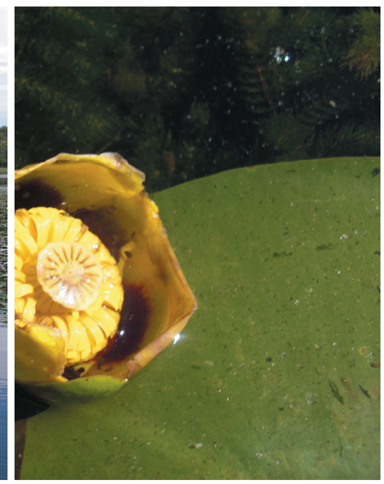
Prepared by:
Emmons & Olivier Resources, Inc.
For the Minnesota Pollution Control Agency
and Minnehaha Creek Watershed District

MCWD Lakes TMDL
– Lake Nokomis, Parley Lake, Lake Virginia, Wassermann Lake

February 2011

water | ecology | community

EOR

wq-iw11-09e

Cover Images

Left Image: Yellow and white water lily bed on Lake Virginia

Right Image: Yellow water lily

Minnehaha Creek Watershed Lakes TMDL: Lake Nokomis, Parley Lake, Lake Virginia, and Wassermann Lake

February 2011

Primary Authors and Contributors

Minnesota Pollution Control Agency
Chris Zadak

Minnehaha Creek Watershed District
Nat Kale
Mike Wyatt

Emmons & Olivier Resources, Inc.
Andrea Plevan
Jennifer Olson

wq-iw11-09e

TMDL Summary Table

<table>
<tr><th>EPA/MPCA Required Elements</th><th colspan="3">Summary</th><th>TMDL Page #</th></tr>
<tr><td>Location</td><td colspan="3">Minnehaha Creek Watershed District in the Upper Mississippi Basin, Hennepin County and Carver County, MN (HUC 07010206).</td><td>4</td></tr>
<tr><td>303(d) Listing Information</td><td colspan="3">Describe the water body as it is identified on the State/Tribe’s 303(d) list:
• Nokomis 27-0019, Parley 10-0042, Virginia 10-0015, Wassermann 10-0048
• Impaired Beneficial Use(s) - Aquatic recreation
• Indicator: Nutrient/Eutrophication Biological Indicators
• Target start/completion date: 2003/2008
• Original listing year: 2002, 2004</td><td>4</td></tr>
<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td colspan="3">Class 2B waters, MN Eutrophication Standards,
MN Rule 7050.0222 Subp. 4
<table>
<tr><th>Parameter</th><th>Eutro-phication Standard, General</th><th>Eutro-phication Standard, Shallow</th><th>Proposed Site-Specific Std</th></tr>
<tr><td>TP (μg/l)</td><td>TP < 40</td><td>TP < 60</td><td>TP < 50</td></tr>
<tr><td>Chlorophyll-a (μg/l)</td><td>chl < 14</td><td>chl < 20</td><td>chl < 20</td></tr>
<tr><td>Secchi depth (m)</td><td>SD > 1.4</td><td>SD > 1.0</td><td>SD > 1.4</td></tr>
<tr><td>Lakes the standards apply to</td><td>Nokomis, Virginia, Wassermann</td><td>Parley</td><td>Nokomis</td></tr>
</table></td><td>34</td></tr>
<tr><td>Loading Capacity (expressed as daily load)</td><td colspan="3">Nokomis: 1.34 lbs TP/day (for requested site-specific standard: 2.03 lbs TP/day)
Parley: 3.5 lbs TP/day
Virginia: 0.84 lbs TP/day
Wassermann: 0.78 lbs TP/day

Critical condition: in summer when TP concentrations peak and clarity is typically at its worst</td><td>57, 70, 82, 91

Critical condition: 93</td></tr>
<tr><td rowspan="9">Wasteload Allocation</td><th>Source</th><th>Permit #</th><th>TMDL Lakes</th><td></td></tr>
<tr><td>Carver County</td><td>MS400070</td><td>Parley, Wassermann</td><td>70, 91</td></tr>
<tr><td>Chanhassen City</td><td>MS400079</td><td>Virginia</td><td>82</td></tr>
<tr><td>Hennepin County</td><td>MS400138</td><td>Nokomis</td><td>57</td></tr>
<tr><td>Laketown Township</td><td>MS400142</td><td>Parley, Wassermann</td><td>70, 91</td></tr>
<tr><td>Metropolitan Airports Commission</td><td>MN0002101</td><td>Nokomis</td><td>57</td></tr>
<tr><td>Minneapolis City</td><td>MN0061018</td><td>Nokomis</td><td>57</td></tr>
<tr><td>Minnehaha Creek Watershed District</td><td>MS400182</td><td>Parley</td><td>70</td></tr>
<tr><td>Minnetrista City</td><td>MS400106</td><td>Parley,</td><td>70</td></tr>
</table>

	Mn/DOT Metro District	MS400170	Nokomis, Parley, Virginia	57, 70, 82
	Richfield City	MS400045	Nokomis	57
	Shorewood City	MS400122	Virginia	82
	Victoria City	MS400126	Parley, Virginia, Wassermann	70, 82, 91
	Waconia City	MS400232	Parley	70
	Construction and industrial stormwater	Various	all	57, 70, 82, 91
	Reserve Capacity (and related discussion in report)	NA		44
Load Allocation	**Source**	**LA**		
	Non-regulated stormwater	various		57, 70, 82, 91
	Internal load	various		
	Atmospheric deposition	various		
Margin of Safety	**Implicit MOS:** Conservative modeling assumptions			40
Seasonal Variation	**Seasonal variation:** Critical conditions in these lakes occur in the summer, when TP concentrations peak and clarity is at its worst. The water quality standards are based on growing season averages. The load reductions are designed so that the lakes will meet the water quality standards over the course of the growing season (June through September).			93
Reasonable Assurance	***Summarize Reasonable Assurance*** MCWD Comprehensive Watershed Management Plan NPDES Phase I and Phase II MS4 permits and SWPPPs Local surface water management plans			94
Monitoring	***Monitoring Plan included?*** yes			102
Implementation	***1. Implementation Strategy included?*** yes ***2. Cost estimate included?*** yes			97
Public Participation	• Public Comment period (dates) • Comments received? • Summary of other key elements of public participation process			95

