum Qs (m/yr) | 0.100 | 0.00 |
| Chl-a Flushing Term | 1.000 | 0.00 |
| Chl-a Temporal CV | 0.620 | 0 |
| Avail. Factor - Total P | 0.330 | 0 |
| Avail. Factor - Ortho P | 1.930 | 0 |
| Avail. Factor - Total N | 0.590 | 0 |
| Avail. Factor - Inorganic N | 0.790 | 0 |

**Burandt Lake 2000 BATHTUB**

| Global Variables | Mean | CV |
|---|---|---|
| Averaging Period (y | 1 | 0.0 |
| Precipitation (m) | 0.65 | 0.2 |
| Evaporation (m) | 0.7 | 0.3 |
| Storage Increase (m | 0 | 0.0 |

| Atmos. Loads (kg/km | Mean | CV |
|---|---|---|
| Conserv. Substance | 0 | 0.00 |
| Total P | 20 | 0.50 |
| Total N | 1000 | 0.50 |
| Ortho P | 15 | 0.50 |
| Inorganic N | 500 | 0.50 |

| Model Options | Code | Description |
|---|---|---|
| Conservative Substance | 0 | NOT COMPUTED |
| Phosphorus Balance | 8 | CANF & BACH, LAKES |
| Nitrogen Balance | 0 | NOT COMPUTED |
| Chlorophyll-a | 1 | P, N, LIGHT, T |
| Secchi Depth | 1 | VS. CHLA & TURBIDITY |
| Dispersion | 1 | FISCHER-NUMERIC |
| Phosphorus Calibration | 1 | DECAY RATES |
| Nitrogen Calibration | 1 | DECAY RATES |
| Error Analysis | 1 | MODEL & DATA |
| Availability Factors | 0 | IGNORE |
| Mass-Balance Tables | 1 | USE ESTIMATED CONCS |
| Output Destination | 1 | NOTEPAD |

**Segment Morphometry** — Internal Loads ( mg/m2-day)

| | | Outflow | Area | Depth | Length | Mixed Depth (m) | | Hypol Depth | | Non-Algal Turb (Conserv. | | | | Total P | | Total N | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seg | Name | Segment | Group | km2 | m | km | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| 1 | burandt lake | 0 | 1 | 0.37 | 3 | 0.5 | 3 | 0.12 | 0 | 0 | 0.58 | 0.2 | 0 | 0 | 2 | 0 | 0 | 0 |

**Segment Observed Water Quality**

| | Conserv | | Total P (ppb) | | Total N (ppb) | | Chl-a (ppb) | | Secchi (m) | | Organic N (ppb) | | TP - Ortho P (pp | | HOD (ppb/day) | | MOD (ppb/day) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seg | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| 1 | 0 | 0 | 71.1 | 0 | 1720 | 0 | 44.8 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Segment Calibration Factors**

| | Dispersion Rate | | Total P (ppb) | | Total N (ppb) | | Chl-a (ppb) | | Secchi (m) | | Organic N (ppb) | | TP - Ortho P (pp | | HOD (ppb/day) | | MOD (ppb/day) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seg | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |

**Tributary Data**

| | | | | Dr Area | Flow (hm3/yr) | Conserv. | | Total P (ppb) | | Total N (ppb) | | Ortho P (ppb) | | Inorganic N (ppb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trib | Trib Name | Segment | Type | km2 | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| 1 | waconia | 1 | 1 | 16.82 | 3.7 | 0.1 | 0 | 0 | 37 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | direct inflow (D1) | 1 | 1 | 0.55 | 0.13 | 0.1 | 0 | 0 | 73 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | scheuble | 1 | 1 | 1.68 | 0.3 | 0.1 | 0 | 0 | 214 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | direct Inlet 2 (D 2) | 1 | 1 | 0.34 | 0.13 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | W10 (between W & B) | 1 | 1 | 0.1 | 0.04 | 0 | 0 | 0 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**APPENDIX B** Cont

