# Vadnais Lake Area WMO Total Maximum Daily Load (TMDL) and Protection Study

Nutrient TMDL:
Gem Lake
Gilfillan Lake
East Goose Lake
West Goose Lake &
Wilkinson Lake

Bacteria TMDL:
Lambert Creek

**April 2014**

**Wenck File #2255-08**

Prepared for:

**VADNAIS LAKE AREA WATER MANAGEMENT ORGANIZATION (VLAWMO)**

Prepared by:


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# Table of Contents

# Table of Contents

# Table of Contents



**TABLES**

# Table of Contents



**FIGURES**

# Table of Contents

# Acronyms

| | |
|---|---|
| Agency | Minnesota Pollution Control Agency |
| BMP | Best Management Practice |
| Carlson TSI | Carlson Trophic Status Index |
| CFR | Code of Federal Regulations |
| cfs | cubic feet per second |
| CFU/ 100 mL | colony forming units per 100 milliliters (bacterial concentration) |
| CN | Curve number |
| CWA | Clear Water Act |
| DO | Dissolved oxygen |
| EPA | Environmental Protection Agency |
| EQuIS | Environmental Quality Information System (MPCA water quality data) |
| LA | Load Allocation (non-permitted sources) |
| lbs | Pounds |
| lbs/ day | pounds per day |
| lbs/ year | pounds per year |
| LF | Lineal feet |
| LID | Low Impact Development |
| LS | Lump sum |
| m | meters |
| MDNR | Minnesota Department of Natural Resources |
| μg/L | micrograms per liter |
| mg/L | milligrams per liter |
| $mi^2$ | square miles |
| MOS | Margin of Safety |
| MPCA | Minnesota Pollution Control Agency |
| MS4 | Municipal Separate Storm Sewer System |
| NASS | National Agricultural Statistics Service |
| NLCD | National Land Cover dataset |
| NLF | Northern Lakes and Forest (Ecoregion) |
| $NO_2$/ $NO_3$-N | Nitrate/ Nitrite- Nitrogen |
| NPS | non-point source |
| P8 | Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds |
| RC | Reserve Capacity |
| SCS | Soil Conservation Service |
| SPRWS | St. Paul Regional Water Service |
| SSTS | subsurface sewage treatment system (formerly ISTS) |
| STORET | EPA's "STOrage and RETrevial" System |
| SWPPP | Storm Water Pollution Prevention Plan |
| TAC | Technical Advisory Committee |

# Acronyms

| | |
|---|---|
| TKN | Total Kjeldahl Nitrogen |
| TMDL | Total Maximum Daily Load |
| TN | Total Nitrogen |
| TP | Total Phosphorus |
| TSS | Total Suspended Solids |
| USGS | United States Geological Survey |
| WLA | Waste Load Allocation (permitted sources) |
| VLAWMO | Vadnais Lake Area Water Management Organization |
| WWTP | Wastewater Treatment Plant |

# EPA TMDL Summary Table

| EPA/MPCA Required Elements | Summary | TMDL Report Section |
|---|---|---|
| **Location** | Located within the Vadnais Lake Area WMO, HUC 07010206 located within the Mississippi River Basin. More specifically Lambert Creek between Goose Lake and Vadnais Lake, Gem Lake, Gilfillan Lake, East Goose Lake, West Goose Lake and Wilkinson Lake located in Ramsey and Anoka Counties in the northern Twin City Metro Area. | Executive Summary & Section 3 |
| **303(d) Listing Information** | Unnamed Creek (Lambert Creek); Highway 96 to Vadnais Lk:<br>#07010206-801<br>Gem Lake: #62-0037-00<br>East Goose Lake: #62-0034-00<br>West Goose Lake: #62-0126-00W<br>Gilfillan Lake: #62-0027-00<br>Wilkinson Lake: #62-0043-00<br><br>This TMDL study addresses six 303d impairments on six water bodies including a bacteria impairment on Lambert Creek and nutrient impairments in the above lakes. | Executive Summary & Section 2 |
| **Applicable Water Quality Standards/ Numeric Targets** | Criteria set forth in Minn R. 7050.0150 (3) and (5). The numeric target for total phosphorous concentration in shallow lakes is 60 µg/L or less. Each of the impaired lakes addressed herein are shallow. Standard applies to the summer growing season.<br><br>Criteria for *E. coli* set forth in Minn. R. 7050.0222 (4). Lambert Creek must not exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples in any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard is in effect between April 1st and October 31st. | Section 2 |

# EPA TMDL Summary Table

| **Loading Capacity (expressed as daily load)** | Section 6, Table 6.1, Table 6.2, Table 6.10 |
|---|---|
| The loading capacity is the total maximum daily load for each of these conditions. The critical period for these lakes is the summer growing season. The loading capacity is set forth in Tables 6.1, 6.2, 6.10 and 6.11. | |

PHOSPHORUS: Total maximum daily total phosphorus load:

| Water Body | lbs P/day | TMDL expressed as lbs P/year |
|---|---|---|
| Gem Lake | 0.150 | 54.9 |
| East Goose Lake | 0.514 | 187.9 |
| West Goose Lake | 0.615 | 224.2 |
| Gilfillan Lake | 0.451 | 164.7 |
| Wilkinson Lake | 0.881 | 321.8 |

*E. COLI:* The TMDL for *E. coli* in Lambert Creek expressed as a daily limit is:

| **Reach** | **Critical Condition** | **TMDL ($10^9$ org)** |
|---|---|---|
| Lambert Creek | High Flow | 21.04 |
| | Wet | 6.54 |
| | Mid-Range | 3.08 |
| | Dry | 1.08 |
| | Low Flow | 0.00 |

# EPA TMDL Summary Table

| | | | | |
|---|---|---|---|---|
| **Wasteload Allocation** | The Wasteload Allocations for each impairment represent MS4s, industrial sources (M-Foods Dairy, LLC), WWTF (none relevant) and the NPDES Construction Permit. Individual WLAs are provided for MS4s and for M-Foods Dairy, LLC. | | | Section 6, Tables 6.11, 6.3, 6.4<br><br>(Daily Loads given here are from tables 6.11 and 6.4. Annual phosphorus loads are given in table 6.3.) |
| | **Source & MS4 Number** | **Gross WLA- *E. coli* (Daily Load, Billions of organisms)** | **Phosphorus (Daily Load, lbs/day)** | |
| | Gem Lake City MS400020 | High Flow:0.68<br>Wet:0.21<br>Mid-range: 0.10<br>Dry: 0.04<br>Low Flow: 0.00 | Gem: 0.065<br>Goose-East: 0.006<br>Goose-West: 0.007 | |
| | Ramsey County MS400191 | High Flow: 0.56<br>Wet: 0.17<br>Mid-range: 0.08<br>Dry: 0.03<br>Low Flow: 0.00 | Gem: 0.025<br>Goose-East: 0.011<br>Goose-West: 0.004<br>Gilfillan: 0.001<br>Wilkinson: 0.006 | |
| | MnDOT MS400170 | High Flow: 1.17<br>Wet : 0.36<br>Mid-range: 0.17<br>Dry: 0.06<br>Low Flow: 0.00 | Gem: 0.014<br>Goose-East: 0.022<br>Goose-West: 0.010<br>Wilkinson: 0.129 | |
| | White Bear Lake City MS400060 | High Flow: 3.74<br>Wet: 1.16<br>Mid-range: 0.55<br>Dry: 0.19<br>Low Flow: 0.00 | Gem: 0.025<br>Goose-East: 0.176<br>Goose-West: 0.020<br>Wilkinson: 0.096 | |
| | Vadnais Heights City MS400057 | High Flow: 8.78<br>Wet: 2.73<br>Mid-range: 1.28<br>Dry: 0.45<br>Low Flow: 0.00 | Gilfillan: <0.001 | |
| | White Bear Township MS4400163 | High Flow: 0.45<br>Wet: 0.15<br>Mid-range: 0.07<br>Dry: 0.02<br>Low Flow: 0.00 | Gilfillan: 0.005<br>Wilkinson: 0.185 | |

# EPA TMDL Summary Table

| | | | | |
|---|---|---|---|---|
| **Wasteload Allocation** | The Wasteload Allocations for each impairment represent MS4s, industrial sources (M-Foods Dairy, LLC), WWTF (none relevant) and the NPDES Construction Permit, which includes MNG49 sites. Individual WLAs are provided for MS4s and for M-Foods Dairy, LLC. | | | Section 6, Tables 6.11, 6.3, 6.4 |
| | Anoka County MS400066<br><br>North Oaks City MS400109<br><br><br>Lino Lakes City MS400100<br><br>M-Foods Dairy, LLC Permit #: MNG255067 | | Wilkinson: <0.001<br><br>Gilfillan: 0.041<br>Wilkinson: 0.072<br><br>Wilkinson: 0.003<br><br>Goose-West: 0.068 | |

# EPA TMDL Summary Table

<table>
<tr><td rowspan="8">Load Allocation</td><td colspan="2">The portion of the loading capacity allocated to existing non-permitted sources.</td><td rowspan="8">Section 6, Tables 6.5-6.9</td></tr>
<tr><td>Source</td><td>Phosphorus Load Allocation (lbs/day)</td></tr>
<tr><td>Augmentation</td><td>Gilfillan Lake: 0.022 lbs P/day (Augmentation)</td></tr>
<tr><td>Atmospheric</td><td>Gem Lake: 0.014 lbs P/day<br>East Goose Lake: 0.076 lbs P/day<br>West Goose Lake: 0.016 lbs P/day<br>Gilfillan Lake: 0.065 lbs P/day<br>Wilkinson Lake: 0.064 lbs P/day</td></tr>
<tr><td>Groundwater</td><td>East Goose Lake: 0.002 lbs P/day<br>Wilkinson Lake: 0.004 lbs P/day</td></tr>
<tr><td>Internal Load</td><td>East Goose Lake: 0.195 lbs P/day<br>West Goose Lake: 0.337 lbs P/day<br>Gilfillan Lake: 0.294 lbs P/day<br>Wilkinson Lake: 0.142 lbs P/day</td></tr>
<tr><td>Upstream Lakes</td><td>West Goose Lake: 0.121 lbs P/day<br>Wilkinson Lake: 0.136 lbs P/day</td></tr>
<tr><td>Septic Systems</td><td>Gem Lake: 0 lbs P/day<br>East Goose Lake: 0 lbs P/day<br>West Goose Lake: 0 lbs P/day<br>Gilfillan Lake: 0 lbs P/day<br>Wilkinson Lake: 0 lbs P/day</td></tr>
<tr><td>Margin of Safety</td><td colspan="2">Both implicit and explicit Margins of Safety are included in these TMDLs. Implicit Margins of Safety are achieved through conservative assumptions of the model and the proposed iterative nutrient reduction strategy with monitoring. Explicit Margins of Safety are also assigned to the TMDL as follows:<br>Gem Lake: 5%<br>East Goose Lake: 5%<br>West Goose Lake: 5%<br>Gilfillan Lake: 5%<br>Wilkinson Lake: 5%<br>Lambert Creek: 10%</td><td>Sections 6.2 and 6.4</td></tr>
</table>

# EPA TMDL Summary Table

| | | |
|---|---|---|
| **Seasonal Variation** | Seasonal variation is accounted for in lake nutrient TMDLs by developing targets for the summer critical period, when 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.<br><br>Seasonal variation is accounted for in bacteria TMDLs through using the load duration method. | Sections 6.3 and 6.4 |
| **Reasonable Assurance** | Reasonable assurance is provided by the cooperative efforts of the Vadnais Lake Area WMO (VLAWMO), a watershed-based organization with statutory responsibility to protect and improve water quality in the water resources in the watershed in which these lakes and river are located. | Section 9 |
| **Monitoring** | VLAWMO currently monitors lake and stream water quality annually to track baseline conditions, and assess progress towards water quality goals. These efforts will continue annually as discussed in Section 9. | Section 9 |
| **Implementation** | This TMDL sets forth an implementation framework and wasteload and load reduction strategies. A separate Implementation Plan will provide more detailed information about implementation strategies within VLAWMO. | Section 8 |
| **Public Participation** | Public Comment period: September 16, 2013 - October 15, 2013<br>Meeting dates: January 22, 2009, August 10, 2009, and May 3, 2012<br>Comments received: Four comment letters were received. | Section 7 |

# Executive Summary

This report sets Total Maximum Daily Loads (TMDL) for six water bodies included on the MPCA's 303(d) list of impaired waters in 2008 (Lambert Creek) and 2010 (Gem, East Goose, West Goose, Gilfillan, and Wilkinson Lakes). The lakes and stream addressed in this report are within the Upper Mississippi River Basin within the jurisdiction of the Vadnais Lake Area Water Management Organization (VLAWMO), which covers approximately 25 square miles in the northeast Twin Cities Metropolitan Area. The watershed encompasses the City of North Oaks and portions of the Cities of White Bear Lake, Gem Lake, Vadnais Heights, Lino Lakes, and White Bear Township, Minnesota. Figure E-1 shows the locations of the impaired waters in the state of Minnesota, and their location within the VLAWMO watershed. Figure E-2 shows the impaired waters and their tributary watersheds.

East and West Goose Lake, Gem Lake, Gilfillan Lake and Wilkinson Lake do not currently meet the Minnesota lake water quality standards for shallow lakes in the North Central Hardwood Forest ecoregion. Water quality in these lakes has remained consistently above the state standard for phosphorus. This TMDL study quantifies the pollutant reductions needed for these impaired waters to meet State water quality standards.

Land uses in the tributary watersheds to the impaired lakes are a mix of agriculture, developed area, and undeveloped areas. The Gilfillan Lake and East Goose Lake subwatersheds are nearly totally developed, while the Wilkinson Lake and West Goose Lake watersheds contain significant areas of parkland and undeveloped area. The Gem Lake watershed is 45 percent undeveloped.

Lambert Creek does not currently meet Minnesota standards for bacteria as evaluated by the use of *E. coli* measurements. The Lambert Creek watershed is a mix of developed, undeveloped, park and recreation, and agriculture land use.

**Lake Nutrient Impairments:**

To address the lake nutrient impairments, TMDLs are set for phosphorus, since it is typically the limiting nutrient for nuisance algal blooms in lakes. The relationships among phosphorus, Secchi depth and chlorophyll-*a* are well established (Heiskary and Walker, 1988; Heiskary and Wilson, 2005 and 2008). As phosphorus is controlled, Secchi depth and chlorophyll-*a* concentrations will also meet state standards. This TMDL is written to solve the TMDL equation for numeric targets for the impaired waters. The TMDL is expressed by the following equation:

$$TMDL = S(LA) + S(WLA) + MOS + RC$$

Where LA= Load Allocation
WLA= Waste Load Allocation
MOS= Margin of Safety
RC= Reserve Capacity

Lake response models were used to set the TMDL for each lake and to calculate the load reductions needed to meet State standards. The lake response models are a numeric description of the relationship between phosphorus loading to a lake, and in lake concentration. The relationship (the model) is based on the size of the lake, drainage area, and settling rate for phosphorus, which are all parameters in the model. The model tells us how many pounds of phosphorus the lake can handle and still meet its designated uses, in other words the Assimilative Capacity. The model also assists in calculating the load reductions based on current concentrations by predicting the lake's response to load reductions.

The lake response models were built, calibrated and validated using GIS-based watershed land use information, measured watershed runoff, and water quality data collected by VLAWMO and the St. Paul Regional Water Supply (SPRWS) between 2000 and 2010. A P8 model was used to predict watershed runoff and loads from unmonitored watersheds. The lake models were calibrated to measured watershed runoff and modeled internal phosphorus loading based on both collected data and literature values. The Gilfillan Lake model and load allocation also considers augmentation of lake levels using water from Pleasant Lake.

Data and models are used to quantify phosphorus from both land-use based and in-lake sources (load partitioning). The partitioning of the loads informs the necessary load reduction strategies. These analyses are described in Sections 4, 5 and 6 of this report and modeling results are included: Appendix A contains the results of lake response modeling; Appendix B contains tables for P8 modeling inputs, load partitioning between MS4s, and load allocations as well as summary tables; and Appendix C contains the results of watershed modeling (P8).

Phosphorus loading to the impaired lakes is driven by watershed and internal loading. For Gem and Wilkinson Lakes, the primary source is watershed loading. For East Goose, West Goose, and Gilfillan Lakes, the primary source is internal loading. The East Goose internal load has been historically impacted by discharge from the White Bear Lake WWTP. Secondary sources for West Goose include the discharge from East Goose Lake as well as watershed loading. Load reductions will be required primarily from internal sources for East Goose, West Goose, and Gilfillan Lakes and from watershed sources for Gem, East Goose, West Goose, and Wilkinson Lakes. An important factor in meeting the TMDL in West Goose Lake is the improvement of East Goose Lake to meet the shallow lake standard (60 µg/L).

Water quality data and lake response models show that the required total phosphorus load reductions to meet state standards in the lakes are:

- 24% reduction in Gem Lake which will come primarily from watershed sources.

- 91% reduction in East Goose Lake which will come primarily from internal sources with some watershed load reduction.
- 70% reduction in West Goose Lake which will come from internal, watershed, and E. Goose Lake loading.
- 62% reduction in Gilfillan Lake which will come primarily from internal loading.
- 63% reduction in Wilkinson Lake which will come from watershed sources.

An MOS has been incorporated into this TMDL to account for uncertainty. Both implicit and explicit MOS is incorporated into the lake nutrient TMDLs. The explicit MOS is 5% of the TMDL for each of the impaired lakes. Due to conservative modeling practices and robust data sets, a large explicit MOS is unnecessary and the small explicit MOS applied (5%) is appropriate.

Each MS4 within the drainage area of the impaired waters was given an individual WLA. RC is included in the WLA.

A combination of internal load management and reduction of phosphorus from watershed runoff will be required to meet phosphorus load reduction goals in VLAWMO's impaired lakes. To meet required watershed load reductions, a mix of capital projects and land-use based BMPs will be necessary. Given the significant level of reductions required for some lakes, meeting lake water quality goals may take more than 10 years.

**Lambert Creek Bacteria Impairment**

The bacteria TMDL for Lambert Creek was set according to the MPCA's Bacteria TMDL Protocol (March 2009). Specifically, a load duration curve was developed from bacterial loads. Bacteria concentrations exceed the state standard across all flow regimes and are not limited to low or high flow conditions. Reductions are required across all flow regimes with the exception of the Low Flow regime. Standing water is common in Lambert Creek when flows are 0 or close to 0. Load reductions in terms of *E. coli* within the listed reach to meet the State standards are as follows:

61% in High Flows
54% in Wet Conditions
37% in Mid-range Flows
56% in Dry Conditions
0% in Low Flows

An explicit MOS of 10% was used. Each MS4 within the drainage area was given an individual WLA. Based on *E. coli* bacteria sources identified in the watershed, the primary implementation strategies will focus on pet waste management, wildlife population tracking and management, and regular city inspections of infrastructure to detect and prevent any sanitary sewage sources.

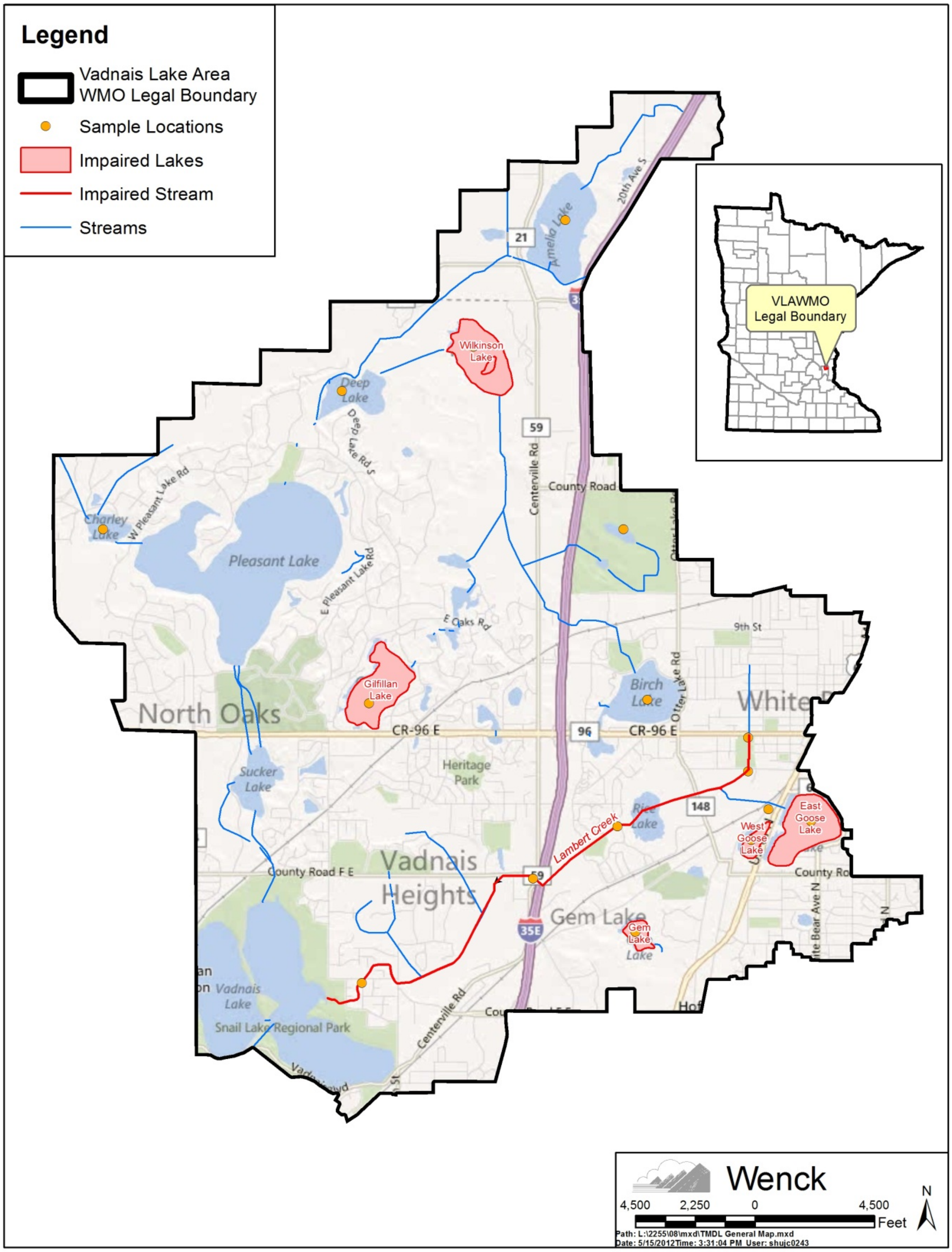


**Figure E. 1. Location of Impaired Waters.**

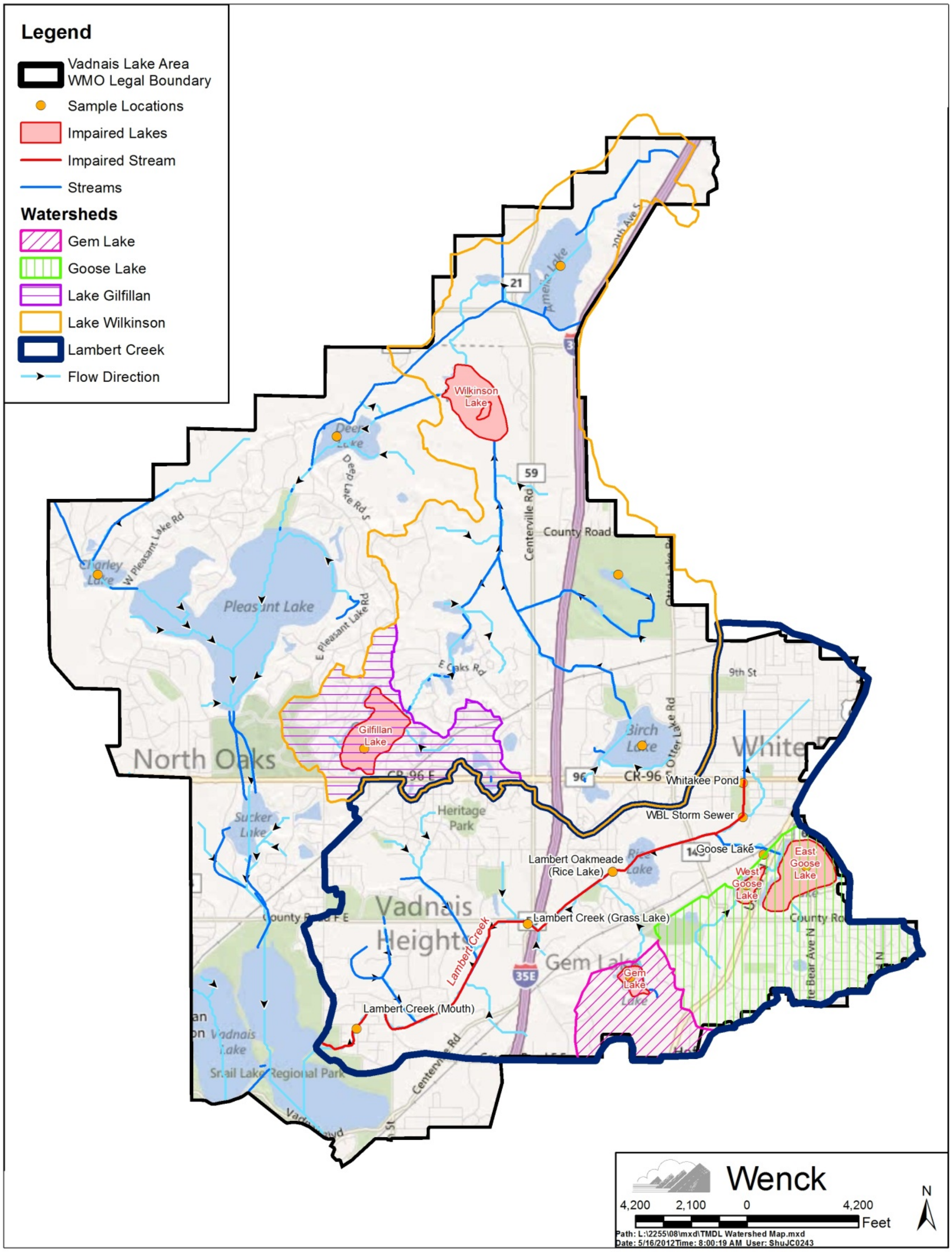


**Figure E. 2. Impaired Waters and Tributary Watersheds.**

# 1.0 Introduction and Problem Statement

Section 303(d) of the Federal Clean Water Act (CWA) requires the Minnesota Pollution Control Agency (MPCA) to identify water bodies that do not meet water quality standards and to develop total maximum daily pollutant loads for those water bodies. A TMDL is the amount of a pollutant that a water body can assimilate without exceeding the established water quality standard for that pollutant. Through a TMDL, pollutant loads are allocated to permitted and non-permitted sources within the watershed that discharge to the water body.

Water quality evaluations conducted by VLAWMO and the State of Minnesota have shown that Gem, Gilfillan, East Goose, West Goose and Wilkinson Lakes and Lambert Creek do not meet established State Water Quality Standards.

This TMDL study addresses nutrient impairments in Gem, Gilfillan, East Goose, West Goose and Wilkinson Lakes and the bacteria impairment in Lambert Creek. The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards in each water body. This TMDL is being established in accordance with section 303(d) of the Clean Water Act. Table 1.1 lists the impairments addressed in this report.

**Table 1. 1. Impairments Addressed in this Report.**

| Listed Reach Name/ AUID | Listed Pollutant | Impaired Use | State Standard | Year Placed in Impairment Inventory | TMDL Target Start | TMDL Target Completion |
|---|---|---|---|---|---|---|
| Unnamed Creek (Lambert Creek); Highway 96 to Vadnais Lk #07010206-801* | Pathogens, (*E. coli*) | Aquatic Recreation | Chronic: 30-day geometric mean is not to exceed 126 cfu/100mL (n≥5 samples)<br>Acute: 10% of values are not to exceed 1,260 cfu/100 mL | 2008 | 2010 | 2014 |
| Gem Lake #62-0037-00 | Nutrient/ Eutrophication Biological Indicators | Aquatic recreation | ≤60 mg/L TP<br>≤20 mg/L Chlorophyll-*a*<br>≥1.0 m Secchi depth | 2010 | 2010 | 2014 |
| Goose Lake East #62-0034-00 | Nutrient/ Eutrophication Biological Indicators | Aquatic recreation | ≤60 mg/L TP<br>≤20 mg/L Chlorophyll-*a*<br>≥1.0 m Secchi depth | 2010 | 2010 | 2014 |

**Table 1.1, cont. Impairments Addressed in this Report.**

| Listed Reach Name/ AUID | Listed Pollutant | Impaired Use | State Standard | Year Placed in Impairment Inventory | TMDL Target Start | TMDL Target Completion |
|---|---|---|---|---|---|---|
| Goose Lake West #62-0126-00W | Nutrient/ Eutrophication Biological Indicators | Aquatic recreation | ≤60 mg/L TP<br>≤20 mg/L Chlorophyll-*a*<br>≥1.0 m Secchi depth | 2010 | 2010 | 2014 |
| Gilfillan #62-0027-00 | Nutrient/ Eutrophication Biological Indicators | Aquatic recreation | ≤60 mg/L TP<br>≤20 mg/L Chlorophyll-*a*<br>≥1.0 m Secchi depth | 2010 | 2010 | 2014 |
| Wilkinson #62-0043-00 | Nutrient/ Eutrophication Biological Indicators | Aquatic recreation | ≤60 mg/L TP<br>≤20 mg/L Chlorophyll-*a*<br>≥1.0 m Secchi depth | 2010 | 2010 | 2014 |

*Previously AUID#'s 07010206-639 and 07010206-637

The Minnesota Pollution Control Agency (MPCA) projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of the VLAWMO TMDLs. The project was scheduled to begin in 2010 and be completed in 2014. Ranking criteria for scheduling TMDL projects include, but are not limited to, impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the water body; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

# 2.0 Water Quality Standards and Numeric Targets

## 2.1 STATE OF MINNESOTA STANDARDS AND DESIGNATED USES

Gem, Gilfillan, East Goose, West Goose and Wilkinson Lakes are shallow lakes classified as class 2B waters for which aquatic life and recreation are the protected beneficial uses. Wilkinson is also listed as 1C, 2B, and 3C and Gem, Gilfillan, East Goose and West Goose are also listed as 3C, 4A, 4B, 5 and 6 waters. The MPCA (Minnesota Pollution Control Agency) first included all four lakes on the 303(d) impaired waters list for Minnesota in 2010. These lakes are impaired by excess nutrient concentrations, which inhibit aquatic recreation.

Under Minnesota Rules 7050.0150 and 7050.0222, Subp. 4, Gem, Gilfillan, East Goose, West Goose and Wilkinson lakes are considered to be shallow lakes located within the North Central Hardwood Forest ecoregion with a numeric target of ≤60 μg/L for total phosphorus. Therefore, this TMDL presents load and wasteload allocations and estimated load reductions assuming an end point of ≤60 μg/L for total phosphorus as a growing season average, defined as June through September (see Table 2.1).

Although the TMDL is set for the total phosphorus standard, chlorophyll-*a* and Secchi depth were also evaluated in this TMDL to assure that the TMDL will result in compliance with State standards. As shown in Table 2.1, shallow-lake numeric standards for chlorophyll-*a* and Secchi depth are ≤20 μg/L and ≥1.0 meters as growing season averages, respectively.

**Table 2.1. TMDLs Numeric Targets for Lakes in the North Central Hardwood Forest Ecoregion.**

| **Parameters** | **Shallow Lakes in the North Central Hardwood Forest Ecoregion[1]** |
|---|---|
| Total phosphorus concentration (μg/L) | **≤60** |
| Chlorophyll-*a* concentration (μg/L) | **≤20** |
| Secchi disk transparency (meters) | **≥1.0** |

[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) (Minnesota Rules 7050.0150, Subp.4).

In establishing the numeric eutrophication standards for lakes, shallow lakes and reservoirs, Minnesota documented the well-established link between high total phosphorus concentrations to both high chlorophyll-*a* concentrations and low Secchi depth (MPCA 2007, SONAR Book 2). Figure 2.1, taken from the MPCA web site, presents the relationship between Secchi depth, chlorophyll-*a* and phosphorus for Minnesota Lakes. This relationship is widely documented by others as well (Heiskary and Walker, 1988; Heiskary and Wilson, 2005).

Achieving the total phosphorus goals for these lakes will result in the lake meeting the corresponding water quality standards for chlorophyll-*a* and Secchi disk transparency within the basin.

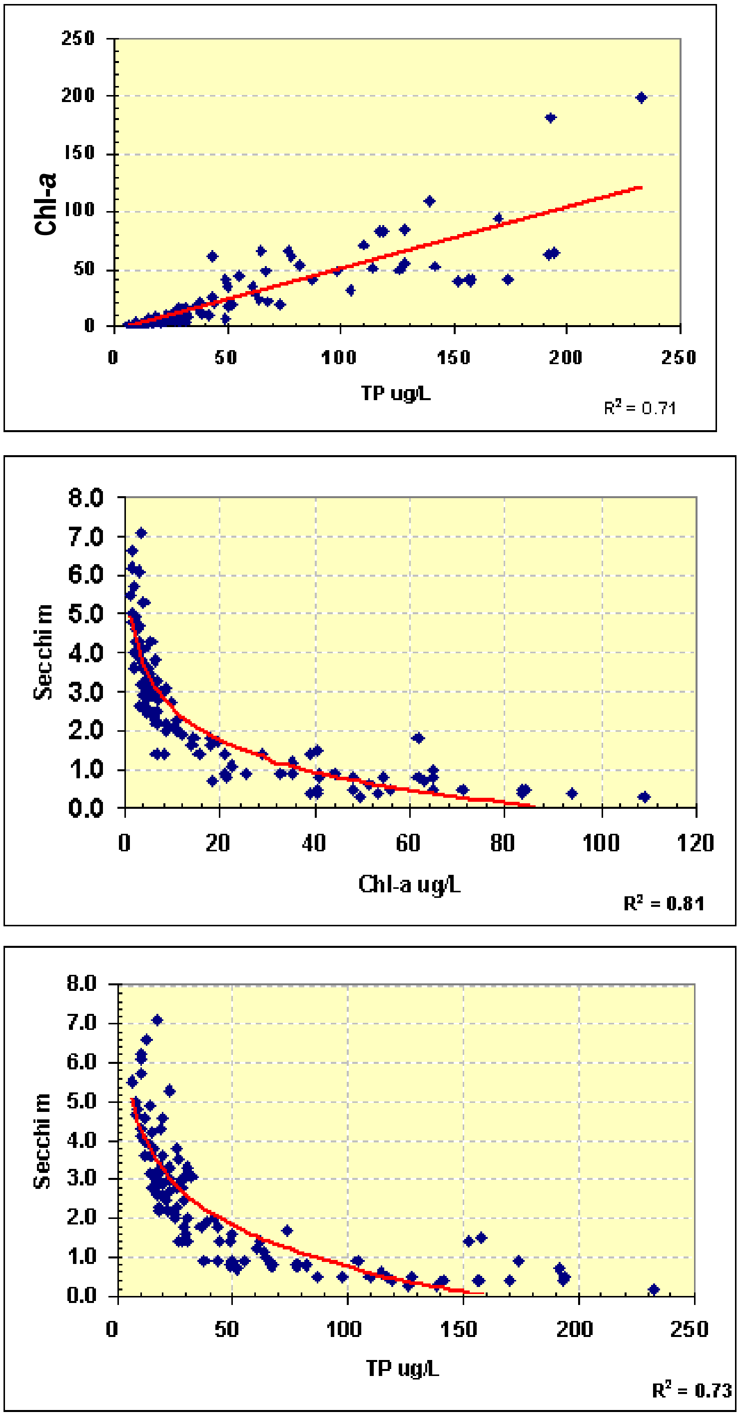


**Figure 2.1. Relationships Among Phosphorus, Chlorophyll-*a* and Secchi Depth in Minnesota Lakes.**
(Source: MPCA website http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/asessment-definitions-andnotes.html?menuid=&missing=0&redirect=1)

Lambert Creek is classified as 2B, 3C, 4A, 4B, 5 and 6 waters. For Lambert Creek, the standards for bacteria are evaluated by the use of *E. coli* measurements. Under Minnesota Rules 7050.0150 and 7050.0222, "*Escherichia (E.) coli* bacteria shall not exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31." Therefore, the goal is not to exceed these standards in the index period.

## 2.2 ANALYSIS OF IMPAIRMENT

Table 2.2 shows the ranges for the June through September averages of total phosphorus (TP) concentration, chlorophyll-*a* (chl-*a*) concentration, and Secchi depth for each impaired lake. Although, Goose Lake is made up of two hydraulically connected (i.e. connected through pipes) basins (divided in to East and West Goose) the water quality in each is significantly different and will be evaluated separately.

**Table 2.2. Growing Season Averages for Water Quality Parameters.**

| Parameter | Gem | Gilfillan | East Goose | West Goose | Wilkinson |
|---|---|---|---|---|---|
| **Calibration Years** | **2000-2005, 2007-2009** | **2006-2010** | **2007-2010** | **2007-2010** | **2001-2005, 2007-2009** |
| Long Term Summer Avg TP [ug/L] | 71.7 | 138.3 | 261.1 | 167.0 | 148.8 |
| Long Term Summer Avg Chl-a [ug/L] | 63.8 | 37.9 | 104.8 | 56.0 | 29.7 |
| Long Term Summer Secchi Depth [m] | 1.24 | 0.42 | 0.27 | 0.46 | 0.67 |

T:\2255 VLAWMO\08_TMDL\Report\[Tables & graphs_new.xlsx]More Tables

All three parameters, for each lake, have exceeded the State standards for class 2B shallow lakes in the North Central Hardwood Forest ecoregion with the exception of the long-term summer Secchi depth for Gem Lake.

Table 2.3 shows the exceedances of the chronic and acute *E. coli* standard from May to October for five sample stations located within the impaired reach of Lambert Creek and one sample station located upstream, tributary to the impaired reach (exceedances in red). Monthly geometric means, total number of samples, and the percentage of samples exceeding the acute standard are tabulated. Geometric means are often used to describe bacteria data over arithmetic means as the geometric mean normalizes the ranges being averaged. Further, geometric means are used as the measurement with regard to the State Standard.

$$Geometric\ mean = \sqrt[n]{x_1 *\ x_2 * \ldots . x_n}$$

Data from 2006 to 2010 was used for the purpose of this TMDL. The State Standard applies April 1st to October 31st; however, no data for Lambert Creek was available for the month of April.

The monthly geometric means of *E. coli* have exceeded the state standard of 126 cfu/100mL in Lambert Creek for most months. In addition, the acute standard of greater than 10% of measured values at or above 1,260 cfu/100mL during the month was exceeded in all months with the exception of May.

**Table 2.3. Monthly Geometric Mean of *E. coli* Values for Lambert Creek System.**

| | | | April | May | | | June | | | July | | | August | | | September | | | October | | | All Months | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling Point | Location | Data Years | | n | Geo | %n > 1260 | n | Geo | %n > 1260 | n | Geo | %n > 1260 | n | Geo | %n > 1260 | n | Geo | %n > 1260 | n | Geo | %n > 1260 | n | Geo | %n > 1260 |
| Lambert Creek Mouth | Within Impaired Reach | 2006-2010 | No Data Collected | 11 | 197 | 9% | 23 | 304 | 13% | 20 | 316 | 10% | 23 | 355 | 9% | 14 | 290 | 0% | 1 | 2098 | 100% | 92 | 307 | 10% |
| Lambert Creek East (Grass L.) | | 2006-2010 | | 11 | 43 | 0% | 23 | 231 | 13% | 24 | 327 | 8% | 26 | 598 | 27% | 14 | 448 | 14% | 1 | 24196 | 100% | 99 | 308 | 15% |
| Lambert Oakmeade (Rice Lake) | | 2006-2010 | | 11 | 162 | 9% | 22 | 304 | 23% | 17 | 413 | 18% | 22 | 104 | 5% | 12 | 119 | 8% | 1 | 408 | 0% | 85 | 192 | 13% |
| Whitaker Pond | | 2008-2010 | | 9 | 26 | 11% | 14 | 160 | 0% | 12 | 239 | 0% | 14 | 328 | 21% | 11 | 439 | 18% | 1 | 55 | 0% | 61 | 184 | 10% |
| White Bear Storm Sewer | | 2006-2008 | | 4 | 208 | 50% | 15 | 585 | 1% | 18 | 601 | 33% | 16 | 1151 | 38% | 7 | 1677 | 57% | 1 | 6131 | 100% | 61 | 772 | 34% |
| Goose Lake | Upstream, tributary | 2006-2010 | | 13 | 39 | 0% | 24 | 185 | 8% | 22 | 159 | 0% | 24 | 254 | 0% | 18 | 161 | 0% | 3 | 127 | 0% | 104 | 155 | 2% |

Notes: n =number of samples

Geo = Geometric mean in MPN/100 mL)

The geometric mean of all data collected within the impaired reach (for all months) is 260 MPN/100 mL

# 3.0 Background

## 3.1 WATER BODY AND WATERSHED DESCRIPTIONS

The impaired waters addressed herein and their drainage areas are located within the jurisdiction of VLAWMO. Lake morphometry for the four impaired lakes is listed in Table 3.1. Note that East and West Goose Lakes were historically one waterbody before Highway 61 separated them. Lambert Creek is also located in the southern edge of the VLAWMO boundary and its subwatershed is 4,942.63 acres.

**Table 3.1. Lake Morphometry.**

| Parameter | Gem | East Goose | West Goose | Gilfillan | Wilkinson |
|---|---|---|---|---|---|
| Surface Area (ac) | 21.6 | 116.3 | 24.1 | 99.2 | 97.1 |
| Average Depth (ft) | 8.5 | 5.5 | 4.4 | 2.6 | 1.7 |
| Maximum Depth (ft) | 16 | 9 | 7 | 5 | 4 |
| Volume (ac-ft) | 183.4 | 634.7 | 105.3 | 359.1 | 165.1 |
| Residence Time (years) | 2.9 | 2.3 | 0.3 | 2.9 | 0.2 |
| Littoral Area % | > 80% | 100% | 100% | 100% | 100% |
| Direct Sub-Watershed (ac) * | 306.34 | 577.55 | 238.78 | 531.35 | 2972.82 |

* Excludes Lake Surface Area
(Source: VLAWMO)

This TMDL study addresses the lakes described above as well as Lambert Creek. However, the VLAWMO Watershed Management Plan addresses the entire VLAWMO watershed and all water bodies included therein. The plan, completed in December of 2007, is a third generation plan and will expire in 2016. Please refer to Figure 2-3 of the Watershed Management Plan for a map of the protected waters and public ditch system under VLAWMO's jurisdiction. A table of physical characteristics for most of the protected waters and wetlands, excluding those addressed in this study (see Table 3.1) is included as Table 3.2. Pleasant, Sucker, and East Vadnais Lakes were listed on the 303(d) impaired waters list for Minnesota in 2010. These lakes are impaired for aquatic consumption due to mercury. All other listed waters within the VLAWMO legal boundary are included in this TMDL study. However, based on a recent evaluation of data, additional lakes (Tamarack, West Vadnais, Pleasant) may be listed for nutrient impairments on the Draft 2014 303(d) list.

**Table 3.2. Physical Characteristics of VLAWMO Lakes.**

| Lake | Surface Area (ac) | Max. Depth (ft) |
|---|---|---|
| **Amelia** | 217 | 3 |
| **Birch** | 127 | 6 |
| **Black** | -- | -- |
| **Charley** | 31 | 21 |
| **Deep** | 53 | 11 |
| **Pleasant** | 585 | 58 |
| **Sucker** | 61 | 26 |
| **Tamarack** | 86 | 3 |
| **Vadnais East** | 394 | 58 |
| **Vadnais West** | 216 | 9 |

**Source: VLAWMO Watershed Management Plan**

VLAWMO operates a Citizens Lake Monitoring Program (CLMP) and also works in conjunction with the St. Paul Regional Water Service (SPRWS) on water quality monitoring. The CLMP monitors several lakes and ponds within the watershed. The SPRWS monitors the direct surface water flow into Vadnais Lake to assure high quality drinking water for over 400,000 consumers. The SPRWS monitors the main chain of lakes (Charley Lake, Pleasant Lake, Sucker Lake and Vadnais Lake) and VLAWMO monitors Lambert Creek, which flows directly into Vadnais Lake. The data received from the monitoring is used by VLAWMO and the Minnesota Pollution Control Agency (MPCA) to determine the health of the state's waters. Data collected through the VLAWMO water quality monitoring program tracks changes in water quality in conjunction with the change in land use around the water bodies. Data is published annually in the VLAWMO Water Quality Monitoring Program Report.

## 3.2 LAND USE

VLAWMO is mostly urbanized, with a 2004 estimated population of approximately 33,748. New low-density land development is occurring near Gem Lake and Wilkinson Lake. Land use within the VLAWMO boundary is shown on Figure 3.1. Land use (by subwatershed) is shown in Table 3.3 below. Larger maps of land use within the drainage areas for individual impaired waters, offering a greater amount of visible detail, are shown in Appendix D.

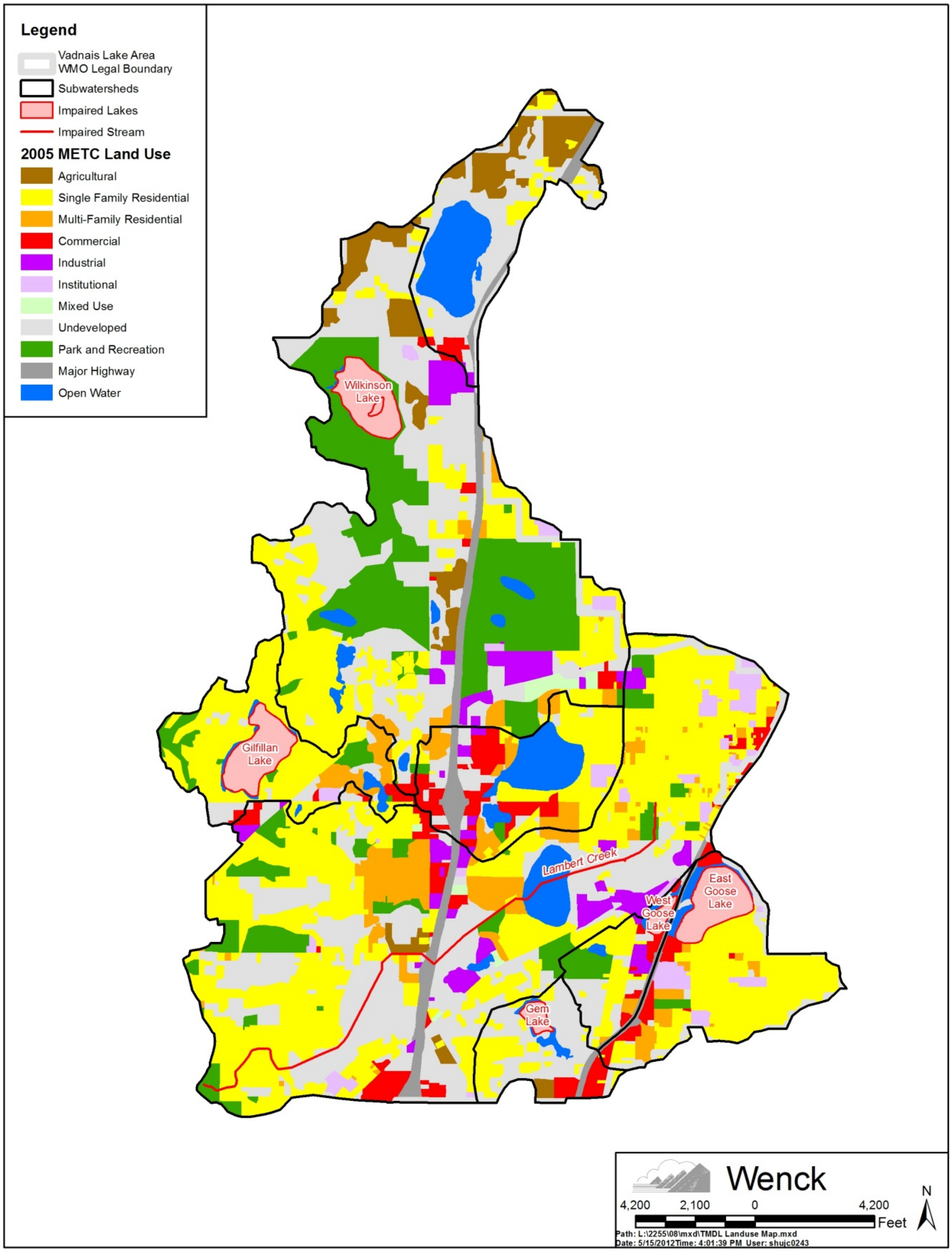


**Figure 3.1. VLAWMO Land Use.**

**Table 3.3. Land Use by Impaired Waters Drainage Area.**

| Impaired Water (Subwatershed Identification[1]) | Gem Lake (2011505) | | East Goose Lake (2011504) | | West Goose Lake (20115044) | | Lake Gilfillan (2007902) | | Lake Wilkinson (2007901, 2007902, 2007903, 2007904) | | Lambert Creek (2011504, 2011505, 20115044, 20115055) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Land Use** | Acres | % | Acres | % | Acres | % | Acres | % | Acres | % | Acres | % |
| **Agricultural** | 12.44 | 4% | 0.0 | 0% | 0.0 | 0% | 0.0 | 0% | 313.83 | 6% | 39.31 | 1% |
| **Commercial** | 35.70 | 11% | 43.36 | 6% | 18.66 | 7% | 14.59 | 2% | 168.16 | 3% | 221.44 | 4% |
| **Industrial** | 0.0 | 0% | 0.0 | 0% | 15.45 | 6% | 0.05 | 0.01% | 145.03 | 3% | 161.72 | 3% |
| **Institutional** | 0.0 | 0% | 46.65 | 7% | 0.0 | 0% | 7.68 | 1% | 54.50 | 1% | 150.25 | 3% |
| **Major Highway** | 10.78 | 3% | 18.77 | 3% | 17.94 | 7% | 0.0 | 0% | 166.00 | 3% | 140.36 | 3% |
| **Mixed Use** | 0.13 | 0.04% | 0.0 | 0% | 0.0 | 0% | 0.0 | 0% | 29.86 | 1% | 11.99 | 0.24% |
| **Multi-Family Residential** | 0.0 | 0% | 49.10 | 7% | 6.82 | 3% | 53.39 | 8% | 204.17 | 4% | 305.16 | 6% |
| **Open Water** | 32.26 | 10% | 112.46 | 16% | 27.96 | 11% | 118.55 | 19% | 545.48 | 11% | 264.83 | 5% |
| **Park and Recreation** | 0.21 | 0.07% | 11.46 | 2% | 36.54 | 14% | 58.47 | 9% | 964.92 | 19% | 312.08 | 6% |
| **Single Family Residential** | 89.32 | 27% | 402.20 | 58% | 74.33 | 28% | 326.69 | 52% | 1213.44 | 24% | 2168.18 | 44% |
| **Undeveloped** | 147.09 | 45% | 9.85 | 1% | 65.17 | 25% | 51.14 | 8% | 1227.26 | 24% | 1167.31 | 24% |
| **Total** | 327.95 | 100% | 693.85 | 100% | 262.87 | 100% | 630.55 | 100% | 5032.65 | 100% | 4942.63 | 100% |

Source: 2005 Met Council Land Use Database and MnDOT Metro provided shape files
1 Subwatershed identification numbers originated from the DNR Lakeshed HU_ID. Identification numbers were modified as necessary during GIS mapping and data processing to provide unique IDs for each subwatershed. Also, note that the land use areas in this table includes the entire watershed for each waterbody whereas Tables B.7 and B.8 in the Appendix only include subwatershed areas downstream of boundary conditions (e.g. upstream lake subwatersheds).

## 3.3 RECREATIONAL USES

The recreational uses for each lake as described by VLAWMO staff are summarized below:

- Gem Lake is surrounded by privately owned land and the lake is primarily used for non-motorized boating and fishing.
- Gilfillan Lake is also surrounded by privately owned land and is used for some swimming and non-motorized boating. The City of North Oaks prohibits fishing on this lake.
- Goose Lake residents use the lake for shoreline fishing as well as some boating. Water ski shows are held weekly every summer in the west basin.
- Wilkinson Lake has a scenic trail, but there is not public access to the lake for fishing and boating.
- Lambert Creek has no official recreational access and houses or wetlands generally border the riparian areas limiting public access and therefore recreational opportunity.

## 3.4 HYDROLOGY

Annual precipitation in the VLAWMO has ranged from 23.1 inches in 2008 to 42.0 inches in 2002 with average precipitation for the past 10 years of 31.5 inches (Table 3.4). The Saint Paul Regional Water Supply (SPRWS) recorded hourly flow at the outlet of the Lambert Creek subwatershed (Station S002-774, Lambert Creek at Kohler Road). Annual runoff at this station ranged from 0.6 to 2.1 inches between 2006 and 2010 (Table 3.5). The runoff values are low due to the location of the VLAWMO within the Anoka Sand Plain, an area dominated by sandy soils and high infiltration rates. Further, the stream drains through a series of wetlands which can increase evapotranspiration and when located in the Anoka Sand Plain can also increase infiltration rates. Figure 3.2 shows watershed drainage patterns and subwatershed boundaries.

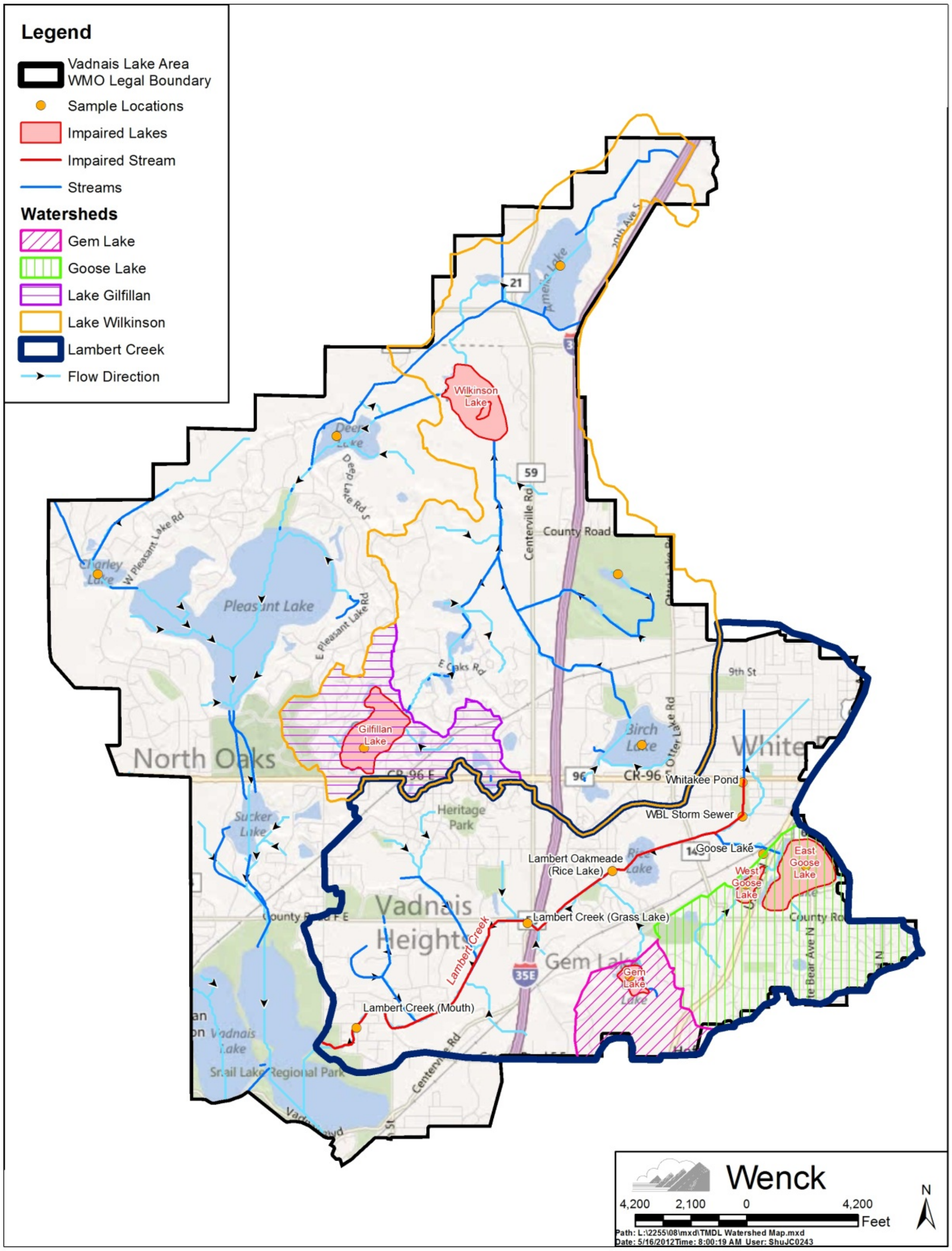


Figure 3.2. Watershed Drainage.

**Table 3.4. Annual Precipitation Amounts for the Vadnais Lake Area.**

| Year | Precipitation [in] |
|---|---|
| 2000 | 34.1 |
| 2001 | 37.8 |
| 2002 | 42.0 |
| 2003 | 26.3 |
| 2004 | 34.3 |
| 2005 | 34.2 |
| 2006 | 28.6 |
| 2007 | 28.9 |
| 2008 | 23.1 |
| 2009 | 27.4 |
| 2010 | 29.5 |
| **AVG** | **31.5** |

**Table 3.5. Annual Runoff as Measured by SPRWS, Lambert Creek near Vadnais Lake.**

| Year | Runoff Depth (in) |
|---|---|
| 2006 | 1.4 |
| 2007 | 0.6 |
| 2008 | 1.9 |
| 2009 | 1.0 |
| 2010 | 2.1 |

T:\2255 VLAWMO\08_TMDL\VLAWMO WOrking File_Current Aug 2011\Lambert Creek\[LambertFlow2010SPRWS.xlsx]Summary

Hourly discharge data for Lambert Creek measured at station S002-774 (Lambert Creek at Kohler Road) was collected by the SPRWS between May 2006 and September 2010. This data was used to compute average daily flow and to construct a flow duration curve for the monitored period. The maximum average daily flow from May 2006 to September 2010 was 27 cfs on May 3, 2008. The lowest average daily flow of 0 cfs was recorded on multiple dates in July 2006, June-August 2007, and July 2009. Figure 3.3 presents a flow duration curve, which was generated from the Lambert Creek station S002-774 flow records.