Table of Contents

Figures

Tables

Abbreviations

DNR	Department of Natural Resources
DO	Dissolved oxygen
EPA	Environmental Protection Agency
HHPLS	Hydrologic, Hydraulic, and Pollutant Loading Study (see MCWD 2003 reference)
JD	Judicial ditch
MAC	Metropolitan Airports Commission
MCWD	Minnehaha Creek Watershed District
MLCCS	Minnesota land cover classification system
Mn/DOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MPRB	Minneapolis Park & Recreation Board
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
ROW	Right-of-way
Std	Standard
TMDL	Total maximum daily load
TP	Total phosphorus
TSI	Trophic State Index

EXECUTIVE SUMMARY

Four lakes in the Minnehaha Creek Watershed District (MCWD) that are on the EPA's 303d list of impaired waters due to excess nutrients (total phosphorus) are the subject of this study. These lakes are Lake Nokomis (27-19), Parley Lake, (10-42), Lake Virginia (10-15), and Wassermann Lake (10-48). The initial work on this TMDL study included five other lakes in Minneapolis: Brownie Lake, Powderhorn Lake, Diamond Lake, Lake of the Isles and Lake Hiawatha. They have been removed from the project for various reasons. Brownie was removed because a review of the in-lake data indicated that it is meeting water quality nutrient standards and has been removed from the list of impaired waters. Powderhorn was likewise removed because a review of the in-lake data indicates that it is meeting water quality nutrient standards (however, additional years of data are needed to confirm the trend in the data before an official removal from the list of impaired waters is done). Diamond was removed because an evaluation was done by MPCA that indicated that it functions more like a wetland than a shallow lake and, therefore, shallow lake water quality standards do not apply to it. Lake of the Isles was listed prior to the establishment of shallow lake water quality standards and was removed because it is meeting those standards. Lake Hiawatha was removed from this project and incorporated into a separate TMDL project that encompasses impairments to Minnehaha Creek, which drains into Hiawatha.

The four listed lakes are all classified as Class 2B, 3C, 4A, 4B, 5, and 6 waters. The most protective of these classes is Class 2 waters, which are protected for aquatic life and recreation. The state eutrophication standards for these lakes are in the following table. A request is being made to EPA to set site-specific standards for Lake Nokomis. This TMDL considers both the eutrophication standards and the requested site-specific standards as dual endpoints for Lake Nokomis. The TMDL will be calculated based on both of these endpoints, to allow for either to be implemented after the standards are finalized.

Parameter	Eutrophication Standard, Shallow Lakes	Eutrophication Standard, General	Requested Site-Specific Standard
TP (µg/l)	TP < 60	TP < 40	TP < 50
Chlorophyll-*a* (µg/l)	chl < 20	chl < 14	chl < 20
Secchi depth (m)	SD > 1.0	SD > 1.4	SD > 1.4
Lakes the standards apply to	Parley	Nokomis, Virginia, Wassermann	Nokomis

The Lake Nokomis watershed is dominated by single family residential neighborhoods, with areas of park and recreation, commercial, and industrial land uses. Wassermann Lake is located within the Parley Lake watershed, with land use primarily agricultural, undeveloped, and parkland. Residential and commercial land uses within this watershed are primarily confined to the City of Victoria. The Lake Virginia watershed includes single family residential, parkland, and other open space. The area directly surrounding Lake Virginia is predominantly single family residential.

Phosphorus is identified as the primary pollutant leading to eutrophication in these lakes. The phosphorus sources include stormwater runoff, internal loading, and atmospheric deposition.

Phosphorus loads from stormwater runoff were estimated using the Simple Method, which uses stormwater runoff volume and total phosphorus event mean concentrations. Loads from stormwater runoff were estimated separately for runoff from regulated (municipal separate storm sewer system (MS4) entities, from the Metropolitan Airports Commission (MAC), and non-regulated runoff). Internal loading was estimated using a mass-balance approach with a lake response model. Loads from atmospheric deposition were estimated using average regional rates.

The loading capacity for each lake was calculated using Bathtub, an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers. The models were calibrated to existing water quality data, and then were used to determine the phosphorus loading capacity of each lake. An implicit margin of safety (MOS) was incorporated by using conservative assumptions.

Individual wasteload allocations (WLAs) were set for each regulated MS4 source, including regulated stormwater runoff from the municipalities, the road authorities (Hennepin County, Carver County, and Mn/DOT), and MCWD. An individual WLA was also set for the portion of the MAC that drains to Lake Nokomis. Categorical WLAs were set for construction stormwater and industrial stormwater.

One load allocation was set for each lake. The load allocation includes phosphorus sources from stormwater runoff not regulated by an MS4 permit, internal loading, atmospheric deposition, and any other unidentified loads.

Lake Nokomis is a eutrophic lake. To meet the state eutrophication standards, an overall phosphorus load reduction of 57% is needed. To meet the requested site-specific standards, the reduction drops to 35%. Parley Lake is a eutrophic to hypereutrophic lake. To meet the state eutrophication standards, an overall phosphorus load reduction of 44% is needed. Lake Virginia is mildly eutrophic. To meet the state eutrophication standards, an overall phosphorus load reduction of 20% is needed. Wassermann Lake is a eutrophic to hypereutrophic lake. To meet the state eutrophication standards, an overall phosphorus load reduction of 62% is needed.

A series of stakeholder meetings were held. Cities, counties, agencies, and park districts were invited to provide input into the project approach and to review draft documents. Public meetings were held to provide information to the public about the project and to solicit input regarding background information and implementation recommendations.

The approach to implementation will include and augment, where needed, actions and strategies in the MCWD Comprehensive Watershed Management Plan (MCWD Plan), approved by the MN Board of Water and Soil Resources and adopted by the MCWD Board of Managers in 2007. The MCWD Plan outlines a framework for water resource management including requirements for local government units. In addition, the MCWD has also adopted rules that regulate activities in the watershed and strive to prevent pollution. Watershed-wide activities and activities specific to the individual lakes are included. A detailed implementation plan for the lakes in this study is in progress.

The monitoring plan includes recommendations for standard in-lake monitoring, as well as additional recommendations for biological monitoring where time and budget allow.

1. BACKGROUND

A. 303(d) Listings

Four lakes in the Minnehaha Creek Watershed District (MCWD) that are on the EPA's 303d list of impaired waters due to excess nutrients (total phosphorus) are the subject of this study. These lakes are Lake Nokomis, Parley Lake, Lake Virginia, and Wassermann Lake (Table 1). The initial work on this TMDL study included five other lakes in Minneapolis: Brownie Lake, Powderhorn Lake, Diamond Lake, Lake of the Isles and Lake Hiawatha. They have been removed from the project for various reasons. Brownie was removed because a review of the in-lake data indicated that it is meeting water quality nutrient standards and has been removed from the list of impaired waters. Powderhorn was likewise removed because a review of the in-lake data indicates that it is meeting water quality nutrient standards (however, additional years of data are needed to confirm the trend in the data before an official removal from the list of impaired waters is done). Diamond was removed because an evaluation was done by MPCA that indicated that it functions more like a wetland than a shallow lake and, therefore, shallow lake water quality standards do not apply to it. Lake of the Isles was listed prior to the establishment of shallow lake water quality standards and was removed because it is meeting those standards. Lake Hiawatha was removed from this project and incorporated into a separate TMDL project that encompasses impairments to Minnehaha Creek, which drains into Hiawatha.