**2000 Modeling Cont'**

| Variable | Predicted Values---> Mean | CV | Rank | Observed Values---> Mean | CV | Rank |
|---|---|---|---|---|---|---|
| TOTAL P MG/M3 | 68.7 | 0.19 | 65.6% | 71.1 | | 67.0% |
| TOTAL N MG/M3 | 1720.0 | | 80.1% | 1720.0 | | 80.1% |
| C.NUTRIENT MG/M3 | 60.8 | 0.15 7 | 4.7% | 62.5 | | 75.8% |
| CHL-A MG/M3 | 31.2 | 0.31 | 94.1% | 44.8 | | 97.9% |
| SECCHI M | 1.0 | 0.19 | 43.5% | 0.8 | | 34.6% |
| ORGANIC N MG/M3 | 911.9 | 0.27 | 90.0% | | | |
| TP-ORTHO-P MG/M3 | 65.2 | 0.30 | 79.3% | | | |
| ANTILOG PC-1 | 871.0 | 0.37 | 83.4% | 1353.5 | | 90.4% |
| ANTILOG PC-2 | 13.5 | 0.18 | 92.0% | 14.8 | | 94.3% |
| (N - 150) / P | 22.9 | 0.19 | 66.8% | 22.1 | | 65.0% |
| INORGANIC N / P | 229.8 | 9.84 | 98.0% | | | |
| TURBIDITY 1/M | 0.6 | 0.20 | 47.8% | 0.6 | 0.20 | 47.8% |
| ZMIX * TURBIDITY | 1.7 | 0.23 | 22.2% | 1.7 | 0.23 | 22.2% |
| ZMIX / SECCHI | 3.1 | 0.21 | 23.7% | 3.8 | 0.12 | 34.0% |
| CHL-A * SECCHI | 29.8 | 0.23 | 93.5% | 35.8 | | 96.2% |
| CHL-A / TOTAL P | 0.5 | 0.27 | 90.7% | 0.6 | | 96.7% |
| FREQ(CHL-a>10) % | 93.6 | 0.06 | 94.1% | 98.3 | | 97.9% |
| FREQ(CHL-a>20) % | 65.8 | 0.27 | 94.1% | 83.9 | | 97.9% |
| FREQ(CHL-a>30) % | 40.2 | 0.47 | 94.1% | 63.2 | | 97.9% |
| FREQ(CHL-a>40) % | 23.8 | 0.64 | 94.1% | 44.9 | | 97.9% |
| FREQ(CHL-a>50) % | 14.2 | 0.79 | 94.1% | 31.3 | | 97.9% |
| FREQ(CHL-a>60) % | 8.6 | 0.91 | 94.1% | 21.7 | | 97.9% |
| CARLSON TSI-P | 65.1 | 0.04 | 65.6% | 65.6 | | 67.0% |
| CARLSON TSI-CHLA | 64.3 | 0.05 | 94.1% | 67.9 | | 97.9% |
| CARLSON TSI-SEC | 60.7 | 0.05 | 56.5% | 63.2 | | 65.4% |

**APPENDIX B** Cont

**2000 Overall Water & Nutrient Balances**

**Overall Water Balance** Averaging 1.00 years

| **TrbType Seg Name** | **Area km2** | **Flow hm3/yr** | **Variance (hm3/yr)2** | **CV -** | **Runoff m/yr** |
|---|---|---|---|---|---|
| 1 1 1 Lake Waconia | 16.8 | 3.7 | 1.37E-01 | 0.10 | 0.22 |
| 2 1 1 D1 | 0.6 | 0.1 | 1.69E-04 | 0.10 | 0.24 |
| 3 1 1 Scheuble Lake | 1.7 | 0.3 | 9.00E-04 | 0.10 | 0.18 |
| 4 1 1 S2 | 0.3 | 0.1 | 0.00E+00 | 0.00 | 0.38 |
| 5 1 1 W2 | 0.1 | 0.0 | 0.00E+00 | 0.00 | 0.40 |
| PRECIPITATION | 0.4 | 0.2 | 2.31E-03 | 0.20 | 0.65 |
| TRIBUTARY INFLOW | 19.5 | 4.3 | 1.38E-01 | 0.09 | 0.22 |
| ***TOTAL INFLOW | 19.9 | 4.5 | 1.40E-01 | 0.08 | 0.23 |
| ADVECTIVE OUTFLOW | 19.9 | 4.3 | 1.46E-01 | 0.09 | 0.22 |
| ***TOTAL OUTFLOW | 19.9 | 4.3 | 1.46E-01 | 0.09 | 0.22 |
| ***EVAPORATION | | 0.3 | 6.04E-03 | 0.30 | |