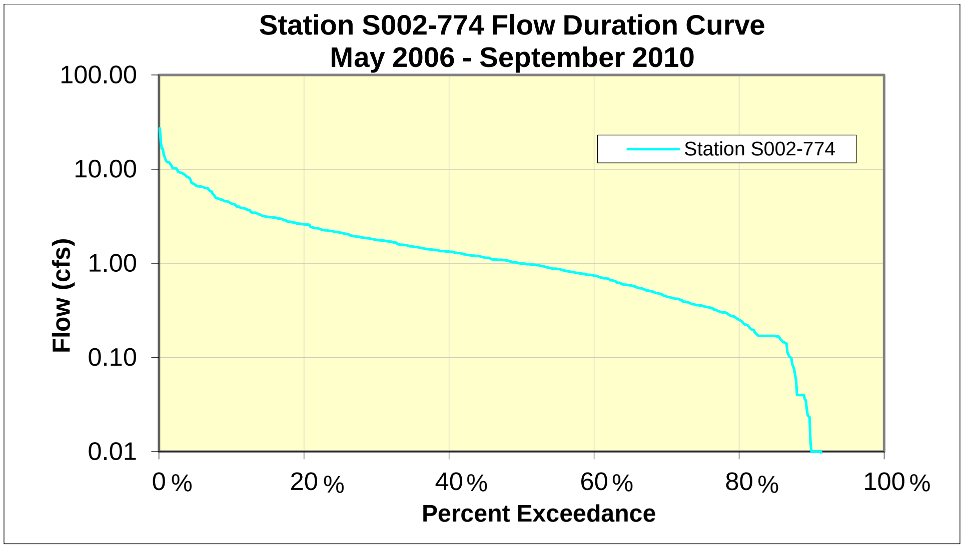


**Figure 3.3. Watershed Outlet Flow Duration Curve.**

## 3.5 WATER QUALITY

VLAWMO monitors water quality within their jurisdiction in conjunction with the SPRWS. As discussed in the previous section, the SPRWS monitors direct surface water flow into Vadnais Lake and also monitors the main chain of lakes (Charley Lake, Pleasant Lake, Sucker Lake, and Vadnais Lake). VLAWMO monitors Lambert Creek and other lakes within its boundaries. This includes the lakes assessed for this TMDL; Wilkinson, Gilfillan, East Goose, West Goose and Gem Lakes. Available water quality monitoring data for each of these lakes from 2000-2009 was generally used for the TMDL as these were the data available during modeling. For calibration of Gilfillan Lake, East Goose Lake and West Goose Lake, the 2010 in-lake water quality data was also used to verify calibration of the models.

### 3.5.1 Lake Water Quality

Historic water quality data collected during the calibration years for each of the impaired lakes is presented in the Figures 3.4 through 3.18. Note that the upper and lower edge of each box represents the standard deviation from the mean for the data range for each year. The numeric standards for each water quality parameter are also displayed.

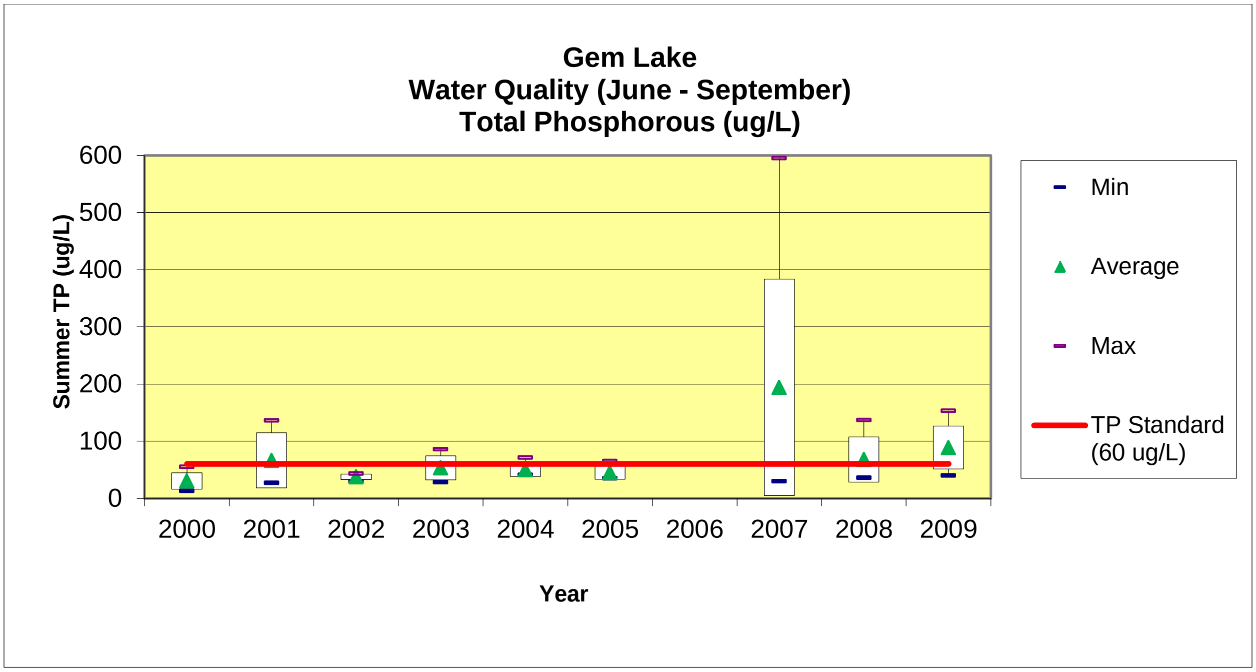


**Figure 3.4. Gem Lake Total Phosphorus Concentrations (June – September).**

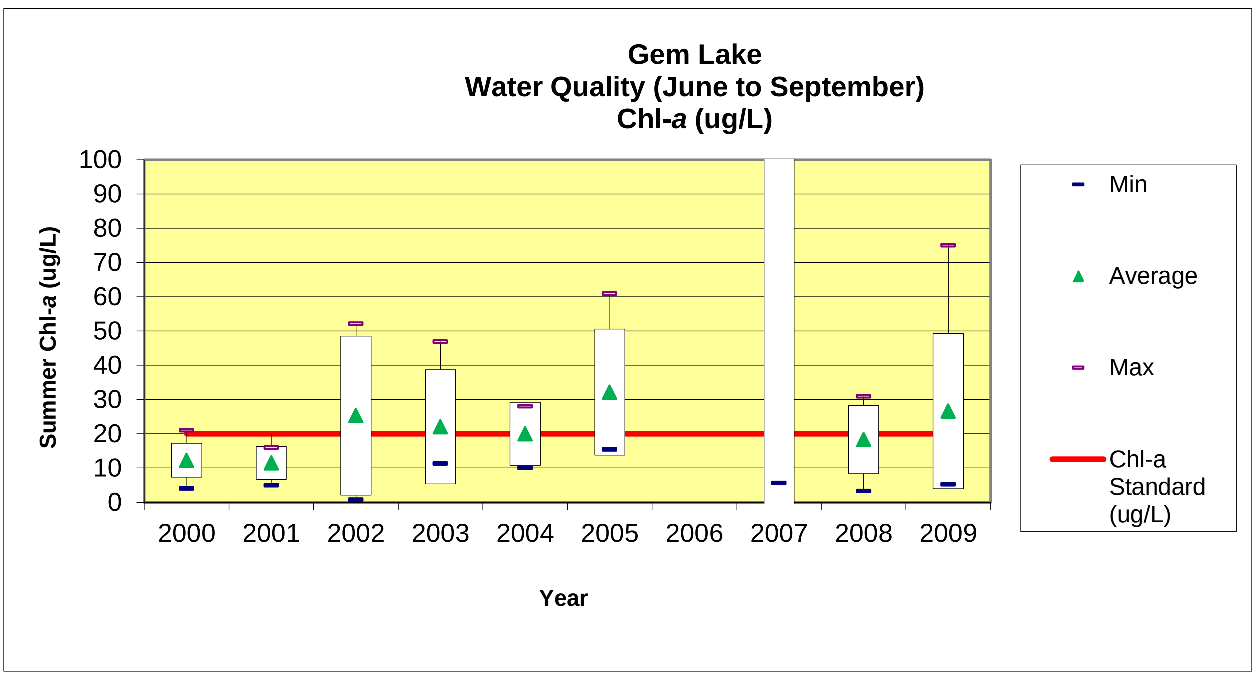


**Figure 3.5. Gem Lake Chlorophyll-*a* Concentrations (June – September).**
Note:2007 data is not fully depicted on this scale due to the high readings of Chl-a measured in July and August of 2007. The average and maximum readings in 2007 were 345 ug/L and 1,163 ug/L, respectively.

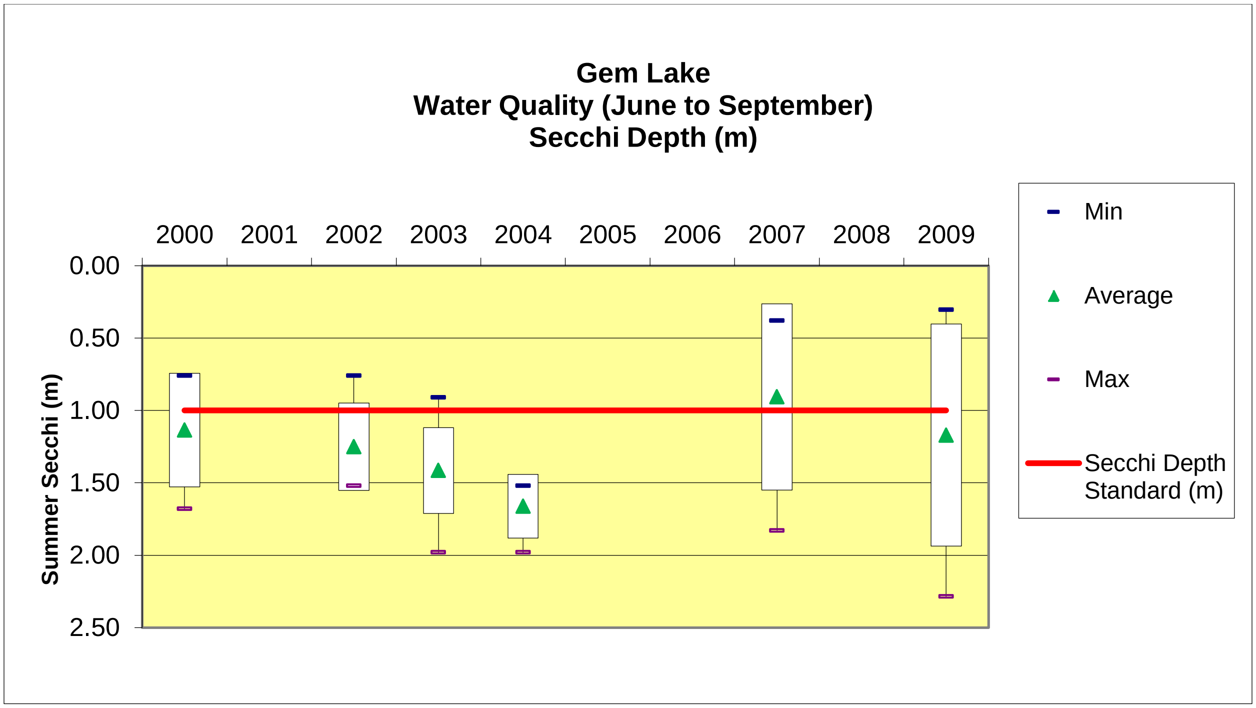


**Figure 3.6. Gem Lake Secchi Depths (June – September).**

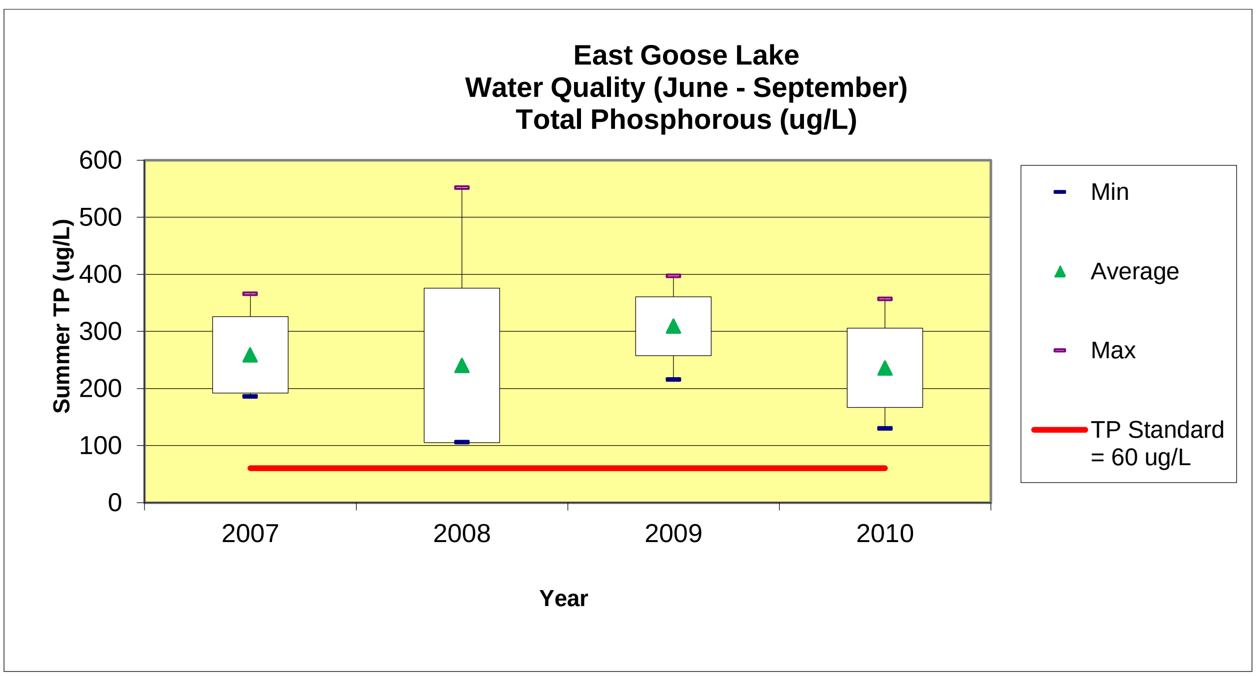


**Figure 3.7. East Goose Lake Total Phosphorus Concentrations (June – September).**

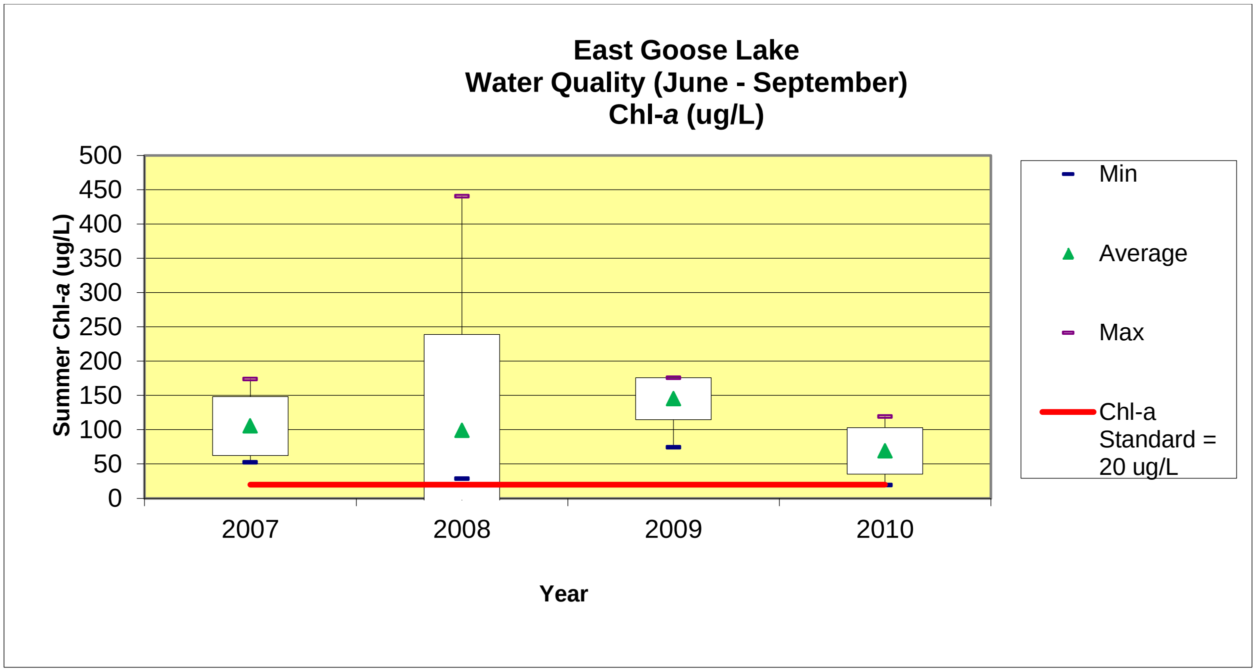


**Figure 3.8. East Goose Lake Chlorophyll-a Concentrations (June – September).**

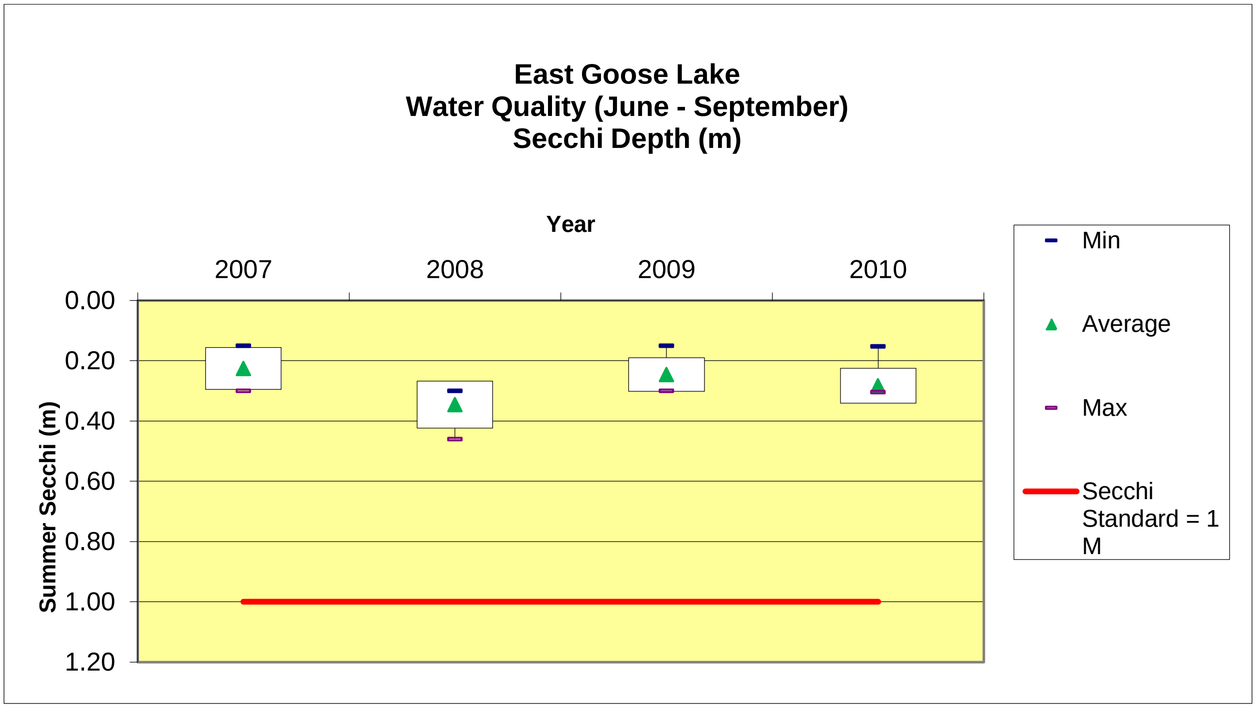


**Figure 3.9. East Goose Lake Secchi Depths (June – September).**

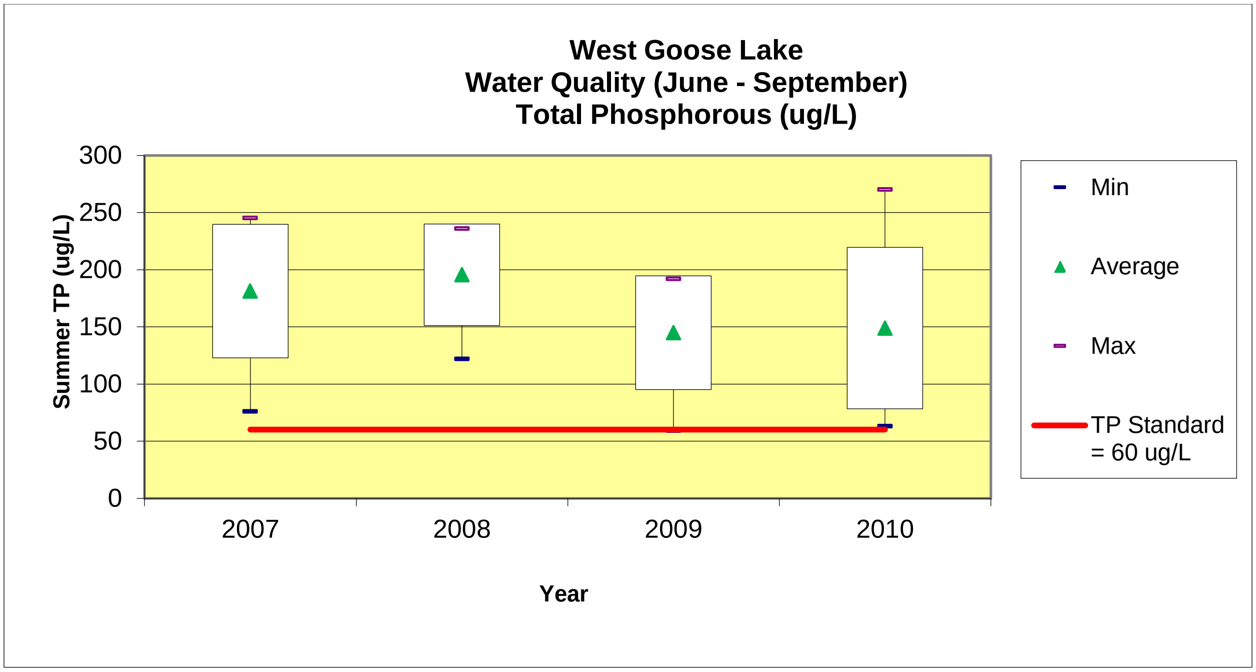


**Figure 3.10. West Goose Lake Total Phosphorus Concentrations (June – September).**

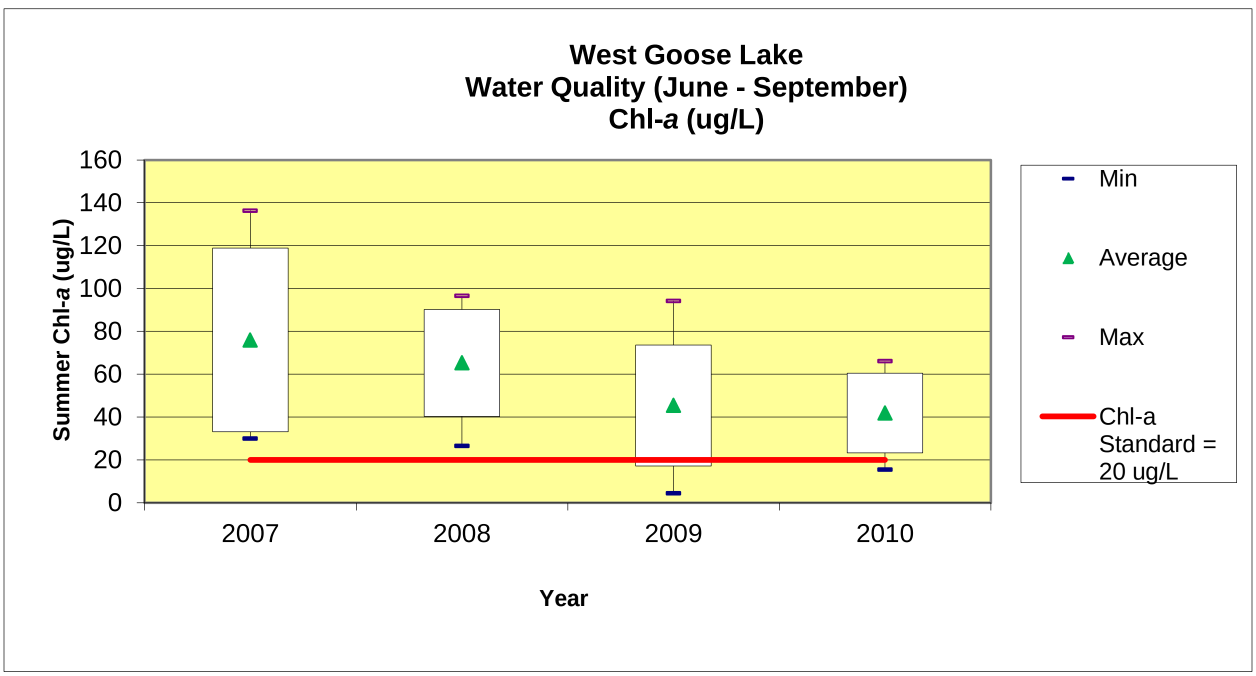


**Figure 3.11. West Goose Lake Chlorophyll-*a* Concentrations (June – September).**

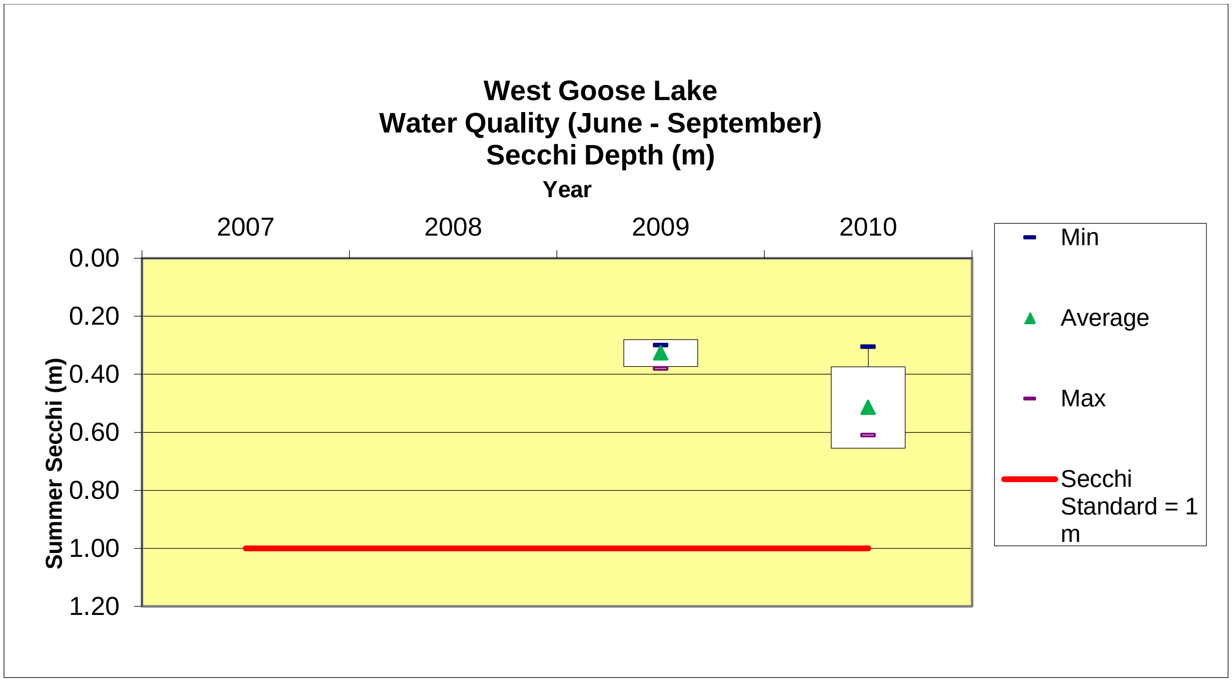


**Figure 3.12. West Goose Lake Secchi Depths (June – September).**

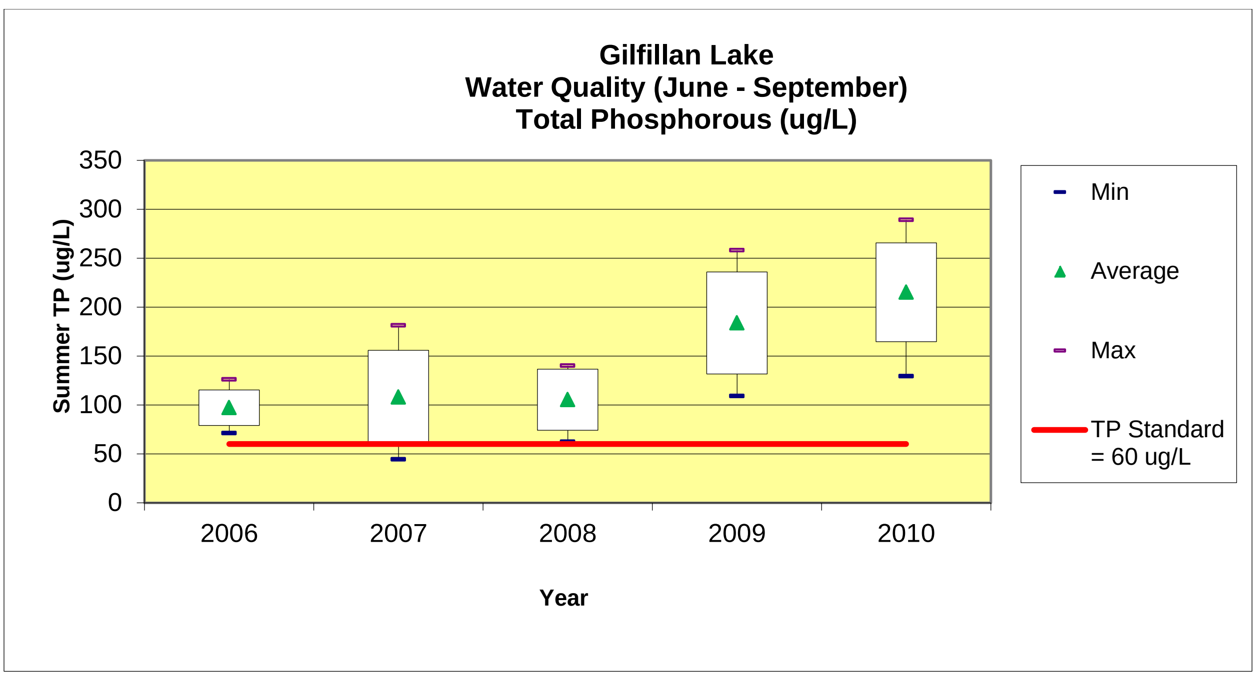


**Figure 3.13. Gilfillan Lake Total Phosphorus Concentrations (June – September).**

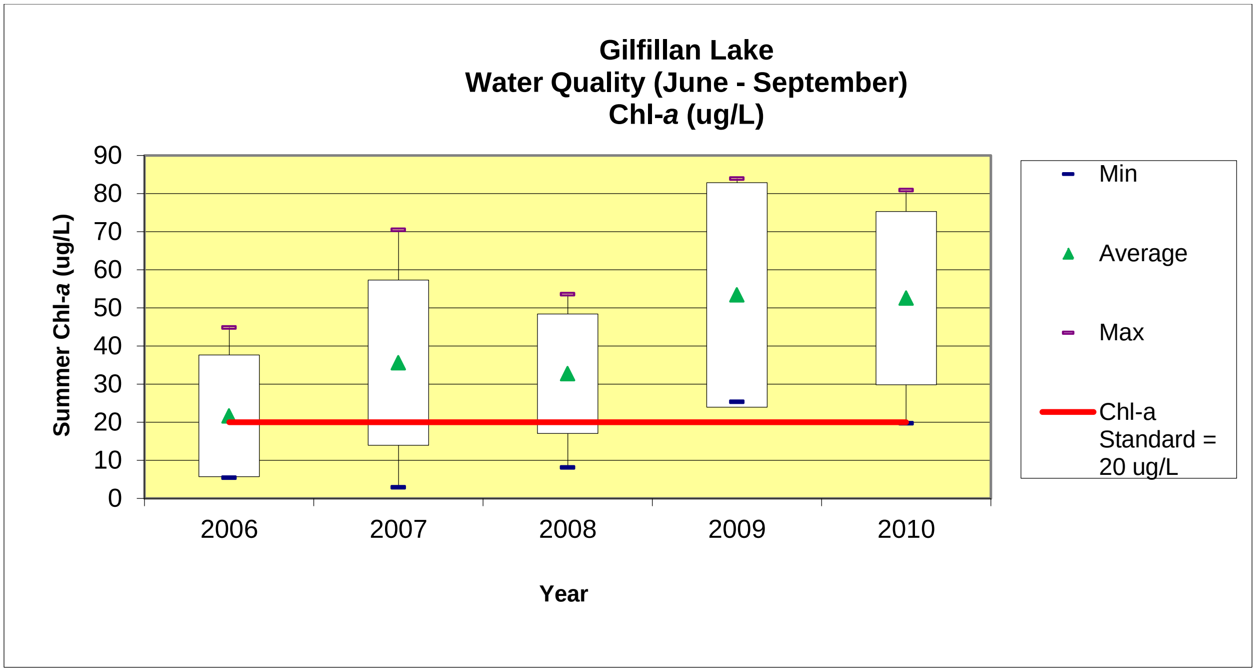


**Figure 3.14. Gilfillan Lake Chlorophyll-*a* Concentrations (June – September).**

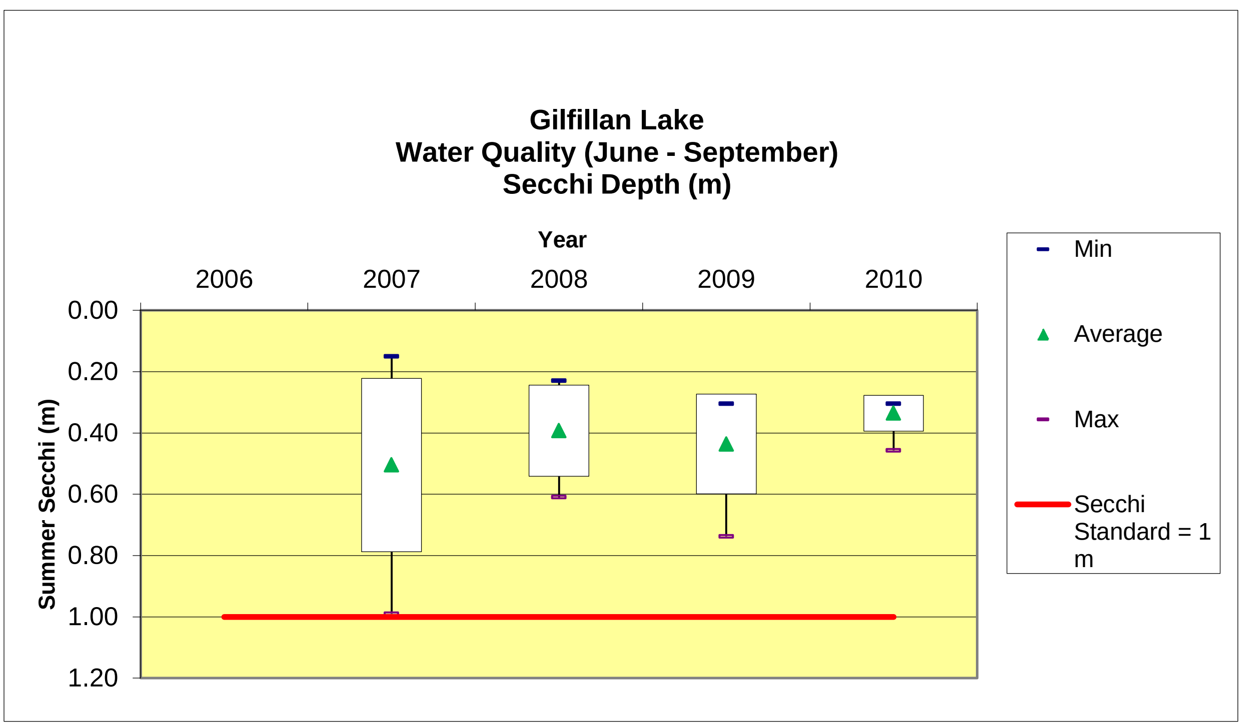


**Figure 3.15. Gilfillan Lake Secchi Depths (June – September).**

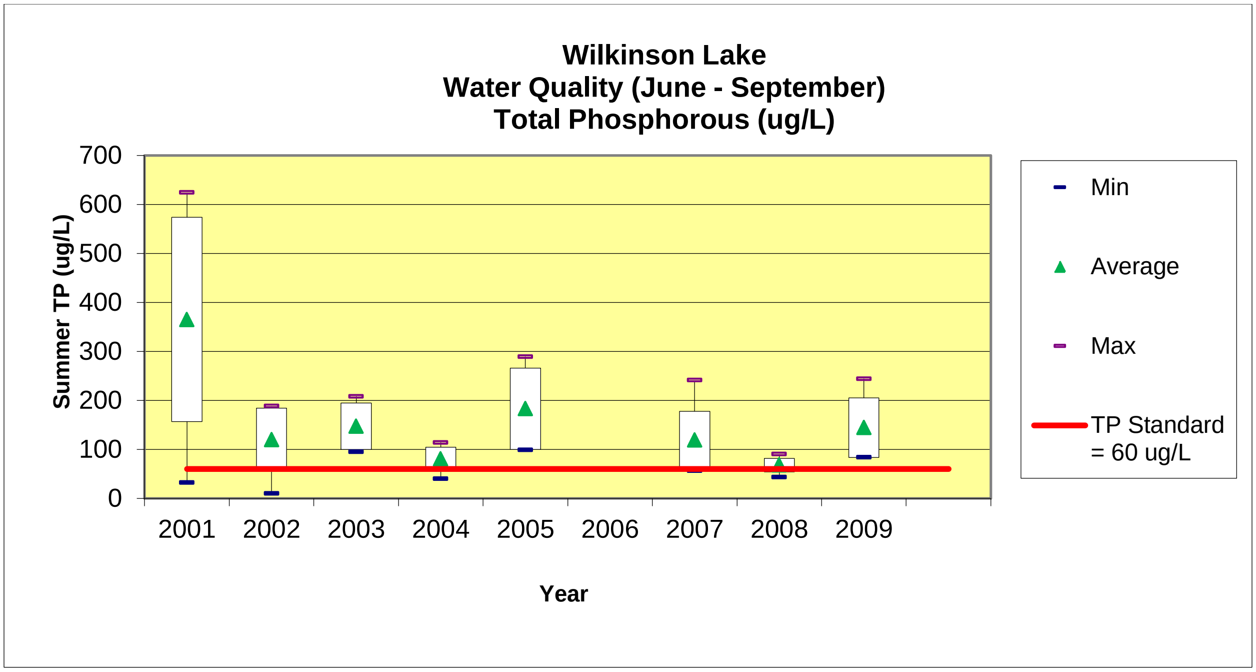


**Figure 3.16. Wilkinson Lake Total Phosphorus Concentrations (June – September).**

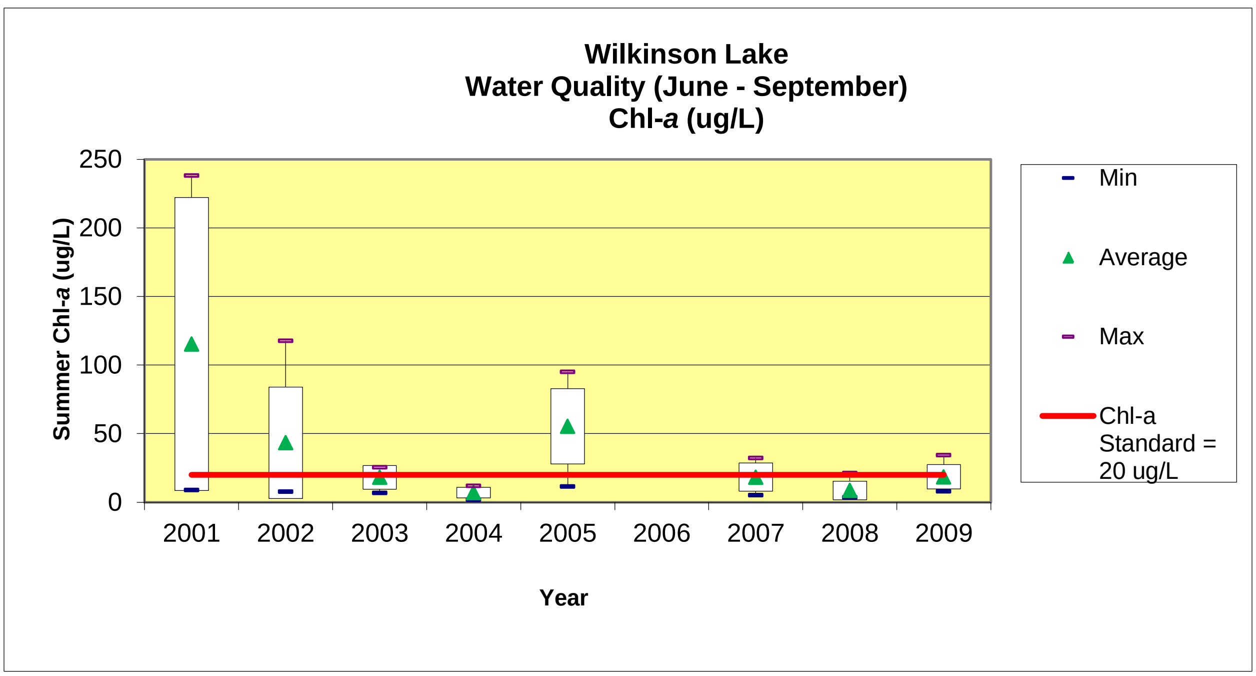


**Figure 3.17. Wilkinson Lake Chlorophyll-*a* Concentrations (June – September).**

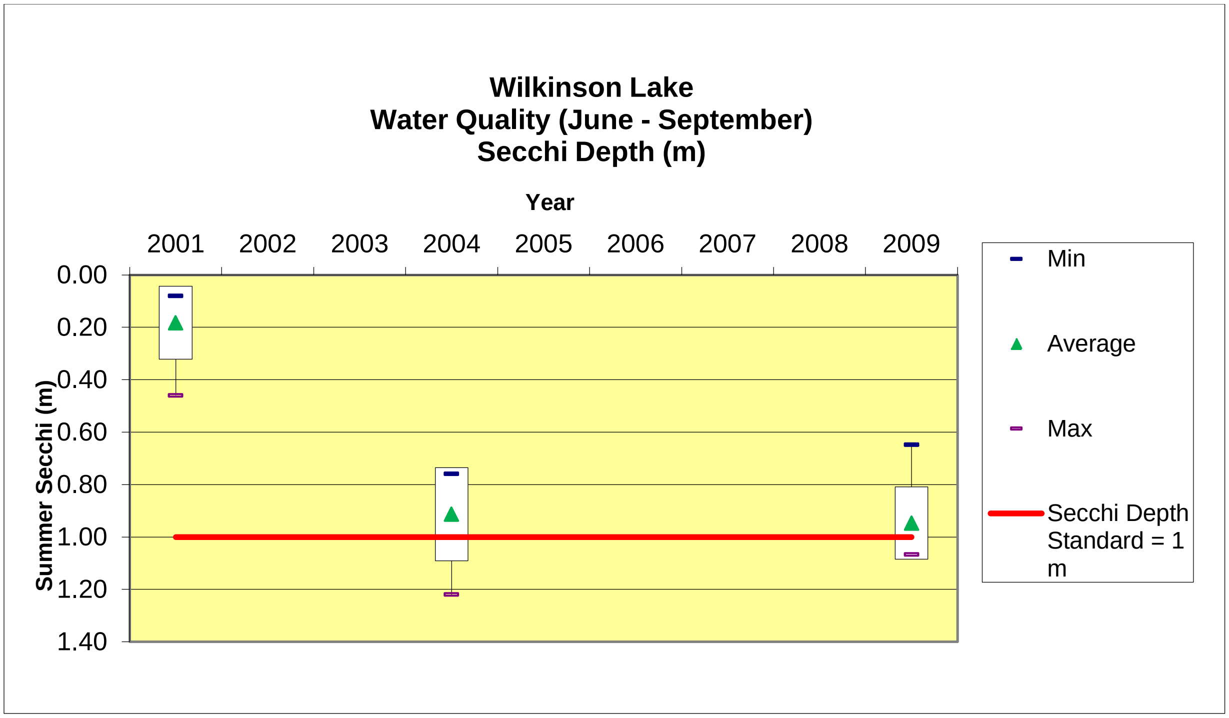


**Figure 3.18. Wilkinson Lake Secchi Depths (June – September).**

### 3.5.2 Lambert Creek Water Quality

*E. coli* bacteria concentrations were measured at five stations within the listed reach of Lambert Creek and one station upstream, tributary to the impaired reach between 2006 and 2010. Box plots displaying the geometric mean *E. coli* bacteria concentrations are presented in Figure 3.19. The upper and lower edge of each box represents the 75$^{th}$ and 25$^{th}$ percentile of the data range for each site. The chronic (126 MPN/100mL) and acute (1,260 MPN/100mL) standards for *E. coli* are displayed on this graph.

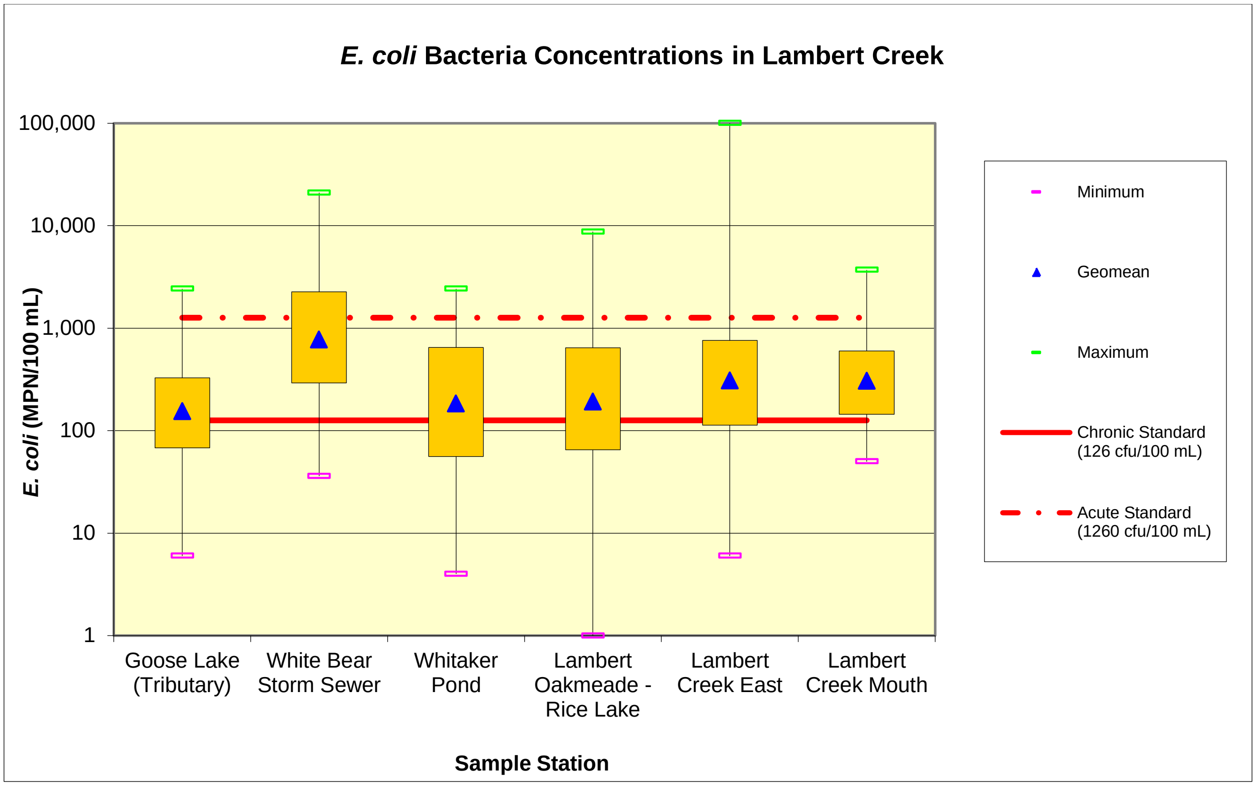


**Figure 3.19. *E. coli* Bacteria Concentrations in Lambert Creek, Upstream to Downstream.**

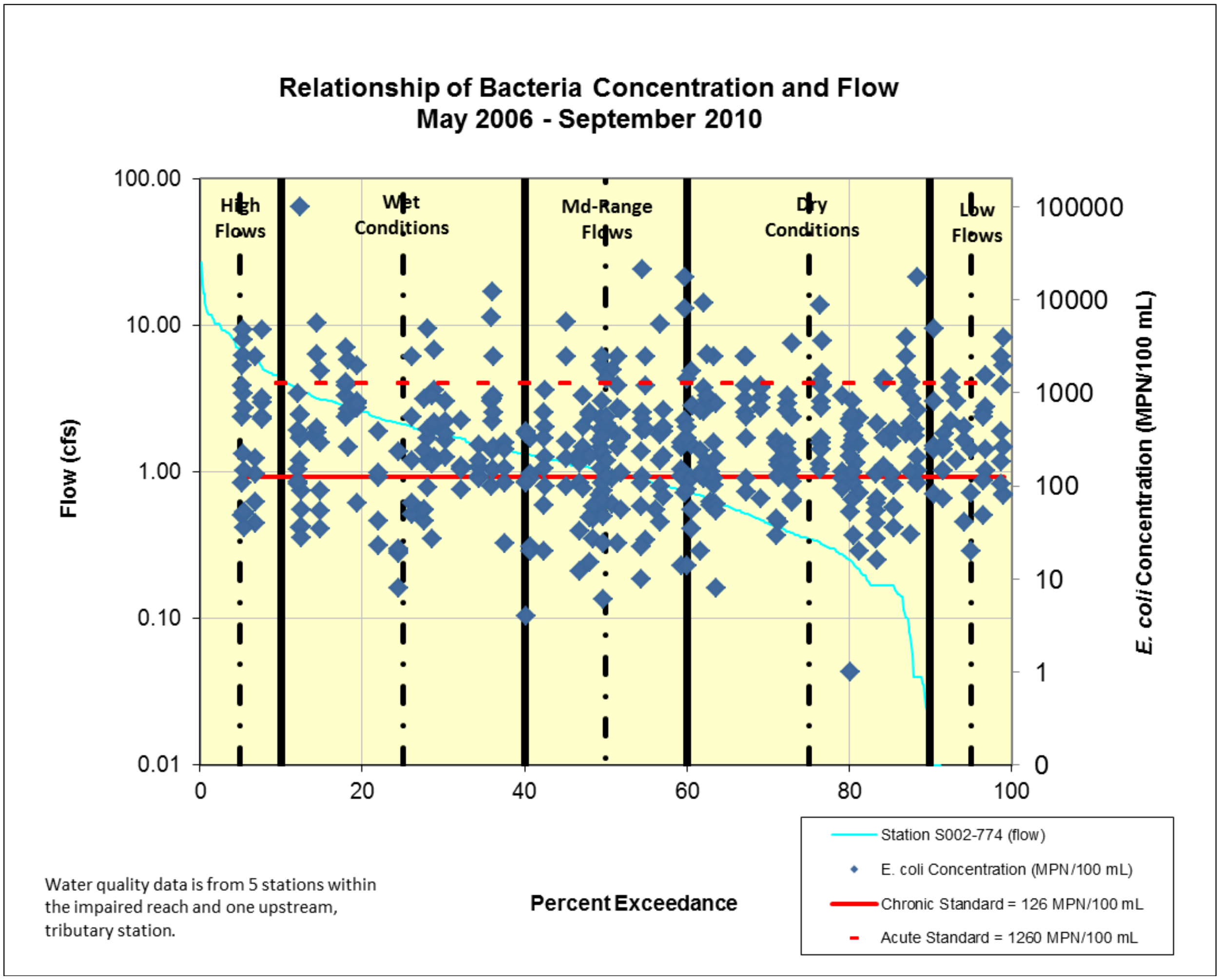


**Figure 3.20. Flow Duration Curve with Bacteria Concentrations.**

The relationship between *E. coli* concentrations and flow is presented on Figure 3.20. From this figure it can be determined that bacteria concentrations exceed the standard across all flow regimes and are not limited to low or high flow conditions. Further, standing water is common in Lambert Creek when flows are 0 or close to 0. Monitoring staff for VLAWMO collected bacteria samples during these conditions as well. Exceedances of the state standard in these conditions are generally indicative of direct deposits (i.e. wildlife fecal matter not delivered through runoff) and/or regrowth in the sediments.

A summary of the discrete *E. coli* samples by month for the five sample stations located within the impaired reach of Lambert Creek is presented in Table 3.6. There were 62 exceedances of the acute standard (16% of total samples collected) and 281 samples exceeding the chronic standard. Exceedances of the State chronic and acute standards occurred in the months of June to October, however, there were more samples collected in June, July, and August.

**Table 3.6. Summary of *E. coli* bacteria samples in impaired reach of Lambert Creek.**

| Sample Month | Total Samples (n) | #>126 MPN/100 mL | #>1260 MPN/100mL | Monthly Geomean | % of samples >1260 mpn/100 mL |
|---|---|---|---|---|---|
| April | No data collected | | | | |
| May | 48 | 18 | 4 | 85 | 8% |
| June | 96 | 68 | 14 | 287 | 15% |
| July | 86 | 68 | 13 | 367 | 15% |
| August | 101 | 78 | 19 | 371 | 19% |
| September | 58 | 45 | 9 | 358 | 16% |
| October | 5 | 4 | 3 | 1475 | 60% |

## 3.6 FISH POPULATIONS

No official fish survey has been recorded for Wilkinson Lake and the fish survey for Gilfillan Lake is out of date. A fish survey of Gem Lake was completed by Blue Water Science for VLAWMO and the MNDNR in 2011. A fish survey of East and West Goose Lakes was funded by VLAWMO and conducted by Blue Water Science the week of July 16, 2012. A final report for this survey has yet to be completed. All information provided below was derived from the DNR web site and information provided by VLAWMO staff and residents:

- The 2011 fish survey of Gem Lake indicated a fish community represented solely by black crappie. Several year classes of the fish were observed. Painted turtles were common and minnows were present in low numbers.
- A 1986 fish survey of Goose Lake showed that the lake was dominated by black bullheads, however a 2012 fish survey (http://vlawmo.org/PDF/Goose%20R12%20-%20fish%20survey.pdf) noted a healthy population of predator fish in Goose Lake. VLAWMO conducted a significant bullhead removal project in 2013 (http://vlawmo.org/projects.cfm?ServiceID=58&PID=58&siteID=1) in Goose Lake.
- Residents and VLAWMO staff report existing populations of walleye and goldfish/koi in Gilfillan Lake. The DNR conducted a fish kill in 2002 to prepare the lake for use as a walleye-rearing pond. In summer of 2010, a resident obtained a DNR permit to stock the lake with 75,000 walleye fry and 5 gallons of minnows for food.
- Residents and VLAWMO staff report significant populations of carp (e.g. goldfish in Gilfillan and common carp in Wilkinson) and other rough fish species present in the impaired lakes, though no recent formal survey exists to verify populations in most lakes.

## 3.7 AQUATIC PLANTS

The abundance and diversity of native aquatic plants drive the health of shallow lake ecosystems and are critical to keeping shallow lakes in a clear state. They provide spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments.

In excess non-native, invasive aquatic plants can limit recreational activities such as boating and swimming. Some non-native species can lead to special problems in lakes. For example, Eurasian water milfoil can reduce plant biodiversity in a lake because it grows in great densities and out-competes all the other plants. Ultimately, this can lead to a shift in the fish community because these high densities favor panfish over larger game fish. Species such as curly-leaf pondweed can cause very specific problems by changing the dynamics of internal phosphorus loading. A qualitative evaluation of lake macrophytes did not establish the presence of these non-native species. However, this should be verified with a formal survey.

The littoral zone is defined as that portion of the lake that is less than 15 feet in depth and is where the majority of the aquatic plants are found. The littoral zone of the lake also provides the essential spawning habitat for most warm water fishes. All of the lakes addressed in this TMDL meet the definition of a shallow lake as each lake area is greater than 80% littoral.

VLAWMO staff conducted qualitative evaluations of the littoral vegetation of Gem Lake, Gilfillan Lake, Goose Lake East and Goose Lake West to get a sense of macrophyte density and diversity and to document the presence or absence of invasive species. Their reported results are displayed in Table 3.7 and discussed below. Maps indicating the densities of each plant species, on a prevalence scale of 1 to 5, at each sampling location are included in Appendix E.

**Table 3.7. Littoral Vegetation Evaluation Results.**

| | Plant Species | | | | | | |
|---|---|---|---|---|---|---|---|
| **Water Body** | **Native Pondweeds** | **Coontail** | **Pickerel Weed** | **Water Lilies** | **Elodea** | **Purple Loosestrife** | **Arrowhead** |
| Gem Lake | X | X | X | X | | X | X |
| East/West Goose Lake | X (narrow-leaf) | | | | X | | |
| Gilfillan Lake | X (bushy) | | | X | X | X | |
| Wilkinson Lake | | X | | X | | | |

### Gem Lake

VLAWMO staff reported that Gem Lake had the most diverse and dense aquatic vegetation of the lakes surveyed for this study. Seven plant species were identified including: purple loosestrife, arrowhead, pondweeds, coontail, pickerel weed, and water lilies. Plants were found almost completely around the lake with the densest vegetation occurring along the southern edge.

East and West Goose Lake

Goose Lake had the lowest diversity of aquatic plant species relative to the other lakes surveyed. VLAWMO staff identified only two species in each basin of the lake: narrow-leaf pondweed and elodea (Canada waterweed).

In East Goose Lake plants were only found along the western edge of the lake, which connects to the western basin.

In West Goose Lake plants were found throughout the lake, but consisted mostly of elodea, which was mostly concentrated along the eastern edge connecting to East Goose. VLAWMO staff noted the presence of blue-green algae in the lake at the time of the survey. A local recreational group, the Ski Otters, provided some additional information on plant communities in West Goose Lake. They indicated that nuisance populations of curly-leaf pondweed were common on the lake prior to 2005 and that they have retained a licensed chemical applicator to treat the lake for curly-leaf pondweed. DNR permits secured between 2005 and 2012 allowed treatment of approximately 10 acres of West Goose Lake for the invasive species. Timing of treatments, coupled with results of VLAWMO staff's qualitative vegetation survey, indicate that the applications have been successful in greatly reducing the population of vegetation in West Goose Lake and have minimized water quality impacts from aquatic plants.

Gilfillan Lake

VLAMWO staff reported Gilfillan Lake has a low diversity of plants species, but has dense vegetation around the entire lake. Plant species identified included Bushy pondweeds, *Elodea* (Canada waterweed), and water lilies. The relative densest vegetation was found along the northwestern and southern edges of the lake. No density counts were performed.