The following applies to all of the impaired lakes in this project:

Impaired Use:	Aquatic recreation
Pollutant or Stressor:	Nutrient/eutrophication biological indicators
Hydrologic Unit Code:	07010206

Table 1. Impaired Waters Listings

Lake Name	Lake ID	Year Listed	Target Start/Completion	CALM Category*
Nokomis	27-19	2002	2003/2008	5B
Parley	10-42	2002	2003/2008	5C
Virginia	10-15	2004	2003/2008	5B
Wassermann	10-48	2002	2003/2008	5B

5B: Impaired by multiple pollutants and at least one TMDL study plan is approved by EPA; 5C: Impaired by one pollutant and no TMDL study plan is approved by EPA

B. Lake and Watershed Descriptions

The Minnehaha Creek Watershed is located in the central portion of Hennepin County and a portion of northern Carver County (Figure 1). The watershed drains approximately 181 square miles (roughly 116,000 acres) and consists of two major water features – Lake Minnetonka and Minnehaha Creek. The upper portion of the watershed drains to Lake Minnetonka, which then flows into the creek at Grays Bay Dam. The creek flows about 22 miles east and then flows over Minnehaha Falls and into the Mississippi River in Minneapolis.

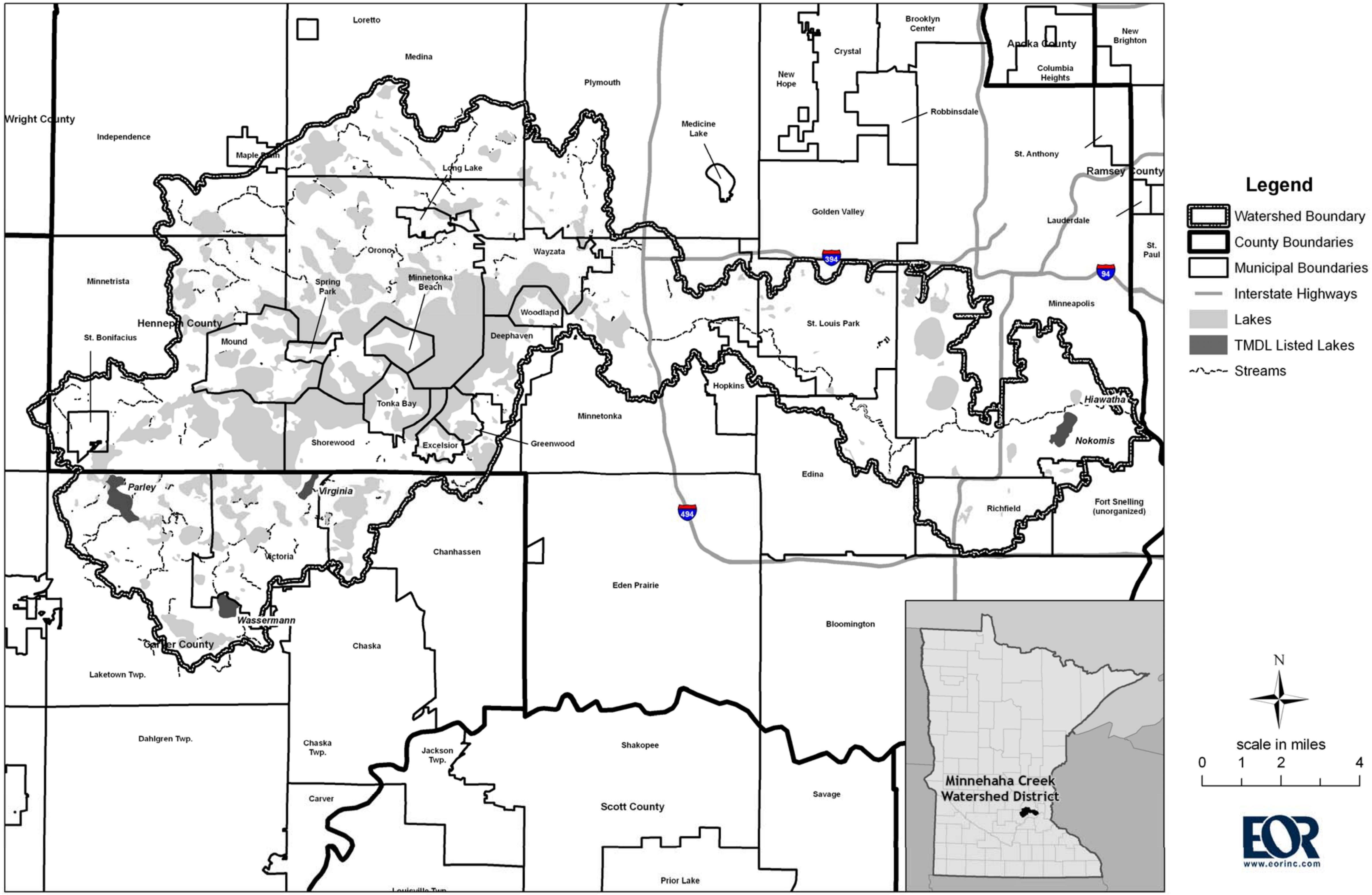


Figure 1. Municipal Boundaries

The linework for this dataset comes from individual counties and is assembled by the Metropolitan Council for the MetroGIS community. The dataset was updated to incorporate recent changes in municipal boundaries in Minneapolis (received January 2008) and Victoria (up-to-date as of the most recent annexation on December 15, 2006; municipal boundaries as presented in the City of Victoria's Comprehensive Plan 2008). Fort Snelling is an unorganized territory (neither a municipality nor a township).

Lower Minnehaha Creek Watershed: Lake Nokomis

Lake Nokomis is located in the lower part of the Minnehaha Creek watershed (Figure 2), in the City of Minneapolis. The lake flows directly into Minnehaha Creek.

Land use and land cover

Land use is dominated by single family residential (Figure 3). Blocks of parks and recreational areas are scattered throughout the watershed, in addition to areas with a high concentration of commercial and industrial land uses. Percent imperviousness is, on the average, higher in the eastern portion of the watershed. Since the watershed is already completely developed, the 2020 land use plan is not substantially different from the 2000 land use plan.