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

| | **Load** | | **Load Variance** | | **Conc** | | **Export** |
|---|---|---|---|---|---|---|---|
| **TrbType Seg Name** | **kg/yr** | **%Total** | **(kg/yr)2** | **%Total** | **CV** | **mg/m3** | **kg/km2/yr** |
| 1 1 1 Lake Waconia | 136.9 | 27.6% | 9.37E+02 | 80.7% | 0.22 | 37.0 | 8.1 |
| 2 1 1 D1 | 9.5 | 1.9% | 4.50E+00 | 0.4% | 0.22 | 73.0 | 17.3 |
| 3 1 1 Scheuble Lake | 64.2 | 12.9% | 2.06E+02 | 17.7% | 0.22 | 214.0 | 38.2 |
| 4 1 1 S2 | 5.8 | 1.2% | 0.00E+00 | | 0.00 | 45.0 | 17.2 |
| 5 1 1 W2 | 2.0 | 0.4% | 0.00E+00 | | 0.00 | 51.0 | 20.4 |
| PRECIPITATION | 7.4 | 1.5% | 1.37E+01 | 1.2% | 0.50 | 30.8 | 20.0 |
| INTERNAL LOAD | 270.3 | 54.5% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | 218.5 | 44.0% | 1.15E+03 | 98.8% | 0.16 | 50.8 | 11.2 |
| ***TOTAL INFLOW | 496.2 | 100.0% | 1.16E+03 | 100.0% | 0.07 | 109.3 | 25.0 |
| ADVECTIVE OUTFLOW | 294.1 | 59.3% | 3.36E+03 | | 0.20 | 68.7 | 14.8 |
| ***TOTAL OUTFLOW | 294.1 | 59.3% | 3.36E+03 | | 0.20 | 68.7 | 14.8 |
| ***RETENTION | 202.1 | 40.7% | 3.11E+03 | | 0.28 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 11.6 | Nutrient Resid. Time (yr | 0.1537 |
| Hydraulic Resid. Time (yrs) | 0.2593 | Turnover Ratio | 6.5 |
| Reservoir Conc (mg/m3) | 69 | Retention Coef. | 0.407 |

**APPENDIX C**
2005 BATHTUB model inputs & outputs

| Model Coefficients | Mean | CV |
|---|---|---|
| Dispersion Rate | 1.000 | 0.70 |
| Total Phosphorus | 1.000 | 0.45 |
| Total Nitrogen | 1.000 | 0.55 |
| Chl-a Model | 1.000 | 0.26 |
| Secchi Model | 1.000 | 0.10 |
| Organic N Model | 1.000 | 0.12 |
| TP-OP Model | 1.000 | 0.15 |
| HODv Model | 1.000 | 0.15 |
| MODv Model | 1.000 | 0.22 |
| Secchi/Chla Slope (m2/mg) | 0.015 | 0.00 |
| Minimum Qs (m/yr) | 0.100 | 0.00 |
| Chl-a Flushing Term | 1.000 | 0.00 |
| Chl-a Temporal CV | 0.620 | 0 |

**Burandt Lake 2005 BATHTUB**

| Global Variables | Mean | CV | Model Options | Code | Description |
|---|---|---|---|---|---|
| Averaging Period (y | 0.5 | 0.0 | Conservative Substance | 0 | NOT COMPUTED |
| Precipitation (m) | 1.1 | 0.2 | Phosphorus Balance | 8 | CANF & BACH, LAKES |
| Evaporation (m) | 0.7 | 0.3 | Nitrogen Balance | 0 | NOT COMPUTED |
| Storage Increase (m | 0 | 0.0 | Chlorophyll-a | 1 | P, N, LIGHT, T |
| | | | Secchi Depth | 1 | VS.CHLA & TURBIDITY |
| **Atmos. Loads (kg/km** | **Mean** | **CV** | Dispersion | 1 | FISCHER-NUMERIC |
| Conserv. Substance | 0 | 0.00 | Phosphorus Calibration | 1 | DECAY RATES |
| Total P | 20 | 0.50 | Nitrogen Calibration | 1 | DECAY RATES |
| Total N | 1000 | 0.50 | Error Analysis | 1 | MODEL & DATA |
| Ortho P | 15 | 0.50 | Availability Factors | 0 | IGNORE |
| Inorganic N | 500 | 0.50 | Mass-Balance Tables | 1 | USE ESTIMATED CONCS |
| | | | Output Destination | 1 | NOTEPAD |