Wilkinson Lake

No formal aquatic plant survey was completed for Wilkinson Lake, however when a depth survey was performed in May 2010, VLAWMO staff also checked for aquatic plants and found that there isn't a diverse plant community within the lake. There were areas of lily pads along the northern edge of the lake and to the east of the fish barrier. Otherwise, the only other plant found was coontail, which was not present in nuisance proportions. The vegetation in the surrounding wetland area consisted mostly of cattail and arrowhead.

## 3.8 SHORELAND CONDITION

Shoreland conditions can impact water quality especially in shallow lakes. Native shorelands with appropriately sized buffers can filter nutrients from stormwater and reduce anthropogenic impacts on lakes. Altered shorelands with riprap, cleared vegetation, or maintained lawns down to the lake edge can promote the introduction of additional nutrients into the lake.

No systematic survey of shoreland condition is available for the impaired lakes. Air photos were reviewed and evident shoreland condition for each lake is described below, however the resolution of the photos does not replace visual inspection:

Gem Lake: Low-density residential lots with significant setbacks from the lake, and mostly vegetated shorelines.

East Goose Lake: Highway 61 comprises the entire western shoreline of the east basin. White Bear Avenue North runs along the north and east shoreline. The remainder of the shoreland is comprised primarily of residential land with some commercial land. There is very little setback between Highway 61 and the lake. The air photos show that much of the shoreland is grassed down to riprap with varying amounts of brush and small trees adjacent to shore. Several of the residential properties have docks and riprapped shorelines with grass.

West Goose Lake: Hoffmann Road is the significant shoreline feature on the west and north side of the lake. Highway 61 separates the east and west basins of the lake and comprises the entire eastern shoreline of the west basin. The south side of the lake is bordered directly by stormwater ponds adjacent to commercial/ industrial areas. There is very little setback between the road and the lake. The air photos show that much of the shoreland is grassed down to riprap with some brush and small trees adjacent to shore.

Gilfillan Lake: This lake is surrounded by the low density residential properties of North Oaks. Several of the shorelines are riprapped or have mowed grass lawns extending down to the lake.

Wilkinson Lake: This lake is bordered by County Highway 59 (Centerville Rd.) to the east and County Road J to the north. However, there is a significant wetland area creating a setback between these roads and the lake. The lake shoreland is comprised entirely of wetland vegetation consisting of cattail and arrowhead.

# 4.0 Pollutant Source Assessment

A key component to developing a TMDL is to understand the sources contributing to the impairment. This section provides a brief description of the potential sources in the watershed contributing to excess nutrients in the lakes and *E. coli* bacteria in Lambert Creek. Both permitted and non-permitted sources are present within the watershed.

## 4.1 PERMITTED SOURCES

Permitted sources can include industrial wastewater effluent, municipal wastewater treatment plant effluent, and construction, industrial, and municipal stormwater runoff. These can each be sources of bacteria or excess nutrients. The following is an inventory of the MPCA permitted sources in the TMDL watershed. Permitted sources for the impairments are shown in the figures in Appendix D.

### 4.1.1 Facilities with NPDES Permits

The MPCA provided a list of permitted sources. The following NPDES permit holders are located within the areas tributary to the impaired waters (Table 4.1).

**Table 4.1. List of Permitted Sources in the Study Area.**

| NPDES Permit Holder | Description | Existing Load (lbs/yr) |
|---|---|---|
| M-Foods Dairy LLC MNG255067 | Non-contact cooling water with no phosphate added. This load is accounted for in the WLA. | 16.5 |
| VEECO MBE Division MNG250093 | Discharge from this facility does not leave the onsite stormwater pond. The facility's permit coverage has been terminated as of May 1, 2012. | NA |
| White Bear Township WTP MNG820022 | No current discharge to any water body. | NA |

The discharge from M-Foods Dairy, LLC consists of untreated noncontact cooling water. The phosphorus content is representative of the phosphorus characteristics of the aquifer from which the water is withdrawn. Minnesota's Noncontact Cooling Water General National Pollutant Discharge Elimination System (NPDES) Permit (MNG255) does not currently contain a phosphorus limit. However, the current permit has expired and the new draft permit includes a proposed phosphorus limit for M-Foods Dairy, LLC consistent with the TMDL WLA (calculated based on the maximum daily flow and the phosphorus concentration measured in the discharge).

### 4.1.2 MS4s

An evaluation of NPDES Phase II permits for municipal separate storm sewer systems (MS4s) showed that the following MS4s are within the drainage areas of the impaired water addressed in this study. These MS4s are covered under General Permit MNR040000. The preferred ID numbers assigned to these permit holders are as follows (Table 4.2):

**Table 4.2. List of NPDES Phase II Stormwater Permit Holders in the TMDL Study Area.**

| | Impaired Water | | | | | |
|---|---|---|---|---|---|---|
| MS4 Permit Holder | Gem Lake | Goose Lake East | Goose Lake West | Gilfillan Lake | Wilkinson Lake | Lambert Creek |
| Gem Lake City MS400020 | Individual WLA | Individual WLA | Individual WLA | NA | NA | Individual WLA |
| Ramsey County MS400191 | Individual WLA | Individual WLA | Individual WLA | Individual WLA | NA | Individual WLA |
| MNDOT MS400170 | Individual WLA | Individual WLA | Individual WLA | NA | Individual WLA | Individual WLA |
| White Bear Lake City MS400060 | Individual WLA | Individual WLA | Individual WLA | NA | Individual WLA | Individual WLA |
| North Oaks City MS400109 | NA | NA | NA | Individual WLA | Individual WLA | NA |
| Vadnais Heights City MS400057 | NA | NA | NA | Individual WLA | NA | Individual WLA |
| White Bear Township MS400163 | NA | NA | NA | Individual WLA | Individual WLA | Individual WLA |
| Anoka County MS400066 | NA | NA | NA | NA | Individual WLA | NA |
| Lino Lakes City MS400100 | NA | NA | NA | NA | Individual WLA | NA |

N/A = Not applicable – does not drain to lake or creek.

Runoff from lakeshore homes and other residential areas have the potential to transport materials such as grass clippings, leaves, car wash wastewater, and animal waste to surface water. All of these materials contain phosphorus and bacteria, which can impair local water quality. The annual average phosphorus load attributed to watershed runoff for each of the impaired lakes is tabulated below (Table 4.3). Watershed phosphorus loading for each lake was determined by using the P8 Urban Catchment Model (Walker 1990) calibrated to measured runoff at the watershed outlet. The P8 Model incorporates load calculations based on an input of the directly connected impervious areas within each watershed, which are defined as those impervious areas that are hydraulically connected (water flow is continuous) to the conveyance system (curbs, catch basins, storm drains, etc.), and therefore to the lake, without flowing over pervious areas.

**Table 4.3. Watershed Phosphorus Load (lbs/yr).**

| Lake | Watershed Load (lbs/yr) |
|---|---|
| Gem | 62.1 |
| Goose - East | 214.8 |
| Goose - West | 110.4 |
| Lake Gilfillan | 17.0 |
| Lake Wilkinson | 740.4 |

### 4.1.3 Construction, Industrial and MNG49 Sand and Gravel Permits

The MPCA issues construction permits for any construction activities disturbing: 1) One acre or more of soil, 2) Less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre or 3) Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The Environmental Protection Agency (EPA) estimates a soil loss of 20 to 150 tons per acre per year from stormwater runoff at construction sites. Such sites vary in the number of acres they disturb.

The Industrial Stormwater General Permit applies to facilities with Standard Industrial Classification Codes in ten categories of industrial activity with significant materials and activities exposed to stormwater. Significant materials include any material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and be carried offsite. The NPDES Stormwater Program requires that the industrial facility obtain a permit and create a Stormwater Prevention Pollution Plan (SWPPP) for the site outlining the structural and/or non-structural best management practices used to manage stormwater and the site's Spill Prevention Control and Countermeasure Plan. An annual report is generated documenting the implementation of the SWPPP.

The entire project area for the lakes addressed in this study are covered by NPDES permits for Phase II MS4s. Therefore, construction and industrial stormwater are included in the WLA for the MS4s.

## 4.2 NON-PERMITTED SOURCES

Below is an inventory of the non-permitted sources in the watershed that have been identified as potential sources of nutrients and/or *E. coli*.

### 4.2.1 Atmospheric Deposition

The atmosphere delivers phosphorus to water and land surfaces both in precipitation and dryfall (dust particles that are suspended by winds and later deposited). Such atmospheric inputs must be accounted for in development of a nutrient budget, though they are generally very small direct inputs to the lake and are impossible to control. A study conducted for the MPCA, "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr

Engineering, 2004), estimated the atmospheric inputs of phosphorus from deposition for different regions of Minnesota. The rates vary based on the precipitation received in a given year and are categorized as below average (dry), average, or above average (wet). The estimated rates of deposition by precipitation year for the Twin Cities Metro Area are shown in Table 4.4.

**Table 4.4. Atmospheric deposition rates per year for the Twin Cities Metro Area.**

| Type of Precipitation Year | Atmospheric Deposition Rate ($kg/km^2$) |
|---|---|
| Dry (<25" precipitation) | 24.9 |
| Average (25"-38") | 26.8 |
| Wet (>38" precipitation) | 29.0 |

Source: Barr Engineering 2004.

The average annual load from atmospheric deposition calculated for each of the impaired lakes is tabulated below (Table 4.5).

**Table 4.5. Atmospheric Deposition Load Per Year.**

| Lake | Atmospheric Deposition (lbs/yr) |
|---|---|
| Gem | 5.2 |
| Goose - East | 27.9 |
| Goose - West | 5.8 |
| Lake Gilfillan | 23.8 |
| Lake Wilkinson | 23.3 |

### 4.2.2 Internal Phosphorus Release

Phosphorus accumulated in the lake sediments released under specific conditions is internal loading. Internal loading can result from sediment anoxia where poorly bound phosphorus is released into the water column in a form readily available for phytoplankton production. The buildup of phosphorus in lake-bottom sediments increases due to increased phosphorus loading from the watershed, historic discharges of wastewater (as is the case in Goose Lake), or the disruption of the lake hydrology and ecology. The outlets of many shallow lakes have been altered to deepen what were at one time Type 4 Wetlands. The shallow lakes addressed in this study all have modified outlets. That hydraulic disruption coupled with the introduction of rough fish species, decimation of native plant communities and increase in watershed loadings can exacerbate internal loading cycles. This is thought to be a contributing factor to each lake in addressed in this study; however, available data does not provide enough information to quantify such impacts.

Internal loading can also result from sediment re-suspension that may result from loss of native plant communities, wind, rough fish activity, and prop wash from motor boat activity. Specific to this study, motor boating is frequent on West Goose Lake in the summer months. Most of the motor boating is attributable to waterskiing activities (the Ski Otter's Water Ski Club holds practices and performances on the lake). Boating stirs up bottom sediments; repeatedly disrupting plant growth and facilitating additional release of soluble phosphorus from sediments. Note that the high internal phosphorus levels in the sediments are likely the result of historical loading to the sediments from the White Bear Lake Wastewater Treatment Plant, which used to discharge to Goose Lake. The sediment disturbance is correlated to the acceleration of the boat as it gets up to speed. Figure 4.1 presents a graphical representation of this correlation. With waterskiing, there is likely more stopping/starting of the boat, which would increase the amount of acceleration time rather than operation at a consistent speed, thus exacerbating the issue. Further, the study referenced in Figure 4.1 was from a deeper lake and employed single motors ranging from ~75 to 240 horsepower. In comparison, it may be that some boats on West Goose Lake use multiple, large horsepower motors per boat.

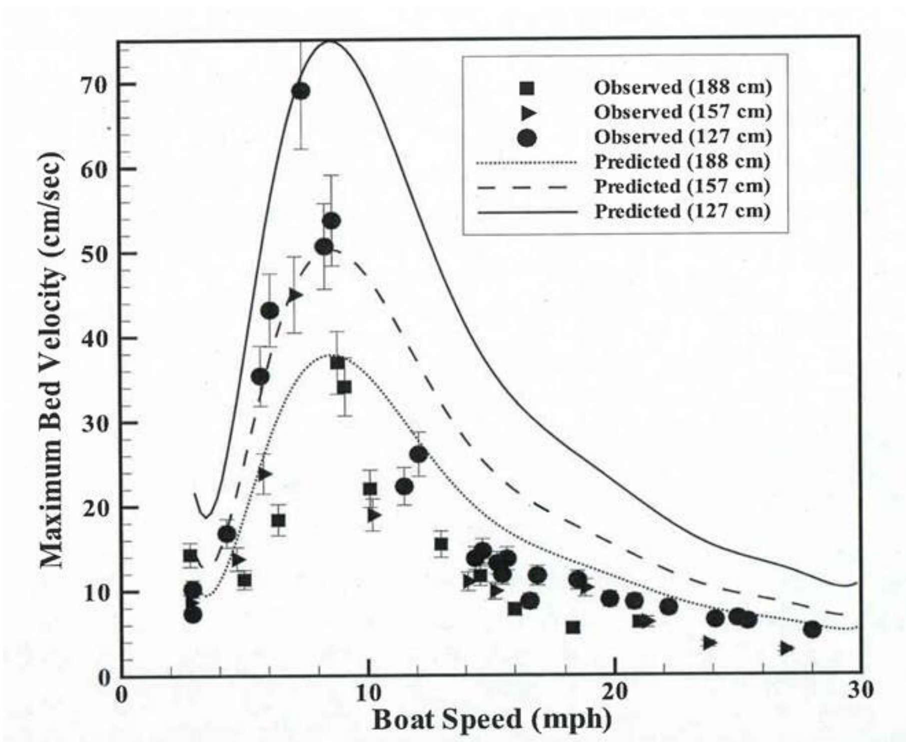


**Figure 4.1. Sediment Bed Velocity and Boat Speed.** (Source: Beachler and Hill 2003)

Additionally, if curly leaf pondweed is not treated, it can increase internal loading because it senesces and releases phosphorus during the summer growing season (late June to early July). Nuisance populations of curly leaf pondweed were not identified in any of the impaired lakes during the qualitative evaluation of lake macrophytes. Further, reports from the Ski Otters and data collected by VLAWMO indicate that the Ski Otters have effectively treated West Goose Lake for vegetation, reducing any water quality impacts from aquatic plants. However, a formal survey is recommended in early spring (before any treatments) to better understand the extent of vegetation such as curly-leaf pondweed in the lake.

In-lake nutrient cycling is an important component of the whole-lake nutrient budget. Internal phosphorus release was modeled by using measured periods of anoxia with literature values for phosphorus release to directly calculate internal phosphorus release rates, and then validated using the Canfield-Bachmann lake response models through which total existing nutrient loads were identified and the P8 modeled watershed loads and measured runoff through which watershed loading was calculated. Table 4.6 lists sediment phosphorus release rates used in the lake response models, the average predicted annual anoxic factor ($AF_{pred}$) applied, and the calculated average annual load. The average annual load was calculated by applying the following equations (Nurnberg 1995):

Internal load = $AF_{pred}$ x RR

$AF_{pred} = -35.4 + 44.2 \log (TP) + 0.95\ z/A^{0.5}$ where z is the mean depth (m) and A the lake surface area in $km^2$)

**Table 4.6. Sediment Phosphorus Release Per Year.**

| Lake | Sediment Release Rate (RR) ($mg/m^2$-day) | Average Annual Anoxic Period ($AF_{pred}$) (days) | Internal Load (lb/yr) |
|---|---|---|---|
| Gem | 0* | 47.1 | 0.0 |
| Goose - East | 24.0 | 71.4 | 1,777.2 |
| Goose - West (anoxic period) | 2.0 | 63.2 | 27.2 |
| Goose - West (boat activities) | 31.0 | - | 399.9 |
| Lake Gilfillan | 7.0 | 58.8 | 364.2 |
| Lake Wilkinson | 1.0 | 59.8 | 51.8 |

* The Gem Lake modeling did not require the addition of internal load in excess of the internal load assumed in the Canfield-Bachmann model.

### West Goose Lake Internal Load Quantification:

Quantification of the two sources of internal load identified in West Goose Lake is discussed below:

- Internal Loading Due to Release of Nutrients from Anoxic Sediments: Sediment release rates were directly measured. Sediment cores were collected by VLAWMO staff and anoxic release rates were measured at the US Army Corps of Engineers laboratory. This release rate was used in conjunction with an anoxic factor calculated as described earlier in this section.
- Internal Loading Due to Re-suspension: Several studies have demonstrated the impact of re-suspension on internal loading in shallow lakes due to motor boating. One such study of three shallow lakes in Florida (Claire, Mizell, and Jessup) showed that internal release rates ranged from 15 to 62 $mg/m^2$-day. A study performed on an urban lake in Wisconsin (Half-Moon) found increased P loading due to motor boat activity (James et.al, 2002). This study estimated a sediment release rate of 1.0 $mg/m^2$-day. The higher release rates are correlated to shallower lakes with unconsolidated substrates, similar to Goose Lake. The

release rate attributed to re-suspension in West Goose Lake was adjusted upwards from 1.0 mg/m$^2$-day until lake-model predictions matched observed conditions. The anoxic factor was determined by reviewing the Ski Otters schedule of practices and shows. The table below compares the resulting release rate in West Goose Lake to the release rates and lake characteristics for study lakes. The resulting release rate is in the middle of the range documented in the studies. Note that the high internal phosphorus levels in the sediments are likely the result of historical loading to the sediments from the White Bear Lake Wastewater Treatment Plant, which used to discharge to Goose Lake.

**Table 4.7. West Goose Calibrated Release Rate and Lake Characteristics Compared with Study Lakes.**

| Lake[1] | Avg Depth (m) | Max Depth (m) | Substrate | Boating | Boating Loading Rates | Lake Size (ha) |
|---|---|---|---|---|---|---|
| Claire | 2.3 | 3.7 | Not listed | 28 to 165 HP Motors | 84 mg/m$^2$ (over 4 days= 21 mg/m$^2$-day) | 8.1 |
| Mizell | 4.0 | 6.1 | Sand at depths to 3.5 m/ Organic Muck in deeper water | 28 to 120 HP Motors | 58 mg/m$^2$ (over 4 days= 14.5 mg/m$^2$-day) | 25.1 |
| Jessup | 1.8 | 3 | Mucky | 28 HP Motors | 249 mg/m$^2$ (over 4 days= 62 mg/m$^2$-day) | 4,422 |
| Half-Moon | 1.6 | 4 | Sandy | 2 motors @ 150 HP motors | 1 mg/m$^2$-day | 50 |
| West Goose [2] | 1.2 | 2.1 | Mucky | 3 motors @ 150 to 200 HP Motors | 31 mg/m$^2$-day | 9.75 |
| Notes: | | | | | | |
| 1. Claire, Mizell and Jessup Lakes are from the Yousef study in 1979; Half- Moon is from the James article in 2002. | | | | | | |
| 2. West Goose Lake Boating Loading Rate is from calibrated lake response model. | | | | | | |

### 4.2.3 Groundwater

Groundwater can be a source or sink for water in a lake and contains varying levels of phosphorus. Therefore, groundwater can contribute phosphorus and effect the hydraulic residence time of lakes. In the case of East Goose and Wilkinson Lakes, groundwater was determined to be a net gain of water to the lakes and therefore constitute a source of water and phosphorus. However, for these two lakes, the contribution was relatively small. For Gem Lake, it was determined there was no interaction between the lake and groundwater. In the case of Gilfillan Lake, a net loss of water from the lake was determined. West Goose has a contribution to the phosphorus load from water discharging into the lake from the M-Foods Dairy facility. This is non-contact cooling water sourced from groundwater and was included in the WLA as it is a permitted point source.

Groundwater contributions to the water and phosphorus budgets for Gem, East Goose, West Goose, and Wilkinson Lakes were determined from a review of the available regional hydrologic atlas and published values for groundwater characteristics in the area. For Gilfillan Lake, since the surface outflow of the lake was known to be zero, the overall water balance, as informed by annual precipitation, evaporation and change in lake level for the lake, was used to determine the groundwater contribution. The water budget for each lake, which includes groundwater interaction, is included in Appendix B. The contribution to the phosphorus load for each lake from groundwater is presented in Table 4.8.

**Table 4.8. Groundwater Phosphorus Load Per Year.**

| Lake | Groundwater Contribution (lbs/yr) |
|---|---|
| Gem | 0.0 |
| Goose - East | 0.8 |
| Goose - West | 0.0 |
| Lake Gilfillan | 0.0 |
| Lake Wilkinson | 1.4 |

### 4.2.4 Subsurface Sewage Treatment Systems (SSTS)

SSTS failures on lakeshore homes can contribute to lake nutrient impairments. Failing or nonconforming SSTS can also be a source of *E. coli* bacteria to streams, especially during dry periods when these sources continue to discharge and runoff driven sources are not active. Poorly treated effluent can contain elevated concentrations of *E. coli* and is considered a threat to public health.

The homes riparian to Gem Lake and Gilfillan Lake are served by SSTS, but the remainder of the study area is served by sanitary sewers. The City of North Oaks maintains detailed records on the age and condition of SSTS surrounding Gilfillan Lake. These records indicate a failure rate of 8% (or 3 of 39 systems). Data gathered by VLAWMO staff for Gem Lake report a potential failure rate of 5% percent of the SSTS surrounding Gem Lake (1 out of the 13 homes surrounding the lake given that the homes are mostly new, soils are ideal for septic systems, and adequate separation between surficial groundwater and septic systems is provided). Contribution to the lake phosphorus load from failing septic systems is tabulated in Table 4.9.

**Table 4.9. Phosphorus Load Per Year From Failing Septics.**

| Lake | Failing Septic System Load (lbs/yr) |
|---|---|
| Gem | 5.1 |
| Goose - East | 0.0 |
| Goose - West | 0.0 |
| Lake Gilfillan | 24.3 |
| Lake Wilkinson | 0.0 |

Most of the homes riparian to Lambert Creek are served by sanitary sewer; however, a small area of Gem Lake with homes riparian to a tributary of Lambert Creek may contribute to the *E. coli* in the creek.

### 4.2.5 Urban Residential Runoff

All areas tributary to the impaired lakes are within the jurisdiction of MS4s (listed in Section 4.1.2).

### 4.2.6 Agricultural Land Use , Non-permitted CAFO Livestock Facilities and Riparian Pastures

A small percentage of the land use in the watershed is agricultural, consisting of small crop farms and greenhouses. Manure application on crops can contribute to *E. coli* and nutrient loads in waterways. These areas are not located directly adjacent to any of the impaired waters within the study, but can still contribute to overall nutrient and bacteria loads. Based on map review and discussions with VLAWMO staff, it was assumed that the impacts from livestock have minimal contributions to the bacteria impairment in Lambert Creek and nutrient impairments in the lakes. However, these areas are located within the jurisdictional boundary of regulated MS4s and any contributions, however minimal, are therefore included in the WLA.

### 4.2.7 Wildlife

Natural background loads for *E. coli* bacteria can be attributed to wildlife. The focus of this assessment was on waterfowl and deer because they are likely contributors of *E. coli* bacteria and are considered good indicators of wildlife densities in general. Geese populations were estimated utilizing the Canada Goose Program Report (Cooper 2004), the City of Eden Prairie Canada Goose Management Plan (2008), and personal communication with Tom Keefe (President, Canada Goose Management, Inc.). Ramsey County provided an estimate of the deer density within the watershed (John Moriarty - Ramsey County Natural Resource Specialist, personal communication). Duck populations were estimated based on statewide population information from the 2011 Waterfowl Breeding Population survey (MNDNR and USFWS, 2011) and Minnesota DNR Wetland Wildlife Population Research. Population estimates are summarized in the table below.

The high density of shallow wetland basins in the area provide excellent waterfowl habitat and contribute to a high waterfowl population, which can cause high levels of bacteria in receiving waters. The headwaters of Lambert Creek and several of the wetlands it flows through are such areas. Adding to this are squirrels, raccoons, foxes and other wildlife present in the watershed. For this assessment, deer, geese and ducks were assumed the main contributors; other wildlife were lumped into one separate category (equivalent to the estimated deer and geese population). As the actual populations are unknown, available population densities were estimated (Table 4.10). Bacteria sourced from wildlife are included in the LA for the TMDL. A formal wildlife survey is recommended to determine if wildlife management is a necessary component for implementation and achieving water quality standards.

**Table 4.10. Deer and Goose Population Estimates in the Lambert Creek Subwatershed.**

| Wildlife | Density (per sq mile) | Population (est.) | *E. coli* Organism Per Unit Per Month (Billions) |
|---|---|---|---|
| Deer | 30 - 35 | 170 – 200 | 9.59 |
| Geese | 8 - 56 | 45 - 320 | 0.20 |
| Ducks | 9 - 26 | 50 – 150 | 46.60 |

# 5.0 Assimilative Capacity

## 5.1 NUTRIENTS

### 5.1.1 Approach

Lake response to nutrient loading was modeled using the BATHTUB suite of models and a significant data set available for the impaired lakes. BATHTUB is a series of empirical eutrophication models that predict the response to phosphorus inputs for morphologically complex lakes and reservoirs (Army Corps of Engineers, 2009). Several models (subroutines) are available for use within the BATHTUB model. The Canfield-Bachmann model within BATHTUB was used to predict the response of the lakes described herein to total phosphorus loads. The Canfield-Bachmann model was developed using data collected from 704 natural lakes to best describe the lake phosphorus sedimentation rate, which is needed to predict the relationship between in-lake phosphorus concentrations and phosphorus load inputs. The phosphorus sedimentation rate is an estimate of net phosphorus loss from the water column through sedimentation to the lake bottom. The phosphorus sedimentation rate is used in concert with lake-specific characteristics such as annual phosphorus loading, mean depth, and hydraulic flushing rate to predict in-lake concentrations of phosphorus as they relate to phosphorus loading. These model predictions are compared to measured data to evaluate how well the model describes the lake system. Once a model is developed that describes the lake system well (i.e. is well calibrated), the resulting relationship between phosphorus load and in-lake water quality is used to determine the assimilative capacity.

To set the TMDL for each impaired lake in the study, the nutrient inputs partitioned between sources for the lake response model were then systematically reduced until the model predicted that each lake met the current total phosphorus standard of 60 mg/L as a growing season mean. In addition to meeting a phosphorus limit of 60 µg/L, chlorophyll-*a* and Secchi depth standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. Rule 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2005). Clear relationships were established between the causal factor total phosphorus and the response variables chlorophyll-*a* and Secchi disk. Based on these relationships, it is expected that by meeting the phosphorus target of 60 µg/L for Gem, Gilfillan, Wilkinson, East Goose, and West Goose Lakes the chlorophyll-*a* and Secchi standards (20 µg/L and 1.0 m, respectively) will likewise be met.

As stated above, a significant set of data was available for these impaired lakes and their tributary watersheds. The modeling conducted for these TMDLs relied on:

- Between 3 to 8 years of measured in-lake water quality,
- Measured watershed runoff/hydrology,

- Modeled watershed phosphorus loadings using the P8 Urban Catchment Model (Walker 1990) calibrated to measured runoff at the watershed outlet,
- watershed specific land use,
- lake morphometry, and
- a combination of measured and modeled internal lake nutrient cycling with measured anoxic periods (Nurnberg, 1988, 1995, and 2005).

This data set and modeling approach provide a robust prediction of not only the assimilative capacity of the lake, but the partitioning between internal and external sources of nutrients to the lakes. The total assimilative capacity of each impaired lake is tabulated below (Table 5.1).

**Table 5.1. Impaired Lake Assimilative Capacity for Total Phosphorus.**

| Lake | Assimilative Capacity (lbs/yr) |
|---|---|
| Gem | 54.9 |
| Goose - East | 187.9 |
| Goose - West | 224.2 |
| Lake Gilfillan | 166.1 |
| Lake Wilkinson | 321.8 |

## 5.2 LAKE NUTRIENT MODEL CALIBRATION/VALIDATION RESULTS

In general, the models fit well compared to annual average lake water quality data so no calibration factors were used. The exception to the model fit is the Gem Lake model which over predicts TP compared to the measured average TP concentration. This is likely due to a notable shift in water quality towards the end of the calibration period; in spite of this shift, the model was calibrated to the average condition to represent the in-lake concentrations recorded for the entire calibration period. The differences between observed and model-predicted average in-lake concentrations were generally within the reported standard deviations for annual average TP for a given year providing a robust calibration. Full results of the modeling are presented in Appendices A and C.

Table 5.2 lists the years of in-lake water quality data that were available for lake response model calibration. Each lake was modeled based on the available years of data using the methods described in the previous section. The fit of the models to the average condition calculated from recorded total phosphorous concentrations (Table 2.2) for each impaired lake is presented in Figure 5.1. Appendix A includes the fit of each lake model to the measured TP concentration for each individual year that was modeled.

**Table 5.2. Years of Available Water Quality Data for Model Calibration and Validation.**

| Impaired Lake | Calibration Years |
|---|---|
| Gem Lake | 2000-2005 and 2007-2009 |
| East Goose Lake | 2007-2009 |
| West Goose Lake | 2007-2010 |
| Gilfillan Lake | 2006-2010 |
| Wilkinson Lake | 2001-2005 and 2007-2009 |

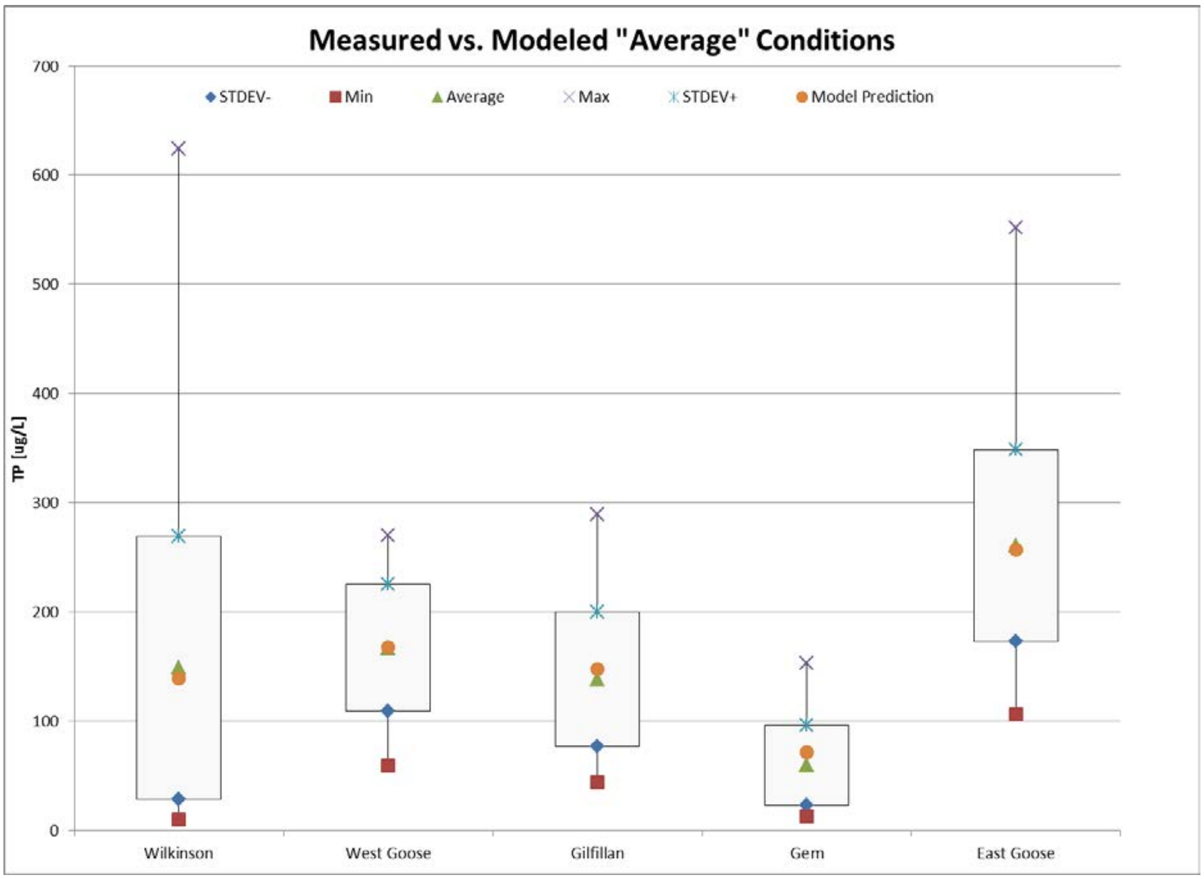


**Figure 5.1 . Lake TP Model Fit.**

Note: The Gem Lake response modeling and depicted measured water quality data excludes two sample data points from 2007 that were determined to be outliers for modeling purposes (240 ug/L measured on July 24, 2007 and 595 ug/L measured on August 7, 2007).

## 5.3 BACTERIA

### 5.3.1 Approach

The bacteria TMDL was set using the load duration approach in accordance with the Bacteria TMDL Protocols (MPCA 2009). The flow duration curve was developed using flow data from station S002-774 located in Lambert Creek near Kohler Road. The station is located near the end of the listed reach and continuous flow data from 2006 to 2010 was available and appropriate for use in developing the TMDL. This data was used in conjunction with the *E. coli* standard to develop the load duration curve for the TMDL.

The load duration curve approach begins by ranking all of the recorded flows over time to determine a percentage of the time specific flow levels are exceeded. These flow values are then multiplied by the State standard for *E. coli*, of 126 org/100 mL, to determine the allowable bacteria load across all flow regimes. The allowable loads are calculated as the total number of organisms/month of *E. coli* bacteria that can be delivered to the water body that will result in a concentration meeting the State standard. The calculated monthly loads are divided by a factor of 30.42 to derive the daily loads that are plotted as a continuous curve on a logarithmic scale, which displays the bacteria load at the State standard across all flow regimes (Figure 6.6).

#### 5.3.1.1 *E. coli* Available for Runoff

The *E. coli* produced in the watershed was divided into several source areas. This process assumes that all *E. coli* produced in the watershed, remains in the watershed. The estimated amount of *E. coli* potentially available each month for runoff is shown in Table 5.3. The daily production estimates for each animal unit or individual were based on literature values for fecal coliform (MPCA 2002) which were converted to be expressed in terms of *E. coli.*

**Table 5.3. Estimated Monthly *E. coli* Bacteria Produced and Available During Runoff Events.**

| Category | Source | Animal Units or Individuals in Subwatershed (Presented as a range of expected values) | *E.coli* Organisms Produced Per Unit Per Month (10^9) (1) | Total *E. coli* Produced Per Month (10^9) | Total *E. coli* Produced by Category Per Month (10^9) | Total E. coli Available Per Month (10^9) (5): Range of Expected Values | Total E. coli Available Per Month (10^9) (5): Value used to calculate numeric TMDL | Percent by Category: Range | Percent by Category: Value used to calculate numeric TMDL |
|---|---|---|---|---|---|---|---|---|---|
| Wildlife | Deer | 170 - 200 | 9.59 | 1,630 - 1,920 | 5,610 - 10,950 | 1,630 - 1,920 | 1,775 | 6 - 45% | 19% |
| | Geese (4) | 45 - 320 | 0.20 | 10 - 60 | | 10 - 60 | 50 | | |
| | Ducks (6) | 50 - 150 | 46.60 | 2,330 - 6,990 | | 2,330 - 6,990 | 4,660 | | |
| | Other Wildlife | Equivalent of Deer and Geese | 9.59 | 1,640 - 1,980 | | 1,640 - 1,980 | 1,825 | | |
| Human | Failing Septic Systems (3) | - | 38.35 | - | - | - | - | - | - |
| Urban Stormwater (2) | Pet Waste | 4,230 - 7,060 | 95.89 | 405,610 - 676,980 | 405,610 - 676,980 | 4,060 - 67,700 | 35,880 | 55 - 94% | 81% |
| | | | | | | **Total** | **44,190** | | |

(1) Derived from literature values in ASAE (1998), Metcalf and Eddy (1991), Horsely and Witten (1996), and Alderisio and DeLuca (1999).

(2) 0.58 dogs/household and 0.73 cats/household (Southeast Minnesota Regional TMDL (MPCA 2002)): Range based on ±25%.

(3) Based on map review, estimated four homes with septic systems adjacent to Lambert Creek. Assumed contribution of zero based on expected failure rates.

(4) Range estimated from the Canada Goose Program Report 2004 and The City of Eden Prairie Canada Goose Management Plan (2008). The "average' geese population was obtained through personal communication with Tom Keefe (President, Canada Goose Management, Inc.).

(5) Estimated that 1% to 10% of the *E. coli* produced per month attributed to pet waste is improperly managed and available for runoff.

(6) Population range estimate interpreted from statewide population information from the 2011 Waterfowl Breeding Population Survey: Minnesota by the MNDNR and USFWS and Minnesota DNR Wetland Wildlife Population Research (http://files.dnr.state.mn.us/fish_wildlife/roundtable/2010/wildlife/wf_pop-harvest.pdf)

Wildlife populations were estimated as previously discussed in Section 4.2.7. Septic system failure was considered as a potential bacteria source however, the contribution is assumed to be zero due to the lack of systems in the sub-watershed. Although most homes in Gem Lake are on septic systems, Gem Lake is an upstream boundary condition of Lambert Creek. Bacteria sourced from failing systems located around the shoreline of the lake were not considered due to dilution and other internal processes occurring in the lake prior to discharge to the creek. Based on a map review, there are only an estimated 4 homes adjacent to a tributary of Lambert Creek with septic systems. The homes are all new and soils and separation from the groundwater table in the area are ideal for proper septic system function. *E. coli* available through urban stormwater was calculated by applying a ratio of cats and dogs per household (see Table 5.3). The number of households in the Lambert Creek sub-watershed was determined using 2010 census data (5,677 households).

#### 5.3.1.2 *E. coli* Delivery Potential

Delivery potential for each quantified source to reach surface waters is dependent on a variety of factors such as proximity to the creek or other conveyances and the quantity of precipitation received. The delivery potential assumptions presented in Table 5.4 are divided into wet weather conditions and dry weather conditions to differentiate between those sources that are precipitation driven versus those which are not. The dry weather sources are septic systems and wildlife with direct access to the creek. There are no known combined sewers. The septic system delivery potential is not presented as greater during wet conditions in that some septic systems are considered failing due to interaction with the water table, but may not have a direct connection to surface waters, dependent on proximity. In this particular case, the assumed septic system failure rate is zero. However, the delivery potential is included for reference. The delivery potential for geese is higher over deer and other wildlife based on the known, consistent proximity of the waterfowl to surface waters.

**Table 5.4. *E. coli* Delivery Potential.**

| Source | Estimated Delivery Potential | |
|---|---|---|
| | Wet Conditions | Dry Conditions |
| Deer | Very Low | Very Low |
| Geese/Ducks | Moderate | Moderate |
| Other Wildlife | Very Low | Very Low |
| Urban Stormwater Runoff | Moderate | N/A |

# 6.0 TMDL

## 6.1 NUTRIENT TMDL

### 6.1.1 Nutrient TMDL Approach

The first step in developing an excess nutrient TMDL for lakes is to determine the total nutrient loading capacity or assimilative capacity for the lake. The method to determine assimilative capacity is described in Section 5 of the report.

### 6.1.2 Nutrient TMDL Load Allocation Approach

The Load Allocation (LA) includes all non-permitted sources, including atmospheric deposition, septic systems, and internal loading. Atmospheric deposition load was calculated as described in section 4.2.1. As atmospheric load is impossible to control on a local basis, no reduction in the source was assumed for the TMDL. Septic discharge is not permitted, so 100% reduction is assumed. As described in section 4.2.2, the sediment phosphorus release rate was estimated to the values found in Table 4.6 to predict the internal loading. Discussions on which lakes required internal load reductions are presented in the sections specific to each lake (Section 6.2). The general approach was to review the capacity for watershed load reductions based on existing land use and potential load reductions. Where watershed load reductions were not feasible, or not sufficient to meet water quality goals, a reduction of internal loading was required. For example, the majority of the Gilfillan Lake watershed is located in the City of North Oaks, which has developed in such a way that the majority of the impervious areas is disconnected from the drainage system and has a phosphorus export rate of 0.03 lbs/acre from the watershed. Nutrient export from the watershed is so low that any reduction would take the allowable load to zero, meaning that no phosphorus discharge would be permitted, no matter how minor. Therefore, this TMDL does not require a reduction in watershed load for Gilfillan, however residential BMPs are still recommended for the area.

### 6.1.3 Nutrient TMDL Wasteload Allocation Approach

The WLA is required to include permitted discharges such as industrial wastewater point and regulated stormwater discharges where applicable. Tables 4.1 and 4.2 show the relevant permitted dischargers and MS4s that will receive WLAs for each TMDL. The WLA comprises the entire watershed load to each lake and was determined through the modeling process as described in Sections 4 and 5 of this report. The WLA for West Goose Lake also includes the permitted discharge from M-Foods Dairy, LLC which was determined from discharge water sampling and the facility's maximum permitted flow. The facility's discharge contains Total Phosphorus concentrations in the 10 µg/L range. If necessary, future expansions of the individual wasteload allocation for this facility are allowable as long as the effluent Total Phosphorus concentration remains at or below the lake's 60 µg/L water quality standard.

Individual WLAs were requested by the MS4s. The approach to partition the WLAs amongst the MS4s for the nutrient impairments as described below was based on two elements:

- The partitioning of the existing load as calculated within P8 to each lake by MS4.
- Assigning load reductions to MS4s for each lake.

The existing loads were partitioned to each MS4 based on the data and modeling tools utilized, which provided a robust estimate of the current total loads from MS4s in the direct watersheds. Individual loads were partitioned to the MS4s based on their respective runoff volume from the 1.5- inch precipitation event as calculated using the SCS method and curve number information derived from the P8 input. Upstream lakes were considered a boundary condition, and their loads were considered part of the LA.

The 1.5-inch event was chosen to be representative as the majority of the annual phosphorus loading and annual runoff is derived from precipitation events 1.5 inches or smaller. The 1.5-inch event also takes into account runoff from pervious areas. The 1.25-inch event was also evaluated but it seemed to underrepresent highly dense commercial or residential areas that were embedded in larger MS4s due to low overall CNs. For example, using the 1.25-inch event, the City of Gem Lake had a very small percentage of volume generated compared with MnDOT and Ramsey County. The 1.5 inch event better quantifies the relative proportion of loads overall.

Note that increased runoff volumes and the associated increase in velocity from highly impervious land uses can alter hydrology and mobilize environmental sources of phosphorus that would otherwise have not contributed to nutrient or bacteria impairments.

The computation process for partitioning the existing watershed nutrient sources to individual MS4s is outlined below. Tables that further detail the calculation process are included in Appendix B.

1. The P8 model input was generated from 2005 Land use data and the hydrologic soil groups within each lake subwatershed. This data was used in conjunction with detailed shapefiles provided by MnDOT of the right-of-way within each watershed to develop composite CNs for use in the WLA partitioning. For each land use type within the subwatershed, the percent impervious area was assigned based on a combination of map review and literature values. A CN of 98 was used to represent the impervious area. A pervious CN was assigned to the remaining area based on the underlying soil type. A composite overall CN was then calculated for each land use type within each lake subwatershed.

2. The individual CNs assigned to each land use within a subwatershed were then applied to the land use types located within each MS4 to derive a composite overall CN for each MS4 within the subwatershed.
3. The calculated CNs for each MS4 were then used in conjunction with the SCS Method to calculate surface water runoff (SRO) for the 1.5 inch rainfall event.

$$SRO = (P-0.2S)^2/(P+0.8S)$$

Where P is precipitation and P=1.5 inch rainfall event and

$$S = (1000/CN) - 10$$

4. The SRO calculated above was converted to a runoff volume based on the area of each MS4 within the subwatershed. The percent of each MS4 contributing to the total SRO volume from the subwatershed was then calculated. The existing annual phosphorus load to each lake was partitioned between the MS4s based on these percentages.

Allocation of the load reduction across all MS4s was based on their existing contribution percentages as calculated above. Each MS4 has an equivalent percent load reductions based on their existing contributions. For example, the required load reduction to Gem Lake is 24%; each of the MS4s discharging to Gem Lake received a load reduction of 24% from their existing loads. This approach provides opportunities for MS4s to work together and the flexibility to site BMPs where they are the most cost effective and to share costs. It provides for maximum local flexibility and facilitates a collaborative effort led by VLAWMO.

The baseline year from which credit for load reductions will be given is 2007. That is to say, work done by an MS4 in 2008 or beyond will count towards an MS4's required load reductions.

It may be necessary to transfer load in the future. This can occur if one regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansion. In these cases, the transfer is WLA to WLA. Load transfers will be based on methods consistent with those used in setting allocations in the TMDL. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer.

### 6.1.4 Nutrient TMDL Margin of Safety

An MOS has been incorporated into this Nutrient TMDL to account for the inherent uncertainty in using models to predict responses in natural systems and to ultimately ensure that the nutrient reduction strategy is protective of the water quality standard. The MOS for this TMDL study is both explicit and implicit through use of conservative modeling assumptions in the development of allocations.

Examples of conservative modeling assumptions used in this TMDL study are described below (implicit MOS).

- The lake response model for total phosphorus used for this TMDL uses the rate of lake sedimentation, or the loss of phosphorus from the water column as a result of settling, to predict total phosphorus concentration. Sedimentation can occur as algae die and settle, as organic material settles, or as algae are grazed by zooplankton. Sedimentation rates in shallow lakes can be higher than rates for deep lakes. Shallow lakes differ from deep lakes in that they tend to exist in one of two states: turbid water and clear water. Lake response models assume that even when total phosphorus concentrations in the lake are at or better than the state water quality standards the lake will continue to be in that turbid state. However, as nutrient load is reduced and other internal load management activities such as fish community management occur to provide a more balanced lake system, shallow lakes will tend to “flip” to a clear water condition. In that balanced, clear water condition, light penetration allows rooted aquatic vegetation to grow and stabilize the sediments, and zooplankton to thrive and graze on algae at a much higher rate than is experienced in turbid waters. Thus in a clear water state more phosphorus will be removed from the water column through settling than the model would predict. The TMDL is set to achieve water quality standards while still in a turbid water state. To achieve the beneficial use, the lake must flip to a clear water state that can support the response variables at higher total phosphorus concentrations due to increased zooplankton grazing, reduced sediment re-suspension, etc. Therefore, this TMDL is inherently conservative by setting allocations for the turbid water state.

The following describes the explicit MOS used during the loading capacity determination.

- Another conservative modeling approach is to use robust data sets for calibration. Several years of in lake water quality were available for the calibration of each lake model, in addition to watershed runoff and bathymetry. These data assist in ensuring that the model adequately represents the average condition. Due to these modeling practices and robust data sets, a large explicit MOS is unnecessary and application of a small explicit MOS is appropriate. For each of the lakes, 5% of the TMDL was assigned as MOS.

## 6.2 NUTRIENT TOTAL MAXIMUM DAILY LOADS

The numerical TMDLs for Gem, Gilfillan, East Goose, West Goose, and Wilkinson Lakes were calculated as the sum of the Wasteload Allocation, Load Allocation and Margin of Safety and are expressed as phosphorus mass per unit time. Results are presented daily and annually. Nutrient loads in this TMDL are set for phosphorus since this is typically the limiting nutrient for nuisance aquatic algae. This TMDL is written to solve the TMDL equation for a numeric target of 60 μg/L of total phosphorus as a summer growing season average.

The TMDL for each lake is presented in Tables 6.1 and 6.2. The allocation to MS4s and other sources are presented in Tables 6.3 and 6.4. Discussion of the existing nutrient budget, required load reductions, and allocation approaches are included in the sections below.

**Table 6.1. Nutrient TMDLs (as annual loads).**

| Annual TP Loading (lb/yr) | TMDL = | LA + | WLA + | MOS |
|---|---|---|---|---|
| Gem | 54.9 | 5.2 | 47.0 | 2.7 |
| Goose - East | 187.9 | 99.8 | 78.7 | 9.4 |
| Goose - West | 224.2 | 173.0 | 40.0 | 11.2 |
| Lake Gilfillan | 164.7 | 139.4 | 17.0 | 8.3 |
| Lake Wilkinson | 321.8 | 126.4 | 179.4 | 16.1 |

**Table 6.2. Nutrient TMDLs (as daily loads).**

| Daily TP Loading (lb/day) | TMDL = | LA + | WLA + | MOS |
|---|---|---|---|---|
| Gem | 0.150 | 0.014 | 0.129 | 0.008 |
| Goose - East | 0.514 | 0.273 | 0.215 | 0.026 |
| Goose - West | 0.614 | 0.474 | 0.109 | 0.031 |
| Lake Gilfillan | 0.451 | 0.382 | 0.047 | 0.022 |
| Lake Wilkinson | 0.881 | 0.346 | 0.491 | 0.044 |

**Table 6.3. Nutrient WLA by MS4 (as annual loads).**

| | | | MS4s | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake | WLA (lbs/yr) | M-Foods Dairy, LLC.(1) | Anoka County | Gem Lake City MS4 | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
| Gem | 47.0 | - | - | 23.9 | - | 5.2 | - | 9.0 | - | 8.9 | - |
| Goose - East | 78.7 | - | - | 2.2 | - | 7.9 | - | 3.9 | - | 64.7 | - |
| Goose - West | 40.0 | 24.7 | - | 2.8 | - | 3.6 | - | 1.6 | - | 7.3 | - |
| Lake Gilfillan | 17.0 | - | - | - | - | - | 14.7 | 0.5 | 0.1 | - | 1.7 |
| Lake Wilkinson | 179.4 | - | 0.1 | - | 1.2 | 47.2 | 26.4 | 1.8 | - | 35.1 | 67.6 |

(1) WLA may be expanded in the future. See Section 6.1.3

**Table 6.4. Nutrient WLA by MS4 (as daily loads).**

| | | | MS4s | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake | WLA (lbs/day) | M-Foods Dairy, LLC.(1) | Anoka County | Gem Lake City MS4 | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
| Gem | 0.129 | - | - | 0.065 | - | 0.014 | - | 0.025 | - | 0.025 | - |
| Goose - East | 0.215 | - | - | 0.006 | - | 0.022 | - | 0.011 | - | 0.176 | - |
| Goose - West | 0.109 | 0.068 | - | 0.007 | - | 0.010 | - | 0.004 | - | 0.020 | - |
| Lake Gilfillan | 0.047 | - | - | - | - | - | 0.041 | 0.001 | <0.001 | - | 0.005 |
| Lake Wilkinson | 0.491 | - | <0.001 | - | 0.003 | 0.129 | 0.072 | 0.006 | - | 0.096 | 0.185 |

(1) WLA may be expanded in the future. See Section 6.1.3

The sections below summarize the existing nutrient sources to the lake, the TMDL and the required load reductions and describe the allocation approach for each lake. The required reduction for each MS4 is applied proportionally to their existing load. That is to say that if a 24% loading reduction is required for a specific lake to meet its goal, each tributary MS4 has a 24% reduction from their existing load of a pollutant. The wasteload reductions required from drainage areas (WLA) presented in the tables within the following sections are the equivalent reductions required of each MS4 within each lake watershed. The percent reductions for each MS4 are listed below. These percent reductions apply ONLY to the watershed area that drains to the impaired water (not reductions needed from internal phosphorus loading); these areas are shown in Appendix D.

- 24% reduction in watershed phosphorus loading to Gem Lake applies to
  - Gem Lake
  - MNDOT
  - Ramsey County
  - White Bear Lake City
- 63% reduction in watershed phosphorus loading to East Goose Lake applies to
  - Gem Lake
  - MNDOT
  - Ramsey County
  - White Bear Lake City
- 86% reduction in watershed phosphorus loading to West Goose Lake applies to
  - Gem Lake
  - MNDOT
  - Ramsey County
  - White Bear Lake City
- 0% reduction in watershed phosphorus loading to Gilfillan Lake applies to
  - North Oaks
  - Vadnais Heights
  - White Bear Lake Township
- 76% reduction in watershed phosphorus loading to Wilkinson Lake applies to
  - Anoka County
  - Lino Lakes
  - MNDOT
  - North Oaks
  - Ramsey County
  - White Bear Lake City
  - White Bear Township

### 6.2.1 Gem Lake

As shown in Figure 6.1, the dominant phosphorus loading in Gem Lake is from watershed sources (permitted MS4s). As such, the primary nutrient load reduction must come from watershed sources (Table 6.5). Eliminating load from septic systems will also be required. In order to meet the TP goal in Gem Lake, approximately an overall 24% reduction in TP is required. The internal loading rate for Gem Lake was set to zero during lake response modeling. Setting the internal loading rate to zero does not imply there is no internal loading occurring. Instead, an internal loading rate of zero indicates that the internal load is no higher than the background levels of internal loading implicitly represented in the Canfield-Bachmann model. Therefore, no reduction to internal loading is identified.

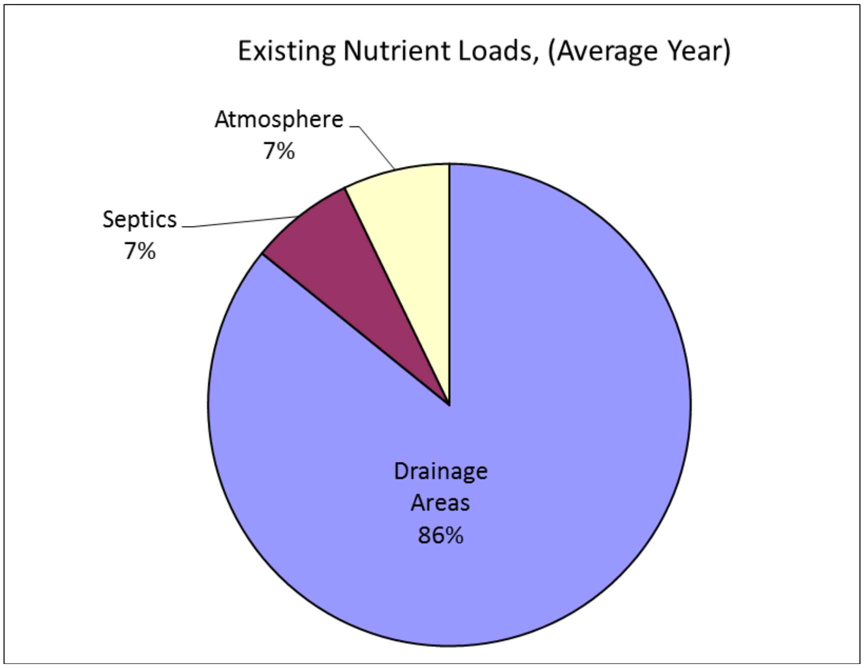


**Figure 6.1. Gem Lake Existing Phosphorus Load Breakdown by Source.**

**Table 6.5. Gem Lake Existing Nutrient Load, TMDL and Required Reductions.**

| | | Existing TP Load | | TP TMDL | | Load Reduction | |
|---|---|---|---|---|---|---|---|
| Allocation | Source | (lbs/year) | (lbs/day) | (lbs/year) | (lbs/day) | (lbs/year) | % |
| WLA | Drainage Areas | 62.1 | 0.170 | 47.0 | 0.129 | 15.1 | 24% |
| LA | Septics | 5.1 | 0.014 | 0.0 | 0.000 | 5.1 | 100% |
| LA | Atmosphere | 5.2 | 0.014 | 5.2 | 0.014 | 0.0 | 0% |
| LA | Internal Load* | 0.0 | 0.000 | 0.0 | 0.000 | 0.0 | NA |
| MOS | | | 0.000 | 2.7 | 0.007 | | |
| | TOTAL | 72.4 | 0.198 | 54.9 | 0.150 | 17.5 | 24% |

*The Gem Lake model did not require the addition of internal load in excess of the load that is implicit in the model.

Note: The margin of safety was deducted from the modeled allowable drainage area load and the total load reduction values (lbs/yr and %) account for the margin of safety.

### 6.2.2 East Goose Lake

The dominant phosphorus loading in East Goose Lake is from internal loading, likely the result of historical loading to the sediments from the White Bear Lake WWTP, which used to discharge to the basin (Figure 6.2). As such, the primary nutrient load reduction must come from a reduction of the internal load (Table 6.6). Significant watershed load reductions are also required. The watershed load reduction of 63% is based on what is expected to be achievable in the watershed (this reduction equates to an aerial export rate of approximately 0.14 lbs/acre). In order to meet the TP goal, an overall reduction of 91% is required.

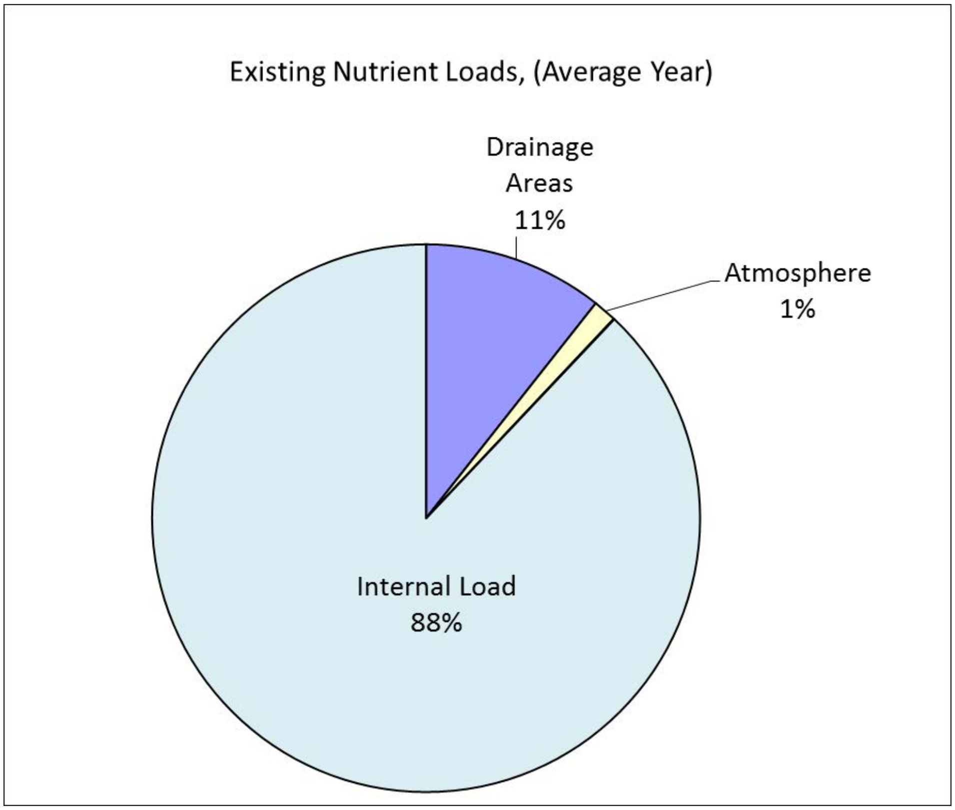


**Figure 6.2. East Goose Lake Existing Phosphorus Load Breakdown by Source.**

**Table 6.6. East Goose Lake Existing Nutrient Load, TMDL and Required Reductions.**

| | | Existing TP Load | | TP TMDL | | Load Reduction | |
|---|---|---|---|---|---|---|---|
| Allocation | Source | (lbs/year) | (lbs/day) | (lbs/year) | (lbs/day) | (lbs/year) | % |
| WLA | Drainage Areas | 214.8 | 0.588 | 78.7 | 0.215 | 136.1 | 63% |
| LA | Atmosphere | 27.9 | 0.076 | 27.9 | 0.076 | 0.0 | 0% |
| LA | Groundwater | 0.8 | 0.002 | 0.8 | 0.002 | 0.0 | 0% |
| LA | Internal Load | 1777.2 | 4.866 | 71.1 | 0.195 | 1706.1 | 96% |
| MOS | | | | 9.4 | 0.026 | | |
| | TOTAL | 2020.7 | 5.532 | 187.9 | 0.514 | 1832.8 | 91% |

Note: The margin of safety was deducted from the modeled allowable drainage area load and the total load reduction values (lbs/yr and %) account for the margin of safety.