The MLCCS land cover classifications were combined into five impervious surface area categories and six vegetative cover type categories for the entire lower Minnehaha Creek watershed (Figure 4). Land cover is not expected to change substantially between now and 2020.

Lake Uses

Lake Nokomis is a heavily used lake located in Lake Nokomis Park in south Minneapolis. Two Minneapolis Park and Recreation Board (MPRB) swimming beaches are operated on the lake, and a public access site is located on the west central shore of the lake. It is also a sailing lake, and sailboat races are common on the lake throughout the summer. Both fishing and ice fishing occur on the lake. A paved trail surrounds the lake, with the trail connected to the nearby Minnehaha Creek trail. The park also includes ball diamonds, a community center, and picnic tables.

Watershed History

One of the first mentions of Lake Nokomis in MPRB board meeting proceedings was December 7, 1891, the day the board designated for acquisition the land for Minnehaha Boulevard from Lyndale Avenue to Minnehaha Falls, crossing Minnehaha Creek between Lake Amelia (location of Lake Nokomis) and Rice Lake (location of Lake Hiawatha). The board discussed at that time controlling the flow of the creek to ensure there would be water over Minnehaha Falls the next summer when the city would host the Republican Party's national convention. In early 1892 Charles Loring, who had been the first president of the MPRB from 1883 to 1890, wrote that he hoped the board would secure Lake Amelia as a reservoir.

In 1907 the MPRB purchased land around what was known at the time as Lake Amelia. The newly acquired land contained areas of open water, wetland, and peat bog. At that time wetlands were considered unsanitary and useless, and the MPRB developed a plan to increase the area of parkland by 100 acres through dredging and filling. The goal was to make the area more desirable for development and to protect public health. Dredging began in 1914, moving nearly 2.5 million cubic yards of material to create beaches, solid shoreline, and parkways around the lake. In the process, the surface area of the lake was changed from 300 acres to 200 acres and the lake was deepened to an average depth of fifteen feet from its original average depth of five to twelve feet. At that time the boundary between Minneapolis and Richfield was at 54th Street and part of the lake was in Richfield. That section of Richfield was annexed by Minneapolis in 1926.

When dredging was done the MPRB allowed the fill to settle for five years before it began grading the area. Even with that wait, the fill continued to settle over the years and additional grading work was done through federal work relief programs in the 1930s. In the end the lake was on average somewhat deeper than planned because when the dredges found sand on the bottom of the lake, they dug deeper to collect that sand for the beach being created on the northwestern shore of the lake.

By the time the last improvements were made to Lake Nokomis, the MPRB had acquired Rice Lake and Minnehaha Creek to the falls. Instead of creating a reservoir of either Nokomis or Hiawatha, the MPRB proposed digging a deep well near Longfellow Gardens and creating a lagoon to store water for the falls there.

Concerns for water quality in all city lakes led to the first study of lake water quality throughout the city in 1973. One of the problems identified with water quality was the elimination of the wetlands and marshes that had once existed on the shores of many city lakes. With increased development of surrounding property over the years, storm water runoff into the lakes became a concern. Not only were the watersheds of the lakes fully developed, but the marshes that had once filtered water into the lakes were long gone. In an effort to restore the capacity of surrounding land to filter storm water runoff the MPRB looked to re-establish the wetlands and native grasses that once existed in places on lakeshores.

A substantial effort to address water quality in Minneapolis lakes was the Blue Water Commission's 1998 Report and Recommendations for the Management of Lake Nokomis and Lake Hiawatha. This was a combined effort among many participants, including the City of Minneapolis, the MCWD, and the MPRB, along with the individual participants on the Blue Water Commission.

Included among the goals that emerged from the Blue Water Commission's report is that Lake Nokomis should be swimmable, fishable, aesthetically pleasing, and should support diverse populations of plants and wildlife. A series of recommendations were made, and several of them have already been implemented, including shoreline improvement, wetland/pond treatment areas, grit chamber installation, and rough fish removal.

Population

Population is expected to increase slightly (approximately 16%) in the cities that intersect the Lake Nokomis watershed (Table 2).

Table 2. Current population and population forecasts for cities and townships within the Lake Nokomis watersheds 2030 Regional Development Framework - Revised Forecasts as of December 10, 2008

County	City or Township	Population				% Change 2000 to 2030
		2000	2010	2020	2030	
Hennepin	Fort Snelling (unorg.)	442	262*	*	*	*
Hennepin	City of Minneapolis	382,747	402,000	423,000	435,000	14%
Hennepin	City of Richfield	34,310	38,300	42,700	47,100	37%

*Population forecasts are not completed by the Metropolitan Council for Fort Snelling, which includes only temporary housing. The 2000 estimate is from U.S. Census data; the 2008 population was 262.