Segment Morphometry

| | | Outflow | | Area | Depth | Length | Mixed Depth (m) | | Hypol Depth | | Non-Algal Turb | | Internal Loads ( mg/m2-day) (Conserv. | | Total P | | Total N | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seg | Name | Segment | Group | km2 | m | km | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | C |
| 1 | burandt lake | 0 | 1 | 0.37 | 3 | 0.5 | 3 | 0.12 | 0 | 0 | 0.41 | 0.2 | 0 | 0 | 1.7 | 0 | 0 | 0 |

Segment Observed Water Quality

| | Conserv | | Total P (ppb) | | Total N (ppb) | | Chl-a (ppb) | | Secchi (m) | | Organic N (ppb) | | TP - Ortho P (pp | | HOD (ppb/day) | | MOD (ppb/day) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seg | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| 1 | 0 | 0 | 56 | 0 | 1200 | 0 | 20.4 | 0 | 1.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Segment Calibration Factors

| | Dispersion Rate | | Total P (ppb) | | Total N (ppb) | | Chl-a (ppb) | | Secchi (m) | | Organic N (ppb) | | TP - Ortho P (pp | | HOD (ppb/day) | | MOD (ppb/day) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seg | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |

Tributary Data

| | | | | Dr Area | Flow (hm3/yr) | | Conserv. | | Total P (ppb) | | Total N (ppb) | | Ortho P (ppb) | | Inorganic N (ppb) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trib | Trib Name | Segment | Type | km2 | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| 1 | waconia | 1 | 1 | 16.82 | 8 | 0.1 | 0 | 0 | 37 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | direct inflow (D1) | 1 | 1 | 0.55 | 0.22 | 0.1 | 0 | 0 | 73 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | scheuble | 1 | 1 | 1.35 | 0.6 | 0.1 | 0 | 0 | 210 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | direct Inlet 2 (D 2) | 1 | 1 | 0.34 | 0.21 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | W10 (between W & B) | 1 | 1 | 0.1 | 0.06 | 0 | 0 | 0 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**2005 Burandt Lake BATHTUB**

| Variable | Predicted Values---> Mean | CV | Rank | Observed Values---> Mean | CV | Rank |
|---|---|---|---|---|---|---|
| TOTAL P MG/M3 | 53.7 | 0.15 | 55.1% | 56.0 | | 56.9% |
| TOTAL N MG/M3 | 1200.0 | | 61.1% | 1200.0 | | 61.1% |
| C.NUTRIENT MG/M3 | 45.8 | 0.11 | 62.2% | 47.2 | | 63.6% |
| CHL-A MG/M3 | 23.9 | 0.29 | 88.8% | 20.4 | | 84.3% |
| SECCHI M | 1.3 | 0.19 | 59.6% | 1.4 | | 63.4% |
| ORGANIC N MG/M3 | 733.7 | 0.25 | 80.4% | | | |
| TP-ORTHO-P MG/M3 | 48.2 | 0.29 | 69.1% | | | |
| ANTILOG PC-1 | 509.2 | 0.34 | 71.2% | 380.8 | | 63.2% |
| ANTILOG PC-2 | 14.2 | 0.17 | 93.3% | 13.5 | | 92.0% |
| (N - 150) / P | 19.5 | 0.15 | 58.1% | 18.8 | | 55.7% |
| INORGANIC N / P | 85.0 | 2.98 | 85.5% | | | |
| TURBIDITY 1/M | 0.4 | 0.20 | 32.6% | 0.4 | 0.20 | 32.6% |
| ZMIX * TURBIDITY | 1.2 | 0.23 | 11.3% | 1.2 | 0.23 | 11.3% |
| ZMIX / SECCHI | 2.3 | 0.21 | 10.6% | 2.1 | 0.12 | 8.5% |
| CHL-A * SECCHI | 31.1 | 0.22 | 94.2% | 28.6 | | 92.7% |
| CHL-A / TOTAL P | 0.4 | 0.27 | 90.2% | 0.4 | | 83.5% |
| FREQ(CHL-a>10) % | 86.4 | 0.11 | 88.8% | 80.0 | | 84.3% |
| FREQ(CHL-a>20) % | 49.2 | 0.38 | 88.8% | 39.0 | | 84.3% |
| FREQ(CHL-a>30) % | 25.0 | 0.59 | 88.8% | 17.6 | | 84.3% |
| FREQ(CHL-a>40) % | 12.8 | 0.77 | 88.8% | 8.1 | | 84.3% |
| FREQ(CHL-a>50) % | 6.7 | 0.92 | 88.8% | 4.0 | | 84.3% |
| FREQ(CHL-a>60) % | 3.7 | 1.04 | 88.8% | 2.0 | | 84.3% |
| CARLSON TSI-P | 61.6 | 0.03 | 55.1% | 62.2 | | 56.9% |
| CARLSON TSI-CHLA | 61.8 | 0.05 | 88.8% | 60.2 | | 84.3% |
| CARLSON TSI-SEC | 56.2 | 0.040.4% | | 55.2 | | 36.= |