### 6.2.3 West Goose Lake

Direct watershed loading to West Goose Lake represents 15% of the annual load compared with 57% from internal sources (Figure 6.3). As such, load reductions to both sources will be required to reduce the phosphorus load to the lake (Table 6.7). The primary driver of internal loading in this lake is the re-suspension of phosphorus from lake sediments from motor boating (dominated specifically by waterskiing as discussed in Section 4.2.2). Note that the high internal phosphorus levels in the sediments are likely the result of historical loading to the sediments from the White Bear Lake Wastewater Treatment Plant, which used to discharge to Goose Lake. In order to meet the TP goal, an overall TP load reduction of 70% is required. This loading reduction also assumes that East Goose Lake (included as an upstream lake) meets its in-lake water quality goal of 60 ug/L.

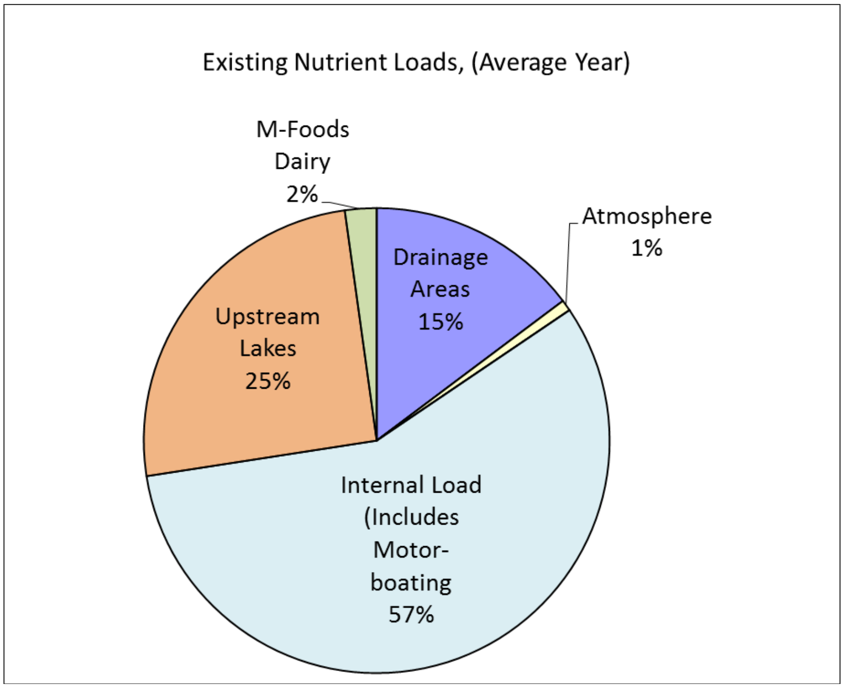


**Figure 6.3. West Goose Lake Existing Phosphorus Load Breakdown by Source.**

**Table 6.7. West Goose Lake Existing Nutrient Load, TMDL and Required Reductions.**

| | | Existing TP Load | | TP TMDL | | Load Reduction | |
|---|---|---|---|---|---|---|---|
| Allocation | Source | (lbs/year) | (lbs/day) | (lbs/year) | (lbs/day) | (lbs/year) | % |
| WLA | Drainage Areas | 110.4 | 0.302 | 15.3 | 0.042 | 95.1 | 86% |
| LA | Atmosphere | 5.8 | 0.016 | 5.8 | 0.016 | 0.0 | 0% |
| LA | Internal Load (Includes Motor-boating) | 427.1 | 1.169 | 123.1 | 0.337 | 304.0 | 71% |
| LA | Upstream Lakes | 189.1 | 0.518 | 44.1 | 0.121 | 145.0 | 77% |
| WLA | M-Foods Dairy* | 16.5 | 0.045 | 24.7 | 0.068 | 0.0 | 0% |
| MOS | | | | 11.2 | 0.031 | | |
| | TOTAL | 748.8 | 2.050 | 224.2 | 0.615 | 524.7 | 70% |

* WLA may be expanded in the future. See Section 6.1.3.

Note: The margin of safety was deducted from the modeled allowable drainage area load and the total load reduction values (lbs/yr and %) account for the margin of safety.

### 6.2.4 Gilfillan Lake

The dominant phosphorus loading in Gilfillan Lake is from internal loading (Figure 6.4). As such, the primary nutrient load reduction must come from a reduction of the internal load (Table 6.8). Eliminating load from septic systems will also be required. In order to meet the TP goal in Gilfillan Lake, an overall 62% reduction in TP is required. The existing areal export rate for TP from the subwatershed is 0.03 lbs/acre. Since watershed loading is below expected background levels, a reduction from the watershed load is not anticipated to be achievable. The majority of the watershed is located in the City of North Oaks, which has developed in such a way that most of the impervious areas are disconnected from the drainage system (reflected by the low areal export from the watershed). The watershed area outside of the City of North Oaks drains through a series of ponds and wetlands that increase infiltration and evapotranspiration and reduce runoff conveying pollutant loads to the lake. Even though a load reduction from the watershed has not been explicitly called for, the implementation recommendations for Gilfillan Lake will include some action items within the watershed.

The outlet of Gilfillan Lake was modified historically to raise the level of the lake. The water level was also augmented through addition of pumped groundwater. A project approved by the Minnesota DNR will once again augment lake levels using water from Pleasant Lake. Construction is complete and augmentation activities have started. Augmentation was accounted for, and included in the load allocation, in the TMDL by generating an annual load calculated from the average TP concentration in Pleasant Lake (54 µg/L) and the volume of water required to make up for the negative water balance (54.5 ac-ft/yr).

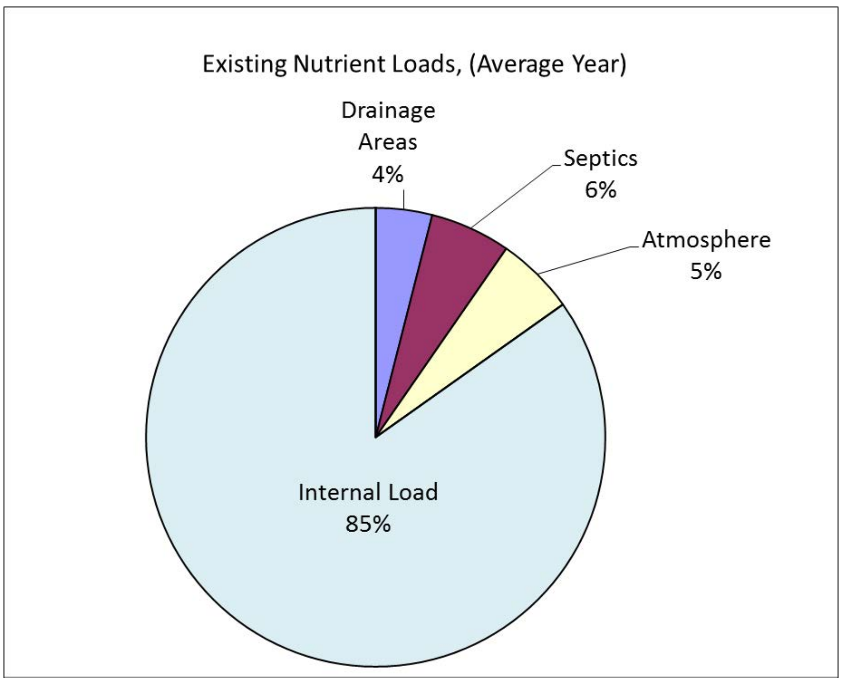


**Figure 6.4. Gilfillan Lake Existing Phosphorus Load Breakdown by Source.**

**Table 6.8. Gilfillan Lake Existing Nutrient Load, TMDL and Required Reductions.**

| | | Existing TP Load | | TP TMDL | | Load Reduction | |
|---|---|---|---|---|---|---|---|
| Allocation | Source | (lbs/year) | (lbs/day) | (lbs/year) | (lbs/day) | (lbs/year) | % |
| WLA | Drainage Areas | 17.0 | 0.047 | 17.0 | 0.047 | 0.0 | 0% |
| LA | Septics | 24.3 | 0.067 | 0.0 | 0.000 | 24.3 | 100% |
| LA | Atmosphere | 23.8 | 0.065 | 23.8 | 0.065 | 0.0 | 0% |
| LA | Internal Load | 364.2 | 0.997 | 107.5 | 0.294 | 264.7 | 73% |
| LA | Augmentation | 0.0 | 0.000 | 8.0 | 0.022 | 0.0 | NA |
| MOS | | | | 8.3 | 0.023 | | |
| | TOTAL | 429.4 | 1.176 | 164.7 | 0.451 | 264.7 | 62% |

Note: The margin of safety was deducted from the modeled allowable internal load and the total load reduction values (lbs/yr and %) account for the margin of safety. The internal load reduction also accounts for the augmentation load.

### 6.2.5 Wilkinson Lake

Phosphorus loading to Wilkinson Lake is predominantly from the watershed load (Figure 6.5). Upstream lakes in the Wilkinson Lake subwatershed include Amelia and Birch Lakes. According to available data, these lakes are currently meeting State Standards with average internal phosphorus concentrations of 38.8 and 32.5 µg/L, respectively. Therefore, no load reduction from the upstream lakes is required. Internal loading comprises a small portion of the total load and with a low sediment release rate for a shallow lake such as Wilkinson (1.0 mg/m2-day) a reduction in internal loading is not necessarily feasible. As such, nutrient load reduction must come from a reduction of direct watershed loads (Table 6.9).

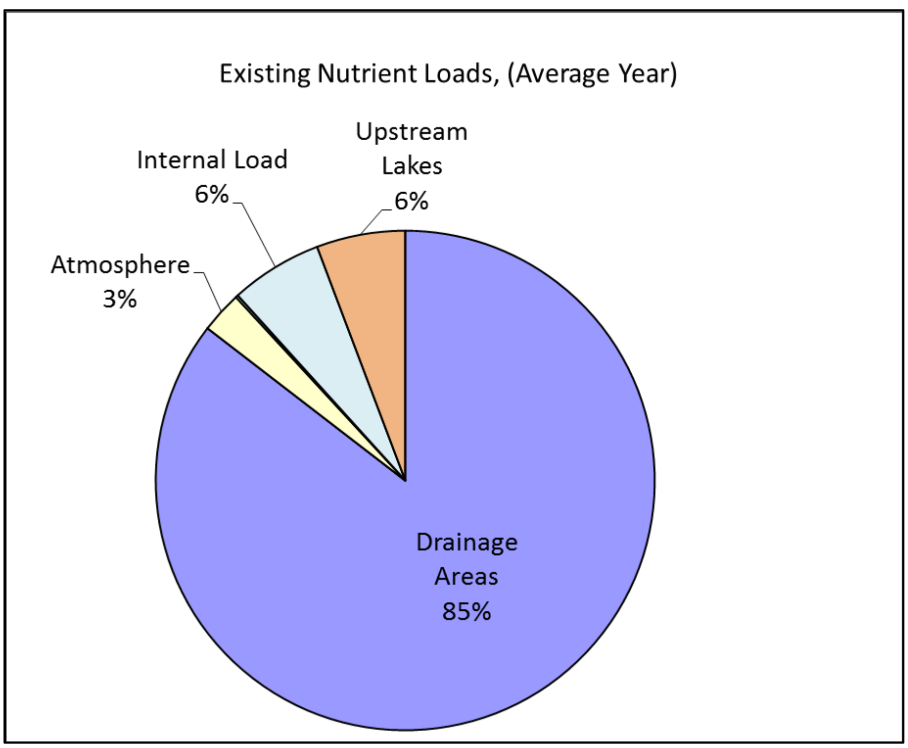


**Figure 6.5. Wilkinson Lake Existing Phosphorus Load Breakdown by Source.**

**Table 6.9. Wilkinson Lake Existing Nutrient Load, TMDL and Required Reductions.**

| | | Existing TP Load | | TP TMDL | | Load Reduction | |
|---|---|---|---|---|---|---|---|
| Allocation | Source | (lbs/year) | (lbs/day) | (lbs/year) | (lbs/day) | (lbs/year) | % |
| WLA | Drainage Areas | 740.4 | 2.027 | 179.4 | 0.491 | 561.0 | 76% |
| LA | Atmosphere | 23.3 | 0.064 | 23.3 | 0.064 | 0.0 | 0% |
| LA | Groundwater | 1.4 | 0.004 | 1.4 | 0.004 | 0.0 | 0% |
| LA | Internal Load | 51.8 | 0.142 | 51.8 | 0.142 | 0.0 | 0% |
| LA | Upstream Lakes | 49.8 | 0.136 | 49.8 | 0.136 | 0.0 | 0% |
| MOS | | | | 16.1 | 0.044 | | |
| | TOTAL | 866.7 | 2.373 | 321.8 | 0.881 | 544.9 | 63% |

Note: The margin of safety was deducted from the modeled allowable drainage area load and the total load reduction values (lbs/yr and %) account for the margin of safety.

## 6.3 NUTRIENT SEASONAL AND ANNUAL VARIATION AND CRITICAL CONDITIONS

The daily load reduction targets in this TMDL are calculated from the current phosphorus budget for each lake. The budget is an average of several years of monitoring data, and includes both wet and dry years. BMPs designed to address excess loads to this lake will be designed for these average conditions; however, the performance will be protective of all conditions. For example, a stormwater pond designed for average conditions may not perform at design standards for wet years; however, the assimilative capacity of the lake will increase due to increased flushing. Additionally, in dry years the watershed load will be naturally down allowing for a larger proportion of the load to come from internal loading. Consequently, averaging across several modeled years addresses annual variability in lake loading.

The critical condition for these lakes is the summer growing season. Minnesota lakes typically demonstrate impacts from excessive nutrients during the summer recreation season (June 1st through September 30th) including excessive algal blooms and fish kills. Lake goals have focused on summer-mean total phosphorus, Secchi transparency and chlorophyll-*a* concentrations. These parameters have been linked to user perception (Heiskary and Wilson 2005). Consequently, the lake response models have focused on the summer growing season as the critical condition. Additionally, these lakes have relatively short residence times and therefore respond to annual loads.

Seasonal variation is accounted for through the use of annual loads and developing targets for the summer period when the frequency and severity of nuisance algal growth will be the greatest. Although the critical period is the summer, lakes are not sensitive to short-term changes in water quality, rather lakes respond to long-term changes such as changes in the annual load. Therefore, seasonal variation is accounted for in the annual loads. Additionally, by setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during all the other seasons.

## 6.4 BACTERIA TMDL

### 6.4.1 Bacteria TMDL Allocation Approach

Bacteria loading for Lambert Creek is described in Section 5 of this report and summarized in Table 5.3. Bacteria available for runoff generated from wildlife is assigned to the load allocation, bacteria available from human sources and urban stormwater are assigned to the WLA. The WLA is distributed amongst the MS4s based on the same methodology used to allocate nutrient loads to MS4s as described in Section 6.1.3 of this report. The distributions are presented on Table 6.11.

Because stream *E. coli* concentrations are dependent upon the daily flow which is dynamic, it is appropriate to express the TMDL and load reduction by an allowable load across all flow conditions as is demonstrated in Figure 6.6 for daily loads. To determine acceptable loads under the critical flow regimes, chronic standard concentrations were multiplied by the flow at each interval. Monthly mean flow data was used to calculate the load duration curve. The daily loads were derived from the calculated monthly loads by dividing by the average number of days per month (30.42).

### 6.4.2 Bacteria Margin of Safety

The margin of safety (MOS) accounts for uncertainties in both characterizing current conditions and the relationship between the load, wasteload, monitored flows and in-stream water quality. A reasonable MOS is necessary in order to account for natural variability. The MOS is also necessary to account for the uncertainty in the effect on observed water quality that the calculated load allocations will have and that the allocations will result in attainment of the water quality standards. An explicit MOS equal to 10% of the total load was used for this TMDL report to quantify such variability. This means that 10% of the loading capacity for each flow regime was subtracted before allocations were made among sources to account for the variation in flow for each regime.

### 6.4.3 Bacteria TMDL

The TMDL loads for daily loads based on the 126 *E. coli* /100 mL standard are shown in Figure 6.6. The dashed lines represent the mid-point of each flow zone, from which the TMDL equation for each flow regime was derived. The flow duration curve with discrete bacteria sampling data was previously presented on Figure 3.20.

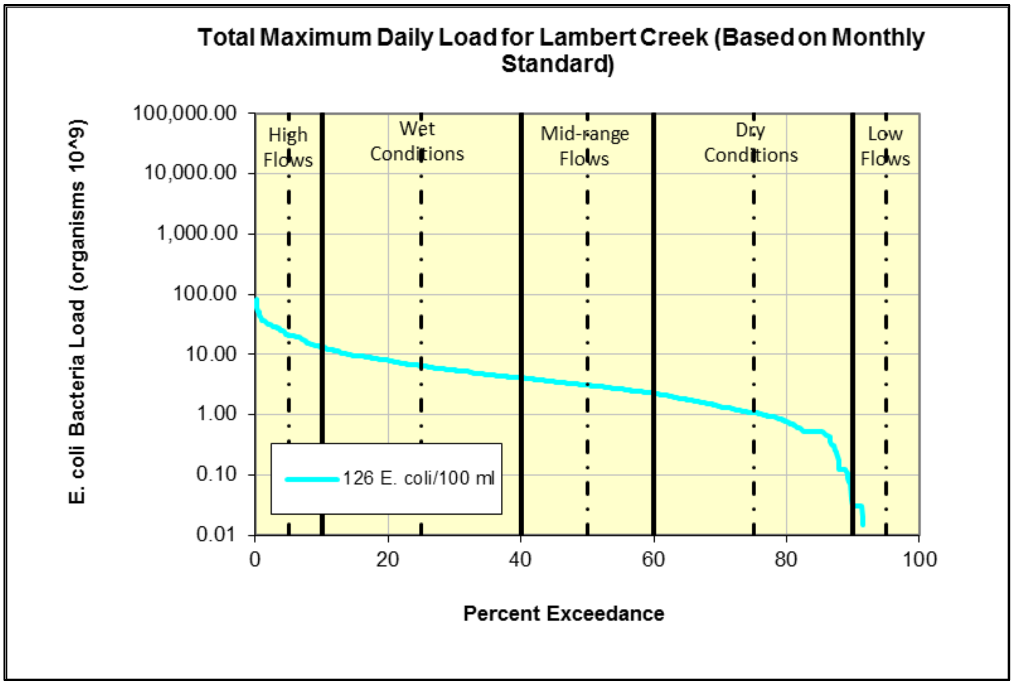


**Figure 6.6. The Total Maximum Daily Load for Lambert Creek.**
Values represent total daily load derived from monthly load (Standard of 126 *E. coli*/100 mL).

To develop the TMDL equation, the seasonal median discharge was calculated for each of five flow conditions. These data were then multiplied by the standard of 126 *E. coli*/100 mL to establish the TMDL (Table 6.10). The required load reduction for each flow regime is also presented on the table below. To calculate the load reduction, the geomean of all data available from each station within the impaired reach from April - October was calculated based on the five flow conditions. The resulting geomean concentration was applied to the median flow to derive the existing load; from which the required load reduction to achieve the TMDL was calculated. The above graph reflects that there are periods where Lambert Creek is dry or experiences no flow. Therefore, there is no TMDL allocation or necessary reduction for the low flow condition. It is of note that even though there are no load reductions required for the low flow condition, the BMPs recommended and applied as part of the TMDL implementation plan are effective at all flows. For example, pet waste management programs are a form of source control and not directly correlated to runoff events. The MS4 Wasteload Allocations are shown in Table 6.11. Wasteload was allocated between the MS4s for the bacteria TMDL in the same manner as for the lake nutrient TMDLs as described in Section 6.1.3.

**Table 6.10. Bacteria TMDL, Expressed as Daily Loads.**

| Daily | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reach | Critical Condition | Current Load (Billions of org) | MS4 Wasteload Allocation (Billions of org) | Load Allocation (Billions of org) | Margin of Safety (Billions of org) | TMDL* (Billions of org) | Reduction Needed |
| Lambert Creek | High Flow | 54.35 | 15.38 | 3.56 | 2.10 | 21.04 | 61% |
| | Wet | 14.26 | 4.78 | 1.11 | 0.65 | 6.54 | 54% |
| | Mid-Range | 4.91 | 2.25 | 0.52 | 0.31 | 3.08 | 37% |
| | Dry | 2.46 | 0.79 | 0.18 | 0.11 | 1.08 | 56% |
| | Low Flow | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | - |

**Table 6.11. MS4 Wasteload Allocation (Daily).**

| | MS4 Wasteload Allocation (Billions of org) (Daily) | | | | | | |
|---|---|---|---|---|---|---|---|
| Critical Condition | Gem Lake City MS4 | MNDOT | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 | Total Waste Load |
| High Flow | 0.68 | 1.17 | 0.56 | 8.78 | 3.74 | 0.45 | 15.38 |
| Wet | 0.21 | 0.36 | 0.17 | 2.73 | 1.16 | 0.15 | 4.78 |
| Mid-Range | 0.10 | 0.17 | 0.08 | 1.28 | 0.55 | 0.07 | 2.25 |
| Dry | 0.04 | 0.06 | 0.03 | 0.45 | 0.19 | 0.02 | 0.79 |
| Low Flow | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

### 6.4.4 Bacteria Seasonal and Annual Variation and Critical Conditions

Seasonal geometric means (defined in Section 2.2) of bacteria data were calculated for Lambert Creek (Table 3.6). Geometric means for *E. coli* bacteria are consistently above the state chronic standard in June through October, with the highest values recorded in October. Exceedances of the acute standard also occur between June and October, with the greatest percentage of exceedances occurring during the month of October (low flows). Fecal bacteria are most productive at temperatures similar to their origination environment in animal digestive tracts. Thus, these organisms are expected to be at their highest concentrations during warmer summer months when stream flow is typically low and water temperatures are highest. High *E. coli* concentrations appear to continue into the fall, which may be attributed to constant sources of *E. coli* and less flow for dilution. However, this data may be skewed as more samples were collected in the summer months with only five samples available for October.

Seasonal and annual variations are accounted for by setting load reduction targets across the observed flow record using the Load Duration Method. Load reductions are required across all flow regimes and in all seasons because exceedances of the state standards (both chronic and acute) were recorded during all flow regimes, and all months during which the standard applies with the exception of the month of May and no data was available for the month of April.

## 6.5 RESERVE CAPACITY/FUTURE GROWTH

The watersheds for these lakes and creek are entirely within MS4 communities. As such, urban stormwater is currently regulated under the NPDES Phase II stormwater permits. The reserve capacity is included in the WLA. The watershed is primarily built out, and all of the development projects that will occur will be covered under the member cities rules in place for development and redevelopment that are protective of water quality. Consequently, future development will have to meet watershed requirements that will account for pollution reductions, both nutrient and bacteria, in this TMDL.

The M-Foods Dairy wasteload allocation is based on monitored Total Phosphorus effluent concentrations in the 10 µg/L range and the facility's maximum permitted flow value. Future expansion of the facility' individual wasteload allocation is allowable as long as the effluent concentration remains at or below the 60 µg/L water quality standard applicable for West Goose Lake.

# 7.0 Public Participation

## 7.1 INTRODUCTION

As a part of the strategy to achieve implementation of the necessary reductions, VLAWMO sought stakeholder and public engagement and participation regarding their concerns, interests, and questions regarding the development of the TMDL. Specifically, meetings were held for a Technical Advisory Committee representing key stakeholders. Additionally, VLAWMO engaged a representative from Northland NEMO (Nonpoint Education for Municipal Officials) to further facilitate public participation.

## 7.2 TECHNICAL ADVISORY COMMITTEE/ STAKEHOLDERS/PUBLIC MEETINGS

A Technical Advisory Committee (TAC) was established as a liaison body with affected local government. The TAC could be kept informed on the progress and data results during development of the TMDL. A larger group of stakeholders including local cities, lake associations for impaired lakes, Minnesota Department of Natural Resources (DNR), the Metropolitan Council, Minnesota Department of Transportation, the Board of Water and Soil Resources and the Minnesota Pollution Control Agency was convened when preliminary results were available. All meetings were open to interested individuals and organizations. A Technical Advisory Committee meeting was held on January 22, 2009.

The first Stakeholder meeting was held August 10, 2009, with the second meeting on May 3, 2012. The May 3, 2012, meeting was facilitated by VLAWMO staff and a representative from Northland NEMO. The list below summarizes the attendance at the May 3, 2012, meeting:

- **50 participants** composed of city council, planning commission, county commissioners, park commissioners, homeowner association members, lake association members, Soil and Water Conservation District (SWCD) supervisors, city administrators, department directors, public works, parks, and planning staff, and other community stakeholder group representatives
- All six cities attended
- All MS4 permit holders with and without an assigned WLA in this TMDL attended except Anoka County

A summary of participant response to a series of multiple choice questions posed at the May 3, 2012 stakeholder meeting is included as Appendix F. Post-workshop comments were also received and will be used to assist in development of a separate Implementation Plan.

Comments received at public meetings were considered and incorporated into the final report as appropriate.

A formal public notice period for this Vadnais Lake Area WMO TMDL and Protection Study was held from September 16, 2013 through October 15, 2013. Four comment letters were received.

A third stakeholder meeting was held on November 15, 2013 to generate ideas from stakeholders about implementation projects that would address water quality problems in East and West Goose Lakes and Lambert Creek. These recommendations will be used in the development of a separate Implementation Plan for this project.

# 8.0 Implementation

## 8.1 IMPLEMENTATION FRAMEWORK

### 8.1.1 The Vadnais Lake Area WMO

VLAWMO's mission is to protect and enhance the water resources within the watershed. Activities include water quality monitoring, wetland protection, and water quality enhancement projects. As such, VLAWMO is well-suited to complete TMDL studies within the watershed and to coordinate implementation in concert with stakeholders.

VLAWMO was formed in 1983 to protect the Vadnais Lake watershed. Vadnais Lake is used as the final water storage reservoir for the drinking water supply system operated by the St. Paul Regional Water Service (SPRWS). VLAWMO was formed through a Joint Powers Agreement (JPA) that was ratified by the six units of municipal government that VLAWMO encompasses to comply with the State of Minnesota Metropolitan Surface Water Management Act. VLAWMO is governed by a six-member Board of Directors that is represented by an elected official from each of the communities.

VLAWMO has a Watershed Management Plan (see copy posted on the VLAWMO website, www.vlawmo.org) which addresses the entire VLAWMO watershed and all water bodies included therein. The Plan, which has been approved by the Minnesota Board of Water and Soil Resources (BWSR), guides water management through goals, policies, management strategies and an implementation program for the watershed. Work done for this TMDL and Protection Study is an extension of the Watershed Management Plan. The plan was completed in December of 2007 and will expire in 2016. Impaired waters within VLAWMO include Pleasant, Sucker, and East Vadnais Lakes, which were listed on the 303(d) impaired waters list for Minnesota in 2010. These lakes are impaired for aquatic consumption due to mercury. All other listed waters within the VLAWMO legal boundary are included in this TMDL study. However, based on a recent evaluation of data, additional lakes (Tamarack, West Vadnais, Pleasant) may be listed for nutrient impairments on the next 303(d) list.

VLAWMO is empowered under Minnesota Statutes 103A – 103H to manage the Vadnais Lake Area Watershed. These statutes address:

- Protection of surface water quality (this includes monitoring, maintaining, and in some cases improving quality).
- Flood control and stormwater management.
- Wetland protection and management through the Wetland Conservation Act and local efforts.
- Groundwater protection and recharge.

### 8.1.2 Member Cities

Because VLAWMO's specific mission is protection and improvement of water quality, it is in the ideal position to coordinate implementation efforts of the member cities. Each city is regulated by the MPCA and issued permit coverage under the NPDES/SDS MS4 General Permit. As such, each is affected by the TMDL process in that each MS4 with a discharge to the water body of concern will receive a WLA associated with each TMDL addressed in this study (as applicable). Further, each city has in place a Local Water Management Plan to address watershed and city goals and objectives; those local plans are periodically updated to reflect resource management plans and adopt or revise strategies for water resource management. In addition to the member cities, Anoka County, Ramsey County, MnDOT, and White Bear Lake Township are MS4 permit holders affected by this TMDL. Each specific lake section below provides a list of the MS4 permit holders affected for each water body.

## 8.2 GEM LAKE PRIORITY LOAD REDUCTION STRATEGIES

As discussed in Section 6.0, the dominant phosphorus loading in Gem Lake is from watershed sources (permitted MS4s).

**Table 8.1. MS4s receiving WLA for Gem Lake TMDL.**

| |
|---|
| Gem Lake City MS4 |
| MnDOT |
| Ramsey County |
| White Bear Lake City MS4 |

Priority management strategies will need to target the watershed nutrient loads. Septic systems are also a source of nutrient load to Gem Lake. State law prohibits discharge from septic systems so a 100% reduction of this contribution is required. Examples of potential reduction strategies include:

- As opportunities arise, retrofit stormwater treatment through a variety of Best Management Practices. As part of NPDES permit requirements, perform maintenance (sediment removal, etc.) activities on stormwater ponds so they can achieve optimal performance for settling out pollutants as designed. Pond expansion and pre-treatment of water before it reaches ponds may be beneficial dependent on drainage area and increased volume. Cost is dependent on size and number of ponds within the watershed.
- Encourage the use of rain gardens and native plantings as a means to increase infiltration and evapotranspiration. Opportunities may range from a single property owner installing an individual rain garden to retrofitting parks and open space with native vegetation rather than mowed turf.
- Identify target areas for increased frequency of street sweeping. Consider replacing mechanical street sweepers with more efficient regenerative air sweepers.
- Review and inspect SSTS and require follow-up maintenance as necessary to eliminate load from failing systems.

- Continue to identify retrofit and BMP implementation opportunities as new technologies emerge.

The number of BMPs necessary to achieve the required phosphorus load reduction is unknown and is dependent on the types of opportunities that arise. Specific BMPs are listed in Table 8.2. Estimated costs and prioritization of implementation are also indicated. Costs are dependent on the type of BMP, number implemented, location, easement requirements, and other factors. Additional BMPs not specifically listed may be applicable when opportunities arise.

**Table 8.2. Gem Lake Reduction Strategy Examples.**

| Potential BMP | Priority | Associated Cost | Unit | Qty | Total Associated Cost |
|---|---|---|---|---|---|
| Raingarden | 0-2 years | $500 to $10,000 | Each | 3 | $1,500 to $30,000 |
| Street Sweeping | 0-2 years | $150,000 | Each | 2 | $300,000 |
| SSTS Inspections/Maintenance | 0-2 years | $25,000 | Annually | 10 | $250,000 |
| Detention Pond Retrofit and Maintenance | 2-5 years | $30,000 to $250,000 | Each | 2 | $60,000 to $500,000 |
| Emerging technologies/yet to be identified opportunities | 5-10 years | $20,000 to $40,000 | Each | 2 | $40,000 to $80,000 |
| **TOTAL TMDL IMPLEMENTATION COST** | | | | | **$651,500 to $1,160,000** |

## 8.3 EAST GOOSE LAKE PRIORITY LOAD REDUCTION STRATEGIES

The dominant phosphorus loading in East Goose Lake is from internal loading, likely the result of historical loading to the sediments from the White Bear Lake WWTP, which used to discharge to the basin. As such, the primary nutrient load reduction must come from a reduction of the internal load (Table 6.6). Significant watershed load reductions are also required to achieve the TMDL. Priority management strategies will need to target both the watershed and internal nutrient loads. Due to the magnitude of the internal load reduction required, strategies to reduce this load should be prioritized ahead of implementation work within the watershed. MS4 permit holders receiving a WLA for East Goose Lake are listed below.

**Table 8.3. MS4s receiving WLA for East Goose Lake TMDL.**

| |
|---|
| Gem Lake City MS4 |
| MnDOT |
| Ramsey County |
| White Bear Lake City MS4 |

Examples of potential reduction strategies for East Goose Lake include:

- Traditionally, very shallow lakes are not good candidates for chemical treatment, such as alum dosing, to control phosphorus loading. However, this option is worth further investigation for implementation in East Goose due to the large internal load reduction required.
- Aquatic plants should periodically be surveyed to track changes in the plant community and monitor growth. Develop a plan to encourage a healthy native plant community to anchor sediments and reduce sediment re-suspension. The informal plant survey completed for East Goose Lake indicated a low diversity of aquatic plants.
- A 1986 fish survey of Goose Lake showed that the lake was dominated by black bullheads, however a 2012 fish survey (http://vlawmo.org/PDF/Goose%20R12%20-%20fish%20survey.pdf) noted a healthy population of predator fish in Goose Lake. VLAWMO also conducted a significant bullhead removal project in 2013 (http://vlawmo.org/projects.cfm?ServiceID=58&PID=58&siteID=1) in Goose Lake.
- The shoreline around East Goose Lake includes property owners with maintained turf down to the shoreline and areas of riprapped shoreline. Encourage property owners to restore their shoreline with native plants and install buffers to reduce erosion and capture direct runoff. Ideally, about 75 percent of the residential shoreline would be native vegetation.
- Encourage the use of rain gardens as a means to increase infiltration and evapotranspiration. Opportunities may range from a single property owner installing an individual rain garden to retrofitting parks and open space with native vegetation rather than mowed turf.
- Identify target areas for increased frequency of street sweeping. Consider replacing mechanical street sweepers with more efficient regenerative air sweepers.
- As opportunities arise, retrofit stormwater treatment through a variety of Best Management Practices. As part of NPDES permit requirements, perform maintenance (sediment removal, etc.) activities on stormwater ponds so they can achieve optimal performance for settling out pollutants as designed. Pond expansion and pre-treatment of water before it reaches ponds may be beneficial dependent on drainage area and increased volume. Cost is dependent on size and number of ponds within the watershed.
- Continue to identify retrofit and BMP implementation opportunities as new technologies emerge.

The number of BMPs necessary to achieve the required phosphorus load reduction is unknown and is dependent on the types of opportunities that arise. Specific BMPs are listed in Table 8.4. Estimated costs and prioritization of implementation are also indicated. Costs are dependent on the type of BMP, number implemented, location, easement requirements, and other factors. Additional BMPs not specifically listed may be applicable when opportunities arise.

**Table 8.4. East Goose Lake Reduction Strategy Examples.**

| Potential BMP | Priority | Associated Cost | Unit | Qty | Total Associated Cost |
|---|---|---|---|---|---|
| Alum Dosing | 0-2 years | $25,000 to $50,000 | LS | 1 | $25,000 to $50,000 |
| Aquatic Plant Survey & Management Plan | 0-2 years | $10,000 | LS | 1 | $10,000 |
| Shoreline Restoration | 2-5 years | $15 | LF | 1800 | $27,000 |
| Raingarden | 2-5 years | $500 to $10,000 | Each | 10 | $5,000 to $100,000 |
| Street Sweeping Equipment | 2-5 years | $150,000 | Each | 2 | $300,000 |
| Detention Pond Retrofit and Maintenance | 5-10 years | $30,000 to $250,000 | Each | 2 | $60,000 to $500,000 |
| Emerging technologies/yet to be identified opportunities | 5-10 years | $20,000 to $40,000 | Each | 2 | $40,000 to $80,000 |
| **TOTAL TMDL IMPLEMENTATION COST** | | | | | **$467,000 to $1,067,000** |

## 8.4 WEST GOOSE LAKE PRIORITY LOAD REDUCTION STRATEGIES

Direct watershed and internal loading both contribute to the West Goose Lake impairment. As such, load reductions to both sources will be required to meet the TMDL and priority management strategies will need to target both the watershed and internal nutrient sources. MS4 permit holders receiving a WLA for West Goose are listed below. M-Foods Dairy, LLC. is also a permitted discharger with a WLA.

**Table 8.5. MS4s receiving WLA for West Goose Lake TMDL.**

| |
|---|
| Gem Lake City MS4 |
| MnDOT |
| Ramsey County |
| White Bear Lake City MS4 |

Due to the magnitude of the total load reduction required, internal and external reduction strategies should be implemented concurrently. Examples of potential reduction strategies include:

- As a reminder, one portion of the internal phosphorus load is the historic loading from the WWTP for this lake which was measured directly through lake sediment cores (see Section 4.2.2). The Ski Otters Club has been treating the lake for vegetation reducing any potential water quality impacts from aquatic plants. Watershed loads were quantified through data and modeling. More than half of the remaining phosphorus load was not accounted for by these other components and is caused by re-suspension of sediments from wind, rough fish activity, loss of native plant communities, and prop wash from motor boat activity (see Section 4.2.2). Collaboration between VLAWMO and the ski club will be a key component to managing the internal load.

- An "Internal Load Management Feasibility Study" could be completed for West Goose Lake that analyzes all internal load reduction options. Traditionally, very shallow lakes are not good candidates for chemical treatment, such as alum dosing, to control phosphorus loading. However, this option and other internal load reduction options are worth further investigation for implementation in West Goose. Note that alum dosing can be effective where motor boating is occurring dependent on the dose applied and the depth of disturbance into the sediment profile achieved by the motor boats.
- Aquatic plants should periodically be surveyed to track changes in the plant community and monitor growth. Develop a plan to encourage a healthy native plant community to anchor sediments and reduce sediment re-suspension. The informal plant survey completed for West Goose Lake indicated a low diversity of aquatic plants.
- A 1986 fish survey of Goose Lake showed that the lake was dominated by black bullheads, however a 2012 fish survey (http://vlawmo.org/PDF/Goose%20R12%20-%20fish%20survey.pdf) noted a healthy population of predator fish in Goose Lake. VLAWMO also conducted a significant bullhead removal project in 2013 (http://vlawmo.org/projects.cfm?ServiceID=58&PID=58&siteID=1) in Goose Lake.
- The shoreline around West Goose Lake includes property owners with maintained turf down to the shoreline and areas of riprapped shoreline. Encourage property owners to restore their shoreline with native plants and install buffers to reduce erosion and capture direct runoff. Ideally, about 75 percent of the residential shoreline would be native vegetation.
- Encourage the use of rain gardens and other infiltration practices as a means to increase infiltration and evapotranspiration. Opportunities may range from a single property owner installing an individual rain garden to retrofitting parks and open space with native vegetation rather than mowed turf.
- Identify target areas for increased frequency of street sweeping. Consider replacing mechanical street sweepers with more efficient regenerative air sweepers.
- As opportunities arise, retrofit stormwater treatment through a variety of Best Management Practices. As part of NPDES permit requirements, perform maintenance (sediment removal, etc.) activities on stormwater ponds so they can achieve optimal performance for settling out pollutants as designed. Pond expansion and pre-treatment of water before it reaches ponds may be beneficial dependent on drainage area and increased volume. Cost is dependent on size and number of ponds within the watershed.
- Continue to identify retrofit and BMP implementation opportunities as new technologies emerge.

The number of BMPs necessary to achieve the required phosphorus load reduction is unknown and is dependent on the types of opportunities that arise. Specific BMPs are listed in Table 8.6. Estimated costs and prioritization of implementation are also indicated. Costs are dependent on the type of BMP, number implemented, location, easement requirements, and other factors. Additional BMPs not specifically listed may be applicable when opportunities arise.

Note that cleanup of East Goose Lake is important for West Goose Lake water quality because water flows from East Goose Lake to West Goose Lake through pipes.

**Table 8.6. West Goose Lake Reduction Strategy Examples.**

| Potential BMP | Priority | Associated Cost | Unit | Qty | Total Associated Cost |
|---|---|---|---|---|---|
| Shoreline Restoration | 0-2 years | $15 | LF | 1000 | $15,000 |
| Raingarden | 0-2 years | $500 to $10,000 | Each | 2 | $1,000 to $20,000 |
| Aquatic Plant Survey & Management Plan | 0-2 years | $10,000 | LS | 1 | $10,000 |
| Street Sweeping Equipment | 2-5 years | $150,000 | Each | 2 | $300,000 |
| Detention Pond Retrofit and Maintenance | 5-10 years | $30,000 to $250,000 | Each | 2 | $30,000 to $250,000 |
| Emerging technologies/yet to be identified opportunities | 5-10 years | $20,000 to $40,000 | Each | 2 | $40,000 to $80,000 |
| Internal Load Management Feasibility Study | 10+ years | $25,000 to $50,000 | LS | 1 | $25,000 to $50,000 |
| **TOTAL TMDL IMPLEMENTATION COST** | | | | | **$421,000 to $725,000** |

## 8.5 GILFILLAN LAKE PRIORITY LOAD REDUCTION STRATEGIES

The dominant phosphorus loading in Gilfillan Lake is from internal loading. As such, the primary nutrient load reduction must come from a reduction of the internal load. Eliminating load from septic systems will also be required. Since watershed loading is below expected background levels, and the surrounding area is fully developed with minimal impervious surface connection to the drainage system, a reduction from the watershed load is not anticipated to be achievable. MS4 permit holders receiving a WLA for Gilfillan Lake are listed below.

**Table 8.7. MS4s receiving WLA for Gilfillan Lake TMDL.**

| |
|---|
| North Oaks City MS4 |
| Vadnais Heights City MS4 |
| Ramsey County |
| White Bear Township MS4 |

Even though a load reduction from the watershed has not been explicitly called for, the recommendations below include some action items within the watershed:

- Aquatic plants should periodically be surveyed to track changes in the plant community and monitor growth. Develop a plan to encourage a healthy native plant community to anchor sediments and reduce sediment re-suspension. The informal plant survey completed for Gilfillan Lake indicated a low diversity of aquatic plants.
- Limited information is available on the fish community in Gilfillan Lake. A survey should be conducted and data analyzed to determine if biological management may be beneficial to managing water quality. A baseline fisheries survey can be used as the basis to develop a rough fish management program (if necessary).
- Review and inspect SSTS and require follow-up maintenance as necessary to eliminate load from failing systems.
- Traditionally, very shallow lakes are not good candidates for chemical treatment, such as alum dosing, to control phosphorus loading. However, this option is worth further investigation for implementation in Gilfillan Lake due to the required internal load reduction.
- The shoreline around Gilfillan Lake includes property owners with maintained turf down to the shoreline and areas of riprapped shoreline. Encourage property owners to restore their shoreline with native plants and install buffers to reduce erosion and capture direct runoff. Ideally, about 75 percent of the residential shoreline would be native vegetation.
- Identify target areas for increased frequency of street sweeping. Consider replacing mechanical street sweepers with more efficient regenerative air sweepers.
- Much of the drainage area surrounding Gilfillan Lake currently flows through a series of stormwater ponds and existing stormwater management features. Inspect existing SW detention ponds as required by the NPDES program to determine quantity of sediment accumulation. Maintenance of these features is key to preserving the quality of the runoff from within the watershed.
- Continue to identify retrofit and BMP implementation opportunities as new technologies emerge.

The number of BMPs necessary to achieve the required phosphorus load reduction is unknown and is dependent on the types of opportunities that arise. Specific BMPs are listed in Table 8.8. Estimated costs and prioritization of implementation are also indicated. Costs are dependent on the type of BMP, number implemented, location, easement requirements, and other factors. Additional BMPs not specifically listed may be applicable when opportunities arise.

**Table 8.8. Gilfillan Lake Reduction Strategy Examples.**

| Potential BMP | Priority | Associated Cost | Unit | Qty | Total Associated Cost |
|---|---|---|---|---|---|
| Aquatic Plant Survey & Management Plan | 0-2 years | $10,000 | LS | 1 | $10,000 |
| Fish Survey & Management Plan | 0-2 years | $10,000 | LS | 1 | $10,000 |
| SSTS | 0-2 years | $25,000 | Annually | 10 | $250,000 |
| Alum Dosing | 2-5 years | $25,000 to $50,000 | LS | 1 | $25,000 to $50,000 |
| Shoreline Restoration | 2-5 years | $15 | LF | 2500 | $37,500 |
| Street Sweeping Equipment | 2-5 years | $150,000 | Each | 2 | $300,000 |
| Detention Pond Maintenance | 5-10 years | $30,000 to $250,000 | Each | 1 | $30,000 to 250,000 |
| **TOTAL TMDL IMPLEMENTATION COST** | | | | | **$367,500 to $587,500** |

## 8.6 WILKINSON LAKE PRIORITY LOAD REDUCTION STRATEGIES

Phosphorus loading to Wilkinson Lake is predominantly from the watershed load. As such, priority management strategies will need to target the watershed nutrient loads. MS4 permit holders located in the Wilkinson Lake watershed are listed below.

**Table 8.9. MS4s receiving WLA for Wilkinson Lake TMDL.**

| |
|---|
| Anoka County |
| Lino Lakes City MS4 |
| MnDOT |
| North Oaks City MS4 |
| Ramsey County |
| White Bear Lake City MS4 |
| White Bear Township MS4 |

Examples of potential reduction strategies include:

- As opportunities arise, retrofit stormwater treatment through a variety of Best Management Practices. As part of NPDES permit requirements, perform maintenance (sediment removal, etc.) activities on stormwater ponds so they can achieve optimal performance for settling out pollutants as designed. Pond expansion and pre-treatment of water before it reaches ponds may be beneficial dependent on drainage area and increased volume. Cost is dependent on size and number of ponds within the watershed.
- Encourage the use of rain gardens and other infiltration BMPs as a means to increase infiltration and evapotranspiration. Opportunities may range from a single property owner installing an individual rain garden to retrofitting parks and open space with native vegetation rather than mowed turf.

- Continue to identify retrofit and BMP implementation opportunities as new technologies emerge.

The number of BMPs necessary to achieve the required phosphorus load reduction is unknown and is dependent on the types of opportunities that arise. Specific BMPs are listed in Table 8.10. Estimated costs and prioritization of implementation are also indicated. Costs are dependent on the type of BMP, number implemented, location, easement requirements, and other factors. Additional BMPs not specifically listed may be applicable when opportunities arise.

**Table 8.10. Wilkinson Lake Reduction Strategy Examples.**

| Potential BMP | Priority | Associated Cost | Unit | Qty | Total Associated Cost |
|---|---|---|---|---|---|
| Raingarden | 0-2 years | $500 to $10,000 | Each | 10 | $5,000 to $100,000 |
| Street Sweeping | 0-2 years | $150,000 | Each | 2 | $300,000 |
| Detention Pond Retrofit and Maintenance | 2-5 years | $30,000 to $250,000 | Each | 5 | $150,000 to $1,250,000 |
| Emerging technologies/yet to be identified opportunities | 5-10 years | $20,000 to $40,000 | Each | 5 | $100,000 to $200,000 |
| **TOTAL TMDL IMPLEMENTATION COST** | | | | | **$555,000 to $1,850,000** |

The City of Lino Lakes has sought clarification from the MPCA regarding how to demonstrate compliance with their assigned WLA for Wilkinson Lake. The MS4 General Permit requires permittees demonstrate they are meeting or making progress toward meeting any applicable WLA. To demonstrate compliance with Parts II.D.6 and III.E of the MS4 General Permit (Permit MNR040000), Lino Lakes can evaluate compliance against the needed load reduction estimated in this TMDL. Specifically, they can demonstrate progress toward meeting a reduction of 3.8 lbs/year to Wilkinson Lake from the baseline loading rate.

## 8.7 LAMBERT CREEK PRIORITY LOAD REDUCTION STRATEGIES

Bacteria loading to Lambert Creek is predominately from urban stormwater with a small contribution to the load from wildlife within the watershed. MS4 permit holders receiving a WLA for the Lambert Creek bacteria TMDL are listed below.

**Table 8.11. MS4s receiving WLA for Lambert Creek bacteria TMDL.**

| |
|---|
| Gem Lake City MS4 |
| MnDOT |
| Ramsey County |
| Vadnais Heights City MS4 |
| White Bear Lake City MS4 |
| White Bear Township MS4 |

Examples of potential reduction strategies include:

- Cities can review their local ordinances and associated enforcement and fines for residents who do not clean up pet waste, and increase enforcement and education about compliance with such an ordinance.
- The cities' illicit connections inspections as required by the NPDES program should prioritize identifying potential sources of bacteria load.
- Installation of infiltration basins and other bioretention areas to decrease bacteria from entering surface waters. Opportunities may range from a single property owner installing an individual rain garden to retrofitting parks and open space with large bioretention areas.
- Due to the high density of ideal habitat for waterfowl, it is likely that nuisance populations of waterfowl may contribute to the bacteria impairment. Meeting the load reductions for this TMDL will require working with area wildlife managers to first assess and then manage populations. Management can be conducted by controlling access to surface waters through streambank restorations. Streambank restorations would focus on deterring waterfowl from accessing the creek and directly loading the creek as well as provide filtration of direct runoff from the riparian area.

The number of BMPs necessary to achieve the required bacteria load reduction is unknown and is dependent on the types of opportunities that arise. Specific BMPs are listed in Table 8.6. Estimated costs and prioritization of implementation are also indicated. Costs are dependent on the type of BMP, number implemented, location, easement requirements, and other factors. Additional BMPs not specifically listed may be applicable when opportunities arise.

**Table 8.12. Lambert Creek Reduction Strategy Examples.**

| Potential BMP | Priority | Associated Cost | Unit | Qty | Total Associated Cost |
|---|---|---|---|---|---|
| Streambank Restoration | 0-2 years | $100 | LF | 2000 | $200,000 |
| Infiltration Basins/Bio-retention | 0-5 years | $30,000 to $250,000 | Each | 5 | $150,000 to $1,250,000 |
| **TOTAL TMDL IMPLEMENTATION COST** | | | | | **$350,000 to $1,450,000** |

## 8.8 WATERSHED WIDE REDUCTION STRATEGIES

In addition to the implementation strategies discussed in the previous sections, the load reduction strategies outlined below should be considered for implementation throughout VLAWMO's entire jurisdiction to protect water quality. Although the VLAWMO watershed is mostly developed, small, incremental reductions are also possible through retrofit and as redevelopment occurs and through the implementation of Best Management Practices (BMPs) throughout the watershed.

*Conduct education and outreach awareness programs:* Educate property owners in the subwatershed about proper fertilizer use, low-impact lawn care practices, pet waste removal and other topics to increase awareness of sources of pollutant loadings to the lakes and encourage the adoption of good individual property management practices.

*Intensive BMP Assessment:* A common implementation action is to retrofit small BMPs as opportunities arise. Cities may complete these as stand-alone projects as funds are available; incorporated into street or park reconstruction projects; or as development and redevelopment provides opportunities. Intensive BMP analysis is a way to identify where small practices such as rain gardens or pond retrofits would be most effective at reducing pollutant loading. It uses a structured assessment to evaluate conditions in a concentrated area to see where there are opportunities to do small things that when they are done in many locations can add up to significant reductions. Intensive assessments of most of the watershed with the exception of the Charlie, Pleasant, Sucker, and Vadnais Lakesheds is already underway or has been completed. The completed studies are:

- Ramsey Conservation District and Metro Conservation Districts, December 2010. Lambert Creek Retrofit ID and Design Project. Prepared for the Vadnais Lake Area Water Management Organization.

- Ramsey Conservation District and Metro Conservation Districts, December 2010. Gem Lake Stormwater Retrofit Assessment. Prepared for the Vadnais Lake Area Water Management Organization and the City of Gem Lake.

Actions identified in the completed studies should be implemented within the appropriate sub-watersheds.

*Construction Stormwater:* The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites $\geq$ 1 acre expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

*Industrial Stormwater:* The wasteload allocation for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES industrial stormwater permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains coverage under the appropriate NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

It is of note that construction and industrial stormwater permits do not apply for the bacteria impairment.

## 8.9 IMPLEMENTATION STRATEGY

The load allocations in the TMDL represent aggressive goals for nutrient and bacteria reductions. Consequently, implementation will be conducted using adaptive management principles (Figure 8.1). Adaptive management is appropriate because it is difficult to predict both the lake response that will occur from implementing strategies with the limited information available to demonstrate expected nutrient reductions, and bacteria response. Future technological advances may alter the course of actions detailed here. Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches.

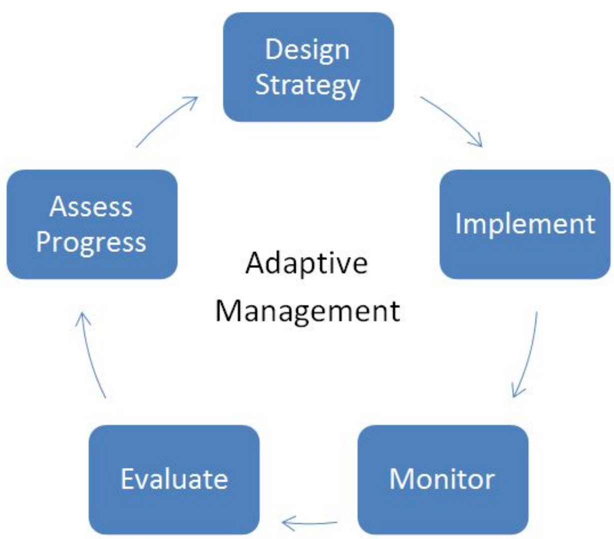


**Figure 8.1. Adaptive Management.**

# 9.0 Reasonable Assurance

## 9.1 INTRODUCTION

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

TMDL implementation will be carried out on an iterative basis so that implementation course corrections based on periodic monitoring and reevaluation can adjust the strategy to meet the standard. After the first phase of load 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).

## 9.2 NPDES MS4 STORMWATER PERMITS

NPDES Phase II stormwater permits are in place for each of the member cities that comprise VLAWMO as well as Ramsey County, Anoka County and MnDOT. Under the stormwater program, permit holders are required to develop and implement a Stormwater Pollution Prevention Program (SWPPP; MPCA, 2004) that identifies Best Management Practices (BMPs) and measurable goals associated with each of six specified minimum control measures.

The pollutant load from construction stormwater is considered to be less than 1 percent of the TMDL and difficult to quantify. Consequently, the WLA for nutrients includes pollutant loading from construction and industrial stormwater sources.

According to federal regulations, NPDES permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated Wasteload Allocations (see 122.44(d)(1)(vii)(B)). To meet this regulation, Minnesota's MS4 general permit requires the following:

> If a USEPA-approved **TMDL(s)** has been developed, you must review the adequacy of your Storm Water Pollution Prevention Program to meet the **TMDL's Waste Load Allocation** set for storm water sources. If the **Storm Water Pollution Prevention Program** is not meeting the applicable requirements, schedules and objectives of the **TMDL**, you must modify your **Storm Water Pollution Prevention Program**, as appropriate, within 18 months after the TMDL is approved.

## 9.3 MONITORING

### 9.3.1 Monitoring, Implementation of Policies, and BMPs

VLAWMO operates a Citizens Lake Monitoring Program (CLMP) and also works in conjunction with the St. Paul Regional Water Service (SPRWS) on water quality monitoring. The CLMP monitors several lakes and ponds within the watershed. The SPRWS monitors the direct surface water flow into Vadnais Lake to assure high quality drinking water for over 400,000 consumers. The SPRWS monitors the main chain of lakes (Charley Lake, Pleasant Lake, Sucker Lake and Vadnais Lake) and VLAWMO monitors Lambert Creek, which flows directly into Vadnais Lake, and other lakes in the Watershed. The data received from the monitoring is used by VLAWMO and the Minnesota Pollution Control Agency (MPCA) to determine the health of the state's waters. Data collected through the VLAWMO water quality monitoring program tracks changes in water quality in conjunction with the change in land use around the water bodies. Data is published annually in the VLAWMO Water Quality Monitoring Program Report (posted on-line: http://www.vlawmo.org)

Each of the impaired waters discussed herein is monitored through the above monitoring program. VLAWMO will evaluate progress toward meeting the water quality goals by continuing to conduct this baseline monitoring and reporting the results annually. Success will be measured by completion of policies and strategies recommended in the TMDL Implementation Plan and improved water quality. It is anticipated that member cities and permitted MS4s will perform monitoring in the watershed as applicable to the partitioned WLA and associated correlation to each NPDES permit.

VLAWMO's annual water quality monitoring report will be expanded to include a summary of any educational initiatives, BMPs and capital projects conducted annually and an estimate of load reductions achieved. The report will also evaluate progress towards goals and recommend adaptive management measures based on results each year.

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# Appendix A

## Lake Response Model Results and Model Fit Graphs

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| GEM LAKE AVG YEAR | | | | Calibration Years '00-'05, '07-'09 | | | |
|---|---|---|---|---|---|---|---|
| | Water Budgets | | | Phosphorus Loading | | | |
| **Inflow from Drainage Areas** | | | | | | | |
| | | Drainage Area | Runoff Depth | Discharge | Phosphorus Concentration | Loading Calibration Factor (CF)[1] | Load |
| | Name | [acre] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 | Watershed | 306.34 | 3.2 | 81.1 | 281.6 | 1.0 | 62.1 |
| 2 | | | | | | 1.0 | |
| 3 | | | | | | 1.0 | |
| 4 | | | | | | 1.0 | |
| 5 | | | | | | 1.0 | |
| | *Summation* | *306.34* | *3.2* | *81.1* | *281.6* | | 62.1 |
| **Failing Septic Systems** | | | | | | | |
| | Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 | Watershed | 306.34 | 13 | 5% | 7.8 | 0.0 | 5.1 |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| | *Summation* | *306.34* | *13* | *5%* | | *0.0* | *5.1* |
| **Inflow from Upstream Lakes** | | | | | | | |
| | Name | | | Discharge [ac-ft/yr] | Estimated P Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 1 | | | | | - | 1.0 | |
| 2 | | | | | - | 1.0 | |
| 3 | | | | | - | 1.0 | |
| | *Summation* | | | *0* | - | | *0* |
| **Atmosphere** | | | | | | | |
| | Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
| | 21.6 | 32.0 | 32.0 | 0.00 | 0.24 | 1.0 | 5.2 |
| | | | Dry-year total P deposition = | | 0.230 | | |
| | | | Average-year total P deposition = | | 0.240 | | |
| | | | Wet-year total P deposition = | | 0.268 | | |
| | | | (Barr Engineering 2007) | | | | |
| **Groundwater** | | | | | | | |
| | Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| | 21.6 | | 0.0 | 0 | 0 | 1.0 | 0 |
| **Internal** | | | | | | | |
| | Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [mg/m²-day] | Calibration Factor [--] | Load [lb/yr] |
| | 21.6 | 47.1 | | | 0.00 | 1.0 | 0 |
| | | | **Net Discharge [ac-ft/yr] =** | **81** | | **Net Load [lb/yr] =** | **72.4** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

## *Lake Response Modeling for Gem Lake Avg Year*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | $P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$ | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 72 | [lb/yr] |
| | | Q (lake outflow) = | 81 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 183 | [ac-ft] |
| | | T = V/Q = | 2.26 | [yr] |
| | | $P_i$ = W/Q = | 328 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **71.6** | **[ug/l]** |
| **Observed In-Lake [TP]** | | | **59.5** | **[ug/l]** |

Note: The observed In-Lake TP concentration reported here excludes two sample data points from 2007.