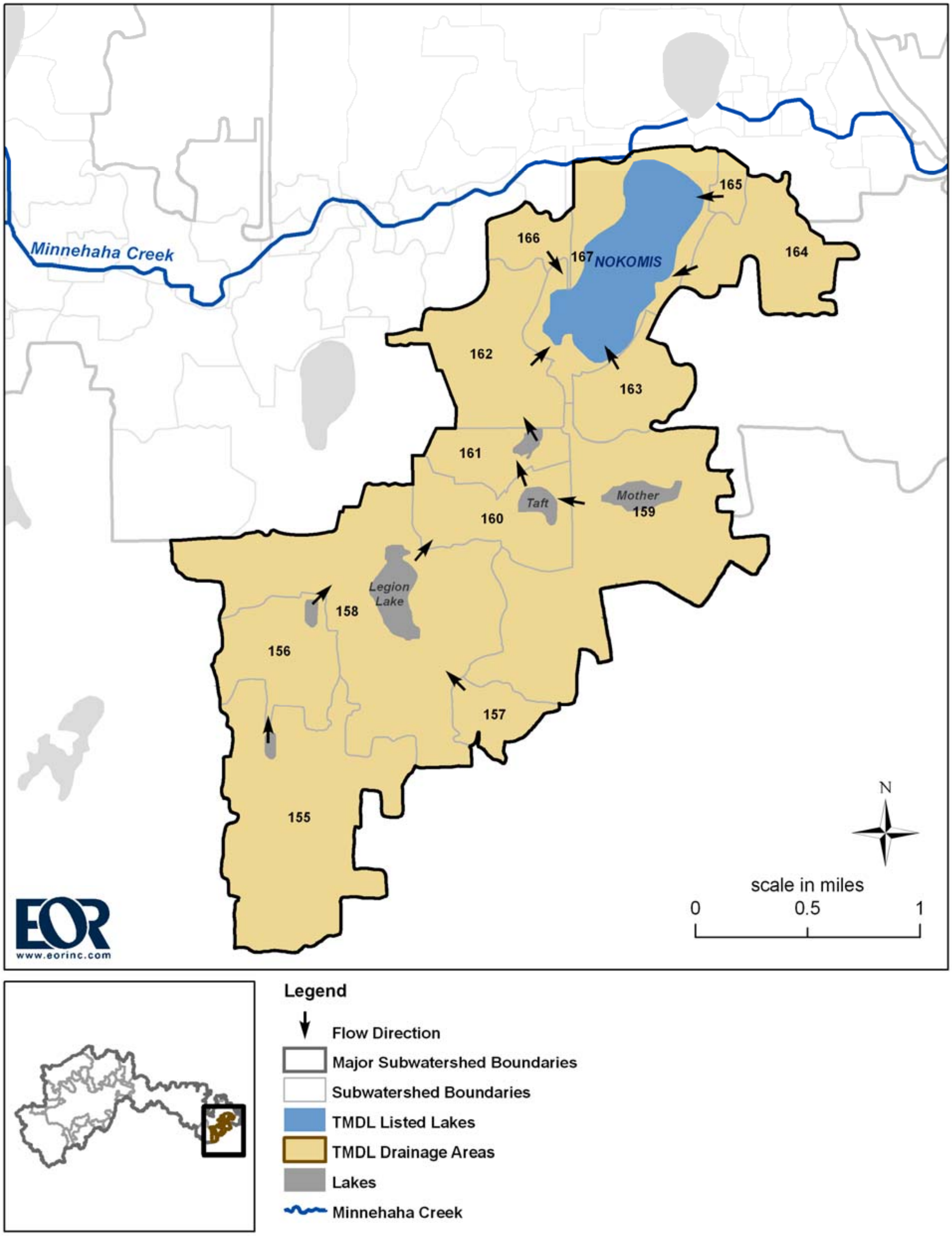


Figure 2. Lake Nokomis Subwatersheds and Drainage Direction

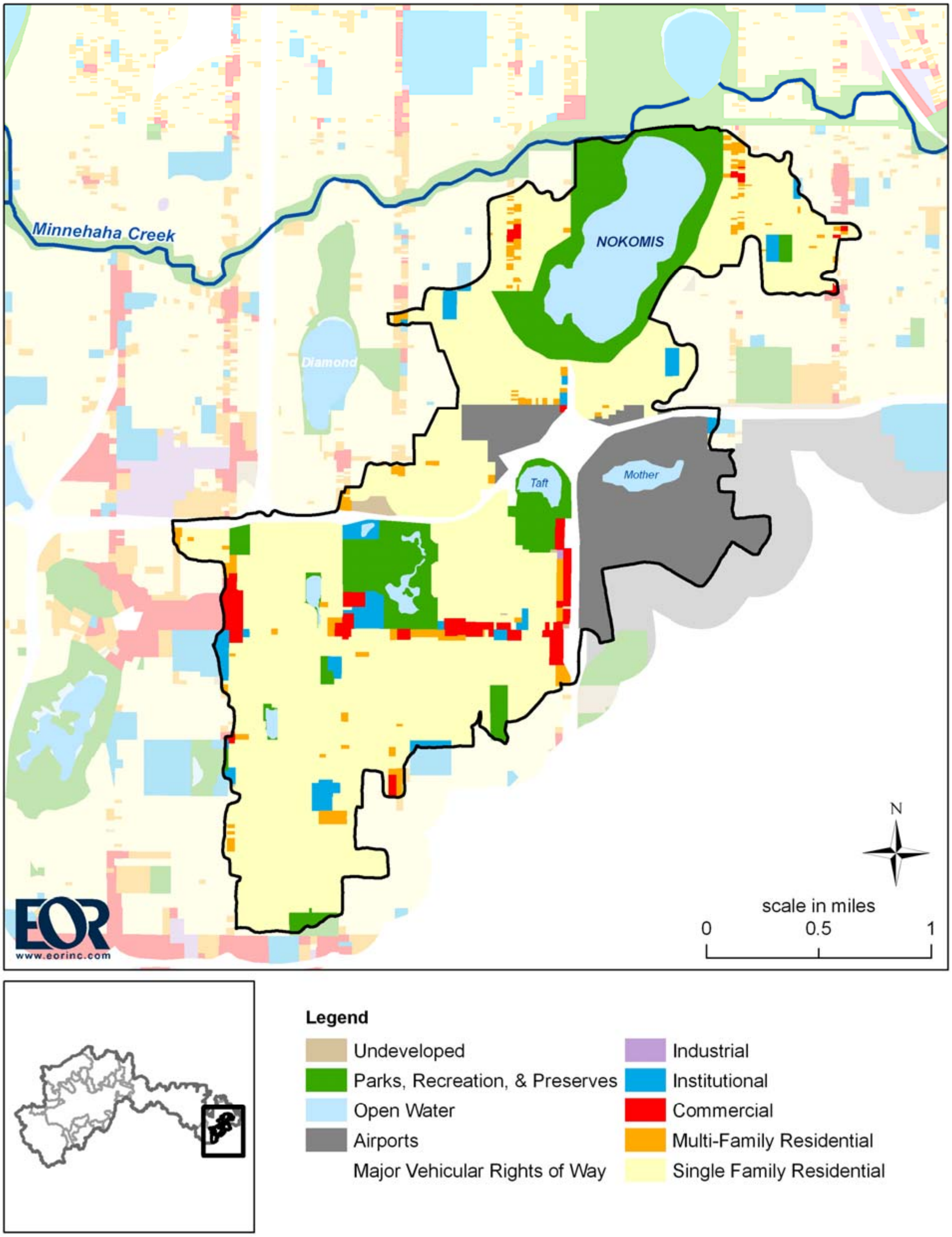


Figure 3. Lake Nokomis Land Use
Generalized Land Use 2000 for the Twin Cities Metropolitan Area