**APPENDIX C** Cont

2005 Overall Water & Nutrient Balances

Overall Water Balance — Averaging 0.50 years

| TrbType | Seg | Name | Area km2 | Flow hm3/yr | Variance (hm3/yr)2 | CV - | Runoff m/yr |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 Lake Waconia | 16.8 | 8.0 | 6.40E-01 | 0.10 | 0.48 |
| 2 | 1 | 1 D1 | 0.6 | 0.2 | 4.84E-04 | 0.10 | 0.40 |
| 3 | 1 | 1 Scheuble Lake | 1.4 | 0.6 | 3.60E-03 | 0.10 | 0.44 |
| 4 | 1 | 1 S2 | 0.3 | 0.2 | 0.00E+00 | .00 | 0.62 |
| 5 | 1 | 1 W2 | 0.1 | 0.1 | 0.00E+00 | 0.00 | 0.60 |
| PRECIPITATION | | | 0.4 | 0.8 | 2.65E-02 | 0.20 | 2.20 |
| TRIBUTARY INFLOW | | | 19.2 | 9.1 | 6.44E-01 | 0.09 | 0.47 |
| ***TOTAL INFLOW | | | 19.5 | 9.9 | 6.71E-01 | 0.08 | 0.51 |
| ADVECTIVE OUTFLOW | | | 19.5 | 9.4 | 6.95E-01 | 0.09 | 0.48 |
| ***TOTAL OUTFLOW | | | 19.5 | 9.4 | 6.95E-01 | 0.09 | 0.48 |
| ***EVAPORATION | | | | 0.5 | 2.41E-02 | 0.30 | |

**Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations**

**Component: TOTAL P**

| TrbType | Seg | Name | Load kg/yr | Load %Total | Load Variance (kg/yr)2 | Load Variance %Total | Conc CV | Conc mg/m3 | Export kg/km2/yr |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 Lake Waconia | 296.0 | 43.0% | 4.38E+03 | 84.2% | 0.22 | 37.0 | 17.6 |
| 2 | 1 | 1 D1 | 16.1 | 2.3% | 1.29E+01 | 0.2% | 0.22 | 73.0 | 29.2 |
| 3 | 1 | 1 Scheuble Lake | 126.0 | 18.3% | 7.94E+02 | 15.3% | 0.22 | 210.0 | 93.3 |
| 4 | 1 | 1 S2 | 9.4 | 1.4% | 0.00E+00 | | 0.00 | 45.0 | 27.8 |
| 5 | 1 | 1 W2 | 3.1 | 0.4% | 0.00E+00 | | 0.00 | 51.0 | 30.6 |
| PRECIPITATION | | | 7.4 | 1.1% | 1.37E+01 | 0.3% | 0.50 | 9.1 | 20.0 |
| INTERNAL LOAD | | | 229.7 | 33.4% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | 450.6 | 65.5% | 5.19E+03 | 99.7% | 0.16 | 49.6 | 23.5 |
| ***TOTAL INFLOW | | | 687.7 | 100.0% | 5.20E+03 | 100.0% | 0.10 | 69.4 | 35.2 |
| ADVECTIVE OUTFLOW | | | 504.2 | 73.3% | 6.35E+03 | | 0.16 | 53.7 | 25.8 |
| ***TOTAL OUTFLOW | | | 504.2 | 73.3% | 6.35E+03 | | 0.16 | 53.7 | 25.8 |
| ***RETENTION | | | 183.5 | 26.7% | 4.16E+03 | | 0.35 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 25.4 | Nutrient Resid. Time (yr | 0.0867 |
| Hydraulic Resid. Time (yrs) | 0.1183 | Turnover Ratio | 5.8 |
| Reservoir Conc (mg/m3) | 54 | Retention Coef. | 0.267 |