**PHOSPHORUS SEDIMENTATION RATE**

$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$

**$P_{sed}$ (phosphorus sedimentation) = 56.6 [lb/yr]**

**PHOSPHORUS OUTFLOW LOAD**

W-$P_{sed}$ = **15.8 [lb/yr]**

## *Load Reduction Table for Gem*

| LOAD | | MODELED IN-LAKE WATER QUALITY PARAMETERS | | | TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED | |
|---|---|---|---|---|---|---|
| **REDUC-TION [%]** | **NET LOAD [lb]** | **[TP] [ug/L]** | **P SEDIMEN-TATION [lb]** | **TP OUT-FLOW [lb]** | **TSI [TP] [--]** | **TSI Avg. [--]** |
| 0% | **72** | 72 | 57 | **16** | 65.7 | **60.8** |
| 5% | **69** | 69 | 53 | **15** | 65.3 | **60.5** |
| 10% | **65** | 67 | 50 | **15** | 64.8 | **60.3** |
| 15% | **62** | 65 | 47 | **14** | 64.2 | **60.0** |
| 20% | **58** | 62 | 44 | **14** | 63.7 | **59.7** |
| 25% | **54** | 59 | 41 | **13** | 63.1 | **59.4** |
| 30% | **51** | 57 | 38 | **13** | 62.4 | **59.0** |
| 35% | **47** | 54 | 35 | **12** | 61.7 | **58.6** |
| 40% | **43** | 51 | 32 | **11** | 60.9 | **58.2** |
| 45% | **40** | 48 | 29 | **11** | 60.1 | **57.7** |
| 50% | **36** | 45 | 26 | **10** | 59.2 | **57.2** |
| 55% | **33** | 42 | 23 | **9** | 58.2 | **56.6** |
| 60% | **29** | 39 | 20 | **9** | 57.0 | **55.9** |
| 65% | **25** | 36 | 17 | **8** | 55.7 | **55.1** |
| 70% | **22** | 32 | 15 | **7** | 54.2 | **54.2** |
| 75% | **18** | 28 | 12 | **6** | 52.4 | **53.1** |
| 80% | **14** | 24 | 9 | **5** | 50.1 | **51.7** |
| 85% | **11** | 20 | 7 | **4** | 47.1 | **49.8** |
| 90% | **7** | 15 | 4 | **3** | 42.8 | **47.0** |
| 95% | **4** | 9 | 2 | **2** | 35.2 | **42.1** |

# GEM LAKE TMDL

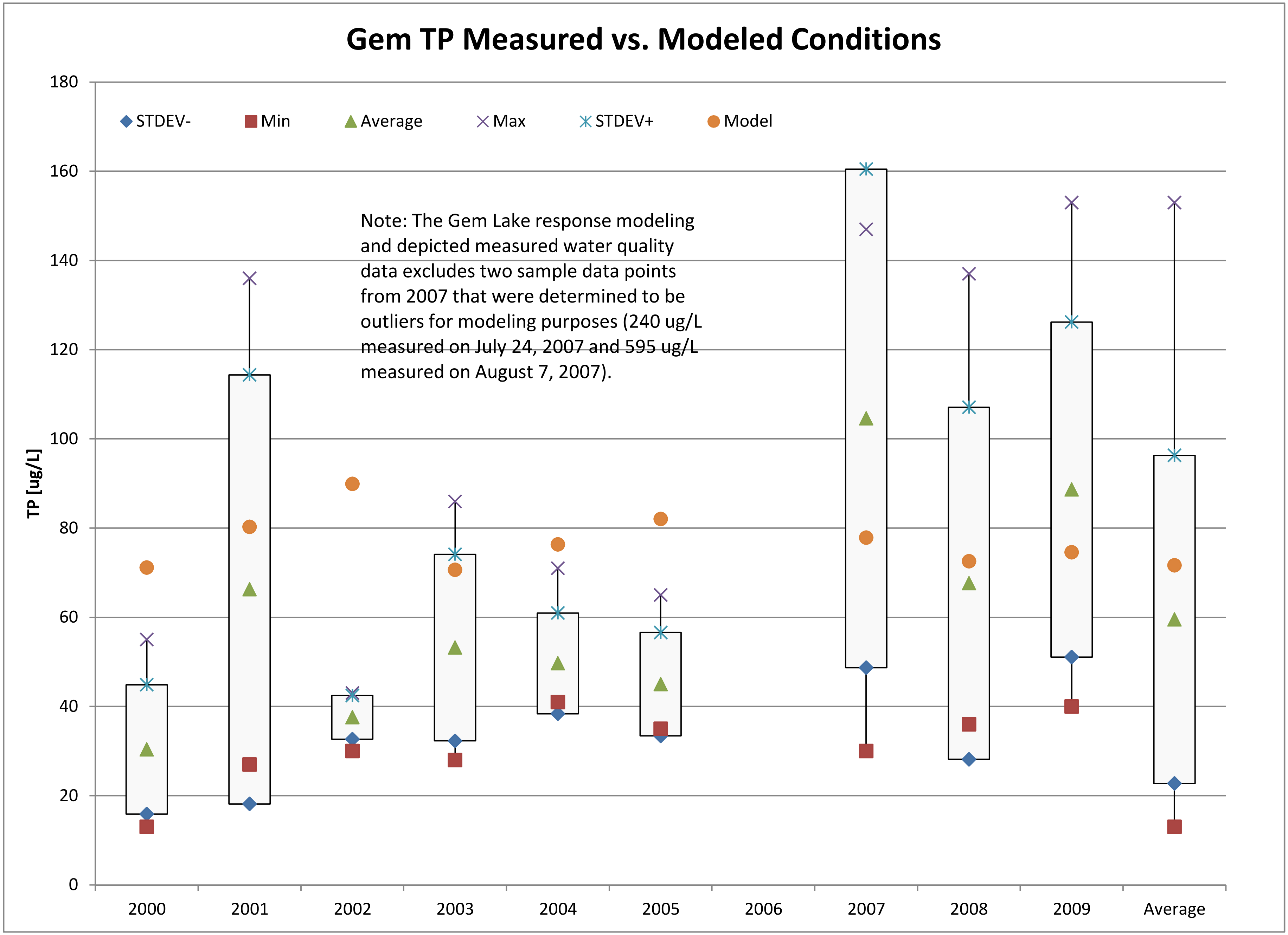
| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|
| ***Inflow from Drainage Areas*** | | | | | | |
| Name | Drainage Area [acre] | Runoff Depth [in/yr] | Discharge [ac-ft/yr] | Phosphorus Concentration [ug/L] | Loading Calibration Factor (CF)[1] [--] | Load [lb/yr] |
| 1 Watershed | 306.34 | 3.2 | 81.1 | 281.6 | 0.80 | 49.7 |
| 2 | | | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *306* | *3.2* | *81.1* | *281.6* | | *49.7* |
| ***Failing Septic Systems*** | | | | | | |
| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 Watershed | 306.34 | 0 | 5% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *306.34* | *0* | *5%* | | *0.0* | *0.0* |
| ***Inflow from Upstream Lakes*** | | | | | | |
| Name | | | Discharge [ac-ft/yr] | Estimated P Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 1 | | | | - | 1.0 | |
| 2 | | | | - | 1.0 | |
| 3 | | | | - | 1.0 | |
| *Summation* | | | *0* | - | | *0* |
| ***Atmosphere*** | | | | | | |
| Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
| 21.6 | 32.0 | 32.0 | 0.00 | 0.24 | 1.0 | 5.2 |
| | | | Dry-year total P deposition = | 0.230 | | |
| | | | Average-year total P deposition = | 0.240 | | |
| | | | Wet-year total P deposition = | 0.268 | | |
| | | | (Barr Engineering 2007) | | | |
| ***Groundwater*** | | | | | | |
| Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 21.6 | | 0.0 | 0 | 0 | 1.0 | 0 |
| ***Internal*** | | | | | | |
| Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [mg/m$^2$-day] | Calibration Factor [--] | Load [lb/yr] |
| 21.6 | 47.1 | | | 0.00 | 1.0 | 0 |
| | | **Net Discharge [ac-ft/yr] =** | **81** | | **Net Load [lb/yr] =** | **54.9** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

## *Lake Response Modeling for Gem Lake TMDL*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | $P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$ | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 55 | [lb/yr] |
| | | Q (lake outflow) = | 81 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 183 | [ac-ft] |
| | | T = V/Q = | 2.26 | [yr] |
| | | $P_i$ = W/Q = | 249 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **59.9** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| | $P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$ | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **42** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| | W-$P_{sed}$ = | | **13** | **[lb/yr]** |


Gem TP Measured vs. Modeled Conditions
STDEV-
Min
Average
Max
STDEV+
Model
Note: The Gem Lake response modeling and depicted measured water quality data excludes two sample data points from 2007 that were determined to be outliers for modeling purposes (240 ug/L measured on July 24, 2007 and 595 ug/L measured on August 7, 2007).
TP [ug/L]
0
20
40
60
80
100
120
140
160
180
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Average

# EAST GOOSE LAKE AVG YEAR — Calibration Years '07-'10

| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|
| ***Inflow from Drainage Areas*** | | | | | | |
| Name | Drainage Area [acre] | Runoff Depth [in/yr] | Discharge [ac-ft/yr] | Phosphorus Concentration [ug/L] | Loading Calibration Factor (CF)[1] [--] | Load [lb/yr] |
| 1 Watershed | 577.55 | 5.5 | 265.9 | 297.0 | 1.0 | 214.8 |
| 2 | | | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *578* | *5.5* | *265.9* | *297.0* | | *214.8* |
| ***Failing Septic Systems*** | | | | | | |
| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 Watershed | 577.55 | 0 | 5% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *577.55* | *0* | *5%* | | *0.0* | *0.0* |
| ***Inflow from Upstream Lakes*** | | | | | | |
| Name | | | Discharge [ac-ft/yr] | Estimated P Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 1 | | | | - | 1.0 | |
| 2 | | | | - | 1.0 | |
| 3 | | | | - | 1.0 | |
| *Summation* | | | *0* | - | | *0* |
| ***Atmosphere*** | | | | | | |
| Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
| 116.3 | 27.2 | 27.2 | 0.00 | 0.24 | 1.0 | 27.9 |
| | | | Dry-year total P deposition = | 0.230 | | |
| | | | Average-year total P deposition = | 0.240 | | |
| | | | Wet-year total P deposition = | 0.268 | | |
| | | | (Barr Engineering 2007) | | | |
| ***Groundwater*** | | | | | | |
| Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 116.0 | | 0.006 | 4.4 | 69.0 | 1.0 | 0.8 |
| ***Internal*** | | | | | | |
| Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [mg/m²-day] | Calibration Factor [--] | Load [lb/yr] |
| 116.0 | 71.4 | | | 24.00 | 1.0 | 1,777.2 |
| | | **Net Discharge [ac-ft/yr] =** | **270.3** | | **Net Load [lb/yr] =** | **2020.7** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

## *Lake Response Modeling for East Goose Avg Year*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | $$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$ | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 2,021 | [lb/yr] |
| | | Q (lake outflow) = | 270 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 635 | [ac-ft] |
| | | T = V/Q = | 2.35 | [yr] |
| | | $P_i$ = W/Q = | 2749 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **258** | **[ug/l]** |
| **Observed In-Lake [TP]** | | | **261.1** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| | $$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$ | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **1,831.4** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| | W-$P_{sed}$ = | | **189.3** | **[lb/yr]** |

| *Load Reduction Table for East Goose* | | | | | | |
|---|---|---|---|---|---|---|
| **LOAD** | | **MODELED IN-LAKE WATER QUALITY PARAMETERS** | | | **TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED** | |
| **REDUC-TION [%]** | **NET LOAD [lb]** | **[TP] [ug/L]** | **P SEDIMEN-TATION [lb]** | **TP OUT-FLOW [lb]** | **TSI [TP] [--]** | **TSI Avg. [--]** |
| 0% | **2,021** | 258 | 1831 | **189** | 84.2 | **75.1** |
| 5% | **1,920** | 250 | 1736 | **184** | 83.8 | **75.0** |
| 10% | **1,819** | 242 | 1641 | **178** | 83.3 | **74.8** |
| 15% | **1,718** | 234 | 1545 | **172** | 82.8 | **74.6** |
| 20% | **1,617** | 226 | 1450 | **166** | 82.3 | **74.4** |
| 25% | **1,516** | 217 | 1356 | **160** | 81.8 | **74.2** |
| 30% | **1,414** | 209 | 1261 | **153** | 81.2 | **73.9** |
| 35% | **1,313** | 200 | 1167 | **147** | 80.5 | **73.6** |
| 40% | **1,212** | 191 | 1072 | **140** | 79.9 | **73.3** |
| 45% | **1,111** | 181 | 978 | **133** | 79.1 | **73.0** |
| 50% | **1,010** | 171 | 885 | **126** | 78.3 | **72.7** |
| 55% | **909** | 160 | 791 | **118** | 77.4 | **72.3** |
| 60% | **808** | 149 | 698 | **110** | 76.3 | **71.8** |
| 65% | **707** | 138 | 606 | **101** | 75.2 | **71.3** |
| 70% | **606** | 125 | 514 | **92** | 73.8 | **70.6** |
| 75% | **505** | 112 | 423 | **82** | 72.2 | **69.8** |
| 80% | **404** | 98 | 332 | **72** | 70.2 | **68.8** |
| 85% | **303** | 82 | 243 | **60** | 67.6 | **67.5** |
| 90% | **202** | 63 | 156 | **46** | 63.9 | **65.5** |
| 95% | **101** | 40 | 72 | **29** | 57.3 | **61.7** |

# EAST GOOSE LAKE TMDL

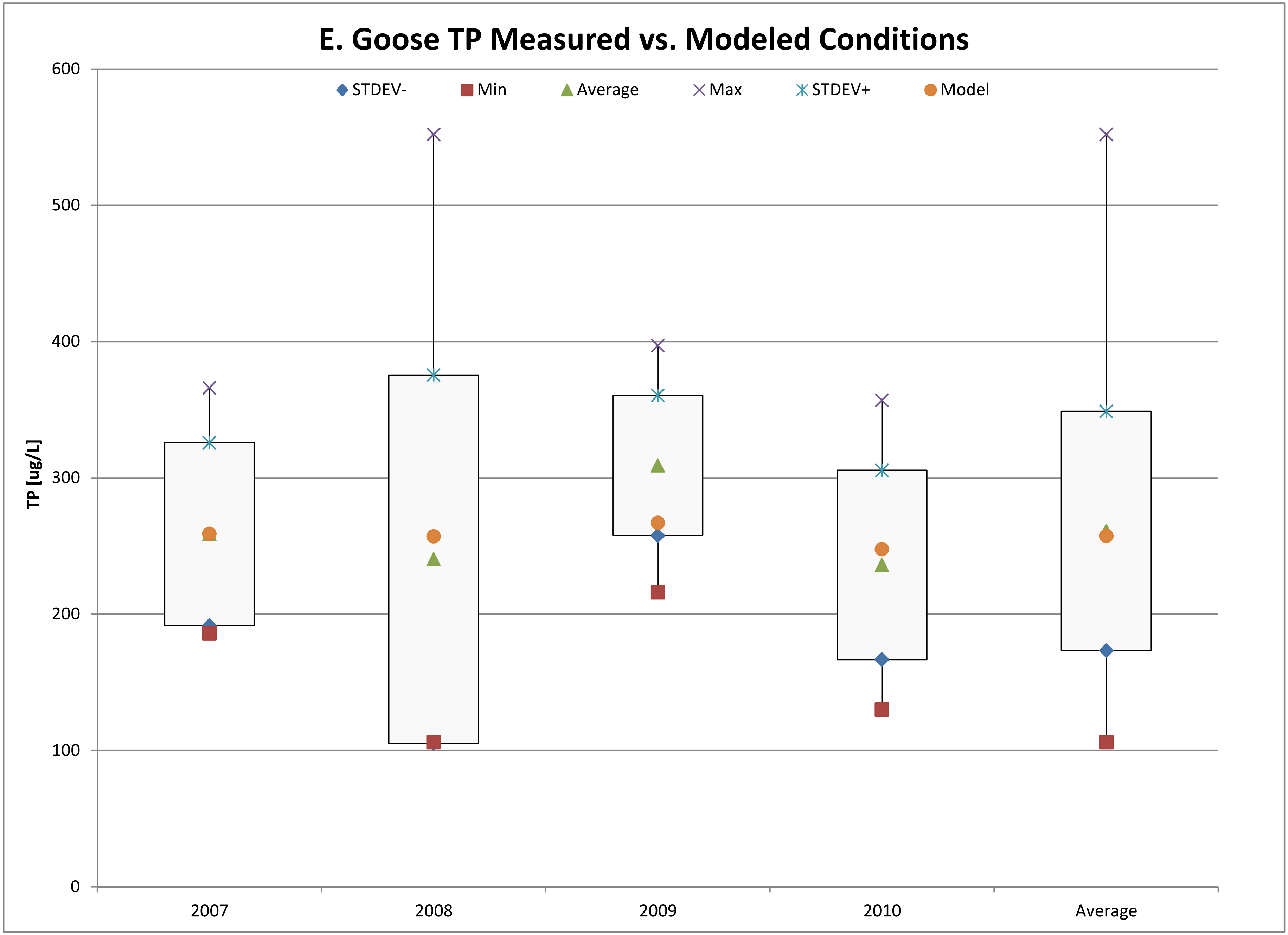
| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|
| ***Inflow from Drainage Areas*** | | | | | | |
| | Drainage Area | Runoff Depth | Discharge | Phosphorus Concentration | Loading Calibration Factor (CF)[1] | Load |
| Name | [acre] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 Watershed | 577.55 | 5.5 | 265.9 | 297.0 | 0.41 | 88.1 |
| 2 | | | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *577.55* | *5.5* | *265.9* | *297.0* | | 88.1 |
| ***Failing Septic Systems*** | | | | | | |
| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 Watershed | 577.55 | 0 | 5% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *577.55* | *0* | *5%* | | *0.0* | *0.0* |
| ***Inflow from Upstream Lakes*** | | | | | | |
| | | | Discharge | Estimated P Concentration | Calibration Factor | Load |
| Name | | | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 | | | | - | 1.0 | |
| 2 | | | | - | 1.0 | |
| 3 | | | | - | 1.0 | |
| *Summation* | | | *0* | - | | *0* |
| ***Atmosphere*** | | | | | | |
| Lake Area | Precipitation | Evaporation | Net Inflow | Aerial Loading Rate | Calibration Factor | Load |
| [acre] | [in/yr] | [in/yr] | [ac-ft/yr] | [lb/ac-yr] | [--] | [lb/yr] |
| 116.3 | 27.2 | 27.2 | 0.00 | 0.24 | 1.0 | 27.9 |
| | | | Dry-year total P deposition = | 0.230 | | |
| | | | Average-year total P deposition = | 0.240 | | |
| | | | Wet-year total P deposition = | 0.268 | | |
| | | | (Barr Engineering 2007) | | | |
| ***Groundwater*** | | | | | | |
| Lake Area | Groundwater Flux | Net Inflow | Net Inflow | Phosphorus Concentration | Calibration Factor | Load |
| [acre] | [m/yr] | cfs | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 116.0 | | 0.006 | 4.4 | 69.0 | 1.0 | 0.8 |
| ***Internal*** | | | | | | |
| Lake Area | Anoxic Factor | Calc Anoxia | | Release Rate | Calibration Factor | Load |
| [acre] | [days] | | | [$mg/m^2$-day] | [--] | [lb/yr] |
| 116.0 | 71.4 | | | 24.00 | 0.04 | 71.1 |
| | | Net Discharge [ac-ft/yr] = | **270.3** | | Net Load [lb/yr] = | **187.9** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

# *TMDL Lake Response Modeling for East Goose TMDL*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | $P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$ | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 188 | [lb/yr] |
| | | Q (lake outflow) = | 270 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 635 | [ac-ft] |
| | | T = V/Q = | 2.35 | [yr] |
| | | $P_i$ = W/Q = | 256 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **60.0** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| | $P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$ | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **143.8** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| | W-$P_{sed}$ = | | **44.1** | **[lb/yr]** |



E. Goose TP Measured vs. Modeled Conditions
TP [ug/L]
0
100
200
300
400
500
600
STDEV-
Min
Average
Max
STDEV+
Model
2007
2008
2009
2010
Average

## *WEST GOOSE LAKE AVG YEAR* — *Calibration Years '07-'10*

| | Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|---|
| ***Inflow from Drainage Areas*** | | | | | | | |
| | | Drainage Area | Runoff Depth | Discharge | Phosphorus Concentration | Loading Calibration Factor (CF)[1] | Load |
| | Name | [acre] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 | Watershed | 238.78 | 7.0 | 139.8 | 290.4 | 1.0 | 110.4 |
| 2 | | | . | | | 1.0 | |
| 3 | | | | | | 1.0 | |
| 4 | | | | | | 1.0 | |
| 5 | | | | | | 1.0 | |
| | *Summation* | *238.78* | *7* | *139.8* | *290.4* | | *110.4* |
| ***Failing Septic Systems*** | | | | | | | |
| | Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 | Watershed | 238.78 | 0 | 5% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| | *Summation* | *238.78* | *0* | *5%* | | *0.0* | *0.0* |
| ***Inflow from Upstream Lakes*** | | | | | | | |
| | | | Runoff Depth | Discharge | Estimated P Concentration | Calibration Factor | Load |
| | Name | Area [ac] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 | East Goose | 577.55 | 5.5 | 270.3 | 257.2 | 1.0 | 189.1 |
| 2 | | | | | | 1.0 | |
| 3 | | | | | - | 1.0 | |
| | *Summation* | | | *270* | *257.2* | | *189.1* |
| ***Atmosphere*** | | | | | | | |
| | Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
| | 24.1 | 27.2 | 27.2 | 0.00 | 0.24 | 1.0 | 5.8 |
| | | | | Dry-year total P deposition = | 0.230 | | |
| | | | | Average-year total P deposition = | 0.240 | | |
| | | | | Wet-year total P deposition = | 0.268 | | |
| | | | | (Barr Engineering 2007) | | | |
| ***M-Foods Dairy*** [2] | | | | | | | |
| | Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| | 24.1 | | 0.8 | 604.9 | 10.0 | 1.0 | 16.5 |
| ***Internal, Sediments*** | | | | | | | |
| | Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [mg/m²-day] | Calibration Factor [--] | Load [lb/yr] |
| | 24.1 | 63.2 | | | 2.00 | 1.0 | 27.2 |
| ***Internal Other*** | | | | | | | |
| | Source | Lake Area [acre] | Duration [days] | | Release Rate [mg/m²-day] | Calibration Factor [--] | Load [lb/yr] |
| 1 | Sediment re-suspension (e.g. boating and wind) | 24.1 | 60.0 | | 31.00 | 1.0 | 399.9 |
| 2 | | | | | | 1.0 | 0 |
| | | | **Net Discharge [ac-ft/yr] =** | **1015.0** | | **Net Load [lb/yr] =** | **748.8** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

[2] Non-contact cooling water sourced from groundwater. Contribution calculated based on discharge sampling and the maximum permitted flow from the facility. There is no other groundwater interaction with the lake.

## *Lake Response Modeling for West Goose Avg Year*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | $$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$ | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 749 | [lb/yr] |
| | | Q (lake outflow) = | 1,015 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 105 | [ac-ft] |
| | | T = V/Q = | 0.10 | [yr] |
| | | $P_i$ = W/Q = | 271 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **167.7** | **[ug/l]** |
| **Observed In-Lake [TP]** | | | **167.0** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| | $$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$ | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **285.9** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| | W-$P_{sed}$ = | | **462.9** | **[lb/yr]** |

| *Load Reduction Table for West Goose* | | | | | | |
|---|---|---|---|---|---|---|
| **LOAD** | | **MODELED IN-LAKE WATER QUALITY PARAMETERS** | | | **TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS** | |
| **REDUC-TION [%]** | **NET LOAD [lb]** | **[TP] [ug/L]** | **P SEDIMEN-TATION [lb]** | **TP OUT-FLOW [lb]** | **TSI [TP] [--]** | **TSI Avg. [--]** |
| 0% | **749** | 168 | 286 | **463** | 78.0 | **73.5** |
| 5% | **711** | 161 | 268 | **444** | 77.4 | **73.3** |
| 10% | **674** | 154 | 250 | **424** | 76.8 | **73.0** |
| 15% | **637** | 147 | 232 | **405** | 76.1 | **72.7** |
| 20% | **599** | 139 | 214 | **385** | 75.3 | **72.4** |
| 25% | **562** | 132 | 197 | **364** | 74.6 | **72.0** |
| 30% | **524** | 125 | 180 | **344** | 73.7 | **71.6** |
| 35% | **487** | 117 | 164 | **323** | 72.8 | **71.2** |
| 40% | **449** | 109 | 148 | **302** | 71.8 | **70.7** |
| 45% | **412** | 102 | 132 | **280** | 70.8 | **70.2** |
| 50% | **374** | 94 | 116 | **258** | 69.6 | **69.6** |
| 55% | **337** | 85 | 101 | **236** | 68.3 | **69.0** |
| 60% | **300** | 77 | 86 | **213** | 66.8 | **68.2** |
| 65% | **262** | 69 | 72 | **190** | 65.1 | **67.3** |
| 70% | **225** | 60 | 59 | **166** | 63.2 | **66.3** |
| 75% | **187** | 51 | 46 | **141** | 60.9 | **65.0** |
| 80% | **150** | 42 | 34 | **116** | 58.0 | **63.4** |
| 85% | **112** | 32 | 23 | **89** | 54.3 | **61.2** |
| 90% | **75** | 22 | 13 | **62** | 48.9 | **58.0** |
| 95% | **37** | 12 | 5 | **32** | 39.7 | **52.3** |

## WEST GOOSE LAKE TMDL

| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|

### Inflow from Drainage Areas

| Name | Drainage Area [acre] | Runoff Depth [in/yr] | Discharge [ac-ft/yr] | Phosphorus Concentration [ug/L] | Loading Calibration Factor (CF)[1] [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 1 Watershed | 238.78 | 7.0 | 139.8 | 290.4 | 0.24 | 26.5 |
| 2 | | . | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *238.78* | *7.0* | *139.8* | *290.4* | | *26.5* |

### Failing Septic Systems

| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
|---|---|---|---|---|---|---|
| 1 Watershed | 238.78 | 0 | 5% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *238.78* | *0* | *5%* | | *0.0* | *0.0* |

### Inflow from Upstream Lakes

| Name | Area [ac] | Runoff Depth [in/yr] | Discharge [ac-ft/yr] | Estimated P Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 1 East Goose | 577.55 | 5.5 | 270.3 | 60.0 | 1.0 | 44.1 |
| 2 | | | | | 1.0 | |
| 3 | | | | - | 1.0 | |
| *Summation* | | | *270.3* | *60.0* | | *44.1* |

### Atmosphere

| Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 24.1 | 27.2 | 27.2 | 0.00 | 0.24 | 1.0 | 5.8 |
| | | | Dry-year total P deposition = | 0.230 | | |
| | | | Average-year total P deposition = | 0.240 | | |
| | | | Wet-year total P deposition = | 0.268 | | |
| | | | (Barr Engineering 2007) | | | |

### M-Foods Dairy [2]

| Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 24.1 | | 0.8 | 604.9 | 15.0 | 1.0 | 24.7 |

### Internal, Sediments

| Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [mg/m²-day] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 24.1 | 63.2 | | | 2.00 | 1.0 | 27.2 |

### Internal Other

| | Source | Lake Area [acre] | Duration [days] | | Release Rate [mg/m²-day] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|---|
| 1 | Sediment re-suspension (e.g. boating and wind) | 24.1 | 60.0 | | 31.00 | 0.24 | 96.0 |
| 2 | | | | | | 1.0 | 0 |
| | | | **Net Discharge [ac-ft/yr] =** | **1015.0** | | **Net Load [lb/yr] =** | **224.2** |

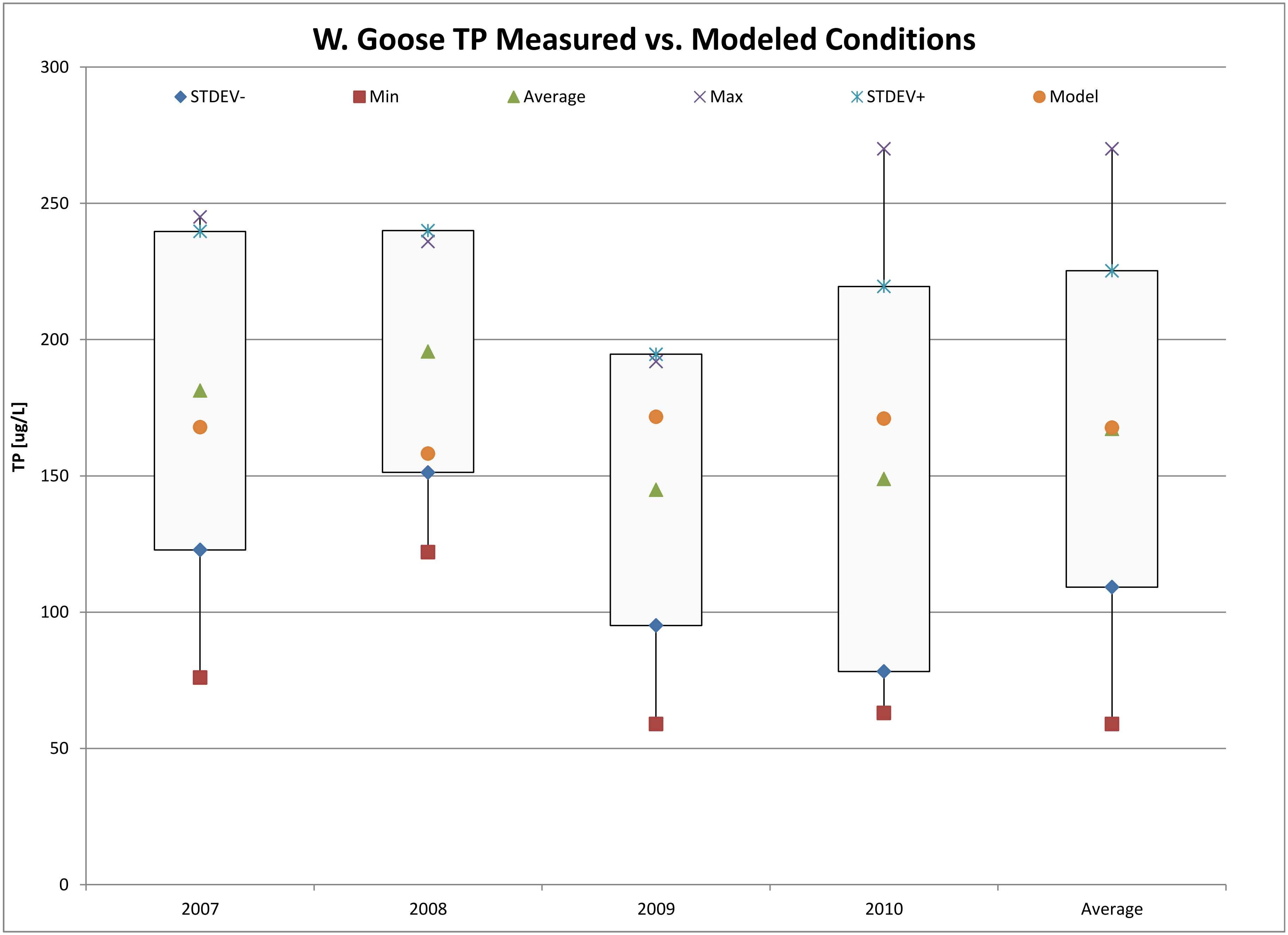
NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

[2] Non-contact cooling water sourced from groundwater. Contribution calculated based on discharge sampling and the maximum permitted flow from the facility. There is no other groundwater interaction with the lake.

## *TMDL Lake Response Modeling for West Goose TMDL*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | $P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$ | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 224 | [lb/yr] |
| | | Q (lake outflow) = | 1,015 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 105 | [ac-ft] |
| | | T = V/Q = | 0.10 | [yr] |
| | | $P_i$ = W/Q = | 81 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **59.9** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| | $P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$ | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **58.8** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| | W-$P_{sed}$ = | | **165.4** | **[lb/yr]** |


W. Goose TP Measured vs. Modeled Conditions
STDEV-
Min
Average
Max
STDEV+
Model
TP [ug/L]
300
250
200
150
100
50
0
2007
2008
2009
2010
Average

# WILKINSON LAKE AVG YEAR Calibration years '01-'05, '07-'09

| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|
| ***Inflow from Drainage Areas*** | | | | | | |
| | Drainage Area | Runoff Depth | Discharge | Phosphorus Concentration | Loading Calibration Factor (CF)[1] | Load |
| Name | [acre] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 Direct Watershed | 2,972.82 | 3.6 | 888.3 | 306.5 | 1.0 | 740.4 |
| 2 | | | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *2,972.82* | *4* | *888.3* | *306.5* | | *740.4* |
| ***Failing Septic Systems*** | | | | | | |
| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 Direct Watershed | 2,972.82 | 0 | 5% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *2,972.82* | *0* | *5%* | | *0.0* | *0.0* |
| ***Inflow from Upstream Lakes*** | | | | | | |
| | Drainage Area | Runoff Depth | Discharge | Estimated P Concentration | Calibration Factor | Load |
| Name | [acre] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 Birch Lake | 517.89 | 9 | 387.7 | 32.5 | 1.0 | 34.3 |
| 2 Gilfillan | 531.35 | 0 | 0 | 148.0 | 1.0 | 0 |
| 3 Amelia | 533.47 | 3 | 147.6 | 38.8 | 1.0 | 15.6 |
| *Summation* | | | *535* | *73.1* | | *49.8* |
| ***Atmosphere*** | | | | | | |
| Lake Area | Precipitation | Evaporation | Net Inflow | Aerial Loading Rate | Calibration Factor | Load |
| [acre] | [in/yr] | [in/yr] | [ac-ft/yr] | [lb/ac-yr] | [--] | [lb/yr] |
| 97.1 | 31.8 | 31.8 | 0.00 | 0.24 | 1.0 | 23.3 |
| | | | Dry-year total P deposition = | 0.230 | | |
| | | | Average-year total P deposition = | 0.240 | | |
| | | | Wet-year total P deposition = | 0.268 | | |
| | | | (Barr Engineering 2007) | | | |
| ***Groundwater*** | | | | | | |
| Lake Area | Groundwater Flux | Net Inflow | Net Inflow | Phosphorus Concentration | Calibration Factor | Load |
| [acre] | [m/yr] | cfs | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 97.1 | | 0.01 | 7.5 | 69.0 | 1.0 | 1.4 |
| ***Internal*** | | | | | | |
| Lake Area | Anoxic Factor | Calc Anoxia | | Release Rate | Calibration Factor | Load |
| [acre] | [days] | | | [$mg/m^2$-day] | [--] | [lb/yr] |
| 97.1 | 59.8 | | | 1.00 | 1.0 | 51.8 |
| | | **Net Discharge [ac-ft/yr] =** | **1431.0** | | **Net Load [lb/yr] =** | **866.8** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

## *Lake Respons Modeling for Wilkinson Calibration Years '01-'05, '07-'09*

| **Modeled Parameter** | **Equation** | **Parameters** | **Value** | **[Units]** |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | $P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$ | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 867 | [lb/yr] |
| | | Q (lake outflow) = | 1,431 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 165 | [ac-ft] |
| | | T = V/Q = | 0.12 | [yr] |
| | | $P_i$ = W/Q = | 223 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **139.4** | **[ug/l]** |
| **Observed In-Lake [TP]** | | | **148.8** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| | $P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$ | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **324.2** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| | W-$P_{sed}$ = | | **542.5** | **[lb/yr]** |

## *Load Reduction Table for Wilkinson*

| LOAD | | MODELED IN-LAKE WATER QUALITY PARAMETERS | | | TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS | |
|---|---|---|---|---|---|---|
| REDUC-TION [%] | NET LOAD [lb] | [TP] [ug/L] | P SEDIMEN-TATION [lb] | TP OUT-FLOW [lb] | TSI [TP] [--] | TSI Avg. [--] |
| 0% | **867** | 139 | 324 | **543** | 75.3 | **71.0** |
| 5% | **823** | 134 | 304 | **520** | 74.7 | **70.7** |
| 10% | **780** | 128 | 283 | **497** | 74.1 | **70.3** |
| 15% | **737** | 122 | 263 | **474** | 73.4 | **70.0** |
| 20% | **693** | 116 | 243 | **450** | 72.7 | **69.6** |
| 25% | **650** | 110 | 223 | **427** | 71.9 | **69.1** |
| 30% | **607** | 103 | 204 | **402** | 71.0 | **68.7** |
| 35% | **563** | 97 | 185 | **378** | 70.1 | **68.1** |
| 40% | **520** | 91 | 167 | **353** | 69.2 | **67.6** |
| 45% | **477** | 84 | 149 | **328** | 68.1 | **66.9** |
| 50% | **433** | 78 | 131 | **302** | 66.9 | **66.2** |
| 55% | **390** | 71 | 114 | **276** | 65.6 | **65.4** |
| 60% | **347** | 64 | 98 | **249** | 64.1 | **64.5** |
| 65% | **303** | 57 | 82 | **222** | 62.4 | **63.4** |
| 70% | **260** | 50 | 67 | **193** | 60.5 | **62.1** |
| 75% | **217** | 42 | 52 | **165** | 58.1 | **60.6** |
| 80% | **173** | 35 | 39 | **135** | 55.3 | **58.6** |
| 85% | **130** | 27 | 26 | **104** | 51.5 | **56.1** |
| 90% | **87** | 18 | 15 | **72** | 46.2 | **52.6** |
| 95% | **43** | 10 | 6 | **38** | 36.9 | **46.5** |

# WILKINSON LAKE TMDL

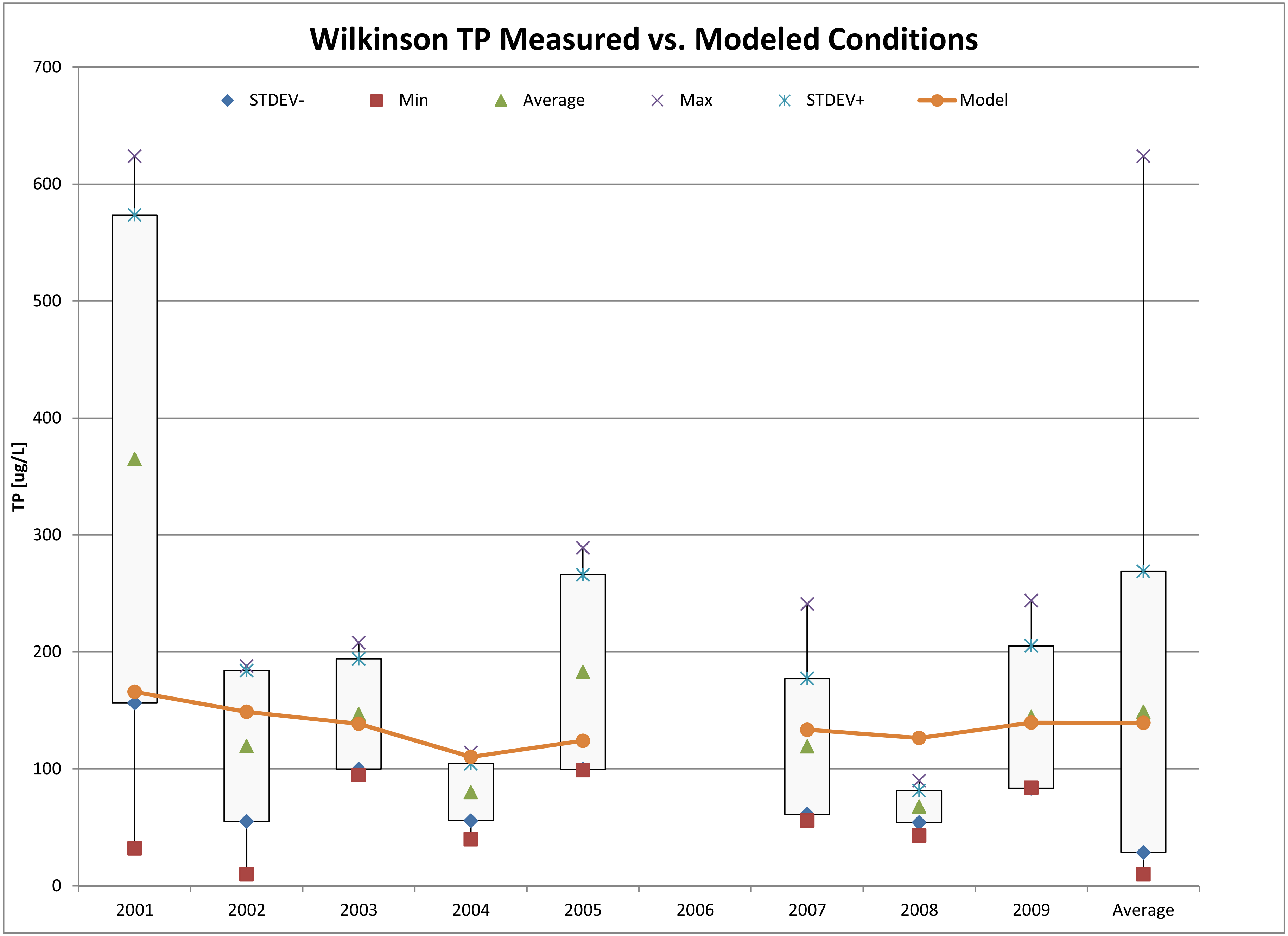
| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|
| ***Inflow from Drainage Areas*** | | | | | | |
| | Drainage Area | Runoff Depth | Discharge | Phosphorus Concentration | Loading Calibration Factor (CF)[1] | Load |
| Name | [acre] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 Direct Watershed | 2,972.82 | 3.6 | 888.3 | 306.5 | 0.264 | 195.5 |
| 2 | | | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *2,972.82* | *4* | *888.3* | *306.5* | | 195.5 |
| ***Failing Septic Systems*** | | | | | | |
| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 Direct Watershed | 2,972.82 | 0 | 5% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *2,972.82* | *0* | *5%* | | *0.0* | *0.0* |
| ***Inflow from Upstream Lakes*** | | | | | | |
| | Drainage Area | Runoff Depth | Discharge | Estimated P Concentration | Calibration Factor | Load |
| Name | [acre] | [in/yr] | [ac-ft/yr] | [ug/L] | [--] | [lb/yr] |
| 1 Birch Lake | 517.89 | 9.0 | 387.7 | 32.5 | 1.0 | 34.3 |
| 2 Gilfillan | 531.35 | 0.0 | 0 | 60.0 | 1.0 | 0 |
| 3 Amelia | 533.47 | 3.3 | 147.6 | 38.8 | 1.0 | 15.6 |
| *Summation* | | | *535* | *43.8* | | *49.8* |
| ***Atmosphere*** | | | | | | |
| Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
| 97.1 | 31.8 | 31.8 | 0.00 | 0.24 | 1.0 | 23.3 |
| | | Dry-year total P deposition = | | 0.230 | | |
| | | Average-year total P deposition = | | 0.240 | | |
| | | Wet-year total P deposition = | | 0.268 | | |
| | | (Barr Engineering 2007) | | | | |
| ***Groundwater*** | | | | | | |
| Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 97.1 | | 0.01 | 7.5 | 69.0 | 1.0 | 1.4 |
| ***Internal*** | | | | | | |
| Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [mg/m$^2$-day] | Calibration Factor [--] | Load [lb/yr] |
| 97.1 | 59.8 | | | 1.00 | 1.0 | 51.8 |
| | | **Net Discharge [ac-ft/yr] =** | **1431.0** | | **Net Load [lb/yr] =** | **321.8** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

## *Lake Response Modeling for Wilkinson Lake TMDL*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| $P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$ | | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 322 | [lb/yr] |
| | | Q (lake outflow) = | 1,431 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 165 | [ac-ft] |
| | | T = V/Q = | 0.12 | [yr] |
| | | $P_i$ = W/Q = | 83 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **59.9** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| $P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$ | | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **88.6** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| $W - P_{sed}$ = | | | **233.3** | **[lb/yr]** |



Wilkinson TP Measured vs. Modeled Conditions
STDEV-
Min
Average
Max
STDEV+
Model
TP [ug/L]
0
100
200
300
400
500
600
700
2001
2002
2003
2004
2005
2006
2007
2008
2009
Average

# Gilfillan Lake Avg Year — Calibration Years '06-'10

| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|

## Inflow from Drainage Areas

| Name | Drainage Area [acre] | Runoff Depth [in/yr] | Discharge [ac-ft/yr] | Phosphorus Concentration [ug/L] | Loading Calibration Factor (CF)[1] [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 1 Watershed | 531.35 | 1.15 | 51 | 122.5 | 1.0 | 17.0 |
| 2 | | | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *531.35* | *1* | *51* | *122.5* | | 17.0 |

## Failing Septic Systems

| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
|---|---|---|---|---|---|---|
| 1 Watershed | 531.35 | 39 | 8% | 7.8 | 0.0 | 24.3 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *531.35* | *39* | *8%* | | *0.0* | *24.3* |

## Inflow from Upstream Lakes

| Name | Discharge [ac-ft/yr] | Estimated P Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|
| 1 | | - | 1.0 | |
| 2 | | - | 1.0 | |
| 3 | | - | 1.0 | |
| *Summation* | *0* | - | | *0* |

## Atmosphere

| Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 99.2 | 27.9 | 25.5 | 19.8 | 0.24 | 1.0 | 23.8 |
| | | | Dry-year total P deposition = | 0.230 | | |
| | | | Average-year total P deposition = | 0.240 | | |
| | | | Wet-year total P deposition = | 0.268 | | |
| | | | (Barr Engineering 2007) | | | |

## Groundwater

| Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 99.2 | | 0.0 | 0.0 | 0 | 1.0 | 0 |

## Internal

| Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [$mg/m^2$-day] | Calibration Factor [--] | Load [lb/yr] |
|---|---|---|---|---|---|---|
| 99.2 | 58.8 | | | 7.00 | 1.0 | 364.2 |
| | | **Net Inflow [ac-ft/yr] =** | **70.9** | | **Net Load [lb/yr] =** | **429.4** |

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

## *Lake Response Modeling for Gilfillan Lake Avg Year*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| $P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$ | as f(W,Q,V) from Canfield & Bachmann (1981) | | | |
| | | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 429 | [lb/yr] |
| | | Q (lake outflow; for Gilfillan Lake, outflow is to groundwater)* = | 125 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 359.10 | [ac-ft] |
| | | T = V/Q = | 2.86 | [yr] |
| | | $P_i$ = W/Q = | 1259 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **147.6** | **[ug/l]** |
| **Observed In-Lake [TP]** | | | **138.3** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| $P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$ | | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **379.1** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| W-$P_{sed}$ = | | | **50.3** | **[lb/yr]** |

* Outflow is to groundwater. Augmentation was not occurring during the calibration period and is not reflected in the existing conditions modeled inflows or lake volume. For Gilfillan Lake existing conditions, inflow ≠ outflow.

| ***Load Reduction Table for Gilfillan*** | | | | | | |
|---|---|---|---|---|---|---|
| **LOAD** | | **MODELED IN-LAKE WATER QUALITY PARAMETERS** | | | **TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS** | |
| **REDUC-TION [%]** | **NET LOAD [lb]** | **[TP] [ug/L]** | **P SEDIMEN-TATION [lb]** | **TP OUT-FLOW [lb]** | **TSI [TP] [--]** | **TSI Avg. [--]** |
| 0% | **429** | 148 | 379 | **50** | 76.2 | **72.2** |
| 5% | **408** | 143 | 359 | **49** | 75.7 | **71.9** |
| 10% | **386** | 139 | 339 | **47** | 75.3 | **71.7** |
| 15% | **365** | 134 | 319 | **46** | 74.8 | **71.4** |
| 20% | **344** | 129 | 300 | **44** | 74.2 | **71.1** |
| 25% | **322** | 124 | 280 | **42** | 73.7 | **70.7** |
| 30% | **301** | 119 | 260 | **41** | 73.1 | **70.4** |
| 35% | **279** | 114 | 240 | **39** | 72.4 | **70.0** |
| 40% | **258** | 109 | 221 | **37** | 71.7 | **69.6** |
| 45% | **236** | 103 | 201 | **35** | 71.0 | **69.1** |
| 50% | **215** | 97 | 182 | **33** | 70.1 | **68.6** |
| 55% | **193** | 91 | 162 | **31** | 69.2 | **68.0** |
| 60% | **172** | 85 | 143 | **29** | 68.2 | **67.3** |
| 65% | **150** | 78 | 124 | **27** | 67.0 | **66.6** |
| 70% | **129** | 71 | 105 | **24** | 65.6 | **65.7** |
| 75% | **107** | 63 | 86 | **22** | 63.9 | **64.6** |
| 80% | **86** | 55 | 67 | **19** | 61.9 | **63.2** |
| 85% | **64** | 45 | 49 | **15** | 59.2 | **61.4** |
| 90% | **43** | 35 | 31 | **12** | 55.3 | **58.8** |
| 95% | **21** | 22 | 14 | **7** | 48.5 | **54.2** |

Note: The relationship shown on this table reflects pre-augmentation conditions. To develop the load reduction to set the TMDL, the augmentation condition was added to the existing conditions model and the load reductions were taken from that condition. Therefore, the existing conditions table included here does not directly show the relationship between load reduction and in lake concentration. However, this relationship can be seen by reversing the reductions in the TMDL model.

# Gilfillan Lake TMDL

| Water Budgets | | | | Phosphorus Loading | | |
|---|---|---|---|---|---|---|
| **Inflow from Drainage Areas** | | | | | | |
| Name | Drainage Area [acre] | Runoff Depth [in/yr] | Discharge [ac-ft/yr] | Phosphorus Concentration [ug/L] | Loading Calibration Factor (CF)[1] [--] | Load [lb/yr] |
| 1 Watershed | 531.35 | 1.2 | 51.1 | 122.5 | 1.0 | 17.0 |
| 2 | | | | | 1.0 | |
| 3 | | | | | 1.0 | |
| 4 | | | | | 1.0 | |
| 5 | | | | | 1.0 | |
| *Summation* | *531.35* | *1* | *51.1* | *122.5* | | 17.0 |
| **Failing Septic Systems** | | | | | | |
| Name | Area [ac] | # of Systems | Failure [%] | Load / System | [lb/ac] | [lb/yr] |
| 1 Watershed | 531.35 | 39 | 0% | 7.8 | 0.0 | 0.0 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| *Summation* | *531.35* | *39* | *0%* | | *0.0* | *0.0* |
| **Inflow from Upstream Lakes** | | | | | | |
| Name | Drainage Area [acre] | Runoff Depth [in/yr] | Discharge [ac-ft/yr] | Estimated P Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 1 Pleasant | 99.20 | 6.6 | 54.5 | 54.0 | 1.0 | 8.0 |
| 2 | | | | - | 1.0 | |
| 3 | | | | - | 1.0 | |
| *Summation* | | | *54.5* | *54.0* | | *8.0* |
| **Atmosphere** | | | | | | |
| Lake Area [acre] | Precipitation [in/yr] | Evaporation [in/yr] | Net Inflow [ac-ft/yr] | Aerial Loading Rate [lb/ac-yr] | Calibration Factor [--] | Load [lb/yr] |
| 99.2 | 27.9 | 25.5 | 19.84 | 0.24 | 1.0 | 23.8 |
| | | | Dry-year total P deposition = | 0.230 | | |
| | | | Average-year total P deposition = | 0.240 | | |
| | | | Wet-year total P deposition = | 0.268 | | |
| | | | (Barr Engineering 2007) | | | |
| **Groundwater** | | | | | | |
| Lake Area [acre] | Groundwater Flux [m/yr] | Net Inflow cfs | Net Inflow [ac-ft/yr] | Phosphorus Concentration [ug/L] | Calibration Factor [--] | Load [lb/yr] |
| 99.2 | | 0.0 | 0 | 0 | 1.0 | 0 |
| **Internal** | | | | | | |
| Lake Area [acre] | Anoxic Factor [days] | Calc Anoxia | | Release Rate [mg/m$^2$-day] | Calibration Factor [--] | Load [lb/yr] |
| 99.2 | 58.8 | | | 7.00 | 0.318 | 115.8 |
| | | **Net Inflow [ac-ft/yr] =** | **125.4** | | **Net Load [lb/yr] =** | **164.7** |

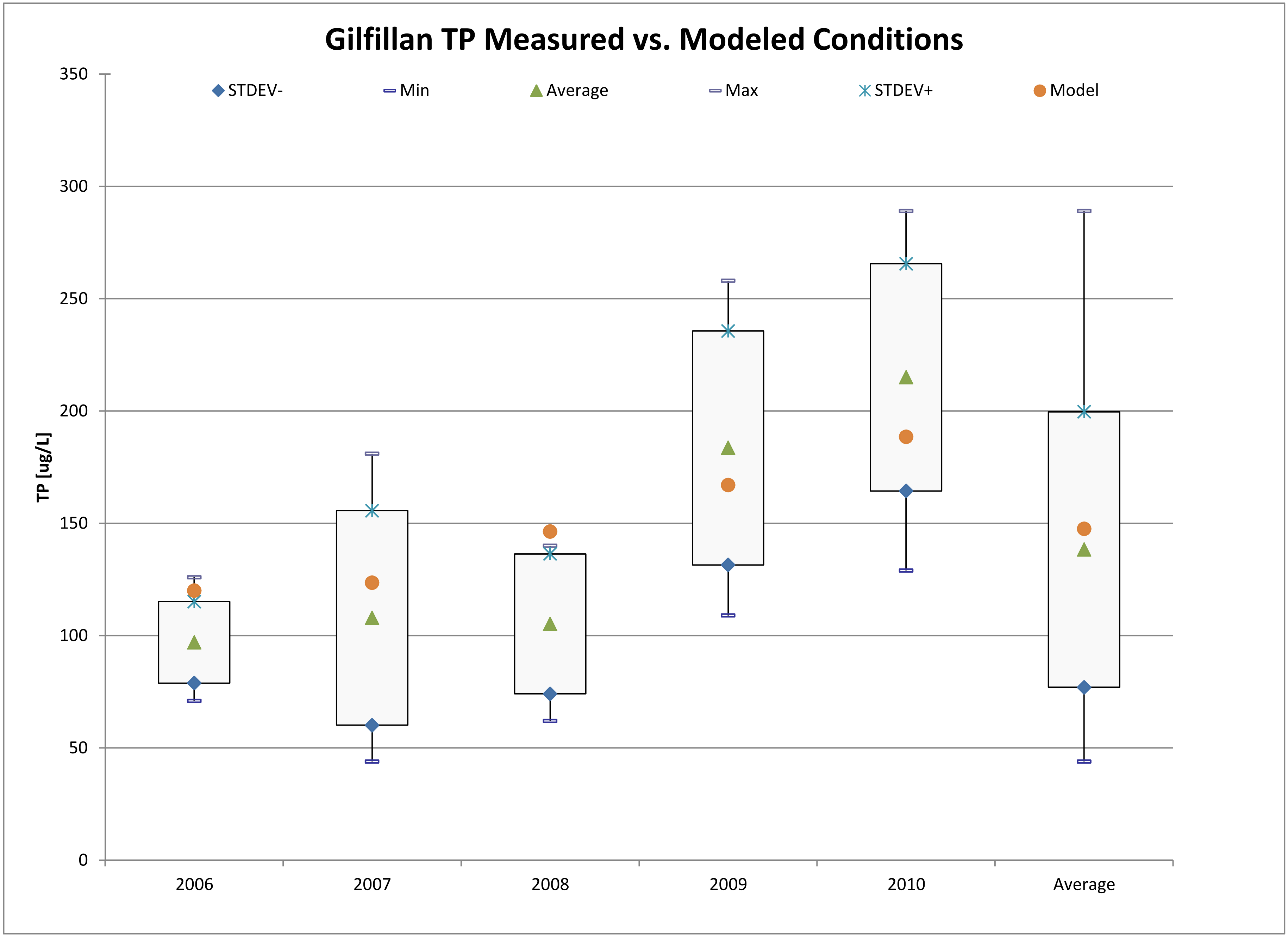
NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

## *Lake Response Modeling for Gilfillan Lake TMDL*

| Modeled Parameter | Equation | Parameters | Value | [Units] |
|---|---|---|---|---|
| **TOTAL IN-LAKE PHOSPHORUS CONCENTRATION** | | | | |
| | | as f(W,Q,V) from Canfield & Bachmann (1981) | | |
| | | $C_P$ = | 1.00 | [--] |
| | | $C_{CB}$ = | 0.162 | [--] |
| | | b = | 0.458 | [--] |
| | | W (total P load = inflow + atm.) = | 165 | [lb/yr] |
| | | Q (lake outflow; for Gilfillan Lake, outflow is to groundwater)* = | 125 | [ac-ft/yr] |
| | | V (modeled lake volume) = | 714 | [ac-ft] |
| | | T = V/Q = | 5.69 | [yr] |
| | | $P_i$ = W/Q = | 483 | [ug/l] |
| **Model Predicted In-Lake [TP]** | | | **60.0** | **[ug/l]** |
| **PHOSPHORUS SEDIMENTATION RATE** | | | | |
| | | **$P_{sed}$ (phosphorus sedimentation) =** | **144.2** | **[lb/yr]** |
| **PHOSPHORUS OUTFLOW LOAD** | | | | |
| W-$P_{sed}$ = | | | **20.5** | **[lb/yr]** |

* Outflow is to groundwater. The TMDL condition model includes inflow from augmentation from Pleasant Lake. The lake volume reflects conditions under augmentation. For the TMDL model, inflow = outflow.