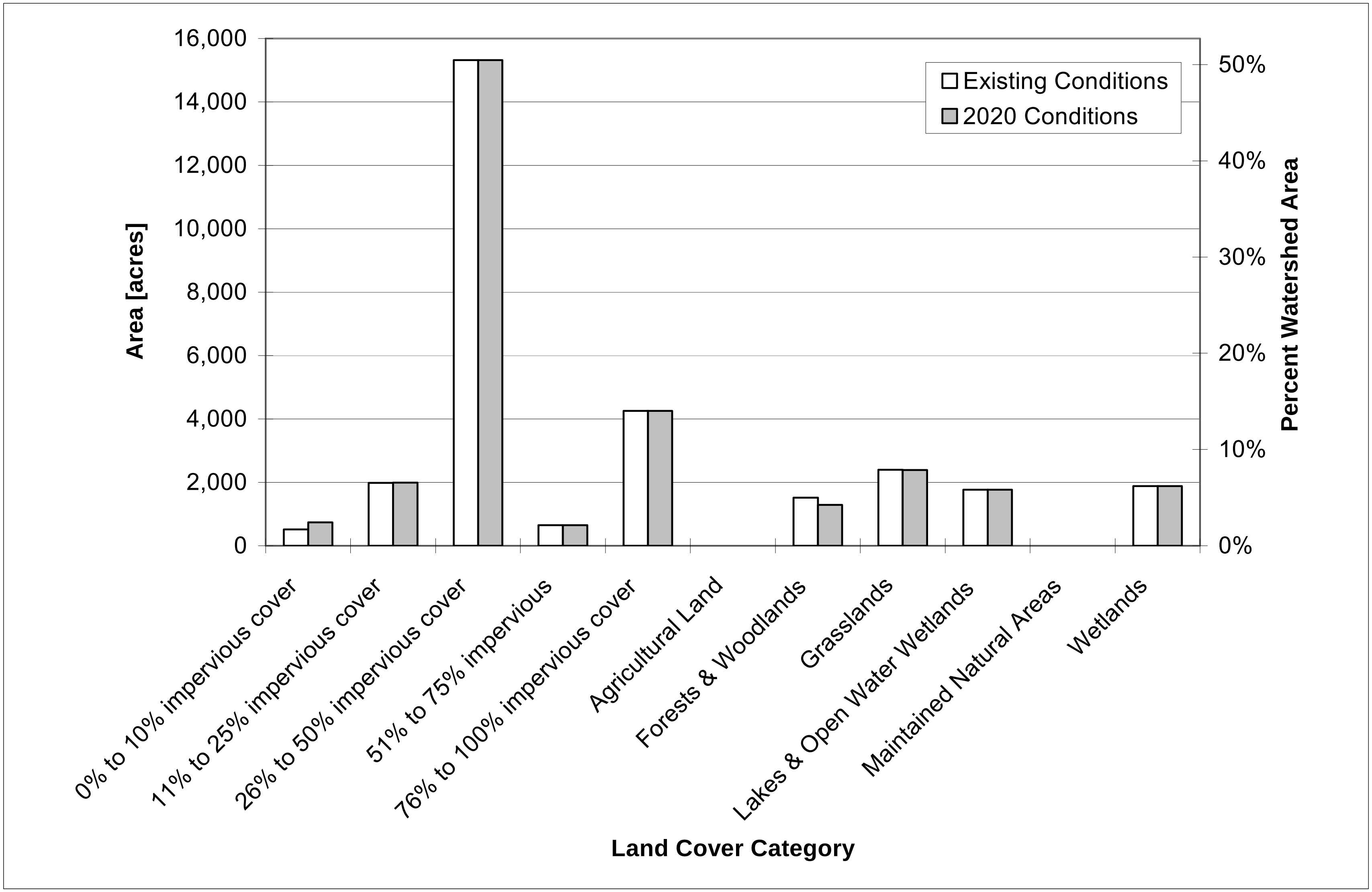


Figure 4. Minnehaha Creek Land Cover
MLCCS Level 3 data; existing conditions from 2002 data, 2020 conditions projected from MLCCS data and projected (2020) land use changes.

Six Mile Creek Lakes: Parley and Wassermann

The Six Mile Creek watershed (Figure 5) is located along the south-western boundary of the MCWD and within the cities of Minnetrista, St. Bonifacius, and Victoria, Laketown Township, and Watertown Township (Figure 1). Through the annexation of Laketown Township, the ultimate municipal boundaries will change and the City of Waconia will include portions of the Parley Lake watershed (Figure 6). This boundary is based on the 1976 orderly annexation agreement between Laketown Township and its surrounding municipalities (Waconia and Victoria); the actual pattern and timing of annexation will happen gradually and cannot be predicted. The watershed is approximately 17,000 acres in size (about 27 sq. miles), and includes 66 subwatershed units (designated SMC-1 through SMC-66). Approximately 3,600 acres are made up of lake and wetland surfaces, accounting for about 21% of the total watershed area.

Lake Pierson, in the southern portion of the watershed, forms the headwaters of Six Mile Creek, which snakes its way north and west through a series of lakes and wetlands before flowing into Halsteds Bay of Lake Minnetonka. Despite its name, Six Mile Creek is approximately 11 miles long (measured from the outlet of Lake Pierson to Halsteds Bay of Lake Minnetonka). Wassermann Lake is located towards the headwaters of the watershed, while Parley Lake is about three-quarters of the way from the headwaters to the mouth. Wassermann Lake is located with the Parley Lake watershed.

Multiple segments of Six Mile Creek have a very low gradient resulting in backwater conditions. Parley Lake is influenced by backwater conditions resulting from the low gradient of Six Mile Creek between Parley Lake and Lake Minnetonka.

Land use and land cover

Land use throughout the watershed is primarily agricultural, undeveloped, and parkland (Figure 7). Residential and commercial land uses within this watershed are primarily confined to the City of Victoria. (The residential areas within St. Bonifacius are downstream of Parley Lake.) Remaining natural areas are primarily confined to the area of Carver Park Reserve (surrounding Lakes Steiger, Auburn, Lunsten, and parts of Zumbra). Within Carver Park Reserve, land cover consists mostly of grasslands, forests, and woodlands. The City of Victoria and the City of Waconia are currently undergoing a process to annex Laketown Township, located to the south and west of the current city boundaries; part of this area is in the Wassermann Lake watershed. The 2020 projected land use plans indicate the expected development in this annexation area, with a large increase in the acreage of single family residential land use (Figure 8).

The MLCCS land cover classifications were combined into five impervious surface area categories and six vegetative cover type categories (Figure 9). Agricultural land and “natural areas” currently dominate the landscape; agriculture makes up over 25% of the landscape, and wetlands, forests, woodlands, and grasslands together make up approximately 40% of the landscape. Under 2020 land use conditions, “11% to 25% impervious cover” becomes the most dominant category (25%), followed by wetlands (15%) and then grasslands (15%). The greatest loss of land cover involves agricultural land.