**APPENDIX C**

**APPENDIX D** Surface Water Data

## 2005 Surface Water Data

Site 451, 0 meters

| Sample Date | Chlorophyll A ug/L | Kjeldahl Nitrogen ug/L | Phosphorus ug/L | Secchi Disk m | OP ug/L |
|---|---|---|---|---|---|
| 4/15/2005 | 14 | 980 | 50 | 1.5 | |
| 4/30/2005 | 17 | 890 | 41 | 1.1 | |
| 5/9/2005 | 13 | 1100 | 47 | | |
| 5/15/2005 | 15 | 700 | 32 | 1.3 | |
| 5/25/2005 | 17 | 870 | 33 | 1.8 | |
| 5/29/2005 | 18 | 1100 | 30 | 2 | |
| 6/6/2005 | 16 | 470 | 24 | 3.1 | 5 |
| 6/12/2005 | 2.3 | 1100 | 30 | 3.6 | |
| 6/20/2005 | 8 | 940 | 38 | 2.6 | 5 |
| 6/29/2005 | 5.2 | 1100 | 36 | 2.6 | |
| 7/6/2005 | 8.6 | 670 | 26 | | 5 |
| 7/15/2005 | 9.2 | 1100 | 72 | 1.1 | |
| 7/18/2005 | 16 | 1100 | 26 | 1.3 | 5 |
| 7/29/2005 | 6.6 | 1300 | 58 | 1.1 | |
| 8/1/2005 | 20 | 1100 | 43 | 1.4 | 5 |
| 8/14/2005 | 8.7 | 1500 | 56 | 0.7 | |
| 8/17/2005 | 49 | 1100 | 48 | 0.7 | 5 |
| 8/29/2005 | 44 | 1800 | 80 | 0.6 | 5 |
| 9/4/2005 | 25 | 1700 | 90 | 0.7 | |
| 9/14/2005 | 60 | 1300 | 81 | 0.9 | |
| 9/18/2005 | 24 | 1900 | 91 | 0.6 | |
| 10/3/2005 | 25 | 1700 | 102 | 0.6 | |