Gilfillan TP Measured vs. Modeled Conditions
STDEV-
Min
Average
Max
STDEV+
Model
TP [ug/L]
350
300
250
200
150
100
50
0
2006
2007
2008
2009
2010
Average

# Appendix B

## WLA Partitioning Summary Tables and Other Information Tables

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**Table B.1: Impaired Waters Sub-watershed Areas**

| Waterbody | Total Subwatershed Area (Includes Lake Surface Area) | | Lake Surface Area | Subwatershed Area (Excluding Lake Surface) |
|---|---|---|---|---|
| | ID# | (acres) | | |
| Gem Lake | 2011505 | 327.94 | 21.6 | 306.34 |
| East Goose Lake | 2011504 | 693.85 | 116.3 | 577.55 |
| West Goose Lake | 20115044 | 262.88 | 24.1 | 238.78 |
| Gilfillan Lake | 2007902 | 630.55 | 99.2* | 531.35 |
| Wilkinson | 2007901 (Birch Lake) | 640.83 | | |
| | 2007903 (Amelia Lake) | 691.33 | | |
| | 2007902 (Gilfillan Lake) | 630.55 | | |
| | 2007904 | 3069.92 | 97.1 | 2972.82 |
| | Total | 5032.63 | 97.1 | 4935.53 |
| Lambert Creek | 2011504 | 693.85 | | |
| | 2011505 | 327.94 | | |
| | 20115044 | 262.88 | | |
| | 20115055 | 3657.95 | | |
| | Total | 4942.62 | | |

* Varies over calibration period due to lake level changes

Sources: Lake Areas were calculated from shorelines digitized from 2010 Aerial Photos

Subwatersheds were delineated to each lake/stream outlet based on topographic maps

## Table B.2: Total Watershed Areas & Land Use Breakdowns (Includes Lake Surface Area)

| Impaired Water (Subwatershed Identification[1]) | Gem Lake (2011505) | | East Goose Lake (2011504) | | West Goose Lake (20115044) | | Lake Gilfillan (2007902) | | Lake Wilkinson (2007901, 2007902, 2007903, 2007904) | | Lambert Creek (2011504, 2011505, 20115044, 20115055) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Land Use** | Acres | % | Acres | % | Acres | % | Acres | % | Acres | % | Acres | % |
| **Agricultural** | 12.44 | 4% | 0.0 | 0% | 0.0 | 0% | 0.0 | 0% | 313.83 | 6% | 39.31 | 1% |
| **Commercial** | 35.70 | 11% | 43.36 | 6% | 18.66 | 7% | 14.59 | 2% | 168.16 | 3% | 221.44 | 4% |
| **Industrial** | 0.0 | 0% | 0.0 | 0% | 15.45 | 6% | 0.05 | 0.01% | 145.03 | 3% | 161.72 | 3% |
| **Institutional** | 0.0 | 0% | 46.65 | 7% | 0.0 | 0% | 7.68 | 1% | 54.50 | 1% | 150.25 | 3% |
| **Major Highway** | 10.78 | 3% | 18.77 | 3% | 17.94 | 7% | 0.0 | 0% | 166.00 | 3% | 140.36 | 3% |
| **Mixed Use** | 0.13 | 0.04% | 0.0 | 0% | 0.0 | 0% | 0.0 | 0% | 29.86 | 1% | 11.99 | 0.24% |
| **Multi-Family Residential** | 0.0 | 0% | 49.10 | 7% | 6.82 | 3% | 53.39 | 8% | 204.17 | 4% | 305.16 | 6% |
| **Open Water** | 32.26 | 10% | 112.46 | 16% | 27.96 | 11% | 118.55 | 19% | 545.48 | 11% | 264.83 | 5% |
| **Park and Recreation** | 0.21 | 0.07% | 11.46 | 2% | 36.54 | 14% | 58.47 | 9% | 964.92 | 19% | 312.08 | 6% |
| **Single Family Residential** | 89.32 | 27% | 402.20 | 58% | 74.33 | 28% | 326.69 | 52% | 1213.44 | 24% | 2168.18 | 44% |
| **Undeveloped** | 147.09 | 45% | 9.85 | 1% | 65.17 | 25% | 51.14 | 8% | 1227.26 | 24% | 1167.31 | 24% |
| **Total** | 327.95 | 100% | 693.85 | 100% | 262.87 | 100% | 630.55 | 100% | 5032.65 | 100% | 4942.63 | 100% |

Source: 2005 Met Council Land Use Database

1 Subwatershed identification numbers originated from the DNR Lakeshed HU_ID. Identification numbers were modified as necessary during GIS mapping and data processing to provide unique IDs for each subwatershed.

Table B.3 Gem Lake Land Use Areas by MS4

| Area Downstream of Boundary Condition (Subwatershed ID# 2011505) | TOTAL | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|---|---|---|---|---|
| Landuse Category/ MS4 | Acres | | | | | % | | | |
| Agricultural | 12.44 | 11.81 | | 0.63 | | 3.86% | | 0.21% | |
| Commercial | 35.70 | 29.50 | | 3.59 | 2.62 | 9.63% | | 1.17% | 0.86% |
| Industrial | 0.00 | | | | | | | | |
| Institutional | 0.00 | | | | | | | | |
| Major Highway | 10.78 | 5.33 | 5.45 | | | 1.74% | 1.78% | | |
| Mixed Use | 0.13 | | | 0.13 | | | | 0.04% | |
| Multi-Family Residential | 0.00 | | | | | | | | |
| Open Water* | 10.66 | 10.66 | | | | 3.48% | | | |
| Park and Recreation | 0.21 | 0.21 | | | | 0.07% | | | |
| Single Family Residential | 89.32 | 81.73 | | 2.02 | 5.58 | 26.68% | | 0.66% | 1.82% |
| Undeveloped | 147.09 | 145.20 | | 0.85 | 1.05 | 47.40% | | 0.28% | 0.34% |
| TOTAL | 306.35 | 284.43 | 5.45 | 7.22 | 9.24 | 92.85% | 1.78% | 2.36% | 3.02% |

* Excludes Lake Area

Table B.4 Goose Lake - East Land Use Areas by MS4

| Area Downstream of Boundary Condition (Subwatershed ID# 2011504) | TOTAL | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|---|---|---|---|---|
| Landuse Category/ MS4 | Acres | | | | | % | | | |
| Agricultural | 0.00 | | | | | | | | |
| Commercial | 43.36 | 3.16 | | 4.07 | 36.13 | 0.54% | | 0.70% | 6.21% |
| Industrial | 0.00 | | | | | | | | |
| Institutional | 46.65 | | | 0.76 | 45.88 | | | 0.13% | 7.89% |
| Major Highway | 18.77 | 0.11 | 17.59 | | 1.07 | 0.02% | 3.03% | | 0.18% |
| Mixed Use | 0.00 | | | | | 0.00% | | | |
| Multi-Family Residential | 49.10 | | | 0.48 | 48.63 | 0.00% | | 0.08% | 8.36% |
| Open Water* | 0.00 | | | | | 0.00% | | 0.00% | 0.00% |
| Park and Recreation | 11.46 | | | 1.09 | 10.36 | | | 0.19% | 1.78% |
| Single Family Residential | 402.20 | 0.31 | | 24.08 | 377.80 | 0.05% | | 4.14% | 64.98% |
| Undeveloped | 9.85 | | | 0.74 | 9.10 | | | 0.13% | 1.57% |
| TOTAL | 581.39 | 3.59 | 17.59 | 31.23 | 528.98 | 0.62% | 3.03% | 5.37% | 90.99% |

* Excludes Lake Area

**Table B.5 Goose Lake - West Land Use Areas by MS4**

| Area Downstream of Boundary Condition (Subwatershed ID# 20115044) | TOTAL | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|---|---|---|---|---|
| **Landuse Category/ MS4** | Acres | | | | | % | | | |
| **Agricultural** | 0.00 | | | | | | | | |
| **Commercial** | 18.66 | | | 2.56 | 16.11 | | | 1.07% | 6.75% |
| **Industrial** | 15.45 | | | 2.79 | 12.66 | | | 1.17% | 5.30% |
| **Institutional** | 0.00 | | | | | | | | |
| **Major Highway** | 17.94 | | 17.72 | 0.21 | 0.01 | | 7.42% | 0.09% | 0.01% |
| **Mixed Use** | 0.00 | | | | | | | | |
| **Multi-Family Residential** | 6.82 | 0.82 | | 1.25 | 4.74 | 0.35% | | 0.52% | 1.99% |
| **Open Water*** | 3.86 | 3.86 | | | | 1.62% | | | |
| **Park and Recreation** | 36.54 | 36.53 | | 0.01 | | 15.30% | | 0.00% | |
| **Single Family Residential** | 74.33 | 56.35 | | 8.28 | 9.69 | 23.60% | | 3.47% | 4.06% |
| **Undeveloped** | 65.17 | 45.85 | | 3.16 | 16.16 | 19.20% | | 1.32% | 6.77% |
| **TOTAL** | 238.77 | 143.42 | 17.72 | 18.25 | 59.38 | 60.07% | 7.42% | 7.64% | 24.87% |

* Excludes Lake Area

**Table B.6 Lake Gilfillan Land Use Areas by MS4**

| Area Downstream of Boundary Condition (Subwatershed ID# 20115044) | TOTAL | North Oaks City MS4 | Vadnais Heights City MS4 | Ramsey County | White Bear Township MS4 | North Oaks City MS4 | Vadnais Heights City MS4 | Ramsey County | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|---|---|
| **Landuse Category/ MS4** | Acres | | | | | % | | | |
| **Agricultural** | 0.00 | | | | | | | | |
| **Commercial** | 14.59 | | 3.62 | 2.10 | 8.87 | | 0.68% | 0.39% | 1.67% |
| **Industrial** | 0.05 | | 0.05 | | | | 0.01% | | |
| **Institutional** | 7.68 | | | 1.23 | 6.44 | | | 0.23% | 1.21% |
| **Major Highway** | 0.00 | | | | | | | | |
| **Mixed Use** | 0.00 | | | | | | | | |
| **Multi-Family Residential** | 53.39 | 9.16 | | 0.18 | 44.05 | 1.72% | | 0.03% | 8.29% |
| **Open Water*** | 19.35 | 5.49 | 3.93 | 0.96 | 8.97 | 1.03% | 0.74% | 0.18% | 1.69% |
| **Park and Recreation** | 58.47 | 43.35 | | 0.41 | 14.71 | 8.16% | | 0.08% | 2.77% |
| **Single Family Residential** | 326.69 | 295.37 | 19.08 | 10.61 | 1.64 | 55.59% | 3.59% | 2.00% | 0.31% |
| **Undeveloped** | 51.14 | 14.83 | 16.56 | 3.73 | 16.02 | 2.79% | 3.12% | 0.70% | 3.02% |
| **TOTAL** | 531.35 | 368.20 | 43.23 | 19.21 | 100.70 | 69.30% | 8.14% | 3.62% | 18.95% |

* Excludes Lake Area

**Table B.7 Lake Wilkinson Land Use Areas by MS4**

| Area Downstream of Boundary Condition (Subwatershed ID# 2007904) | TOTAL | Anoka County | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | White Bear Lake City MS4 | White Bear Township MS4 | Anoka County | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Landuse Category/ MS4** | Acres | | | | | | | | % | | | | | | |
| **Agricultural** | 157.40 | 1.96 | 95.66 | | 17.89 | 0.75 | | 41.14 | 0.07% | 3.22% | | 0.60% | 0.03% | | 1.38% |
| **Commercial** | 29.85 | 0.02 | 0.05 | | 1.84 | 0.72 | 11.15 | 16.07 | 0.001% | 0.002% | | 0.06% | 0.02% | 0.37% | 0.54% |
| **Industrial** | 124.71 | | | | | 2.16 | 5.66 | 116.90 | | | | | 0.07% | 0.19% | 3.93% |
| **Institutional** | 32.57 | | | | 5.78 | 1.29 | | 25.50 | | | | 0.19% | 0.04% | | 0.86% |
| **Major Highway** | 74.40 | | | 72.78 | | | 0.01 | 1.61 | | | 2.45% | | | 0.00% | 0.05% |
| **Mixed Use** | 29.86 | | | | | 0.29 | 28.56 | 1.01 | | | | | 0.01% | 0.96% | 0.03% |
| **Multi-Family Residential** | 74.41 | | | | 9.48 | 1.48 | 19.94 | 43.50 | | | | 0.32% | 0.05% | 0.67% | 1.46% |
| **Open Water*** | 49.03 | | | | 23.65 | | | 25.38 | | | | 0.80% | | | 0.85% |
| **Park and Recreation** | 896.26 | | 0.03 | | 496.31 | 12.25 | 34.70 | 352.97 | | 0.001% | | 16.69% | 0.41% | 1.17% | 11.87% |
| **Single Family Residential** | 639.32 | 2.24 | 22.45 | | 365.21 | 10.76 | 23.39 | 215.28 | 0.08% | 0.76% | | 12.28% | 0.36% | 0.79% | 7.24% |
| **Undeveloped** | 865.01 | 6.11 | 132.83 | | 418.31 | 23.22 | 31.30 | 253.24 | 0.21% | 4.47% | | 14.07% | 0.78% | 1.05% | 8.52% |
| **TOTAL** | 2972.84 | 10.34 | 251.03 | 72.78 | 1338.46 | 52.92 | 154.71 | 1092.61 | 0.35% | 8.44% | 2.45% | 45.02% | 1.78% | 5.20% | 36.75% |

* Excludes Lake Area

**Table B.8 Lambert Creek Land Use Areas by MS4**

| Area Downstream of Boundary Condition (Subwatershed ID# 20115055) | TOTAL | Gem Lake City MS4 | MNDOT | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 | Gem Lake City MS4 | MNDOT | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Landuse Category/ MS4** | Acres | | | | | | | % | | | | | |
| **Agricultural** | 26.87 | | | 2.94 | 23.93 | | | | | 0.08% | 0.65% | | |
| **Commercial** | 122.25 | | | 8.26 | 77.63 | 35.39 | 0.98 | | | 0.23% | 2.12% | 0.97% | 0.03% |
| **Industrial** | 146.22 | | | 3.56 | 35.43 | 56.85 | 50.38 | | | 0.10% | 0.97% | 1.55% | 1.38% |
| **Institutional** | 103.49 | 1.72 | | 4.81 | 16.07 | 78.04 | 2.85 | 0.05% | | 0.13% | 0.44% | 2.13% | 0.08% |
| **Major Highway** | 97.15 | | 79.24 | 7.17 | 3.91 | 6.83 | | | 2.17% | 0.20% | 0.11% | 0.19% | |
| **Mixed Use** | 11.86 | | | 0.12 | 7.45 | 0.42 | 3.87 | | | 0.00% | 0.20% | 0.01% | 0.11% |
| **Multi-Family Residential** | 248.99 | | | 4.57 | 131.35 | 41.16 | 71.92 | | | 0.12% | 3.59% | 1.13% | 1.97% |
| **Open Water** | 92.14 | | | | 1.32 | 0.38 | 90.44 | | | | 0.04% | 0.01% | 2.47% |
| **Park and Recreation** | 263.86 | 18.96 | | 7.58 | 168.00 | 40.48 | 28.84 | 0.52% | | 0.21% | 4.59% | 1.11% | 0.79% |
| **Single Family Residential** | 1602.03 | 86.30 | | 39.66 | 819.44 | 475.94 | 180.69 | 2.36% | | 1.08% | 22.40% | 13.01% | 4.94% |
| **Undeveloped** | 943.07 | 67.39 | | 22.66 | 629.85 | 58.62 | 164.55 | 1.84% | | 0.62% | 17.22% | 1.60% | 4.50% |
| **TOTAL** | 3657.95 | 174.38 | 79.24 | 101.33 | 1914.37 | 794.12 | 594.52 | 4.77% | 2.17% | 2.77% | 52.33% | 21.71% | 16.25% |

Sources (Tables B.1 to B.8): Met Council 2005 Land Use Database

T:\2255 VLAWMO\08_TMDL\Report\[Tables.xlsx]Landuse by subwatershed

| | Table B.9: Percent Watershed Area by MS4 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Lake** | **Anoka County** | **Gem Lake City MS4** | **Lino Lakes City MS4** | **MNDOT** | **North Oaks City MS4** | **Ramsey County** | **Vadnais Heights City MS4** | **White Bear Lake City MS4** | **White Bear Township MS4** |
| Gem | | 92.85% | | 1.78% | | 2.36% | | 3.02% | |
| Goose - East | | 0.62% | | 3.03% | | 5.37% | | 90.99% | |
| Goose - West | | 60.07% | | 7.42% | | 7.64% | | 24.87% | |
| Lake Gilfillan | | | | | 69.30% | 3.62% | 8.14% | | 18.95% |
| Lake Wilkinson | 0.35% | | 8.44% | 2.45% | 45.02% | 1.78% | | 5.20% | 36.75% |
| Lambert Creek | | 4.77% | | 2.17% | | 2.77% | 52.33% | 21.71% | 16.25% |

**Table B.10: P8 Model Results Summary**

| Waterbody | Subwatershed ID# | Annual Average Runoff Volume (ac-ft/yr) | Annual Average Runoff Depth (in/yr) |
|---|---|---|---|
| **Gem Lake** | 2011505 | 81 | 3.2 |
| **East Goose Lake** | 2011504 | 266 | 5.5 |
| **West Goose Lake** | 20115044 | 140 | 7 |
| **Gilfillan Lake** | 2007902 | 51 | 1.2 |
| **Wilkinson** | 2007901 | 388 | 9.0 |
| | 2007903 | 148 | 3.3 |
| | 2007904 | 888 | 3.6 |

*** Source: P8 model**

**Table B.11: Watershed Phosphorus Loading**

| Waterbody | Subwatershed ID# | Subwatershed Area*** (acres) | Phosphorus Concentration (ug/l) | | Phosphorus Load (lbs/yr) | | Phosphorus Export (lbs/acre/yr) | |
|---|---|---|---|---|---|---|---|---|
| | | | Benchmark | TMDL | Benchmark | TMDL | Benchmark | TMDL |
| Gem Lake | 2011505 | 306.34 | 281.6 | 225.2 | 62.1 | 49.7 | 0.203 | 0.162 |
| East Goose Lake | 2011504 | 577.55 | 297.0 | 121.8 | 214.8 | 88.1 | 0.372 | 0.152 |
| West Goose Lake | 20115044 | 238.78 | 290.4 | 69.7 | 110.4 | 26.5 | 0.462 | 0.111 |
| Gilfillan Lake | 2007902 | 531.35 | 122.5 | 122.5 | 17.0 | 17.0 | 0.032 | 0.032 |
| Wilkinson | 2007901* (Birch Lake) | 517.89 | 32.5 | 32.5 | 34.3 | 34.3 | 0.066 | 0.066 |
| | 2007903* (Amelia Lake) | 533.47 | 38.8 | 38.8 | 15.6 | 15.6 | 0.029 | 0.029 |
| | 2007904 | 2972.82 | 306.5 | 80.9 | 740.4 | 195.5 | 0.249 | 0.066 |
| | 2007902 Gilfillan Lake** | 531.35 | 148.0 | 60.0 | 0.0 | 0.0 | 0 | 0 |

* Measured Lake Outflow
** Gilfillan Lake did not discharge during the calibration period
*** Excludes lake surface area

**Table B.12: Lake Water Budgets**

| Waterbody | Calibration Years | Recommended Baseline | Average Annual Watershed Runoff ac-ft/yr | in/yr over watershed | Discharge from Upstream Lakes*** ac-ft/yr | Precipitation* in/yr over lake surface | ac-ft/yr | M-Foods Dairy, LLC in/yr over lake surface | ac-ft/yr | Groundwater in/yr over lake | ac-ft/yr | Evaporation in/yr over lake | ac-ft/yr | Surface Outflow in/yr over lake | ac-ft/yr | Σ inputs + Σ outputs (ac-ft/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gem Lake | 2000-2005 and 2007-2009 | 2007 | 81.1 | 3.2 | - | 32.0 | 57.6 | - | - | 0.0 | 0.0 | (32.0) | (57.6) | (45.0) | (81.0) | 0.1 |
| East Goose Lake | 2007-2009 | 2007 | 265.9 | 5.5 | - | 27.2 | 263.6 | - | | 0.5 | 4.4 | (27.2) | (263.6) | (27.9) | (270.0) | 0.3 |
| West Goose Lak | 2007-2010 | 2007 | 139.8 | 7 | 270.3 | 27.2 | 54.6 | 301.2 | 604.9 | - | - | (27.2) | (54.6) | (505.4) | (1015.0) | (0.0) |
| Gilfillin Lake** | 2006-2010 | 2007 | 51.1 | 1.2 | - | 27.9 | 230.2 | - | - | (15.2) | (125.4) | (25.5) | (210.4) | 0.0 | 0.0 | (54.5) |
| Wilkinson Lake | 2001-2005 and 2007-2009 | 2007 | 888.3 | 3.6 | 535.0 | 31.8 | 257.3 | - | - | 0.9 | 7.5 | (31.8) | (257.3) | (176.8) | (1431.0) | (0.2) |

* Average precipitation varies due to variation in calibration years

** Gilfillan Lake level/ volume was declined over the calibration period (pumping to augment the lake and artificially raise the lake level was not performed). A more recent calibration period was used to reflect changing lake levels and lake volumes through calibration period (evident in water balance). The loss modeled translates into about 6.6 inches per year based on an average condition observed over the calibration period

*** For Wilkinson lake, calculated based on 9 in/yr of runoff over the Birch Lake sub-watershed and 3.3 in/yr of runoff over the Amelia Lake sub-watershed

**Table B.13: Lake Phosphorus Budgets**

| | Phosphorus Sources | | | | | | | Phosphorus Sinks | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Watershed | Septic Systems | Upstream Lakes | Atmosphere | M-Foods Dairy, LLc. | Groundwater | Internal | Phosphorus Sedimentation | Lake Outflow | Σ sources + Σ sinks |
| Waterbody | lbs/yr | | | | | | | | | |
| Gem Lake | 62.1 | 5.1 | 0.0 | 5.2 | - | 0.0 | 0.0 | (56.6) | (15.8) | 0.0 |
| East Goose Lake | 214.8 | 0.0 | 0.0 | 27.9 | - | 0.8 | 1777.2 | (1831.4) | (189.3) | 0.0 |
| West Goose Lake | 110.4 | 0.0 | 189.1 | 5.8 | 16.5 | - | 427.1 | (285.9) | (462.9) | 0.1 |
| Gilfillan Lake | 17.0 | 24.3 | 0.0 | 23.8 | - | 0.0 | 364.2 | (379.1) | (50.3) | (0.1) |
| Wilkinson Lake | 740.4 | 0.0 | 49.8 | 23.3 | - | 1.4 | 51.8 | (324.2) | (542.5) | 0.0 |

(Source: Canfield Backmann Modeling)

**Table B.14: TMDL Equations (lbs/day)**

| Annual TP Loading (lb/yr) | TMDL = | LA + | WLA + | MOS |
|---|---|---|---|---|
| Gem | 54.9 | 5.2 | 47.0 | 2.7 |
| Goose - East | 187.9 | 99.8 | 78.7 | 9.4 |
| Goose - West | 224.2 | 173.0 | 40.0 | 11.2 |
| Lake Gilfillan | 164.7 | 139.4 | 17.0 | 8.3 |
| Lake Wilkinson | 321.8 | 126.4 | 179.4 | 16.1 |

**Table B.15: TMDL Equations (lbs/yr)**

| Daily TP Loading (lb/day) | TMDL = | LA + | WLA + | MOS |
|---|---|---|---|---|
| Gem | 0.150 | 0.014 | 0.129 | 0.008 |
| Goose - East | 0.514 | 0.273 | 0.215 | 0.026 |
| Goose - West | 0.614 | 0.474 | 0.109 | 0.031 |
| Lake Gilfillan | 0.451 | 0.382 | 0.047 | 0.022 |
| Lake Wilkinson | 0.881 | 0.346 | 0.491 | 0.044 |

**Table B.16: MS4 WLA (lbs/year)**

| Lake | WLA (lbs/yr) | M-Foods Dairy, LLC.(1) | MS4s Anoka County | Gem Lake City MS4 | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gem | 47.0 | - | - | 23.9 | - | 5.2 | - | 9.0 | - | 8.9 | - |
| Goose - East | 78.7 | - | - | 2.2 | - | 7.9 | - | 3.9 | - | 64.7 | - |
| Goose - West | 40.0 | 24.7 | - | 2.8 | - | 3.6 | - | 1.6 | - | 7.3 | - |
| Lake Gilfillan | 17.0 | - | - | - | - | - | 14.7 | 0.5 | 0.1 | - | 1.7 |
| Lake Wilkinson | 179.4 | - | 0.1 | - | 1.2 | 47.2 | 26.4 | 1.8 | - | 35.1 | 67.6 |

(1) WLA may be expanded in the future. See Section 6.1.3

**Table B.17: MS4 WLA (lbs/day)**

| Lake | WLA (lbs/day) | M-Foods Dairy, LLC.(1) | **MS4s** Anoka County | Gem Lake City MS4 | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gem | 0.129 | - | - | 0.065 | - | 0.014 | - | 0.025 | - | 0.025 | - |
| Goose - East | 0.215 | - | - | 0.006 | - | 0.022 | - | 0.011 | - | 0.176 | - |
| Goose - West | 0.109 | 0.068 | - | 0.007 | - | 0.010 | - | 0.004 | - | 0.020 | - |
| Lake Gilfillan | 0.047 | - | - | - | - | - | 0.041 | 0.001 | <0.001 | - | 0.005 |
| Lake Wilkinson | 0.491 | - | <0.001 | - | 0.003 | 0.129 | 0.072 | 0.006 | - | 0.096 | 0.185 |

(1) WLA may be expanded in the future. See Section 6.1.3

Table B.18: SUMMARY DATA FOR GEM LAKE SUBWATERSHED

| | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 | Overall |
|---|---|---|---|---|---|
| Resultant CN | 64 | 78 | 81 | 78 | 65 |
| Resultant Area (ac) | 284.4 | 5.5 | 7.2 | 9.2 | 306.35 |
| % Area | 93% | 2% | 2% | 3% | 100% |
| Overall % Impervious | 20% | 46% | 54% | 45% | |
| Overall Impervious Area (ac) | 57.76 | 2.51 | 3.88 | 4.12 | 68.27 |
| S | 5.73 | 2.82 | 2.39 | 2.79 | |
| SRO (inches) | 0.021 | 0.233 | 0.305 | 0.237 | 0.796 |
| RO Volume (ac-ft) | 0.489 | 0.106 | 0.184 | 0.183 | 0.961 |
| % SRO= Proposed Partition of Existing Loads | 50.86% | 11.02% | 19.11% | 19.01% | 100.00% |

<--Calculate SRO using SCS Method=(P-0.2S)^2/(P+0.8S)
Where S=(1000/CN)-10

And Runoff Event P (inches)= 1.5

Table B.19: Gem Lake Nutrient Sources by Category (lbs TP/ year)

| | Watershed | Septics | Internal | Precipitation & Groundwater | Total | TP Concentration (ug/L) |
|---|---|---|---|---|---|---|
| Average Year | 62 | 5 | 0 | 5 | 72 | 72 |
| W/ Reductions | 50 | 0 | 0 | 5 | 55 | 60 |
| % Reduction | 20% | 100% | NA | 0% | 24% | 16% |

(Source: Canfield Bachmann Model)

Table B.20: Gem Lake Overall CN calcs

| Lake | Subwatershed ID | Landuse Type: | Area (ac) | Impervious Area (%) | Impervious Area (ac) | Impervous CN | Pervious Area (%) | Pervious Area (ac) | Pervious CN | Resultant CN-Categorical CN for Gem Lake Sub by Landuse |
|---|---|---|---|---|---|---|---|---|---|---|
| Gem Lake | 2011505 | Agricultural | 12.44 | 5% | 0.62 | 98 | 95% | 11.82 | 61 | 63 |
| Gem Lake | 2011505 | Commercial | 35.70 | 85% | 30.35 | 98 | 15% | 5.36 | 61 | 92 |
| Gem Lake | 2011505 | Major Highway | 10.78 | 46% | 4.96 | 98 | 54% | 5.82 | 61 | 78 |
| Gem Lake | 2011505 | Mixed Use | 0.13 | 85% | 0.11 | 98 | 15% | 0.02 | 69 | 94 |
| Gem Lake | 2011505 | Open Water | | | | | | | | |
| Gem Lake | 2011505 | Park and Recreation | 0.21 | 12% | 0.03 | 98 | 88% | 0.19 | 55 | 60 |
| Gem Lake | 2011505 | Single Family Residential | 89.32 | 34% | 30.37 | 98 | 66% | 58.95 | 64 | 76 |
| Gem Lake | 2011505 | Undeveloped | 147.09 | 0% | 0.00 | 98 | 100% | 147.09 | 55 | 55 |
| | | Total | 295.68 | | 66.43 | | | 229.25 | | |
| | | | | | 22.47% | | | 77.53% | | |

Table B.21: Gem Lake Area of Landuse Category by MS4 (acres)

| Landuse Category | TOTAL AREA (AC) | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|---|
| Agricultural | 12.44 | 11.81 | | 0.63 | |
| Commercial | 35.70 | 29.50 | | 3.59 | 2.62 |
| Major Highway | 10.78 | 5.33 | 5.45 | | |
| Mixed Use | 0.13 | | | 0.13 | |
| Open Water | 10.66 | 10.66 | | | |
| Park and Recreation | 0.21 | 0.21 | | | |
| Single Family Residential | 89.32 | 81.73 | | 2.02 | 5.58 |
| Undeveloped | 147.09 | 145.20 | | 0.85 | 1.05 |
| TOTAL | 306.35 | 284.43 | 5.45 | 7.22 | 9.24 |
| | | 93% | 2% | 2% | 3% |

Table B. 22: CATEGORICAL CNs by Landuse for Gem Lake Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|
| Agricultural | 63 | 63 | 63 | 63 |
| Commercial | 92 | 92 | 92 | 92 |
| Major Highway | 78 | 78 | 78 | 78 |
| Mixed Use | 94 | 94 | 94 | 94 |
| Open Water | | | | |
| Park and Recreation | 60 | 60 | 60 | 60 |
| Single Family Residential | 76 | 76 | 76 | 76 |
| Undeveloped | 55 | 55 | 55 | 55 |

Based on soil types and watershed % impervious area

Table B.23: CATEGORICAL % Impervious by Landuse for Gem Lake Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|
| Agricultural | 5% | 5% | 5% | 5% |
| Commercial | 85% | 85% | 85% | 85% |
| Major Highway | 46% | 46% | 46% | 46% |
| Mixed Use | 85% | 85% | 85% | 85% |
| Open Water | | | | |
| Park and Recreation | 12% | 12% | 12% | 12% |
| Single Family Residential | 34% | 34% | 34% | 34% |
| Undeveloped | 0% | 0% | 0% | 0% |
| Overall % Impervious | 20% | 46% | 54% | 45% |
| Overall Impervious Area (ac) | 57.76 | 2.51 | 3.88 | 4.12 |

Table B.24: Gem Lake P8 Input

| **Subwatershed** | **Total Subwatershed Area (ac)** | **Landuse Type:** | **Landuse area (ac)** | **%Imperv** | **Impervious Area (ac)** | **Perv CN** |
|---|---|---|---|---|---|---|
| **GEM 2011505** | 327.94 | Agricultural | 12.44 | 5% | 0.62 | 61 |
| | | Commercial | 35.70 | 85% | 30.35 | 61 |
| | | Major Highway | 10.78 | 46% | 4.96 | 61 |
| | | Mixed Use | 0.13 | 85% | 0.11 | 69 |
| | 32.26 | <--Total Open Water | | | | |
| | | Park and Recreation | 0.21 | 12% | 0.03 | 55 |
| | | Single Family Residential | 89.32 | 34% | 30.37 | 64 |
| some new residential, wooded, wetlands--> | | Undeveloped | 147.09 | 0% | 0.00 | 55 |
| | | **Total (minus open water)** | 295.68 | 22% | 66.4 | **58.9** |
| | | | Directly connected | 8% | | |

Table B.25: SUMMARY DATA FOR EAST GOOSE LAKE SUBWATERSHED

| East Goose | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 | Overall |
|---|---|---|---|---|---|
| Resultant CN | 92 | 88 | 75 | 75 | 75 |
| Resultant Area (ac) | 3.6 | 17.6 | 31.2 | 529.0 | 581.39 |
| % Area | 1% | 3% | 5% | 91% | 100% |
| Overall % Impervious | 80% | 66% | 36% | 36% | |
| Overall Impervious Area (ac) | 2.86 | 11.54 | 11.35 | 191.37 | 217.12 |
| S | 0.92 | 1.36 | 3.37 | 3.40 | |
| SRO (inches) | 0.775 | 0.581 | 0.163 | 0.159 | 1.678 |
| RO Volume (ac-ft) | 0.232 | 0.852 | 0.423 | 7.010 | 8.517 |
| % SRO= Proposed Partition of Existing Loads | 2.72% | 10.00% | 4.97% | 82.30% | 100% |

<--Calculate SRO using SCS Method=(P-0.2S)^2/(P+0.8S)
Where S=(1000/CN)-10
And Runoff Event P (inches)= 1.5

Table B.26: East Goose Lake Nutrient Sources by Category (lbs TP/ year)

| | **Watershed** | **Septics** | **Internal*** | **Precipitation & Groundwater** | **Total** | **Modeled Average TP Concentrations (ug/L)** |
|---|---|---|---|---|---|---|
| Average Year | 215 | 0 | 1,777 | 29 | 2,021 | 258 |
| W/ Load Reductions | 88 | 0 | 71 | 29 | 188 | 60 |
| % Reduction | 59% | 0% | 96% | 0% | 91% | 78% |

(Source: Canfield Bachmann modeling)

Table B.27: East Goose Lake Overall CN calcs

| Lake | Subwatershed ID | Landuse Type: | Area (ac) | Impervious Area (%) | Impervious Area (ac) | Impervous CN | Pervious Area (%) | Pervious Area (ac) | Pervious CN | Resultant CN-Categorical CN for Goose Lake EAST Lake Sub by Landuse |
|---|---|---|---|---|---|---|---|---|---|---|
| Goose Lake EAST | 2011504 | Commercial | 43.36 | 85% | 36.86 | 98 | 15% | 6.50 | 69 | 94 |
| Goose Lake EAST | 2011504 | Institutional | 46.65 | 30% | 13.99 | 98 | 70% | 32.65 | 61 | 72 |
| Goose Lake EAST | 2011504 | Major Highway | 18.77 | 66% | 12.31 | 98 | 34% | 6.46 | 69 | 88 |
| Goose Lake EAST | 2011504 | Multi-Family Residential | 49.10 | 65% | 31.92 | 98 | 35% | 17.19 | 61 | 85 |
| Goose Lake EAST | 2011504 | Open Water | | | | | | | | |
| Goose Lake EAST | 2011504 | Park and Recreation | 11.46 | 12% | 1.37 | 98 | 88% | 10.08 | 61 | 65 |
| Goose Lake EAST | 2011504 | Single Family Residential | 402.20 | 30% | 120.66 | 98 | 70% | 281.54 | 61 | 72 |
| Goose Lake EAST | 2011504 | Undeveloped | 9.85 | 0% | 0.00 | 98 | 100% | 9.85 | 69 | 69 |
| | | total | 581.39 | | 217.12 | | | 364.27 | | |
| | | | | | 37.34% | | | 62.66% | | |

Table B.28: East Goose Area of Landuse Category by MS4 (acres)

| Landuse Category | TOTAL | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|---|
| Commercial | 43.36 | 3.16 | 0.00 | 4.07 | 36.13 |
| Institutional | 46.65 | 0.00 | 0.00 | 0.76 | 45.88 |
| Major Highway | 18.77 | 0.11 | 17.59 | 0.00 | 1.07 |
| Multi-Family Residential | 49.10 | 0.00 | 0.00 | 0.48 | 48.63 |
| Open Water | | | | | |
| Park and Recreation | 11.46 | 0.00 | 0.00 | 1.09 | 10.36 |
| Single Family Residential | 402.20 | 0.31 | 0.00 | 24.08 | 377.80 |
| Undeveloped | 9.85 | 0.00 | 0.00 | 0.74 | 9.10 |
| TOTAL | 581.39 | 3.59 | 17.59 | 31.23 | 528.98 |
| % | | 0.62% | 3.03% | 5.37% | 90.99% |

Table B.29: CATEGORICAL CNs by Landuse for East Goose Lake Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|
| Commercial | 94 | 94 | 94 | 94 |
| Institutional | 72 | 72 | 72 | 72 |
| Major Highway | 88 | 88 | 88 | 88 |
| Multi-Family Residential | 85 | 85 | 85 | 85 |
| Open Water | | | | |
| Park and Recreation | 65 | 65 | 65 | 65 |
| Single Family Residential | 72 | 72 | 72 | 72 |
| Undeveloped | 69 | 69 | 69 | 69 |
| Resultant | 92 | 88 | 75 | 75 |

Based on soil types and watershed % impervious area

Table B.30: CATEGORICAL % Impervious by Landuse for East Goose Lake Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|
| Commercial | 85% | 85% | 85% | 85% |
| Institutional | 30% | 30% | 30% | 30% |
| Major Highway | 66% | 66% | 66% | 66% |
| Multi-Family Residential | 65% | 65% | 65% | 65% |
| Open Water | | | | |
| Park and Recreation | 12% | 12% | 12% | 12% |
| Single Family Residential | 30% | 30% | 30% | 30% |
| Undeveloped | 0% | 0% | 0% | 0% |
| Overall % Impervious | 80% | 66% | 36% | 36% |
| Overall Impervious Area (ac) | 2.86 | 11.54 | 11.35 | 191.37 |

Table B.31: East Goose Lake P8 Input

| **Subwatershed** | **Area (ac)** | **Landuse Type:** | **Landuse area (ac)** | **%Imperv** | **Perv CN** |
|---|---|---|---|---|---|
| **East GOOSE 2011504** | 693.90 | Commercial | 43.36 | 85 | 69 |
| | | Institutional | 46.65 | 30 | 61 |
| | | Major Highway | 18.77 | 98 | 69 |
| | | Multi-Family Residential | 49.10 | 65 | 61 |
| **e. GOOSE water** | 112.5 | Open Water | | | |
| | | Park and Recreation | 11.46 | 12 | 61 |
| | | Single Family Residential | 402.20 | 30 | 61 |
| | | Undeveloped | 9.85 | 0 | 69 |
| | | **Total** | 581.39 | 38.4 | 62.0 |
| | | | Indirect | 19.2 | one half |
| | | | Direct | 19.2 | one half |

Table B.32: SUMMARY DATA FOR WEST GOOSE LAKE SUBWATERSHED

| West Goose | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 | Overall |
|---|---|---|---|---|---|
| Resultant CN | 68 | 88 | 78 | 82 | 74 |
| Resultant Area (ac) | 143.4 | 17.7 | 18.3 | 59.4 | 238.77 |
| % Area | 60% | 7% | 8% | 25% | 100% |
| Overall % Impervious | 15% | 66% | 43% | 50% | |
| Overall Impervious Area (ac) | 21.83 | 11.62 | 7.84 | 29.82 | 71.11 |
| S | 4.80 | 1.36 | 2.74 | 2.18 | |
| SRO (inches) | 0.054 | 0.581 | 0.245 | 0.348 | 1.229 |
| RO Volume (ac-ft) | 0.650 | 0.858 | 0.373 | 1.724 | 3.605 |
| % SRO= Proposed Partition of Existing Loads | 18.03% | 23.81% | 10.34% | 47.82% | 100% |

<--Calculate SRO using SCS Method=(P-0.2S)^2/(P+0.8S)
Where S=(1000/CN)-10
And Runoff Event P (inches)= 1.5

Table B.33: West Goose Lake Nutrient Sources by Category (lbs TP/ year)

| | Watershed | M-Foods Dairy, LLC. | Septics | Internal (includes motorboating) | Precipitation & Groundwater | Total | TP Concentration (ug/L) |
|---|---|---|---|---|---|---|---|
| Average Year | 110 | 25 | 0 | 397 | 6 | 727 | 164 |
| W/ Reductions | 27 | 25 | 0 | 123 | 6 | 225 | 60 |
| % Reduction | 76% | 0% | 0% | 69% | 0% | 69% | 64% |

(Source: Canfield Bachmann modeling)

Table B.34: West Goose Lake Overall CN Calcs

| Lake | Subwatershed ID | Landuse Type: | Area (ac) | Impervious Area (%) | Impervious Area (ac) | Impervous CN | Pervious Area (%) | Pervious Area (ac) | Pervious CN | Resultant CN- Categorical CN for Goose Lake WEST Sub by Landuse |
|---|---|---|---|---|---|---|---|---|---|---|
| Goose Lake WEST | 20115044 | Commercial | 18.66 | 85% | 15.86 | 98 | 15% | 2.80 | 69 | 94 |
| Goose Lake WEST | 20115044 | Industrial | 15.45 | 80% | 12.36 | 98 | 20% | 3.09 | 61 | 91 |
| Goose Lake WEST | 20115044 | Major Highway | 17.94 | 66% | 11.77 | 98 | 34% | 6.17 | 69 | 88 |
| Goose Lake WEST | 20115044 | Multi-Family Residential | 6.82 | 65% | 4.43 | 98 | 35% | 2.39 | 61 | 85 |
| Goose Lake WEST | 20115044 | Open Water | 3.86 | | | | | | | |
| Goose Lake WEST | 20115044 | Park and Recreation | 36.54 | 12% | 4.39 | 98 | 88% | 32.16 | 61 | 65 |
| Goose Lake WEST | 20115044 | Single Family Residential | 74.33 | 30% | 22.30 | 98 | 70% | 52.03 | 61 | 72 |
| Goose Lake WEST | 20115044 | Undeveloped | 65.17 | 0% | 0.00 | 98 | 100% | 65.17 | 69 | 69 |
| | | total | 238.77 | | 71.11 | | | 163.81 | | |
| | | | | | 29.78% | | | 68.60% | | |

Table B.35: West Goose Lake Area of Landuse Category by MS4 (acres)

| Landuse Category | TOTAL | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|---|
| Commercial | 18.66 | | | 2.56 | 16.11 |
| Industrial | 15.45 | 0.00 | | 2.79 | 12.66 |
| Major Highway | 17.95 | 0.00 | 17.72 | 0.21 | 0.01 |
| Multi-Family Residential | 6.82 | 0.82 | | 1.25 | 4.74 |
| Open Water | 3.86 | 3.86 | | | |
| Park and Recreation | 36.54 | 36.53 | | 0.01 | |
| Single Family Residential | 74.33 | 56.35 | | 8.28 | 9.69 |
| Undeveloped | 65.17 | 45.85 | | 3.16 | 16.16 |
| TOTAL | 238.77 | 143.42 | 17.72 | 18.25 | 59.38 |

Table B.36: CATEGORICAL CNs by Landuse for West Goose Lake Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|
| Commercial | 94 | 94 | 94 | 94 |
| Industrial | 91 | 91 | 91 | 91 |
| Major Highway | 88 | 88 | 88 | 88 |
| Multi-Family Residential | 85 | 85 | 85 | 85 |
| Open Water | | | | |
| Park and Recreation | 65 | 65 | 65 | 65 |
| Single Family Residential | 72 | 72 | 72 | 72 |
| Undeveloped | 69 | 69 | 69 | 69 |
| | 68 | 88 | 78 | 82 |

Based on soil types and watershed % impervious area

Table B.37: CATEGORICAL % Impervious by Landuse for West Goose Lake Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | White Bear Lake City MS4 |
|---|---|---|---|---|
| Commercial | 85% | 85% | 85% | 85% |
| Industrial | 80% | 80% | 80% | 80% |
| Major Highway | 66% | 66% | 66% | 66% |
| Multi-Family Residential | 65% | 65% | 65% | 65% |
| Open Water | | | | |
| Park and Recreation | 12% | 12% | 12% | 12% |
| Single Family Residential | 30% | 30% | 30% | 30% |
| Undeveloped | 0% | 0% | 0% | 0% |
| Overall % Impervious | 15% | 66% | 43% | 50% |
| Overall Impervious Area (ac) | 21.83 | 11.62 | 7.84 | 29.82 |

Table B.38: West Goose Lake P8 Input

| Subwatershed | Area (ac) | Landuse Type: | Landuse area (ac) | %Imperv | Perv CN |
|---|---|---|---|---|---|
| **West GOOSE 20115044** | 262.90 | Commercial | 18.66 | 85 | 69 |
| "little Goose" | | Industrial | 15.45 | 80 | 69 |
| | | Major Highway | 17.94 | 98 | 69 |
| | | Multi-Family Residential | 6.82 | 65 | 61 |
| **w. GOOSE water** | 28 | Open Water | | | |
| | | Park and Recreation | 36.54 | 12 | 61 |
| | | Single Family Residential | 74.33 | 30 | 61 |
| | | Undeveloped | 65.17 | 0 | 69 |
| | | **Total** | 234.91 | 32.7 | 65.0 |
| | | | Indirect | | 10.91 One third |
| | | | Direct | | 21.83 two thirds |

*** East Goose is also tributary to West Goose. See Tab in this file for P8 calcs**

Table B.39: SUMMARY DATA FOR GILFILLAN LAKE SUBWATERSHED

| | North Oaks City MS4 | Vadnais Heights City MS4 | Ramsey County | White Bear Township MS4 | Overall | |
|---|---|---|---|---|---|---|
| Resultant CN | 69 | 61 | 67 | 65 | 68 | |
| Area by MS4 (ac) | 368.2 | 43.2 | 19.2 | 100.7 | 531.36 | |
| % Area | 69% | 8% | 4% | 19% | 100% | |
| Overall % Impervious | 26% | 20% | 28% | 28% | | |
| Overall Impervious Area (ac) | 96.34 | 8.84 | 5.44 | 27.74 | 138.35 | |
| S | 4.39 | 6.45 | 4.84 | 5.36 | | <--Calculate SRO using SCS Method=(P-0.2S)^2/(P+0.8S) |
| SRO (inches) | 0.077 | 0.0067 | 0.0526 | 0.0317 | 0.168 | Where S=(1000/CN)-10 |
| RO Volume (ac-ft) | 2.368 | 0.024 | 0.084 | 0.266 | 2.743 | And Runoff Event P (inches)= 1.5 |
| % SRO= Proposed Partition of Existing Loads | 86.35% | 0.88% | 3.07% | 9.70% | 100% | |

Table B.40: Gilfillan Lake Nutrient Sources by Category (lbs TP/ year)

| | Watershed Load | Septics | Internal | Atmospheric+ Groundwater | Augmentation | Total | Concentration (ug/L) |
|---|---|---|---|---|---|---|---|
| Existing | 17 | 24 | 364 | 24 | 0 | 429 | 148 |
| TMDL* | 17 | 0 | 124 | 24 | 1 | 166 | 60 |
| % Reduction | 0% | 100% | 66% | 0% | -- | 61% | 59% |

* Includes augmentation of clean water from Pleasant Lake
(Source: Canfield Bachmann modeling)

Table B.41: Gilfillan Lake Overall CN calcs

| Lake | Subwatershed ID | Landuse Type: | Area (ac) | Impervious Area (%) | Impervious Area (ac) | Impervous CN | Pervious Area (%) | Pervious Area (ac) | Pervious CN | Resultant CN-Categorical CN for Gilfillan Lake Sub by Landuse |
|---|---|---|---|---|---|---|---|---|---|---|
| Lake Gilfillan | 2007902 | Commercial | 14.59 | 85% | 12.40 | 98 | 15% | 2.19 | 69 | 94 |
| Lake Gilfillan | 2007902 | Industrial | 0.05 | 80% | 0.04 | 98 | 20% | 0.01 | 69 | 92 |
| Lake Gilfillan | 2007902 | Institutional | 7.68 | 30% | 2.30 | 98 | 70% | 5.37 | 61 | 72 |
| Lake Gilfillan | 2007902 | Multi-Family Residential | 53.39 | 37% | 19.75 | 98 | 63% | 33.64 | 61 | 75 |
| Lake Gilfillan | 2007902 | Open Water | 19.35 | | 0.00 | | | 0.00 | | |
| Lake Gilfillan | 2007902 | Park and Recreation | 58.47 | 10% | 5.85 | 98 | 90% | 52.63 | 61 | 65 |
| Lake Gilfillan | 2007902 | Single Family Residential | 326.69 | 30% | 98.01 | 98 | 70% | 228.68 | 61 | 72 |
| Lake Gilfillan | 2007902 | Undeveloped | 51.14 | 0% | 0.00 | 98 | 100% | 51.14 | 55 | 55 |
| | | total | 531.36 | | 138.35 | | | 373.65 | | |
| | | | | | 26.04% | | | 70.32% | | |

Table B.42: Gilfillan Lake Area of Landuse Category by MS4 (acres)

| Landuse Category | Area (ac) | North Oaks City MS4 | Vadnais Heights City MS4 | Ramsey County | White Bear Township MS4 |
|---|---|---|---|---|---|
| Commercial | 14.59 | | 3.62 | 2.10 | 8.87 |
| Industrial | 0.05 | | 0.05 | | |
| Institutional | 7.68 | | | 1.23 | 6.44 |
| Multi-Family Residential | 53.39 | 9.16 | | 0.18 | 44.05 |
| Open Water | 19.35 | 5.49 | 3.93 | 0.96 | 8.97 |
| Park and Recreation | 58.47 | 43.35 | | 0.41 | 14.71 |
| Single Family Residential | 326.69 | 295.37 | 19.08 | 10.61 | 1.64 |
| Undeveloped | 51.14 | 14.83 | 16.56 | 3.73 | 16.02 |
| TOTAL | 531.36 | 368.2 | 43.2 | 19.2 | 100.7 |
| | % Area ---> | 69% | 8% | 4% | 19% |

Table B.43: CATEGORICAL CNs by Landuse for Gilfillan Lake Subwatershed

| CN | North Oaks City MS4 | Vadnais Heights City MS4 | Ramsey County | White Bear Township MS4 |
|---|---|---|---|---|
| Commercial | 94 | 94 | 94 | 94 |
| Industrial | 92 | 92 | 92 | 92 |
| Institutional | 72 | 72 | 72 | 72 |
| Multi-Family Residential | 75 | 75 | 75 | 75 |
| Open Water | | | | |
| Park and Recreation | 65 | 65 | 65 | 65 |
| Single Family Residential | 72 | 72 | 72 | 72 |
| Undeveloped | 55 | 55 | 55 | 55 |
| Overall CN | 69 | 61 | 67 | 65 |

Based on soil types and watershed % impervious area

Table B.44: CATEGORICAL % Impervious by Landuse for Gilfillan Lake Subwatershed

| CN | North Oaks City MS4 | Vadnais Heights City MS4 | Ramsey County | White Bear Township MS4 |
|---|---|---|---|---|
| Commercial | 85% | 85% | 85% | 85% |
| Industrial | 80% | 80% | 80% | 80% |
| Institutional | 30% | 30% | 30% | 30% |
| Multi-Family Residential | 37% | 37% | 37% | 37% |
| Open Water | | | | |
| Park and Recreation | 10% | 10% | 10% | 10% |
| Single Family Residential | 30% | 30% | 30% | 30% |
| Undeveloped | 0% | 0% | 0% | 0% |
| Overall % Impervious | 26% | 20% | 28% | 28% |
| Overall Impervious Area (ac) | 96.34 | 8.84 | 5.44 | 27.74 |

Table B.45: Gilfillan Lake P8 Input

| **Subwatershed** | **Area (ac)** | **Landuse Type:** | **Landuse area (ac)** | **%Imperv** | **Perv CN** |
|---|---|---|---|---|---|
| **Gilfillan 2007902** | 531.36 | Commercial | 14.59 | 85 | 69 |
| | | Industrial | 0.05 | 80 | 69 |
| | | Institutional | 7.68 | 30 | 61 |
| | | Multi-Family Residential | 53.39 | 37 | 61 |
| **Gilfillan** | 19.35 | Open Water (orig 118.55) | | | |
| **All impervious indirectly connected** | | Park and Recreation | 58.47 | 10 | 61 |
| | | Single Family Residential | 326.69 | 30 | 61 |
| | | Undeveloped | 51.14 | 0 | 55 |
| | | **Total** | 512.01 | 27.0 | 60.6 |

Table B.46: SUMMARY DATA FOR Wilkinson Lake Subwatershed

| Wilkinson | Anoka County | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | White Bear Lake City MS4 | White Bear Township MS4 | Overall | |
|---|---|---|---|---|---|---|---|---|---|
| Resultant CN | 60 | 60 | 83 | 62 | 64 | 73 | 66 | 64 | |
| Resultant Area (ac) | 10.3 | 251.0 | 72.8 | 1338.5 | 52.9 | 154.7 | 1092.6 | 2972.8 | |
| % Area | 0.3% | 8.4% | 2.4% | 45.0% | 1.8% | 5.2% | 36.8% | 100.0% | |
| Overall % Impervious | 8% | 5% | 47% | 11% | 14% | 35% | 20% | 0% | |
| Overall Impervious Area (ac) | 0.79 | 11.56 | 34.42 | 141.50 | 7.27 | 54.41 | 214.28 | 0.00 | |
| S | 6.59 | 6.80 | 2.05 | 6.14 | 5.74 | 3.67 | 5.23 | 5.57 | <--Calculate SRO using SCS Method=(P-0.2S)^2/(P+0.8S) |
| SRO (inches) | 0.005 | 0.003 | 0.379 | 0.012 | 0.020 | 0.132 | 0.036 | 0.587 | Where S=(1000/CN)-10 |
| RO Volume (ac-ft) | 0.004 | 0.059 | 2.297 | 1.288 | 0.090 | 1.708 | 3.290 | 8.738 | And Runoff Event P (inches)= 1.5 |
| % SRO= Proposed Partition of Existing Loads | 0.05% | 0.68% | 26.29% | 14.74% | 1.03% | 19.55% | 37.66% | | |

Table B.47: Wilkinson Lake Nutrient Sources by Category (lbs TP/ year)

| TMDL | Watershed Load | Septics | Internal | Atmospheric+ Groundwater | Upstream Lakes | Concentration (ug/L) | Total |
|---|---|---|---|---|---|---|---|
| Existing | 740 | 0 | 52 | 25 | 50 | 139 | 867 |
| TMDL | 196 | 0 | 52 | 25 | 50 | 60 | 322 |
| % Reduction | 74% | 0% | 0% | 0% | 0% | 57% | 63% |

(Source: Canfield Bachmann modeling)

Table B.48: Wilkinson Lake Overall CN calcs

| Lake | Subwatershe | **Landuse Type:** | Area (ac) | Impervious Area (%) | Impervious Area (ac) | Impervous CN | Pervious Area (%) | Pervious Area (ac) | Pervious CN | Resultant CN- Categorical CN for Wilkenson Sub by Landuse |
|---|---|---|---|---|---|---|---|---|---|---|
| Lake Wilkinson | 2007904 | Agricultural | 157.40 | 5% | 7.87 | 98 | 95% | 149.53 | 61 | 63 |
| Lake Wilkinson | 2007904 | Commercial | 29.85 | 85% | 25.37 | 98 | 15% | 4.48 | 69 | 94 |
| Lake Wilkinson | 2007904 | Industrial | 124.71 | 80% | 99.77 | 98 | 20% | 24.94 | 69 | 92 |
| Lake Wilkinson | 2007904 | Institutional | 32.57 | 20% | 6.51 | 98 | 80% | 26.05 | 61 | 68 |
| Lake Wilkinson | 2007904 | Major Highway | 74.40 | 47% | 35.19 | 98 | 53% | 39.21 | 69 | 83 |
| Lake Wilkinson | 2007904 | Mixed Use | 29.86 | 85% | 25.38 | 98 | 15% | 4.48 | 69 | 94 |
| Lake Wilkinson | 2007904 | Multi-Family Residential | 74.41 | 37% | 27.53 | 98 | 63% | 46.88 | 61 | 75 |
| Lake Wilkinson | 2007904 | Open Water | 49.03 | | | | | | | |
| Lake Wilkinson | 2007904 | Park and Recreation | 896.26 | 5% | 44.81 | 98 | 95% | 851.45 | 61 | 63 |
| Lake Wilkinson | 2007904 | Single Family Residential | 639.32 | 30% | 191.80 | 98 | 70% | 447.53 | 61 | 72 |
| Lake Wilkinson | 2007904 | Undeveloped | 865.01 | 0% | 0.00 | 98 | 100% | 865.01 | 55 | 55 |
| | | total | 2972.84 | | 464.24 | | | 2459.56 | | |
| | | | | | 15.62% | | | 82.73% | | |

Table B.49: Wilkinson Lake Area of Landuse Category by MS4 (acres)

| Landuse Category | TOTAL | Anoka County | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|---|
| Agricultural | 157.40 | 1.96 | 95.66 | | 17.89 | 0.75 | | 41.14 |
| Commercial | 29.85 | 0.02 | 0.05 | | 1.84 | 0.72 | 11.15 | 16.07 |
| Industrial | 124.71 | | | | | 2.16 | 5.66 | 116.90 |
| Institutional | 32.57 | | | | 5.78 | 1.29 | | 25.50 |
| Major Highway | 74.40 | | | 72.78 | | | 0.01 | 1.61 |
| Mixed Use | 29.86 | | | | | 0.29 | 28.56 | 1.01 |
| Multi-Family Residential | 74.41 | | | | 9.48 | 1.48 | 19.94 | 43.50 |
| Open Water | 49.03 | | | | 23.65 | | | 25.38 |
| Park and Recreation | 896.26 | | 0.03 | | 496.31 | 12.25 | 34.70 | 352.97 |
| Single Family Residential | 639.32 | 2.24 | 22.45 | | 365.21 | 10.76 | 23.39 | 215.28 |
| Undeveloped | 865.01 | 6.11 | 132.83 | | 418.31 | 23.22 | 31.30 | 253.24 |
| TOTAL | 2972.84 | 10.34 | 251.03 | 72.78 | 1338.46 | 52.92 | 154.71 | 1092.60 |

Table B.50: CATEGORICAL CNs by Landuse for Wilkenson Lake Subwatershed

| Landuse Category | Anoka County | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|
| Agricultural | 63 | 63 | 63 | 63 | 63 | 63 | 63 |
| Commercial | 94 | 94 | 94 | 94 | 94 | 94 | 94 |
| Industrial | 92 | 92 | 92 | 92 | 92 | 92 | 92 |
| Institutional | 68 | 68 | 68 | 68 | 68 | 68 | 68 |
| Major Highway | 83 | 83 | 83 | 83 | 83 | 83 | 83 |
| Mixed Use | 94 | 94 | 94 | 94 | 94 | 94 | 94 |
| Multi-Family Residential | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| Open Water | | | | | | | |
| Park and Recreation | 63 | 63 | 63 | 63 | 63 | 63 | 63 |
| Single Family Residential | 72 | 72 | 72 | 72 | 72 | 72 | 72 |
| Undeveloped | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
| | 60 | 60 | 83 | 62 | 64 | 73 | 66 |