Lake Uses

Both Wassermann Lake and Parley Lake have a DNR public access and boat ramp. The primary uses of Wassermann Lake are boating, fishing, water skiing, and tubing. There is a water skiing course at the south end of the lake. The primary uses of Parley Lake are boating and fishing.

Watershed Management

The March 2004 Victoria Southwest Area Final Alternative Urban Areawide Review (AUAR) details the surface water management regulations that will be required as the annexation area develops. The city's Shoreland District will include a 1,000-ft buffer around Wassermann Lake, in which certain development regulations regarding lot dimensions and setback requirements will be in effect.

Population

Substantial population changes in the cities that intersect the watersheds of Parley Lake and Lake Wassermann are expected between now and 2030 (Table 3). Population is expected to increase dramatically in Victoria by 2030, and is expected to double in Minnetrista. Laketown Township has an expected population of zero in 2030 due to its incorporation into its surrounding cities.

Table 3. Current population and population forecasts for cities and townships within the Parley Lake and Wassermann Lake watersheds

2030 Regional Development Framework - Revised Forecasts as of December 10, 2008

County	City or Township	Population				% Change 2000 to 2030
		2000	2010	2020	2030	
Carver	Laketown Township	2,331	1,800	830	0	-100%
Carver	City of Victoria	4,025	10,700	19,600	28,000	596%
Carver	City of Waconia	6,814	10,600	20,000	25,000	267%
Hennepin	City of Minnetrista	4,358	6,600	9,400	13,300	205%