## 2005 Hypolimnetic Data

Site 451, top-mid-bottom

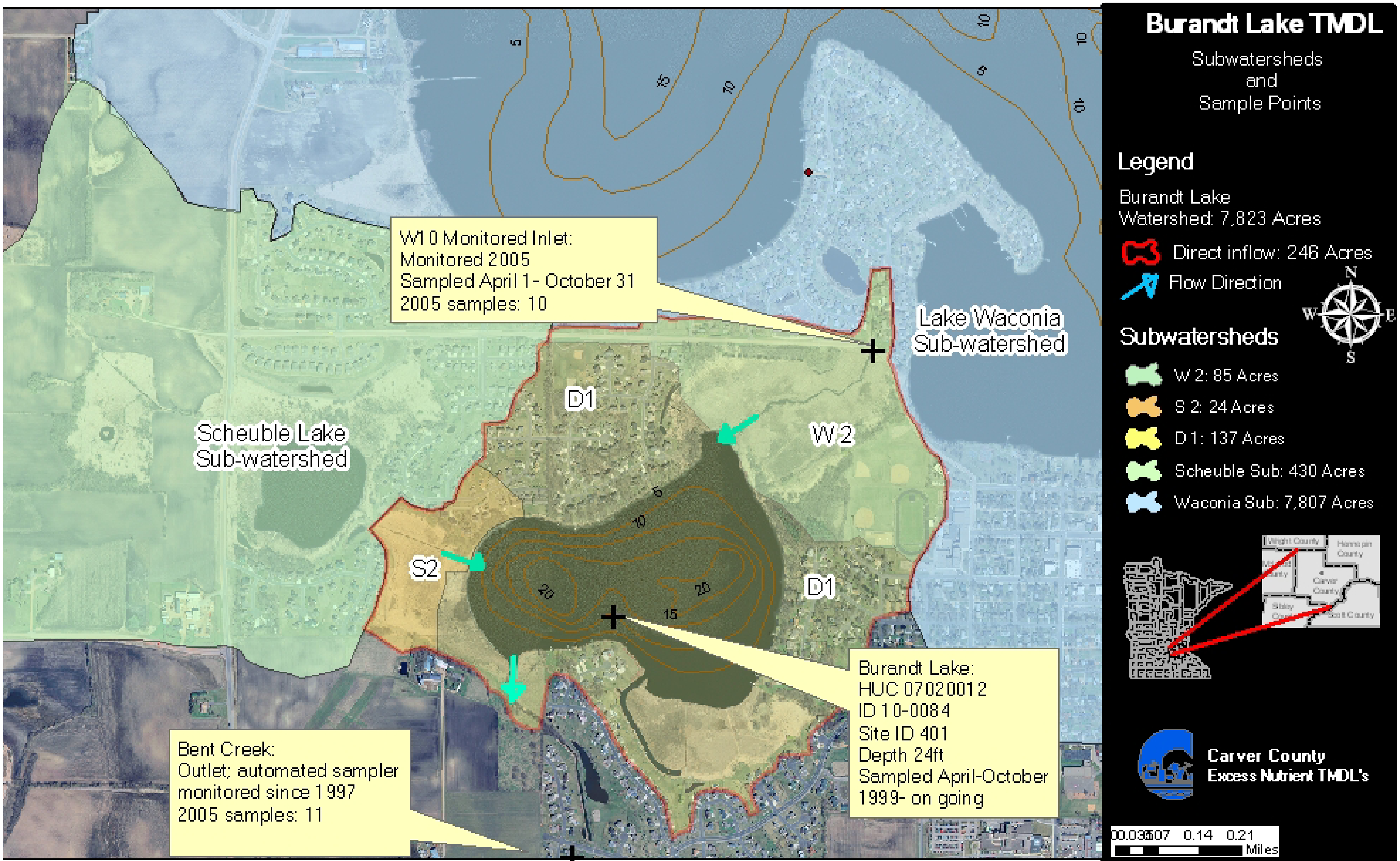
| Sample Date | depth M | TKN ug/L | TP ug/L | OP ug/L |
|---|---|---|---|---|
| 6/6/2005 | 0 | 470 | 24 | 5 |
| 6/20/2005 | 0 | 940 | 38 | 5 |
| 7/6/2005 | 0 | 670 | 26 | 5 |
| 7/18/2005 | 0 | 1100 | 26 | 5 |
| 8/1/2005 | 0 | 1100 | 43 | 5 |
| 8/17/2005 | 0 | 1100 | 48 | 5 |
| 8/29/2005 | 0 | 1800 | 80 | 5 |
| 6/6/2005 | 4 | 550 | 19 | 5 |
| 6/20/2005 | 4 | 680 | 40 | 5 |
| 7/6/2005 | 4 | 530 | 22 | 5 |
| 7/18/2005 | 4 | 830 | 24 | 5 |
| 8/1/2005 | 4 | 1000 | 38 | 5 |
| 8/17/2005 | 4 | 1000 | 57 | 5 |
| 8/29/2005 | 4 | 1500 | 71 | 5 |
| 9/14/2005 | 4 | 1500 | 78 | |
| 6/6/2005 | 7 | 660 | 37 | 5 |

**APPENDIX D** Cont

| | | | | | |
|---|---|---|---|---|---|
| 6/20/2005 | 7 | 880 | 49 | 12 | |
| 7/6/2005 | 7 | 670 | 55 | 78 | |
| 7/18/2005 | 6 | 2800 | 245 | 91 | |
| 8/1/2005 | 6 | 1100 | 92 | 52 | |
| 8/17/2005 | 7 | 2300 | 191 | 233 | |
| 8/29/2005 | 6 | 1700 | 94 | 11 | |
| 9/14/2005 | 6 | 1600 | 83 | | |
| | | | | | |
| **2000 Surface Water Data** | | | | | |
| Site 451, 0 meters | | | | | |
| **Sample Date** | **Chlorophyll A ug/L** | **Kjeldahl Nitrogen ug/L** | **Phosphorus ug/L** | **Secchi Disk m** | |
| *6/11/2000* | 49 | *1.2* | *60* | 1.3 | |
| *6/28/2000* | 26 | *1.4* | *50* | 1.2 | |
| *7/9/2000* | 8.8 | *1.6* | *60* | 0.7 | |
| *7/31/2000* | 21 | *1.4* | *50* | 1.1 | |
| *8/14/2000* | 31 | *1.6* | *50* | 0.9 | |
| *8/31/2000* | 59 | *1.6* | *80* | 0.7 | |
| *10/17/2000* | 84 | *2.1* | *110* | 0.8 | |

**APPENDIX D**

**APPENDIX E** Map of BATHTUB modeled subwatersheds and sample points.




**APPENDIX E**

**APPENDIX F**
City of Waconia
Current & 2030 Urban Boundaries