Based on soil types and watershed % impervious area

Table B.51: CATEGORICAL % Impervious by Landuse for Wilkinson Lake Subwatershed

| Landuse Category | Anoka County | Lino Lakes City MS4 | MNDOT | North Oaks City MS4 | Ramsey County | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|
| Agricultural | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| Commercial | 85% | 85% | 85% | 85% | 85% | 85% | 85% |
| Industrial | 80% | 80% | 80% | 80% | 80% | 80% | 80% |
| Institutional | 20% | 20% | 20% | 20% | 20% | 20% | 20% |
| Major Highway | 47% | 47% | 47% | 47% | 47% | 47% | 47% |
| Mixed Use | 85% | 85% | 85% | 85% | 85% | 85% | 85% |
| Multi-Family Residential | 37% | 37% | 37% | 37% | 37% | 37% | 37% |
| Open Water | | | | | | | |
| Park and Recreation | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| Single Family Residential | 30% | 30% | 30% | 30% | 30% | 30% | 30% |
| Undeveloped | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Overall % Impervious | 8% | 5% | 47% | 11% | 14% | 35% | 20% |
| Overall Impervious Area (ac) | 0.79 | 11.56 | 34.42 | 141.50 | 7.27 | 54.41 | 214.28 |

Table B.52: Wilkinson Lake P8 Input

| Subwatershed | Area (ac) | Landuse Type: | Landuse area (ac) | %Imperv | Perv CN | |
|---|---|---|---|---|---|---|
| Wilkinson 2007904 | 3069.94 | Agricultural | 157.40 | 5 | 61 | |
| | | Commercial | 29.85 | 85 | 69 | |
| | | Industrial | 124.71 | 80 | 69 | |
| | | Institutional | 32.57 | 20 | 61 | |
| | | Major Highway | 74.40 | 98 | 69 | |
| | | Mixed Use | 29.86 | 85 | 69 | |
| | | Multi-Family Residential | 74.41 | 37 | 61 | |
| **Wilkinson** | 97.1 | Open Water | 49.03 | | | |
| | | Park and Recreation | 896.26 | 5 | 61 | |
| | 3069.94 | Single Family Residential | 639.32 | 30 | 61 | |
| | | Undeveloped | 865.01 | 0 | 55 | |
| | | **Total** | 2972.84 | 16.9 | 58.9 | |
| | | Direct | | 8.44 | | |
| | | Indirect | | 8.44 | | split 50/50 |

Table B.53: SUMMARY DATA FOR Lambert Creek Subwatershed

| Lambert Creek | Gem Lake City MS4 | MNDOT | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 | Overall | |
|---|---|---|---|---|---|---|---|---|
| Resultant CN | 73 | 86 | 76 | 74 | 75 | 64 | 73 | |
| Resultant Area (ac) | 174.4 | 79.2 | 101.3 | 1914.4 | 794.1 | 594.5 | 3658.0 | |
| % Area | 4.8% | 2.2% | 2.8% | 52.3% | 21.7% | 16.3% | 100.0% | |
| Overall % Impervious | 0% | 0% | 0% | 0% | 0% | 0% | 0% | <--Calculate SRO using SCS Method=(P-0.2S)^2/(P+0.8S) |
| Overall Impervious Area (ac) | 0.16 | 0.59 | 0.30 | 0.22 | 0.33 | 0.21 | 0.00 | Where S=(1000/CN)-10 |
| S | 3.68 | 1.62 | 3.17 | 3.45 | 3.41 | 5.56 | 3.70 | And Runoff Event P (inches)= 1.5 |
| SRO (inches) | 0.131 | 0.494 | 0.185 | 0.154 | 0.158 | 0.025 | 1.147 | |
| SRO (ac-ft) | 22.85 | 39.17 | 18.77 | 293.99 | 125.32 | 15.02 | 515.11 | |
| SRO % | 4.44% | 7.60% | 3.64% | 57.07% | 24.33% | 2.92% | 100.00% | |

Table B.54: Lambert Creek Overall CN calcs

| Waterbody | Subwatershed ID | **Landuse Type:** | Area (ac) | Impervious Area (%) | Impervious Area (ac) | Impervous CN | Pervious Area (%) | Pervious Area (ac) | Pervious CN | Resultant CN-Categorical CN for Lambert Creek Sub by Landuse |
|---|---|---|---|---|---|---|---|---|---|---|
| Lambert Creek | 20115055 | Agricultural | 26.87 | 12% | 3.22 | 98 | 88% | 23.65 | 61 | 65 |
| Lambert Creek | 20115055 | Commercial | 122.25 | 85% | 103.91 | 98 | 15% | 18.34 | 69 | 94 |
| Lambert Creek | 20115055 | Industrial | 146.22 | 80% | 116.98 | 98 | 20% | 29.24 | 69 | 92 |
| Lambert Creek | 20115055 | Institutional | 103.49 | 30% | 31.05 | 98 | 70% | 72.44 | 61 | 72 |
| Lambert Creek | 20115055 | Major Highway | 97.15 | 59% | 57.13 | 98 | 41% | 40.03 | 69 | 86 |
| Lambert Creek | 20115055 | Mixed Use | 11.86 | 34% | 4.03 | 98 | 66% | 7.83 | 64 | 76 |
| Lambert Creek | 20115055 | Multi-Family Residential | 248.99 | 37% | 92.13 | 98 | 63% | 156.86 | 61 | 75 |
| Lambert Creek | 20115055 | Open Water | 92.14 | 0% | 0.00 | 98 | 100% | 92.14 | | 0 |
| Lambert Creek | 20115055 | Park and Recreation | 263.86 | 12% | 31.66 | 98 | 88% | 232.20 | 55 | 60 |
| Lambert Creek | 20115055 | Single Family Residential | 1602.03 | 30% | 480.61 | 98 | 70% | 1121.42 | 61 | 72 |
| Lambert Creek | 20115055 | Undeveloped | 943.07 | 0% | 0.00 | 98 | 100% | 943.07 | 78 | 78 |
| | | total | 3657.95 | | 920.72 | | | 2737.23 | | |
| | | | | | 25.17% | | | 74.83% | | |

Table B.55: Lambert Creek Area of Landuse Category by MS4 (acres)

| Landuse Category | TOTAL | Gem Lake City MS4 | MNDOT | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|---|
| Agricultural | 26.87 | | | 2.94 | 23.93 | | |
| Commercial | 122.25 | | | 8.26 | 77.63 | 35.39 | 0.98 |
| Industrial | 146.22 | | | 3.56 | 35.43 | 56.85 | 50.38 |
| Institutional | 103.49 | 1.72 | | 4.81 | 16.07 | 78.04 | 2.85 |
| Major Highway | 97.15 | | 79.24 | 7.17 | 3.91 | 6.83 | |
| Mixed Use | 11.86 | | | 0.12 | 7.45 | 0.42 | 3.87 |
| Multi-Family Residential | 248.99 | | | 4.57 | 131.35 | 41.16 | 71.92 |
| Open Water | 92.14 | | | | 1.32 | 0.38 | 90.44 |
| Park and Recreation | 263.86 | 18.96 | | 7.58 | 168.00 | 40.48 | 28.84 |
| Single Family Residential | 1602.03 | 86.30 | | 39.66 | 819.44 | 475.94 | 180.69 |
| Undeveloped | 943.07 | 67.39 | | 22.66 | 629.85 | 58.62 | 164.55 |
| TOTAL | 3657.95 | 174.38 | 79.24 | 101.33 | 1914.37 | 794.12 | 594.52 |

Based on soil types and watershed % impervious area

Table B.56: CATEGORICAL CNs by Landuse for Lambert Creek Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|
| Agricultural | 65 | 65 | 65 | 65 | 65 | 65 |
| Commercial | 94 | 94 | 94 | 94 | 94 | 94 |
| Industrial | 92 | 92 | 92 | 92 | 92 | 92 |
| Institutional | 72 | 72 | 72 | 72 | 72 | 72 |
| Major Highway | 86 | 86 | 86 | 86 | 86 | 86 |
| Mixed Use | 76 | 76 | 76 | 76 | 76 | 76 |
| Multi-Family Residential | 75 | 75 | 75 | 75 | 75 | 75 |
| Open Water | 0 | 0 | 0 | 0 | 0 | 0 |
| Park and Recreation | 60 | 60 | 60 | 60 | 60 | 60 |
| Single Family Residential | 72 | 72 | 72 | 72 | 72 | 72 |
| Undeveloped | 78 | 78 | 78 | 78 | 78 | 78 |
| Composite CN | 73 | 86 | 76 | 74 | 75 | 64 |

Table B.57: CATEGORICAL % Impervious by Landuse for Lambert Creek Subwatershed

| Landuse Category | Gem Lake City MS4 | MNDOT | Ramsey County | Vadnais Heights City MS4 | White Bear Lake City MS4 | White Bear Township MS4 |
|---|---|---|---|---|---|---|
| Agricultural | 12% | 12% | 12% | 12% | 12% | 12% |
| Commercial | 85% | 85% | 85% | 85% | 85% | 85% |
| Industrial | 80% | 80% | 80% | 80% | 80% | 80% |
| Institutional | 30% | 30% | 30% | 30% | 30% | 30% |
| Major Highway | 59% | 59% | 59% | 59% | 59% | 59% |
| Mixed Use | 34% | 34% | 34% | 34% | 34% | 34% |
| Multi-Family Residential | 37% | 37% | 37% | 37% | 37% | 37% |
| Open Water | 0% | 0% | 0% | 0% | 0% | 0% |
| Park and Recreation | 12% | 12% | 12% | 12% | 12% | 12% |
| Single Family Residential | 30% | 30% | 30% | 30% | 30% | 30% |
| Undeveloped | 0% | 0% | 0% | 0% | 0% | 0% |
| Overall % Impervious | 16% | 59% | 30% | 22% | 33% | 21% |
| Overall Impervious Area (ac) | 28.68 | 46.59 | 30.42 | 421.44 | 266.01 | 127.58 |

**Notes (Appendix B Tables):**

Tables exclude lake surface area

Runoff from other open water was assumed to be approximatly equal to evaporation for P8 and for CN calcs.

# Appendix C

## Watershed Model Results (P8)

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**Table C.1: Gem Lake** 306.34 acres

| Year | Annual Runoff (in) | Annual Runoff Volume (ac-ft) | Annual TP Load (lbs) | Average Annual Concentration (ug/L) | Areal Export Rate (lbs/acre/yr) |
|---|---|---|---|---|---|
| 2000 | 2.1 | 54 | 67 | 339 | 0.218 |
| 2001 | 3.4 | 87 | 90 | 311 | 0.294 |
| 2002 | 4.9 | 125 | 117 | 310 | 0.383 |
| 2003 | 2.1 | 54 | 66 | 328 | 0.217 |
| 2004 | 4.4 | 112 | 89 | 247 | 0.291 |
| 2005 | 4.3 | 110 | 103 | 285 | 0.336 |
| 2007 | 2.9 | 74 | 79 | 319 | 0.256 |
| 2008 | 2.3 | 59 | 68 | 325 | 0.221 |
| 2009 | 2.2 | 56 | 71 | 349 | 0.231 |
| Average | 3.2 | 81 | 83 | 312 | 0.272 |
| | | | Stdev | 31 | |
| | | | Average - Stdev= | 282 | |

Note (Table C.1): For the Gem Lake Canfield Bachmann modeling, the low end of the Stdev range for the average annual concentration was used to calibrate the model (282 ug/L). This concentration equates to a load of 62.1 lbs/yr or 0.203 lbs/acre/yr.

**Table C.2: East Goose Lake** 577.55 acres

| Year | Annual Runoff (in) | Annual Runoff Volume (ac-ft) | Annual TP Load (lbs) | Average Annual Concentration (ug/L) | Areal Export Rate (lbs/acre/yr) |
|---|---|---|---|---|---|
| 2007 | 4.4 | 213 | 171 | 295 | 0.297 |
| 2008 | 3.8 | 184 | 148 | 294 | 0.255 |
| 2009 | 3.8 | 184 | 157 | 314 | 0.273 |
| 2010* | 10.1 | 489 | 380 | 285 | 0.658 |
| Average | 5.5 | 268 | 214 | 297 | 0.371 |

* Through 8/31/2010

**Table C.3: West Goose Lake** 238.78 acres

| Year | Annual Runoff (in) | Annual Runoff Volume (ac-ft) | Annual TP Load (lbs) | Average Annual Concentration (ug/L) | Areal Export Rate (lbs/acre/yr) |
|---|---|---|---|---|---|
| 2007 | 6.4 | 127 | 109 | 319 | 0.456 |
| 2008 | 5.5 | 109 | 95 | 220 | 0.396 |
| 2009 | 5.6 | 111 | 100 | 333 | 0.417 |
| 2010* | 10.6 | 211 | 163 | 289 | 0.683 |
| Average | 7.0 | 140 | 117 | 290 | 0.488 |

* Through 8/31/2010

**Table C.4: Gilfillan Lake** 531.35 acres

| Year | Annual Runoff (in) | Annual Runoff Volume (ac-ft) | Annual TP Load (lbs) | Average Annual Concentration (ug/L) | Areal Export Rate (lbs/acre/yr) |
|---|---|---|---|---|---|
| 2006 | 0.9 | 40 | 13 | 120 | 0.024 |
| 2007 | 1.1 | 49 | 17 | 129 | 0.031 |
| 2008 | 0.7 | 31 | 10 | 119 | 0.018 |
| 2009 | 0.7 | 31 | 11 | 133 | 0.020 |
| 2010 | 2.37 | 105 | 30 | 111 | 0.057 |
| Average | 1.2 | 51 | 16 | 122 | 0.030 |

**Table C.5: Wilkinson Lake (2007904)** 2972.82 acres

| Year | Annual Runoff (in) | Annual Runoff Volume (ac-ft) | Annual TP Load (lbs) | Average Annual Concentration (ug/L) | Areal Export Rate (lbs/acre/yr) |
|---|---|---|---|---|---|
| 2001 | 5.7 | 1423 | 1231 | 318 | 0.41 |
| 2002 | 5.1 | 1271 | 1075 | 311 | 0.36 |
| 2003 | 1.8 | 452 | 457 | 372 | 0.15 |
| 2004 | 4.6 | 1131 | 688 | 224 | 0.23 |
| 2005 | 4.2 | 1032 | 761 | 271 | 0.26 |
| 2007 | 2.9 | 729 | 571 | 288 | 0.19 |
| 2008 | 2.3 | 566 | 475 | 309 | 0.16 |
| 2009 | 2.0 | 502 | 492 | 360 | 0.17 |
| Average | 3.6 | 888 | 719 | 306 | 0.24 |

**Table C.6: Wilkinson Lake (2007901)**

| Year | Annual Runoff (in) | Annual Runoff Volume (ac-ft) | Annual TP Load (lbs) | Birch Lake Average Annual Concentration (ug/L) | Areal Export Rate (lbs/acre/yr) |
|---|---|---|---|---|---|
| 2001 | 9.9 | 427 | 56 | 48 | 0.087 |
| 2002 | 11.5 | 497 | 41 | 30 | 0.063 |
| 2003 | 5.7 | 246 | 15 | 23 | 0.024 |
| 2004 | 12.3 | 532 | 49 | 34 | 0.077 |
| 2005 | 11.8 | 507 | 28 | 20 | 0.043 |
| 2007 | 7.6 | 330 | 38 | 42 | 0.059 |
| 2008 | 6.7 | 289 | 26 | 33 | 0.041 |
| 2009 | 6.3 | 273 | 22 | 30 | 0.035 |
| Average | 9.0 | 388 | 34 | 33 | 0.053 |

Note (Table C.6): P8 modeling for the Birch Lake sub-watershed (517.89 acres excluding open water) was performed to determine annual runoff rates.  Runoff volumes were applied to the measured in lake concentrations for lake response modeling to determine the annual TP load to Wilkinson Lake in lbs.  This calculated annual load is presented in the table above.  The areal export rate reported was calculated using the entire sub-watershed area of 640.83 acres.

**Table C.7: Wilkinson Lake (2007903)**

| Year | Annual Runoff (in) | Annual Runoff Volume (ac-ft) | Annual TP Load (lbs) | Amelia Lake Average Annual Concentration (ug/L) | Areal Export Rate (lbs/acre/yr) |
|---|---|---|---|---|---|
| 2001 | 3.7 | 165 | 13 | 29 | 0.019 |
| 2002 | 5.1 | 225 | 21 | 34 | 0.030 |
| 2003 | 1.6 | 70 | 5 | 24 | 0.007 |
| 2004 | 5.1 | 226 | 14 | 23 | 0.020 |
| 2005 | 4.5 | 200 | 10 | 18 | 0.014 |
| 2007 | 2.6 | 115 | 30 | 95 | 0.043 |
| 2008 | 2.1 | 92 | 7 | 26 | 0.009 |
| 2009 | 2.0 | 88 | 15 | 61 | 0.021 |
| Average | 3.3 | 148 | 16 | 39 | 0.022 |

Note (Table C.7): P8 modeling for the Amelia Lake sub-watershed (533.47 acres excluding open water) was performed to determine annual runoff rates.  Runoff volumes were applied to the measured in lake concentrations for lake response modeling to determine the annual TP load to Wilkinson Lake in lbs.  This calculated annual load is presented in the table above.  The areal export rate reported was calculated using the entire sub-watershed area of 691.33 acres.

Notes (Tables C.1-C.7):

P8 model inputs for each modeled lake shed excluded all areas with an open water land use designation.  The P8 model outputs for annual runoff volume and TP concentration were applied to the lake shed area excluding only the actual lake area for lake response modeling.  Due to the slight difference in these lake shed areas, aerial export rates shown in Tables C.1-C.7 may vary slightly from those reported in Table B.11 (which were calculated from the lake response modeling results).

# Appendix D

## Subwatershed Air Photos, Landuse, and MS4 Maps for Each Impaired Water Body

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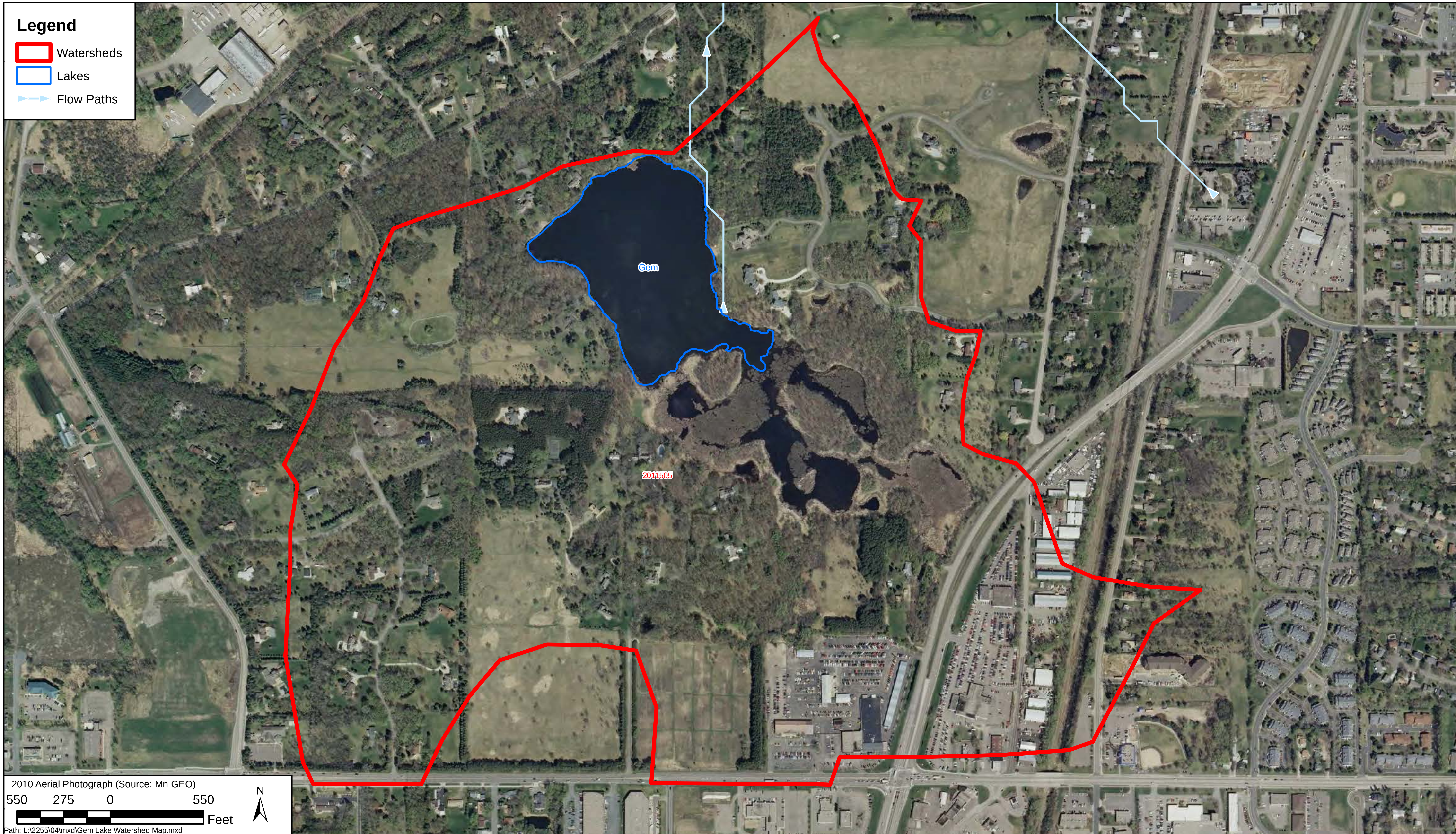


VADNAIS LAKE AREA WMO

Gem Lake Watershed

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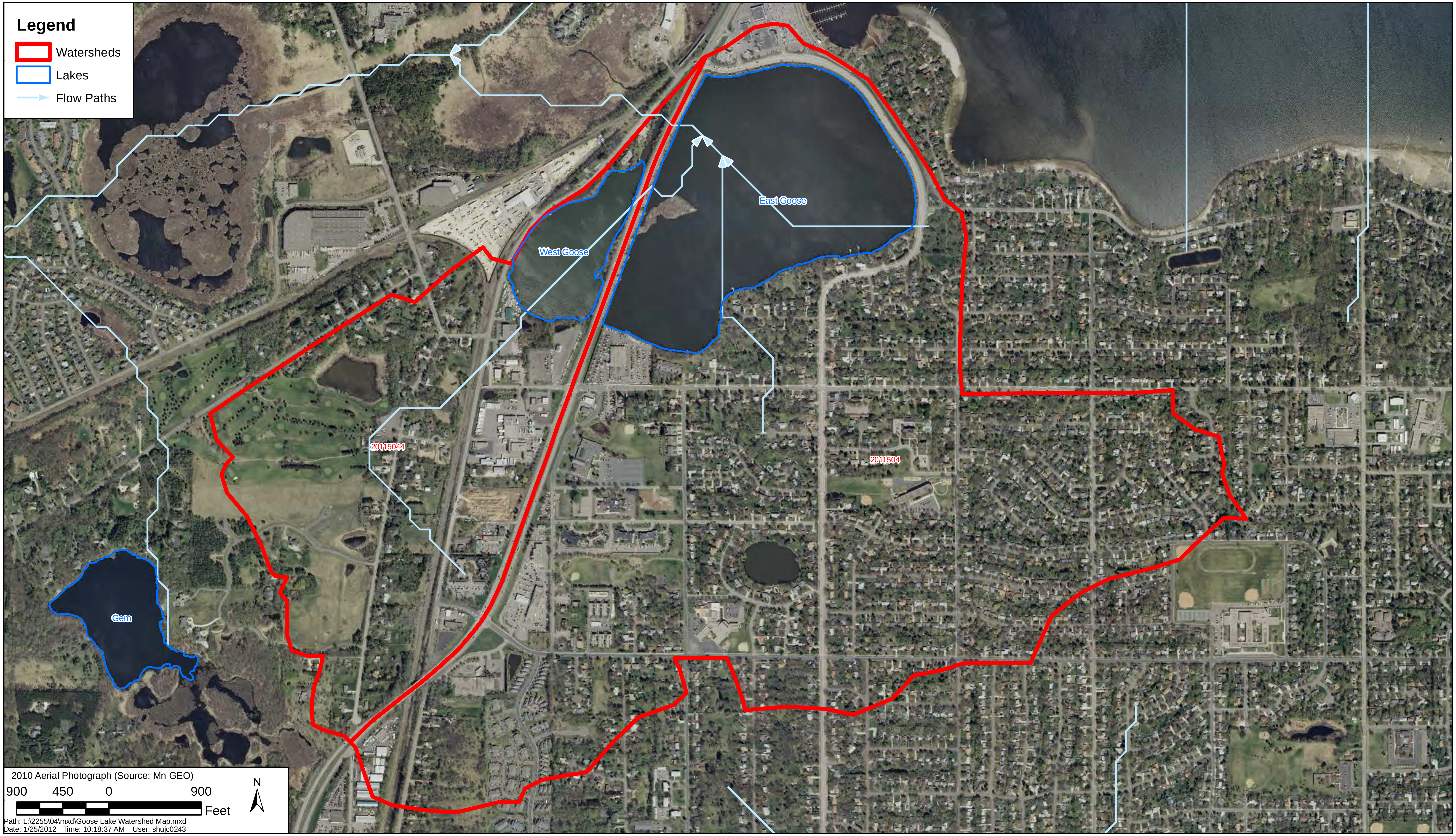
JAN 2012

Figure 1

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Goose Lake Watershed

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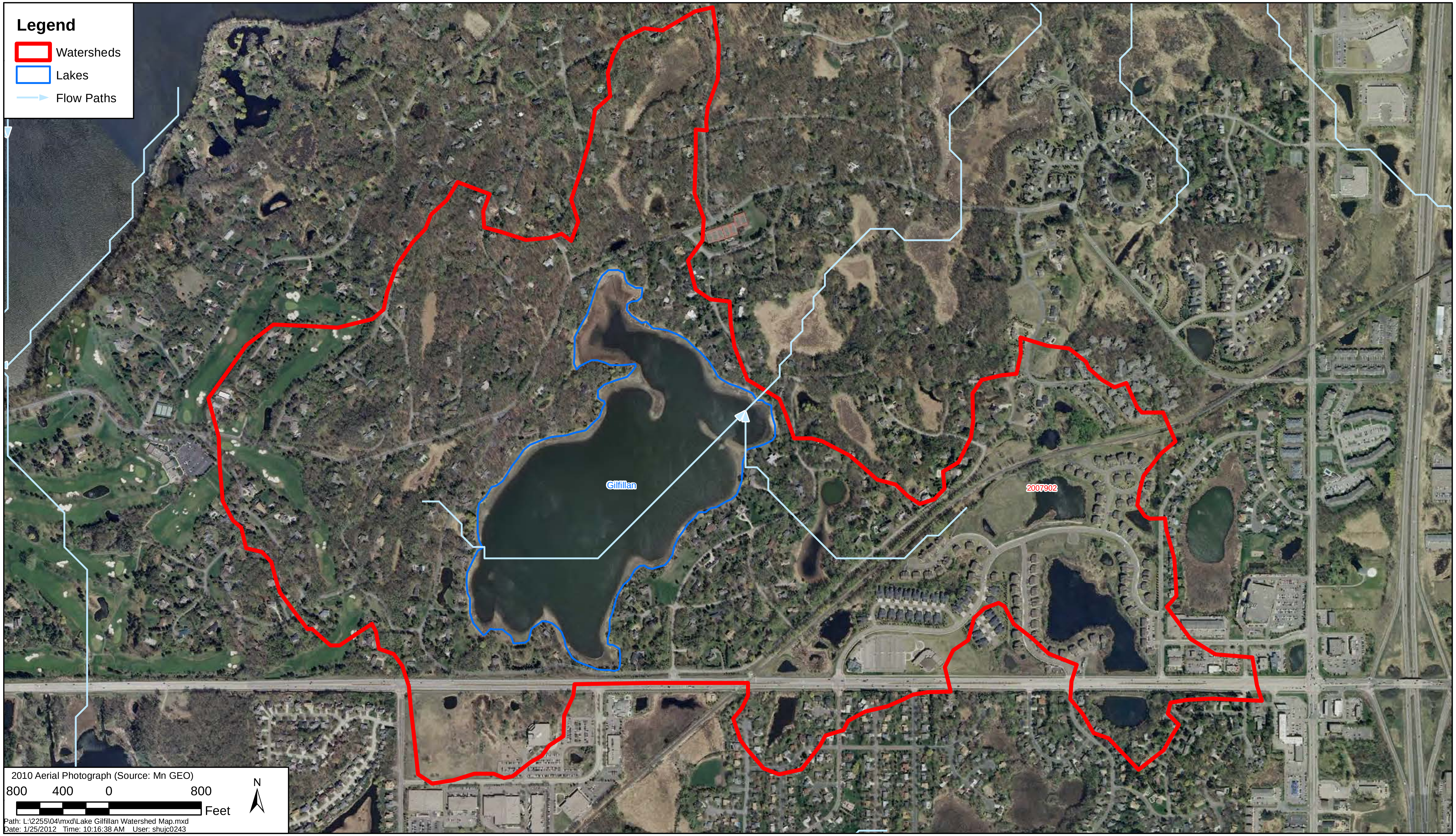
Figure 1

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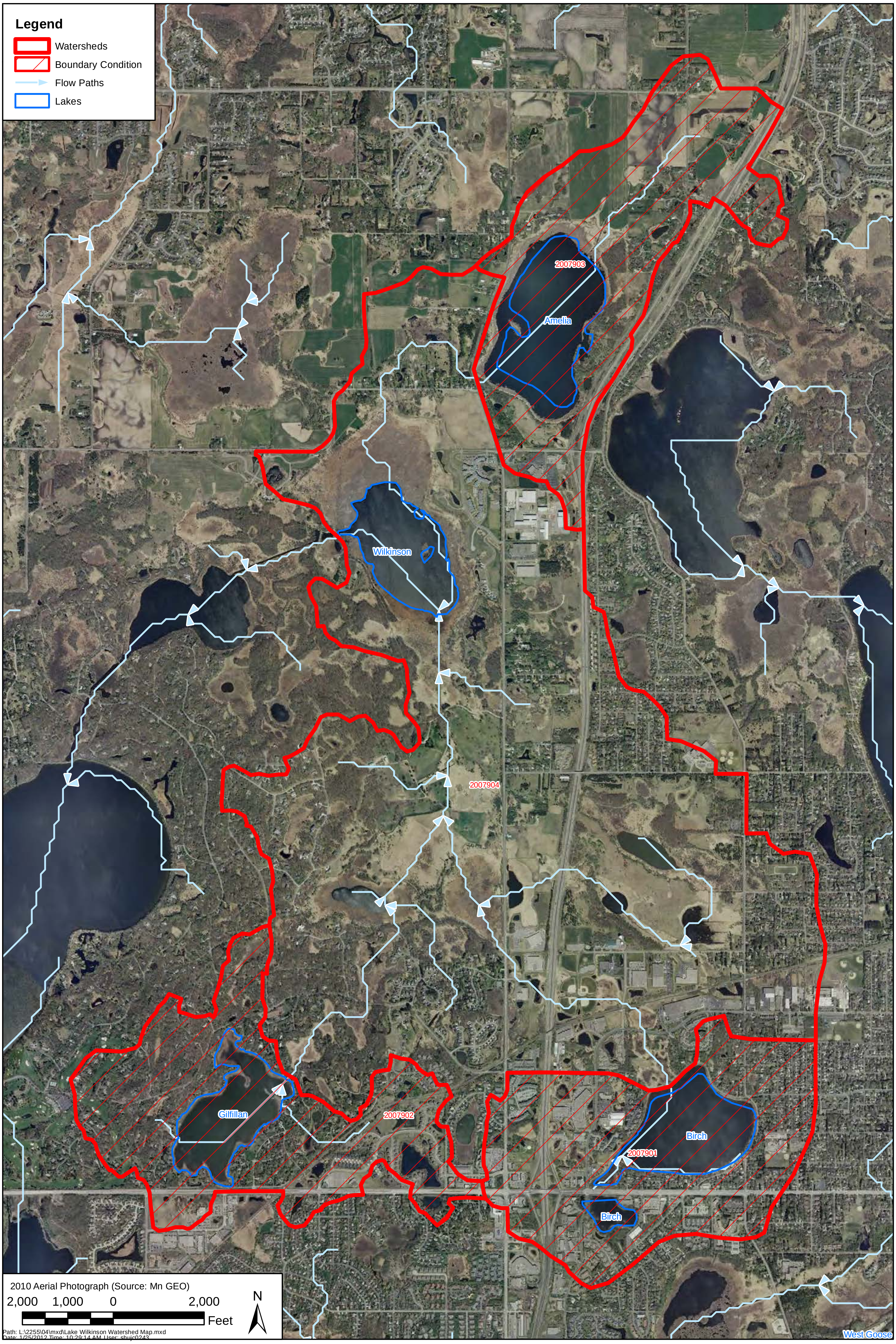
|---|---|---|
| Lake Gilfillan Watershed | | Figure 1 |

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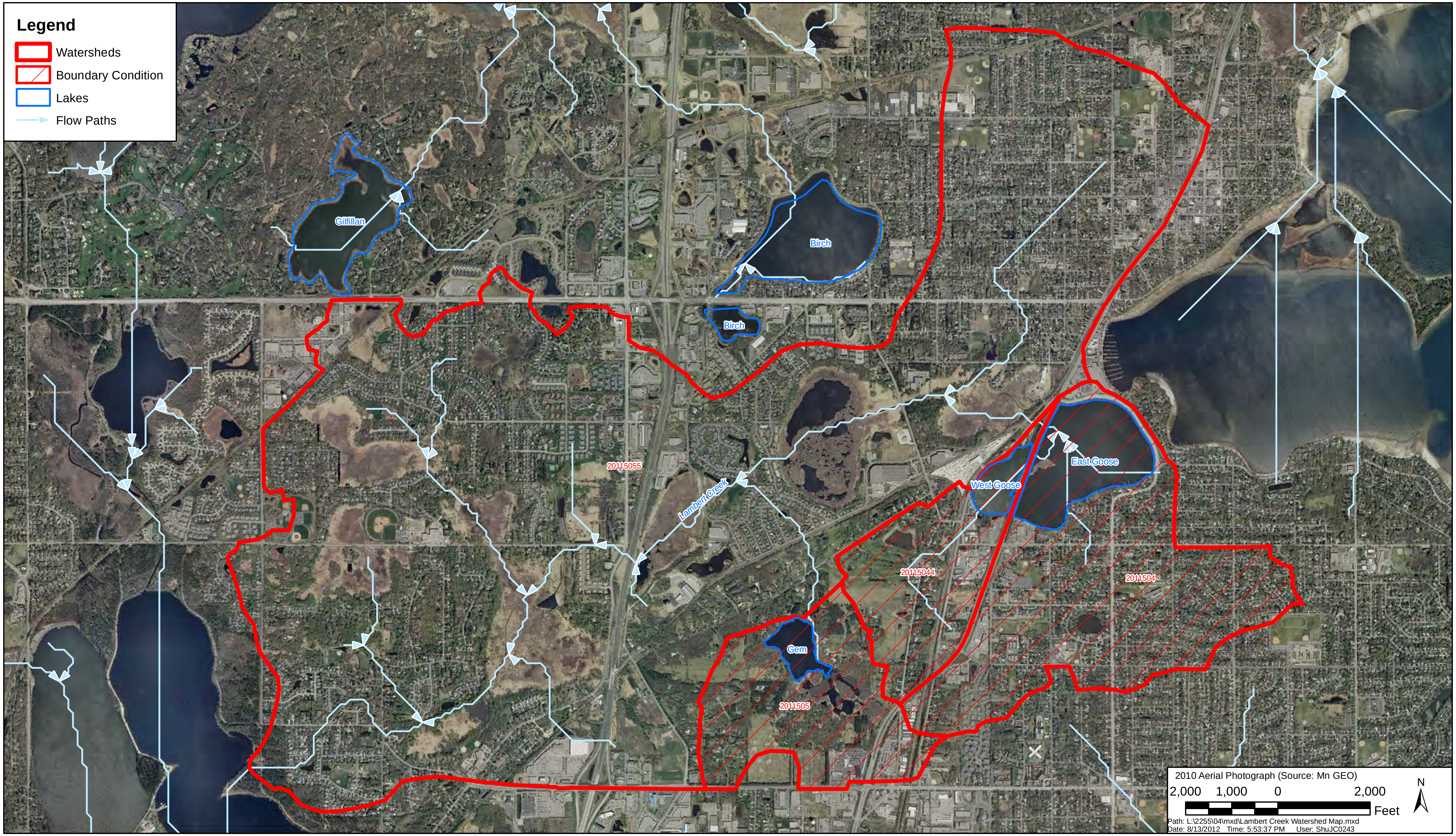
|---|---|---|---|
| Lake Wilkinson Watershed | | | Figure 1 |

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Lambert Creek Watershed

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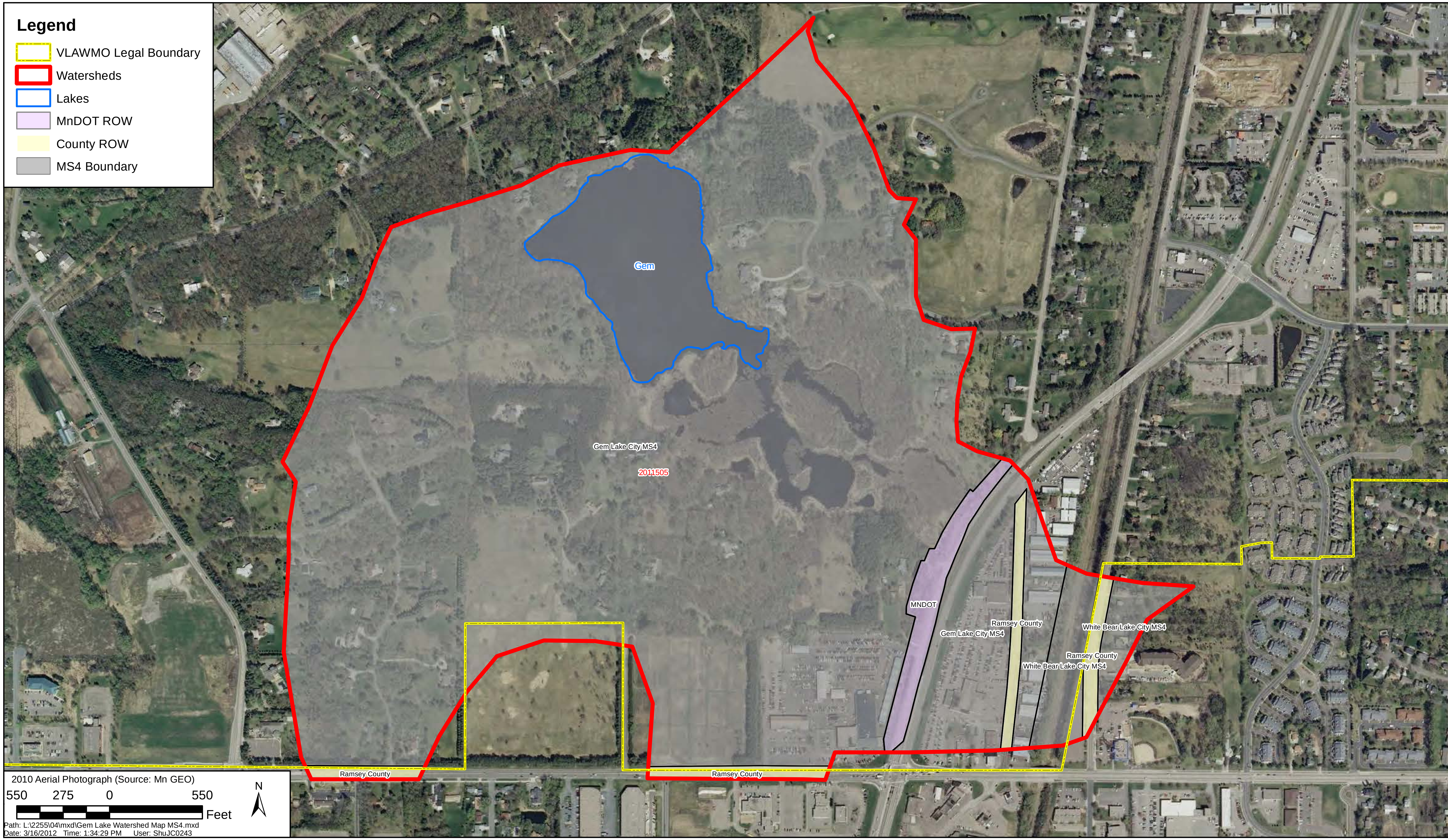
Figure 1




VADNAIS LAKE AREA WMO

Gem Lake Watershed and MS4 Boundary Map

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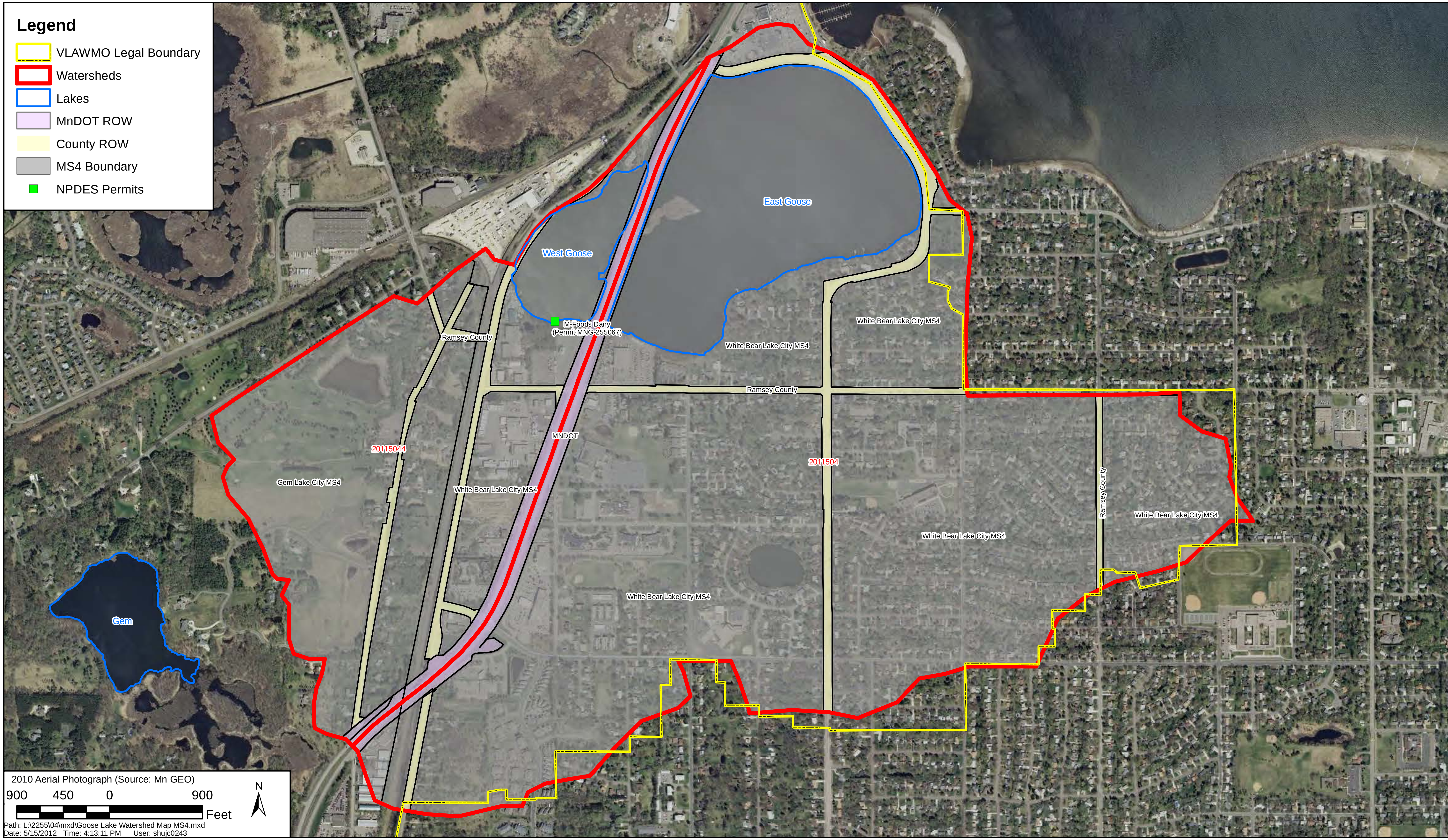
Figure 1




VADNAIS LAKE AREA WMO

Goose Lake Watershed and MS4 Boundary Map

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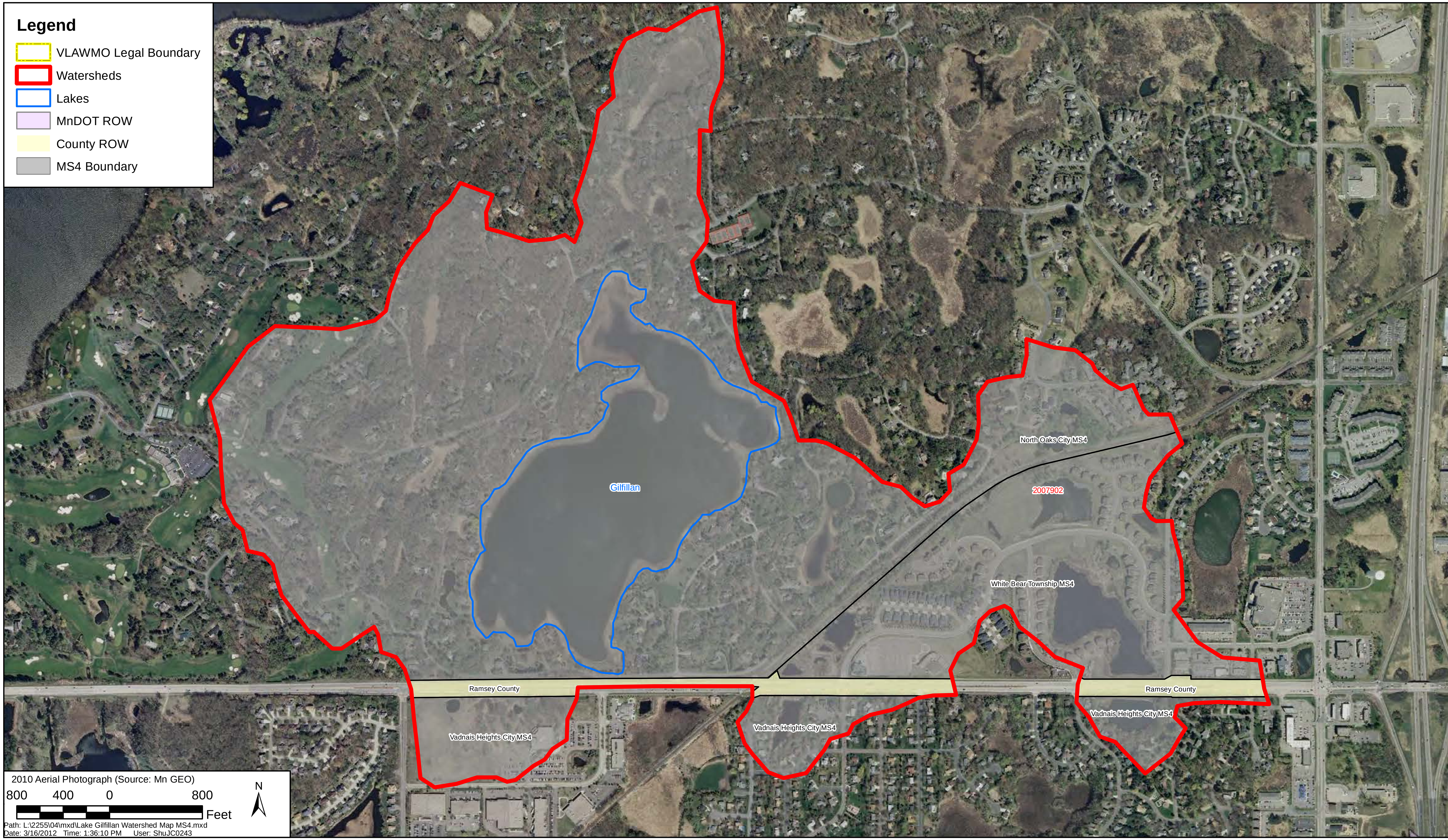
Figure 1




VADNAIS LAKE AREA WMO

Lake Gilfillan Watershed and MS4 Boundary Map

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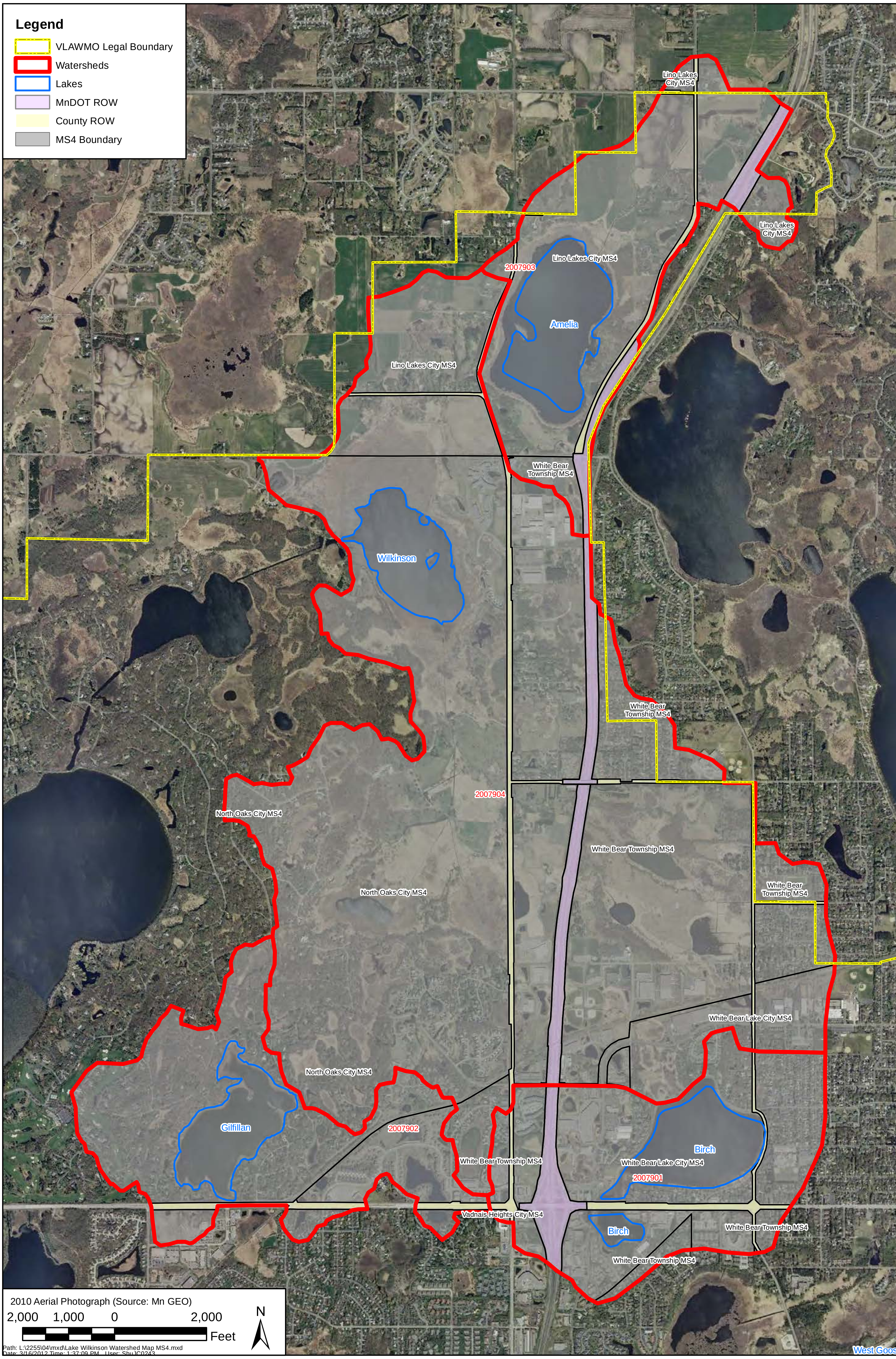
Figure 1




VADNAIS LAKE AREA WMO

Lake Wilkinson Watershed and MS4 Boundary Map

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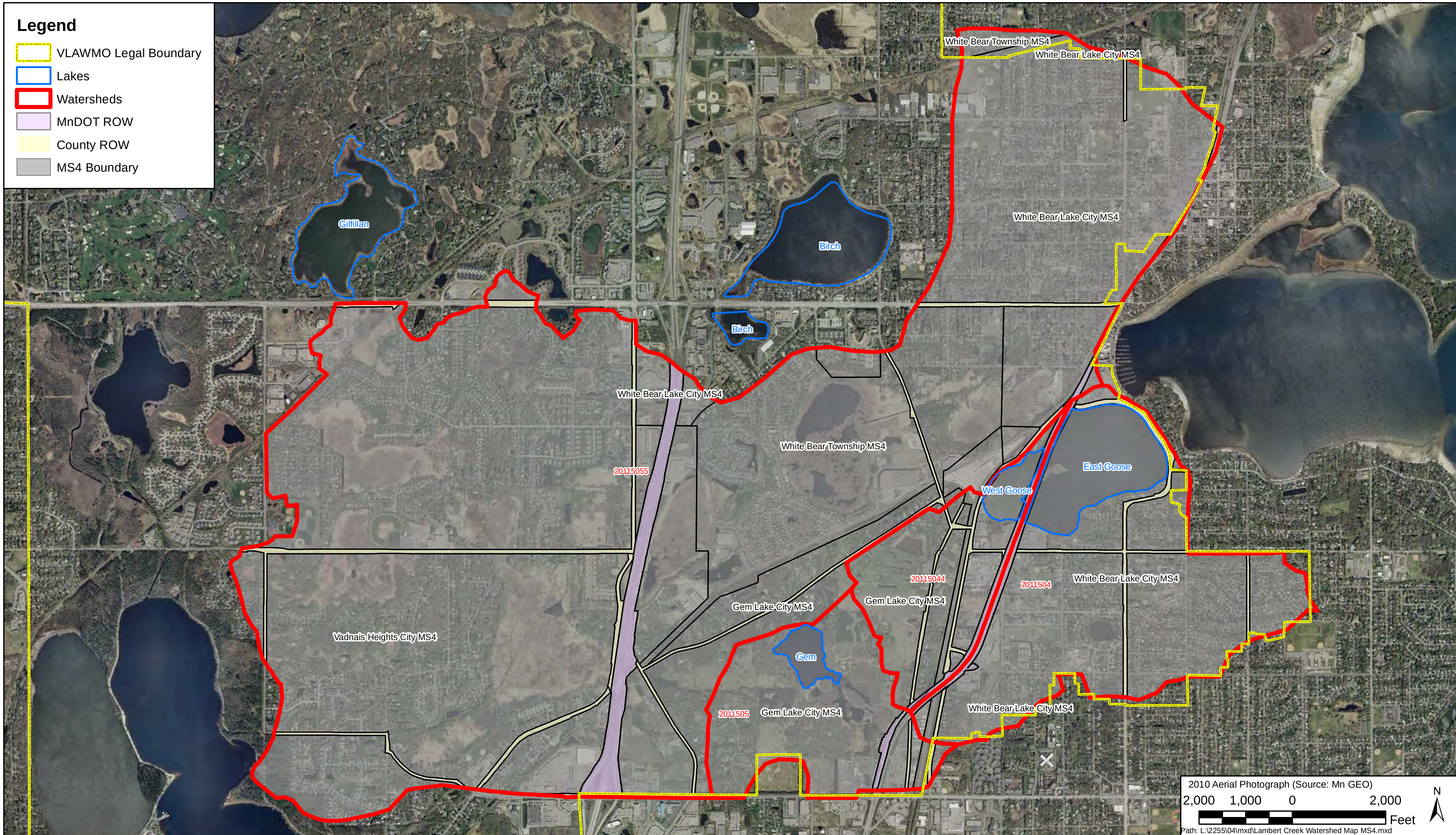
Figure 1




VADNAIS LAKE AREA WMO

Lambert Creek Watershed and MS4 Boundary Map

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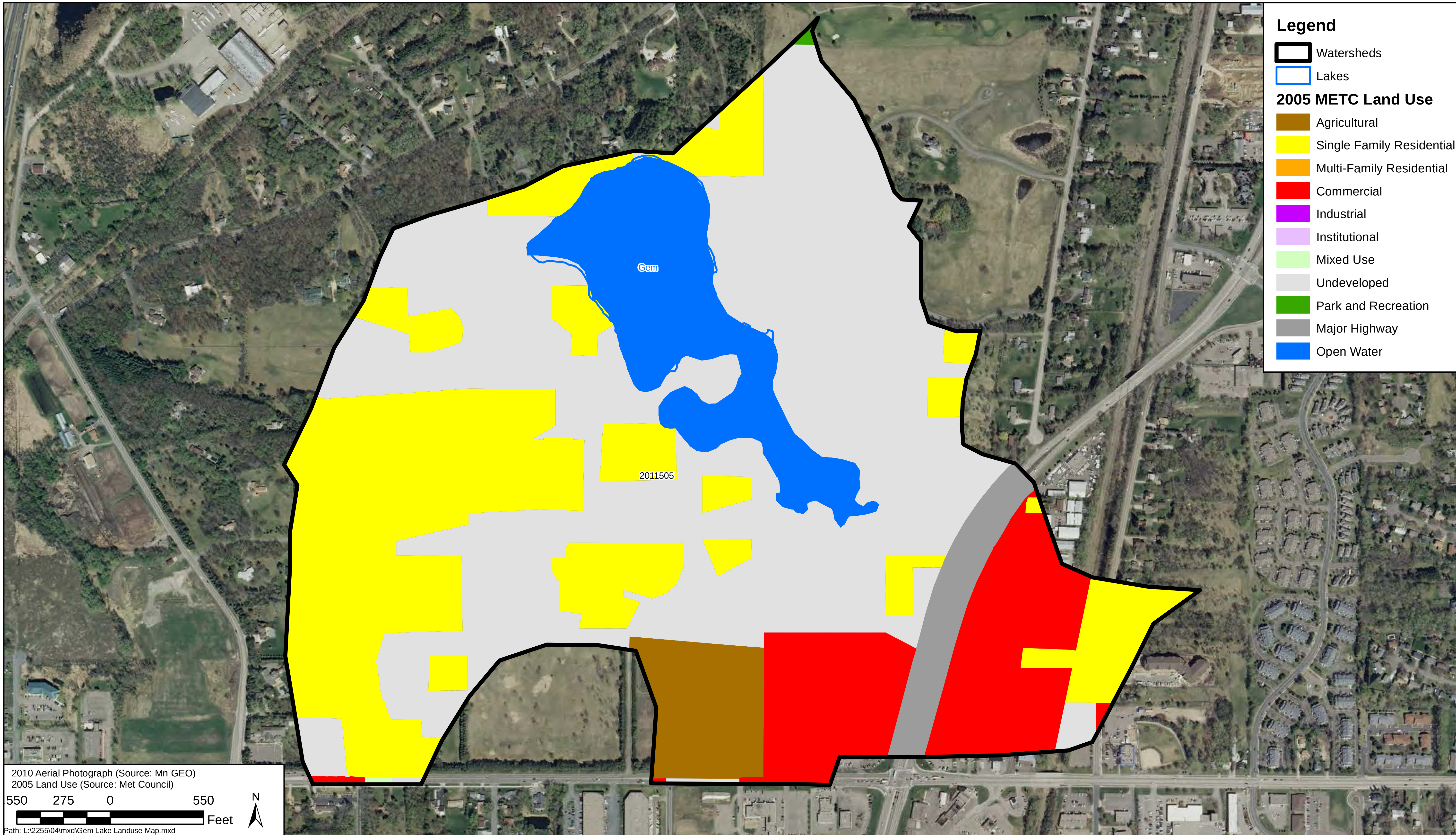
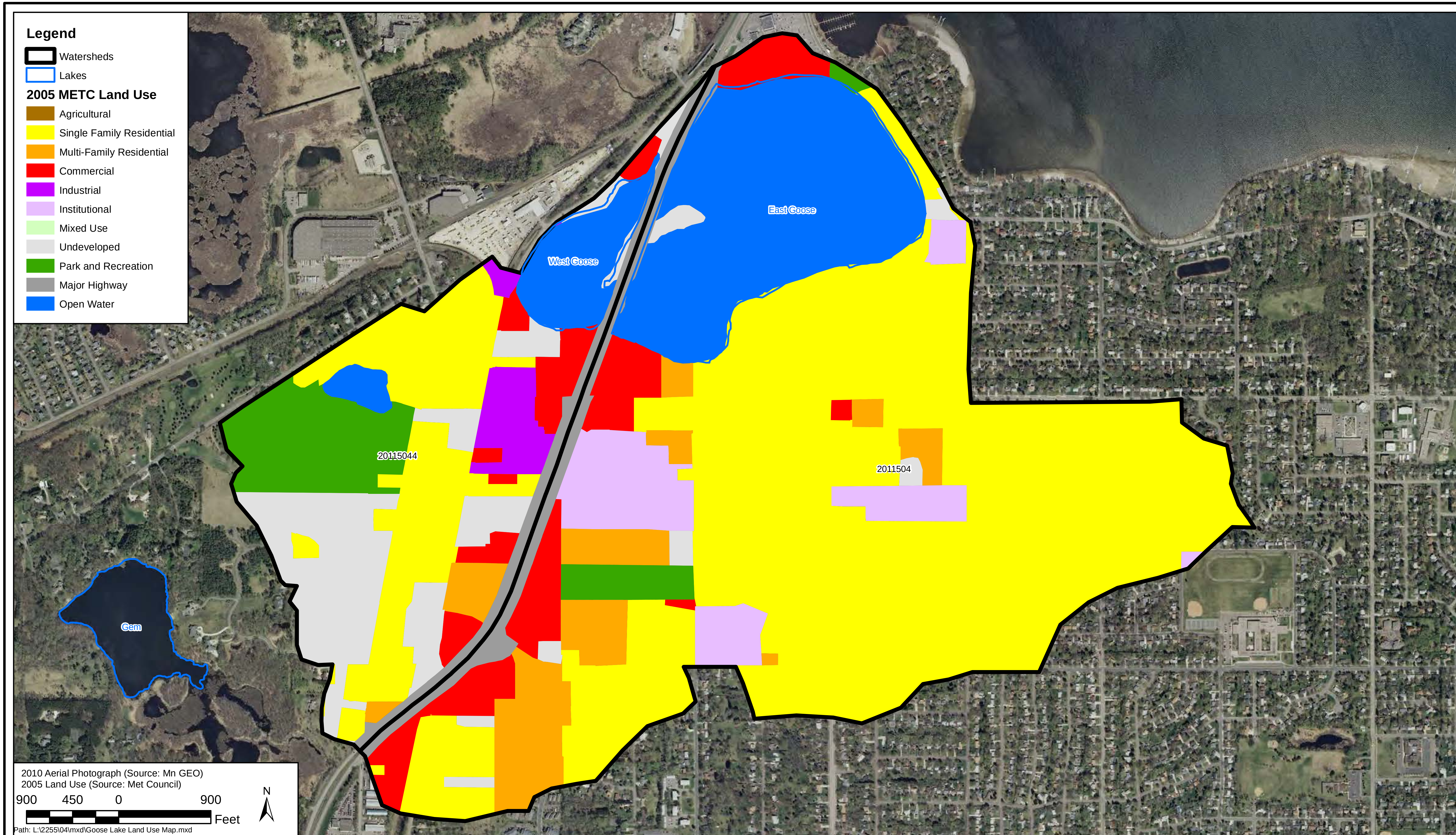
Figure 1




| VADNAIS LAKE AREA WMO | Wenck | NOV 2011 |
|---|---|---|
| Gem Lake Watershed 2005 Land Use | Engineers - Scientists<br>Business Professionals<br>www.wenck.com<br>1800 Pioneer Creek Center<br>Maple Plain, MN 55359-0429<br>1-800-472-2232 | Figure 1 |




VADNAIS LAKE AREA WMO

Goose Lake Watershed Land Use Map

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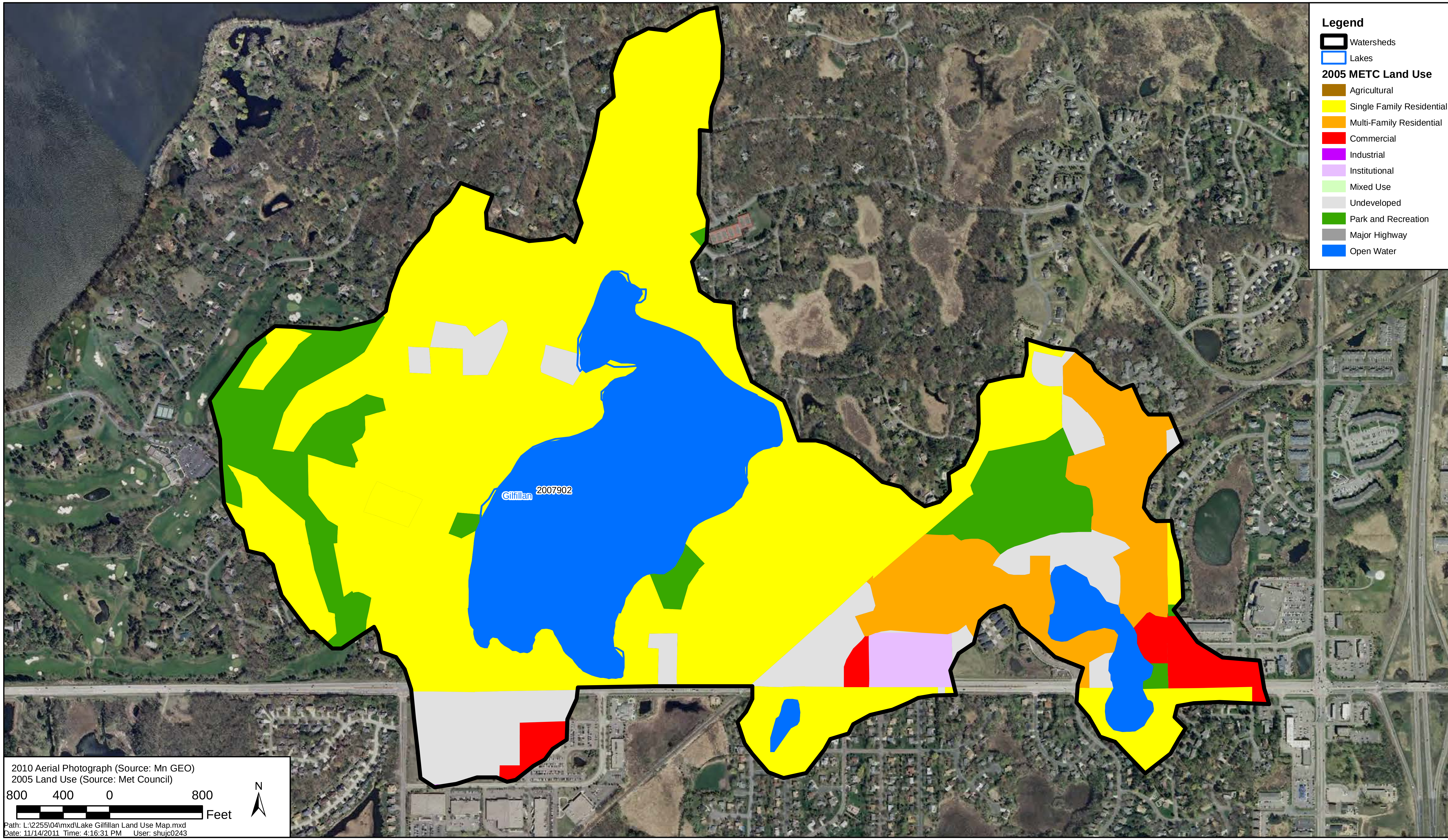
NOV 2011

Figure 1




VADNAIS LAKE AREA WMO

Lake Gilfillan Watershed Land Use Map

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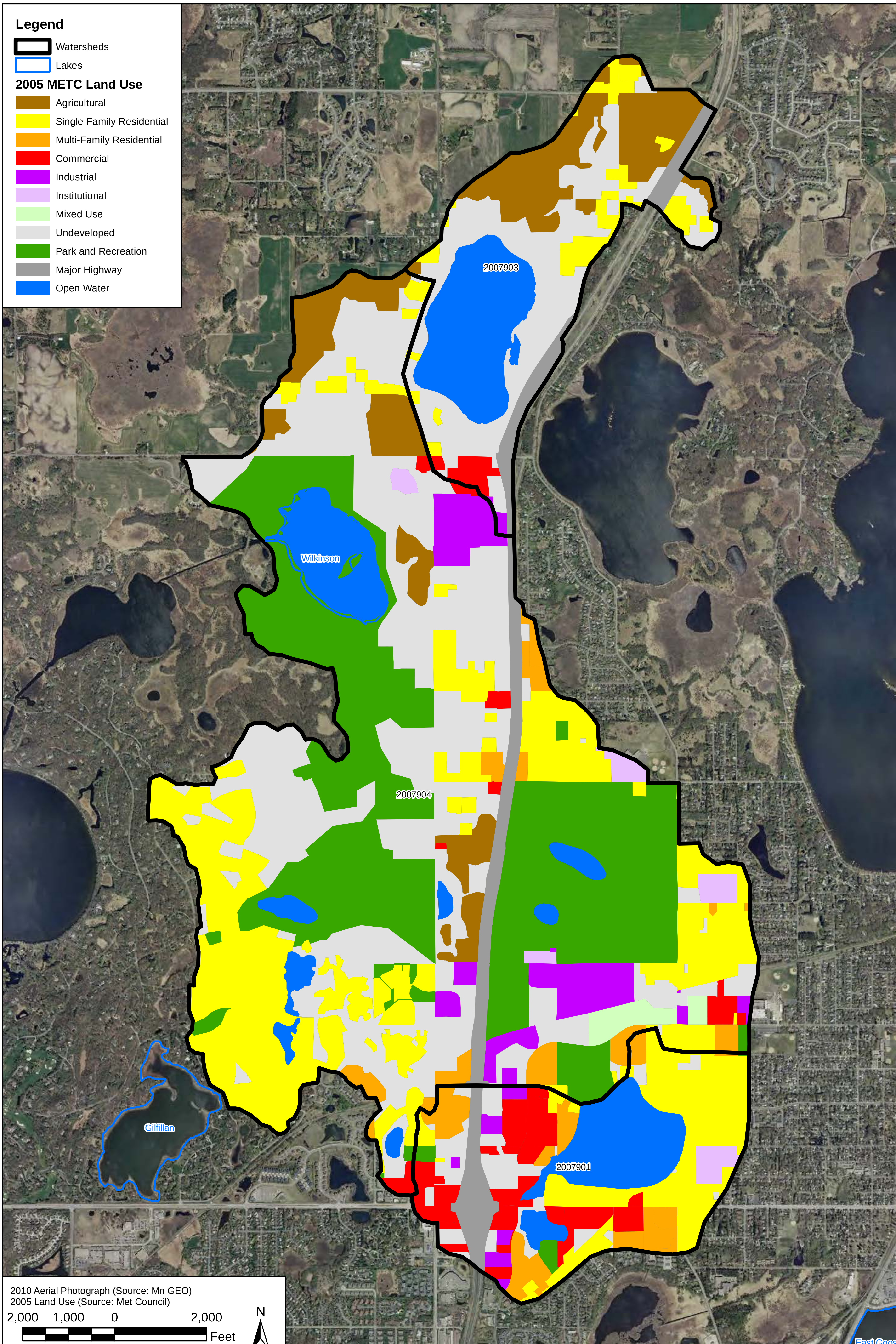
NOV 2011

Figure 1




VADNAIS LAKE AREA WMO

Lake Wilkinson Watershed Land Use Map

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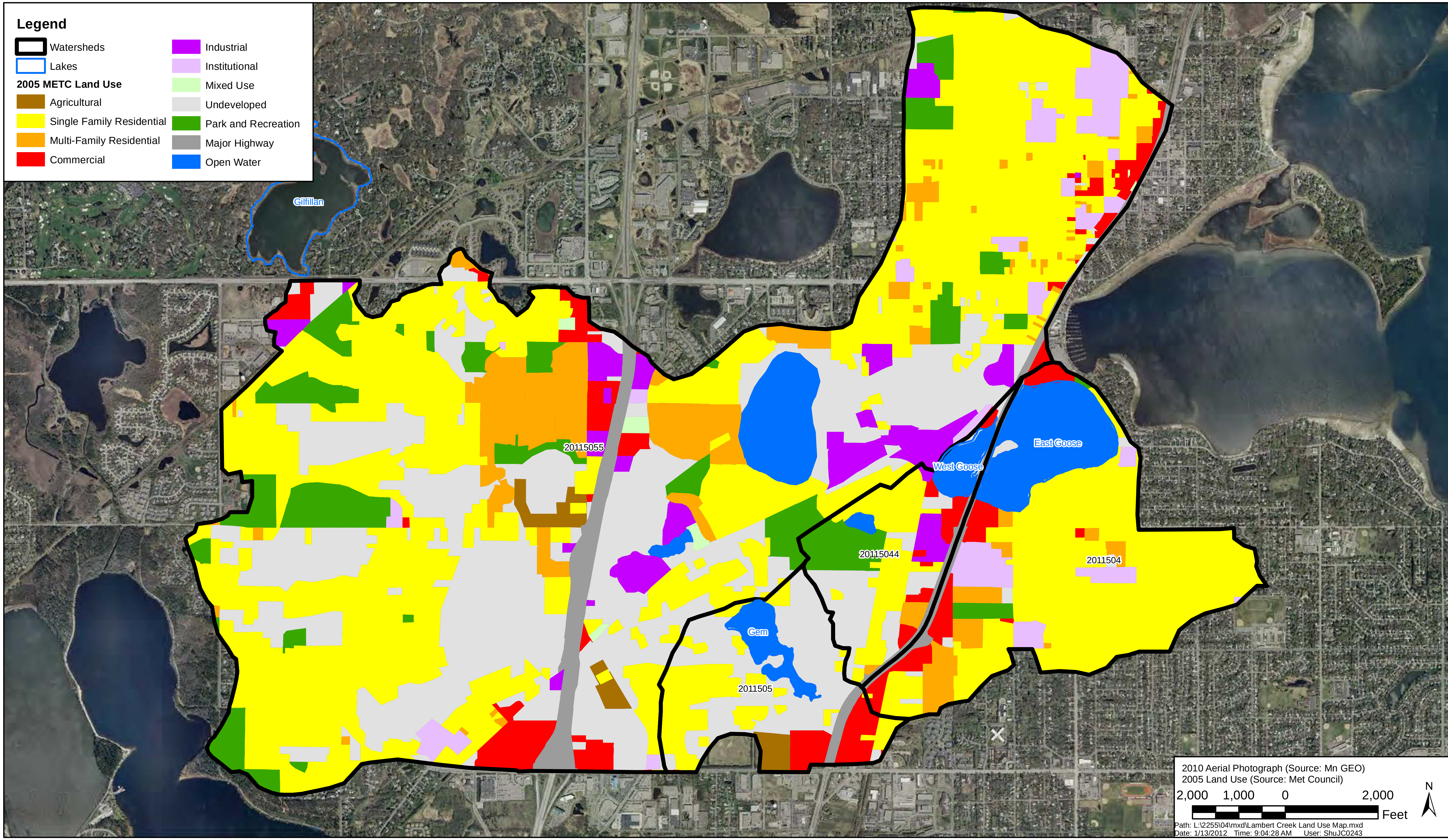
Figure 1




VADNAIS LAKE AREA WMO

Lambert Creek Watershed Land Use Map

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Figure 1

# Appendix E

## VLAWMO Informal Plant Surveys for Impaired Lakes Map Results

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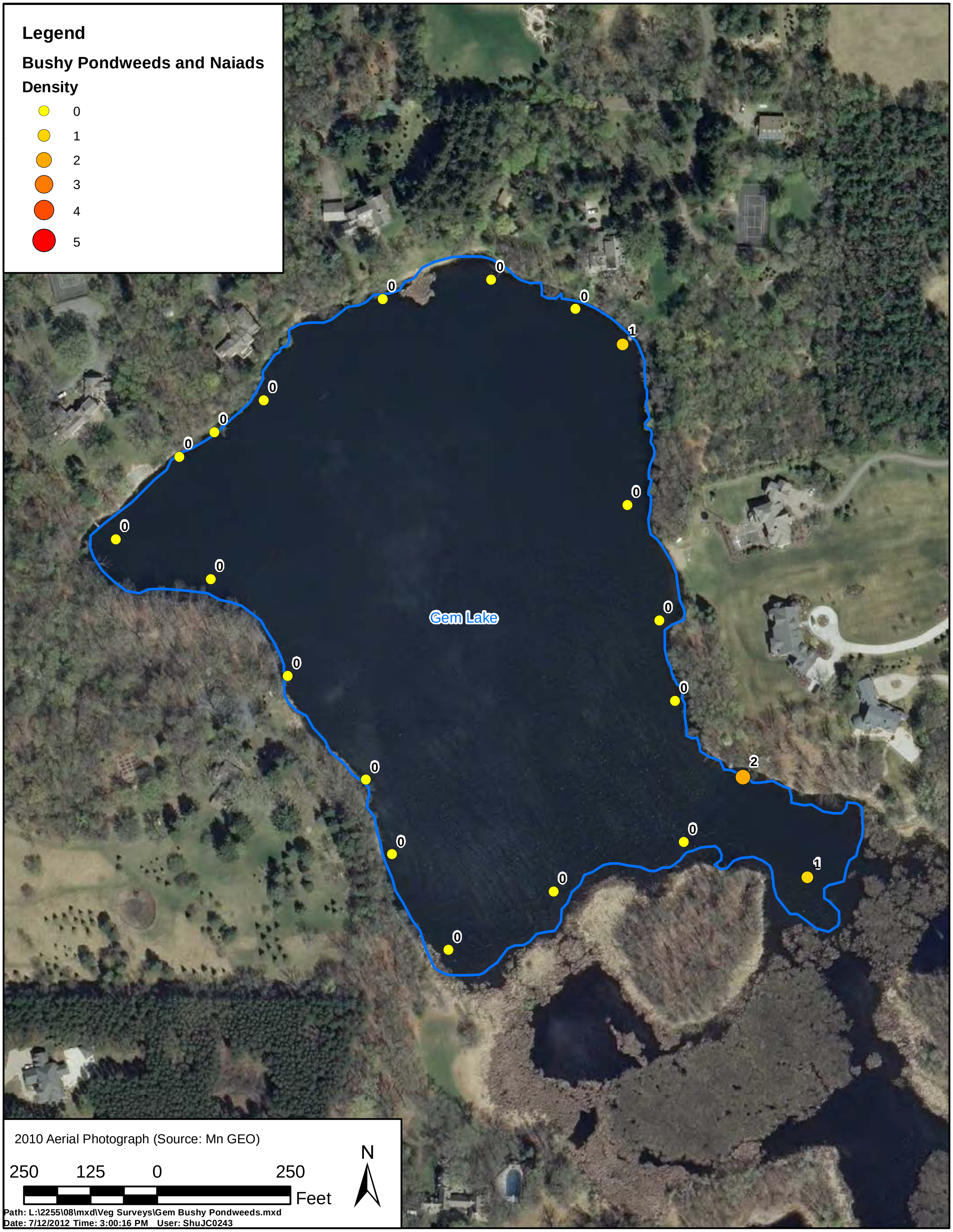


VADNAIS LAKE AREA WMO

Gem Lake- Bushy Pondweeds and Naiads

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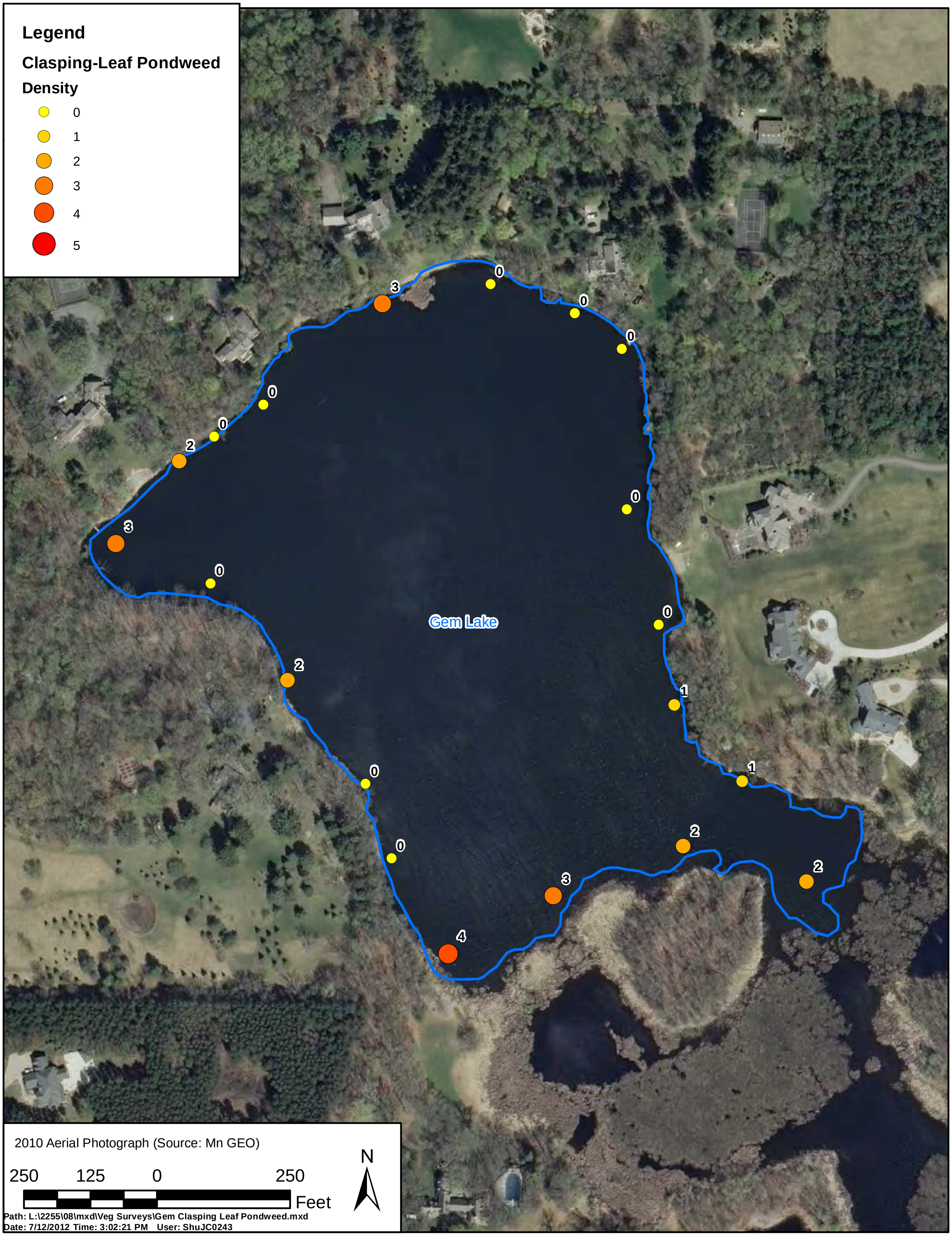


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Gem Lake- Clasping Leaf Pondweed

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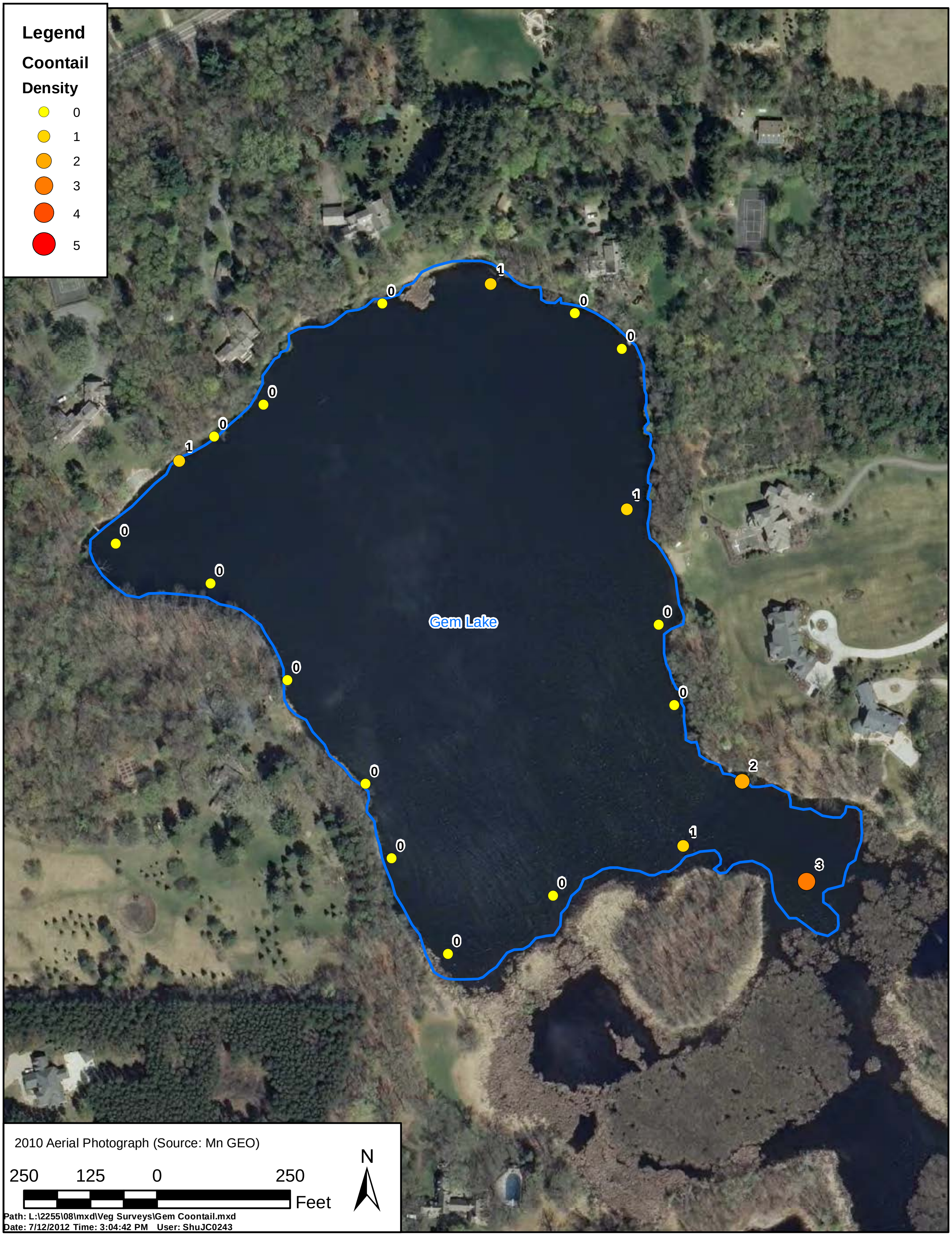


VADNAIS LAKE AREA WMO

Gem Lake- Coontail

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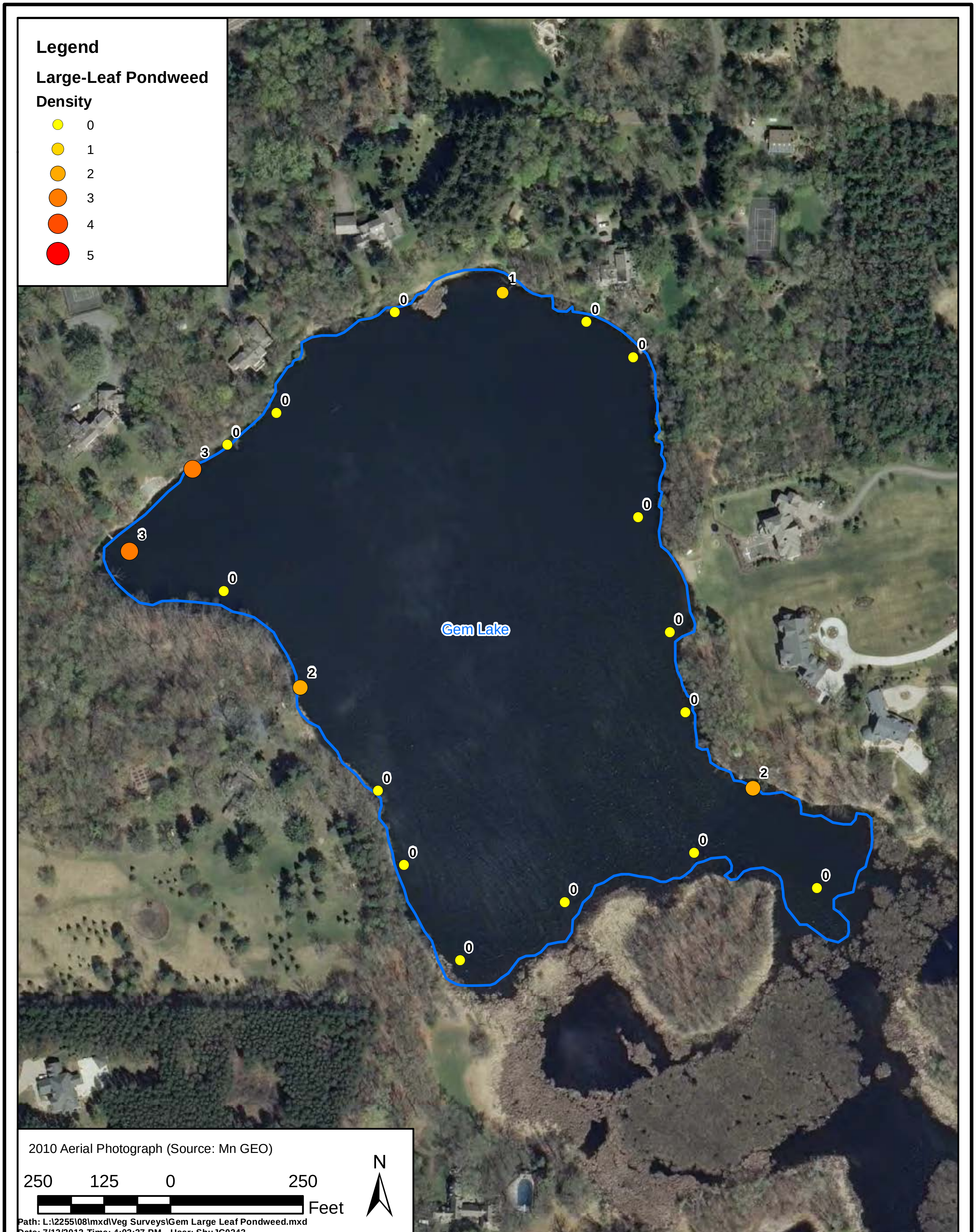


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Gem Lake- Large Leaf Pondweed

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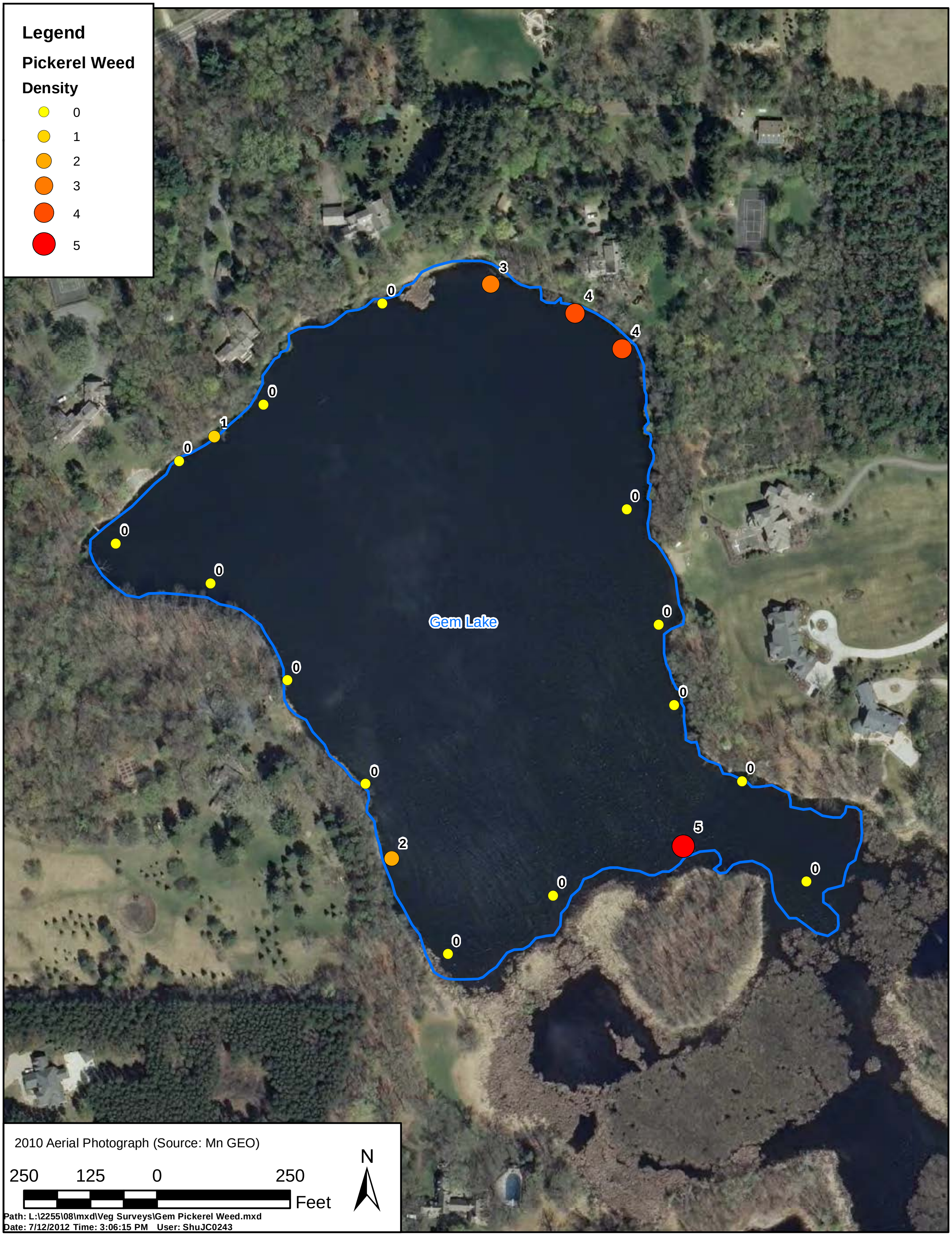


| | | | |
|---|---|---|---|
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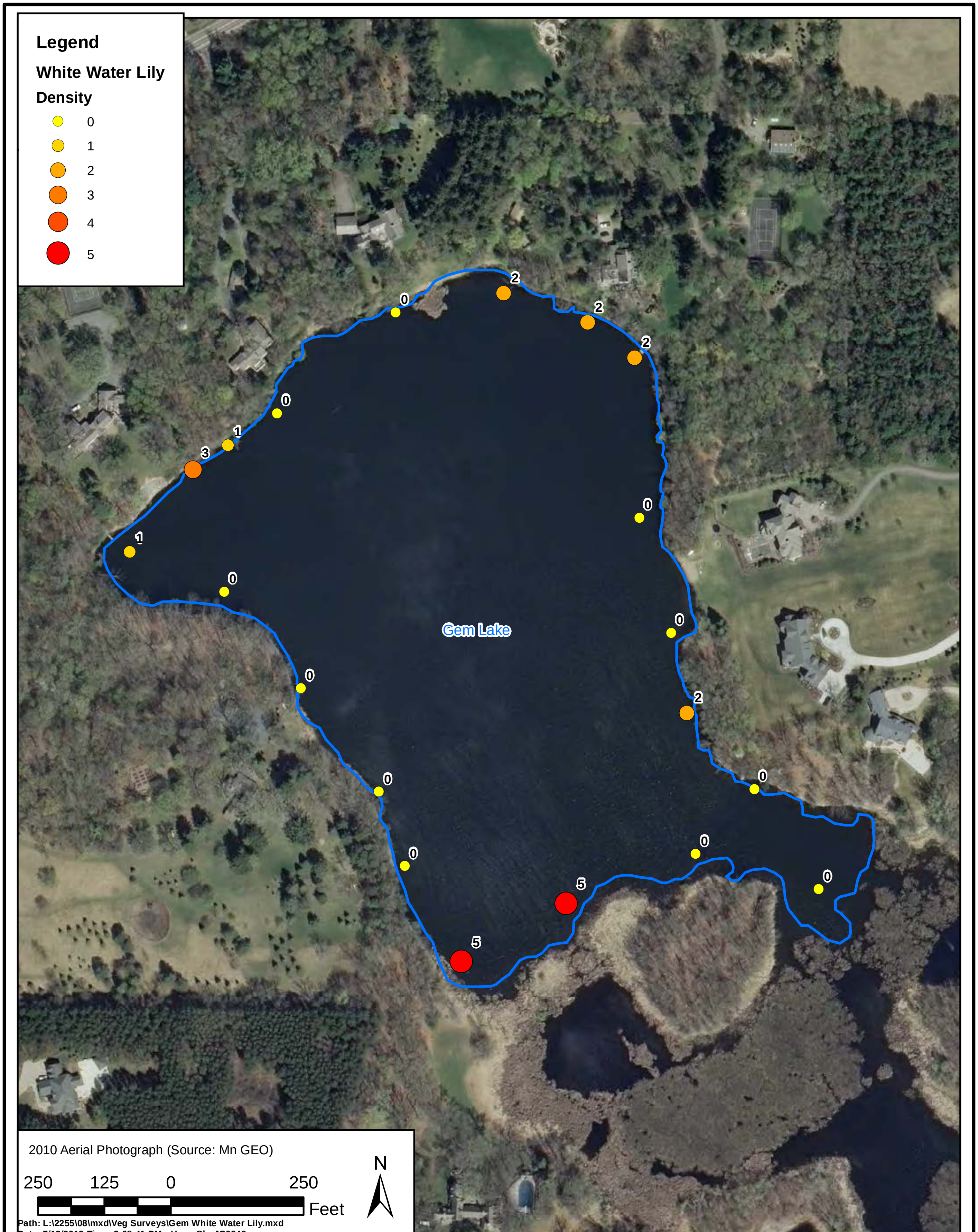
| Gem Lake- Pickerel Weed | | | |

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Gem Lake- White Water Lily

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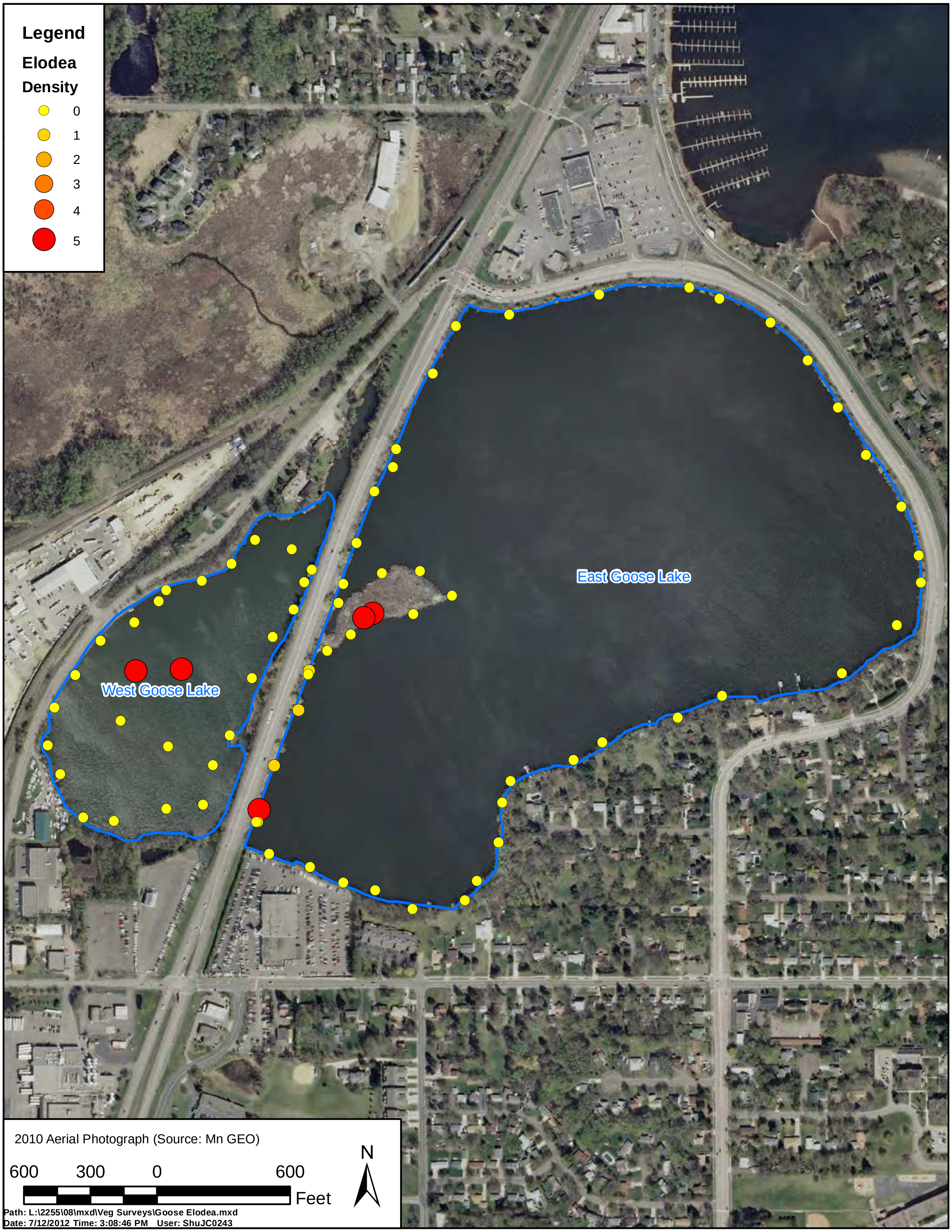


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Goose Lake- Elodea

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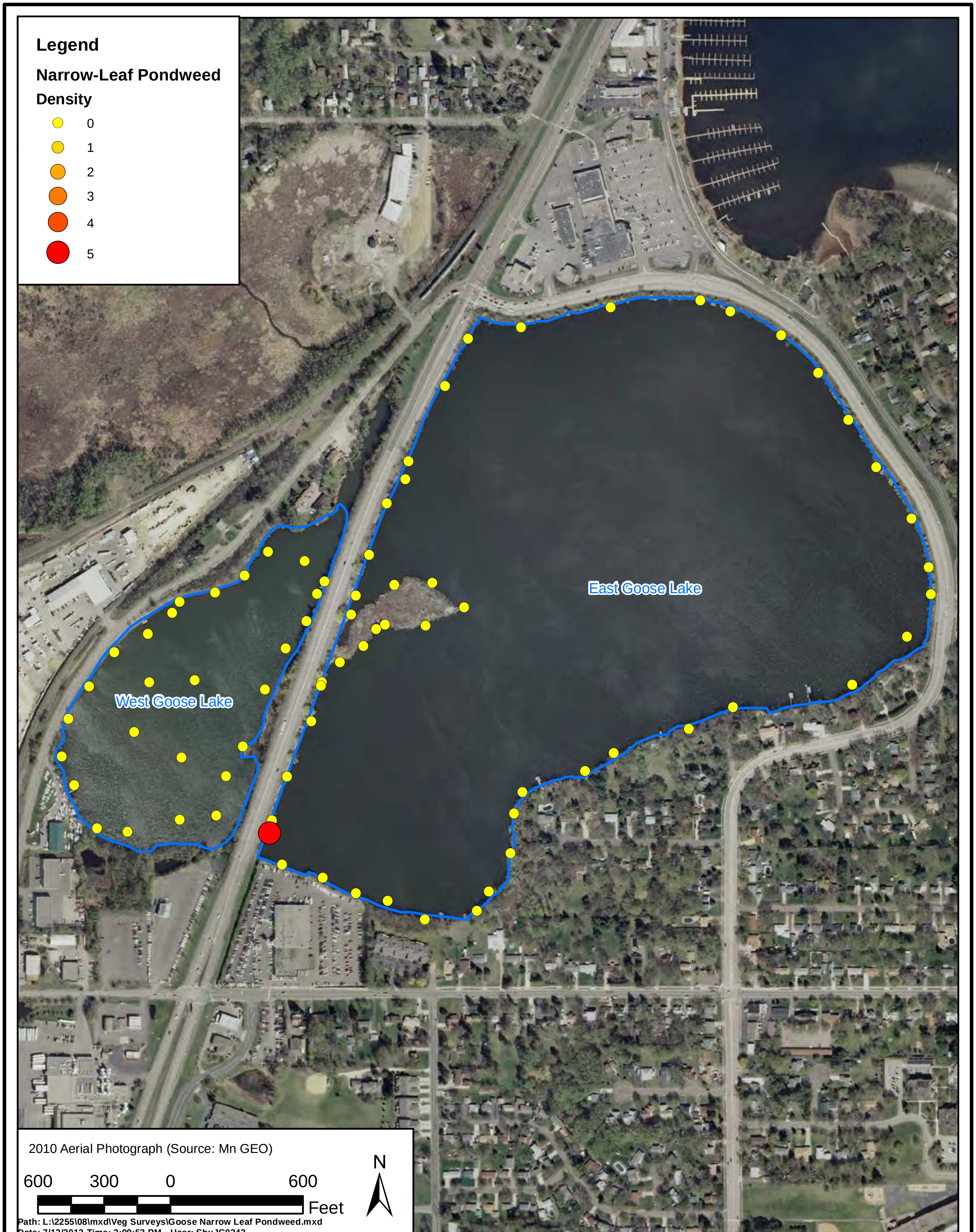


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Goose Lake- Narrow Leaf Pondweed

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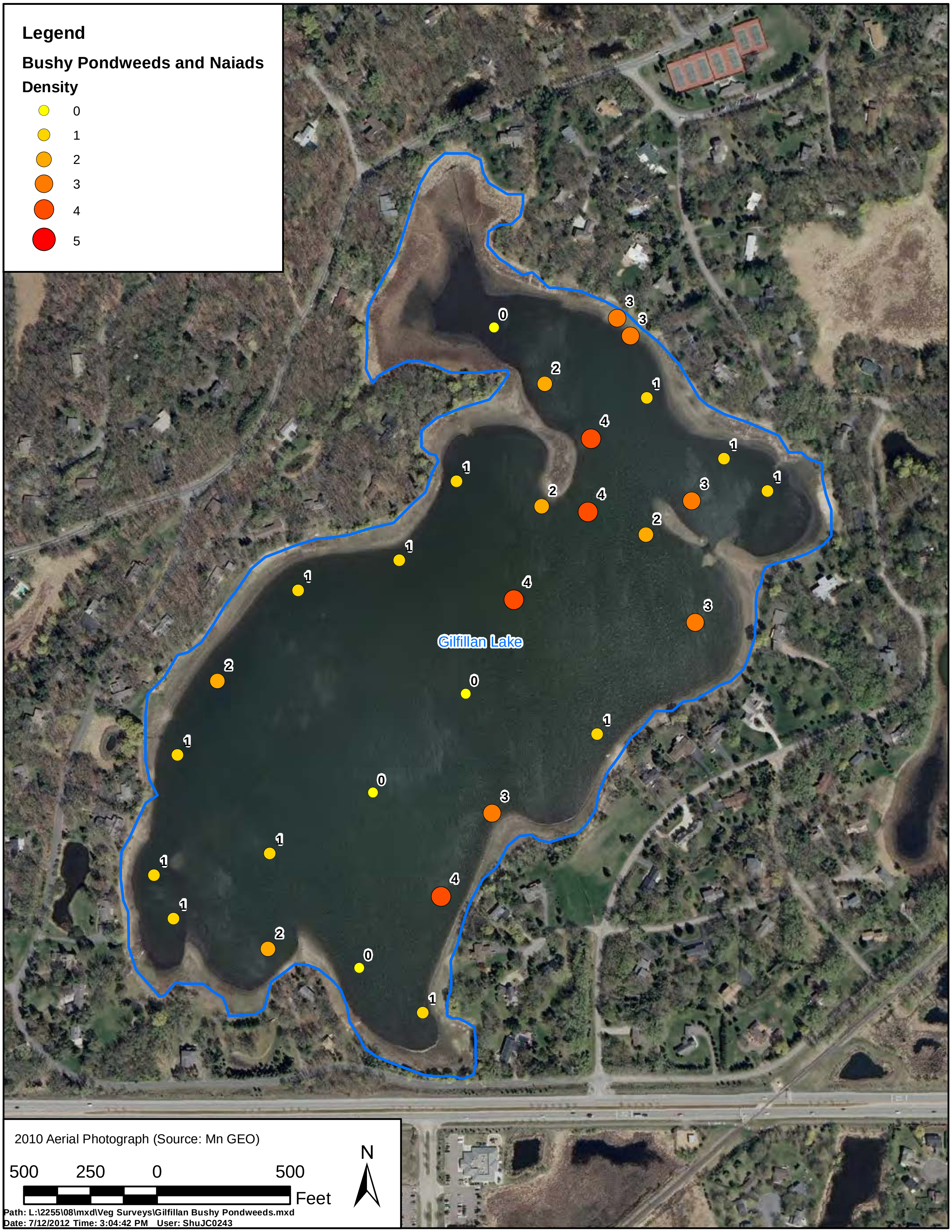


VADNAIS LAKE AREA WMO

Gilfillan Lake- Bushy Pondweeds and Naiads

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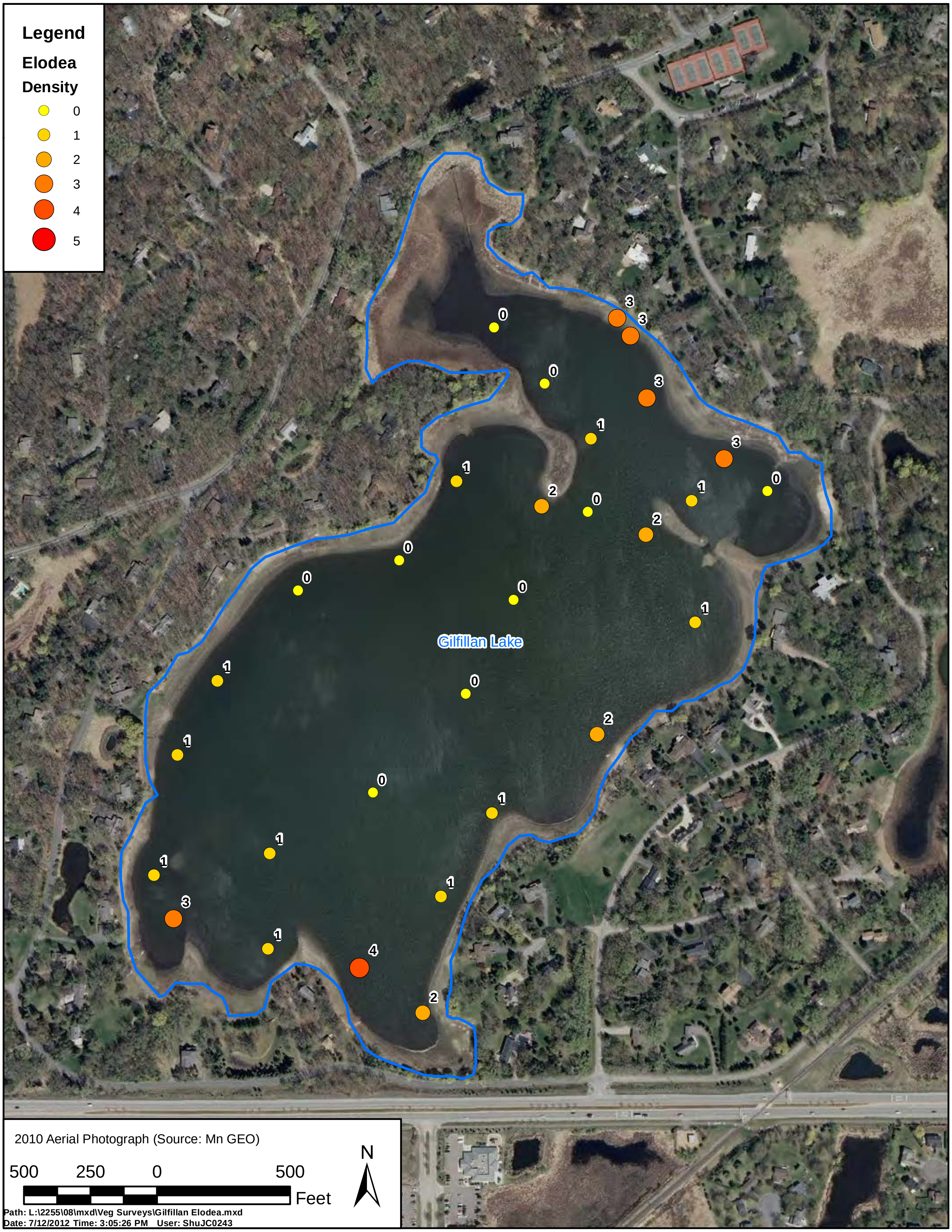


VADNAIS LAKE AREA WMO

Gilfillan Lake- Elodea

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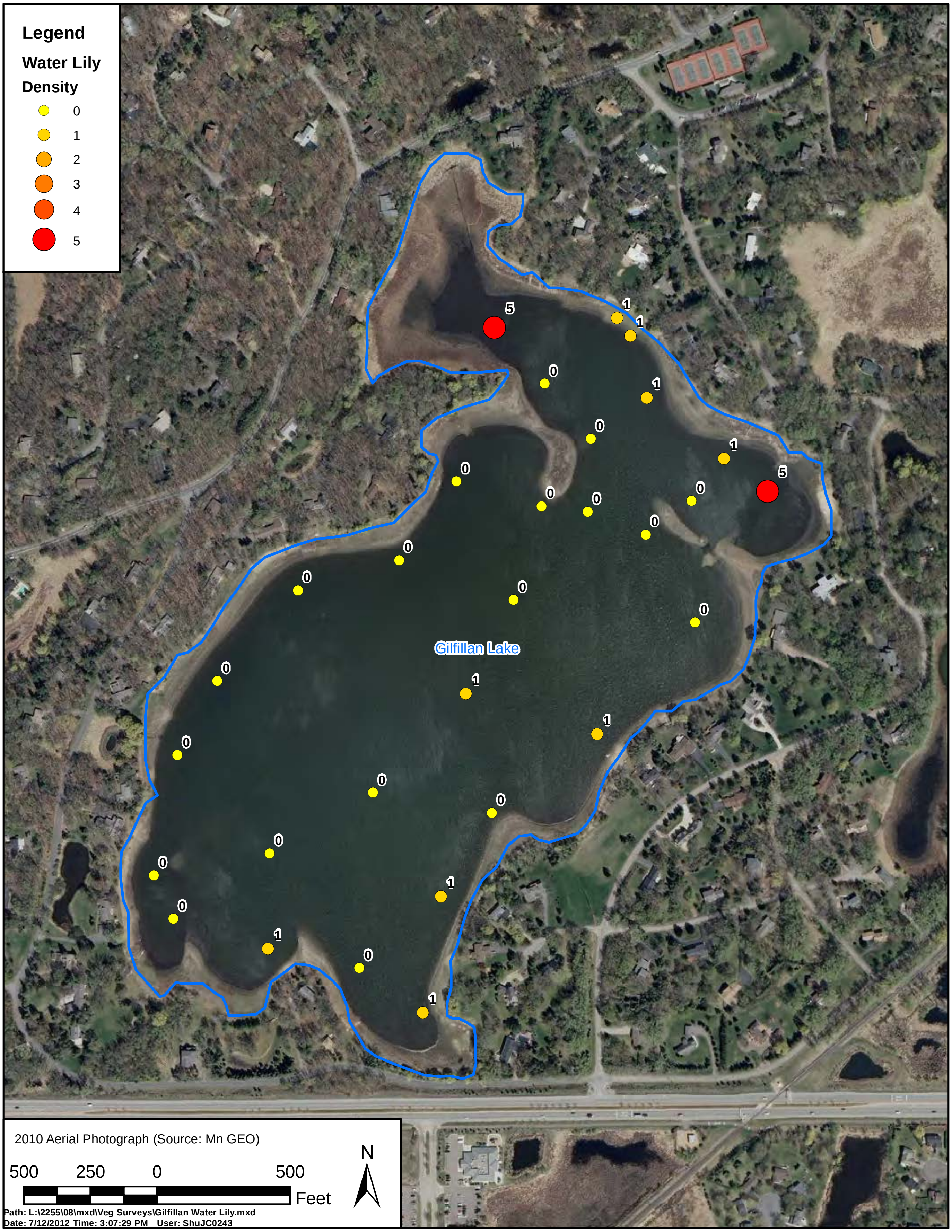


VADNAIS LAKE AREA WMO

Gilfillan Lake- Water Lily

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# Appendix F

## May 3, 2012 TMDL Open House & Workshop Summary

**Results of electronic, end-of-workshop assessment and stakeholder input.**

Participants responded to a series of 11 multiple choice questions using the instantaneous Turning Point electronic assessment system. Some summary statements are below:

- 42% of the participants indicated the TMDL has large implications to their city or organization. 21% said a little. 11% no impacts. 26% did not know yet.
- 61% of the participants only slightly better understood the bacteria reductions needed. 22% indicated they understood them much better.
- 33% of the participants indicated that their city or organization could do a lot to implement new practices and policies to achieve the reductions. 39% indicated they thought their city or organization could do a little. No one said they could not do anything, however, 11% did not know yet what they could do.
- 76% indicated a good to very good understanding of the sources of the pollutants to the five lakes and Lambert Creek.
- Participants highly varied in their understanding of how the recommended reductions were determined and assigned. 42% said good/very good understanding, 37% said average/fair, 21% said poor, 0% said very poor
- 50% agreed strongly with the target reductions, 22% somewhat agreed, 11% strongly disagreed, and 17% indicated they did not know their level of agreement quite yet.