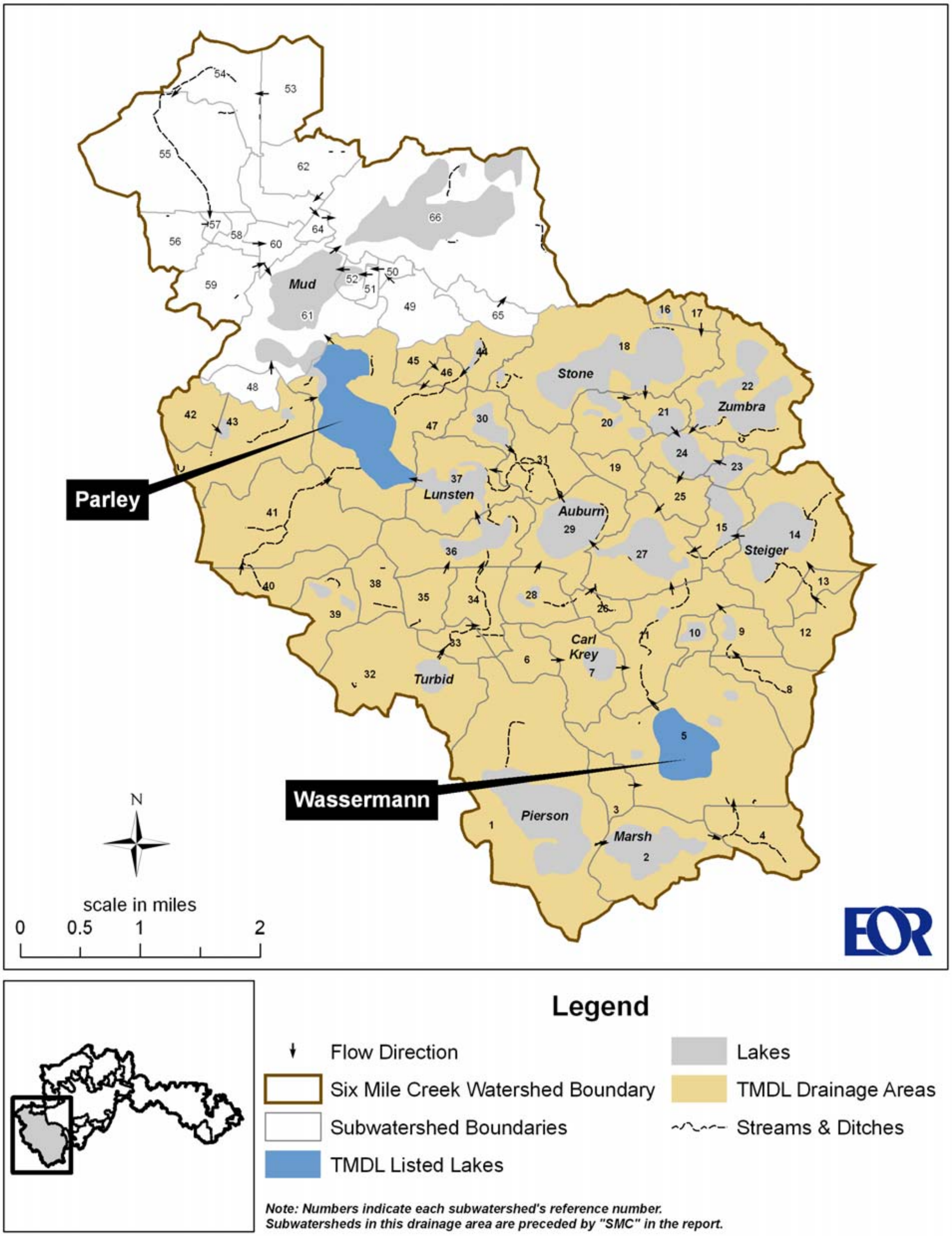


Figure 5. Six Mile Creek Subwatersheds and Drainage Direction

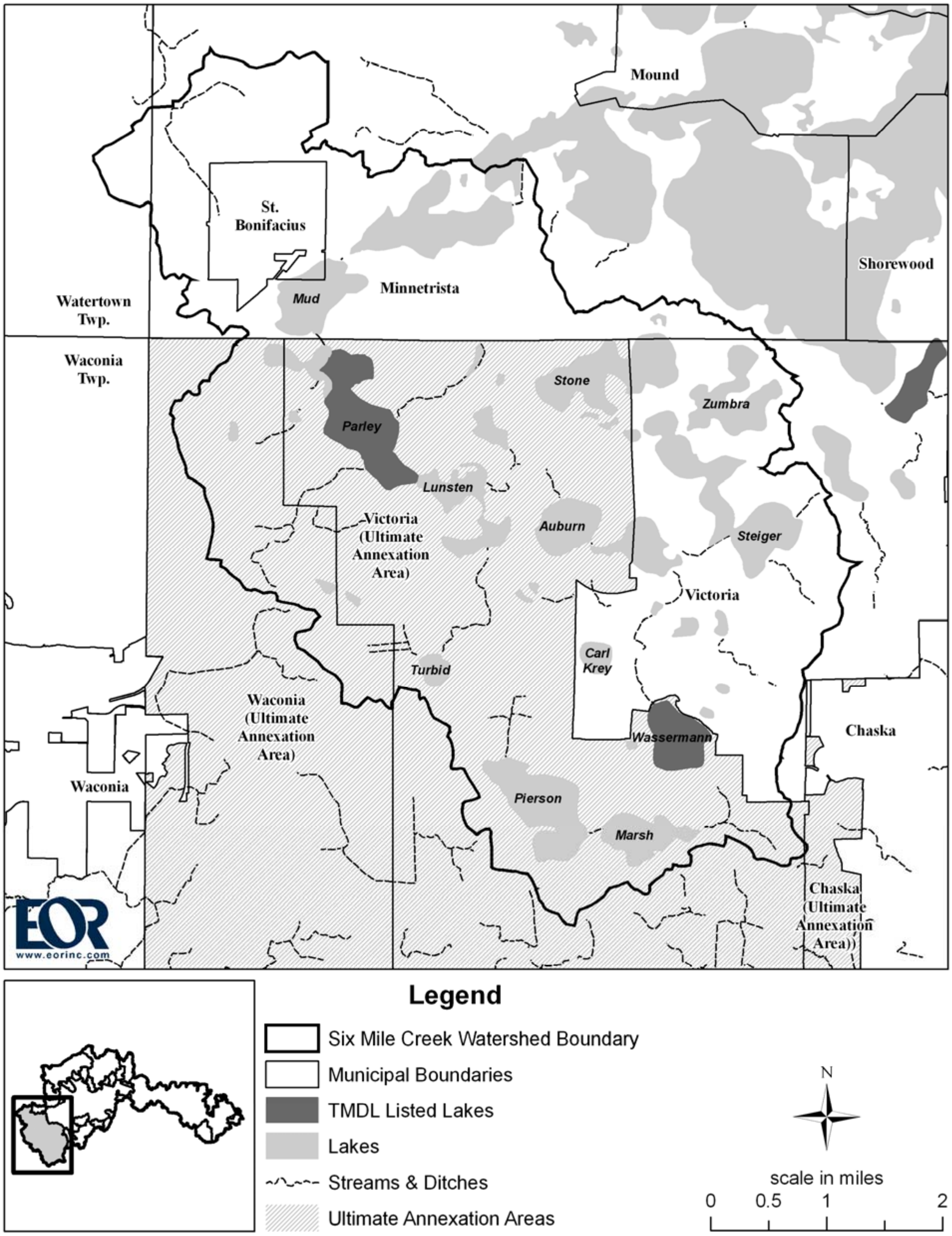


Figure 6. Six Mile Creek Ultimate Municipal Boundaries

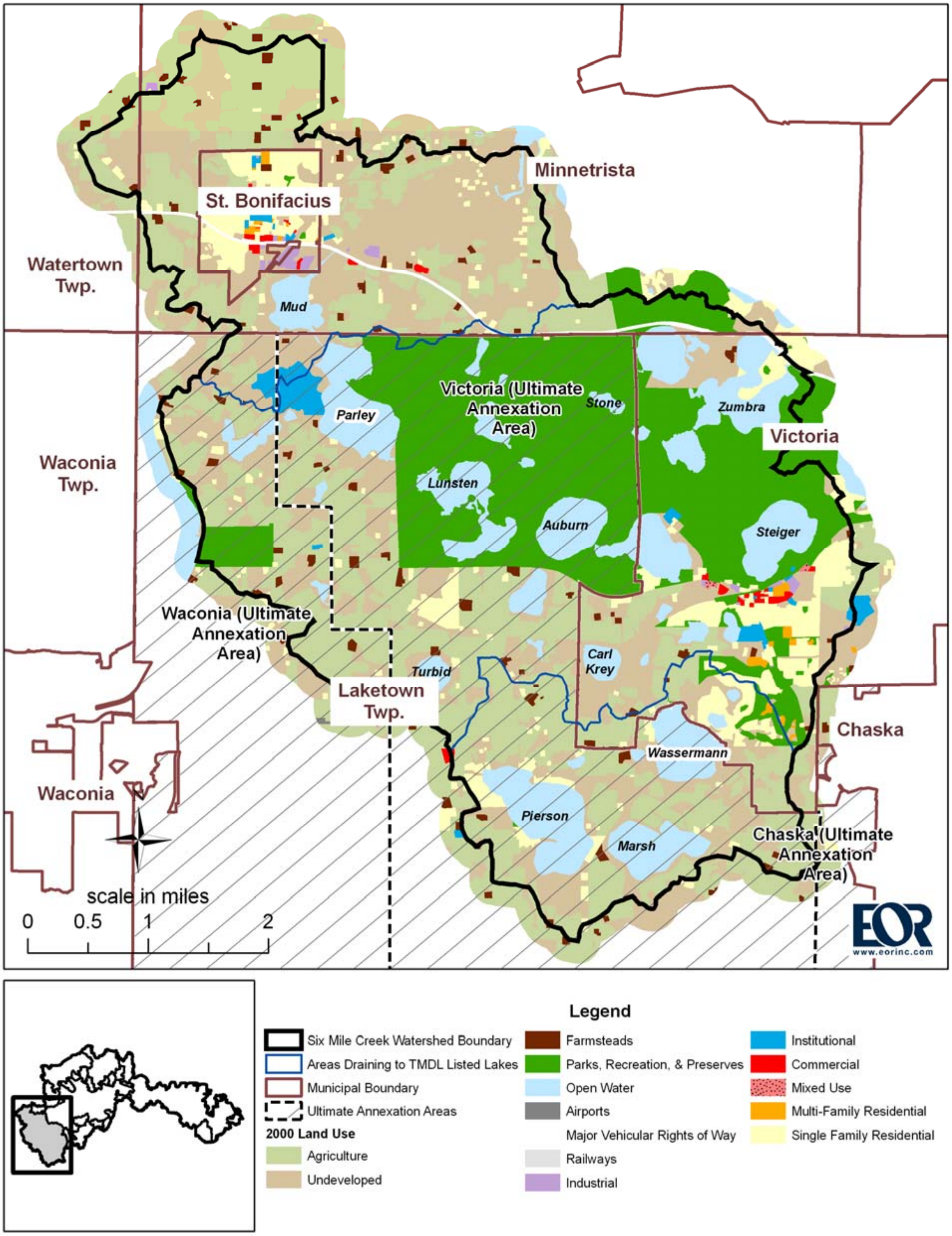


Figure 7. Six Mile Creek Land Use

Generalized Land Use 2000 for the Twin Cities Metropolitan Area

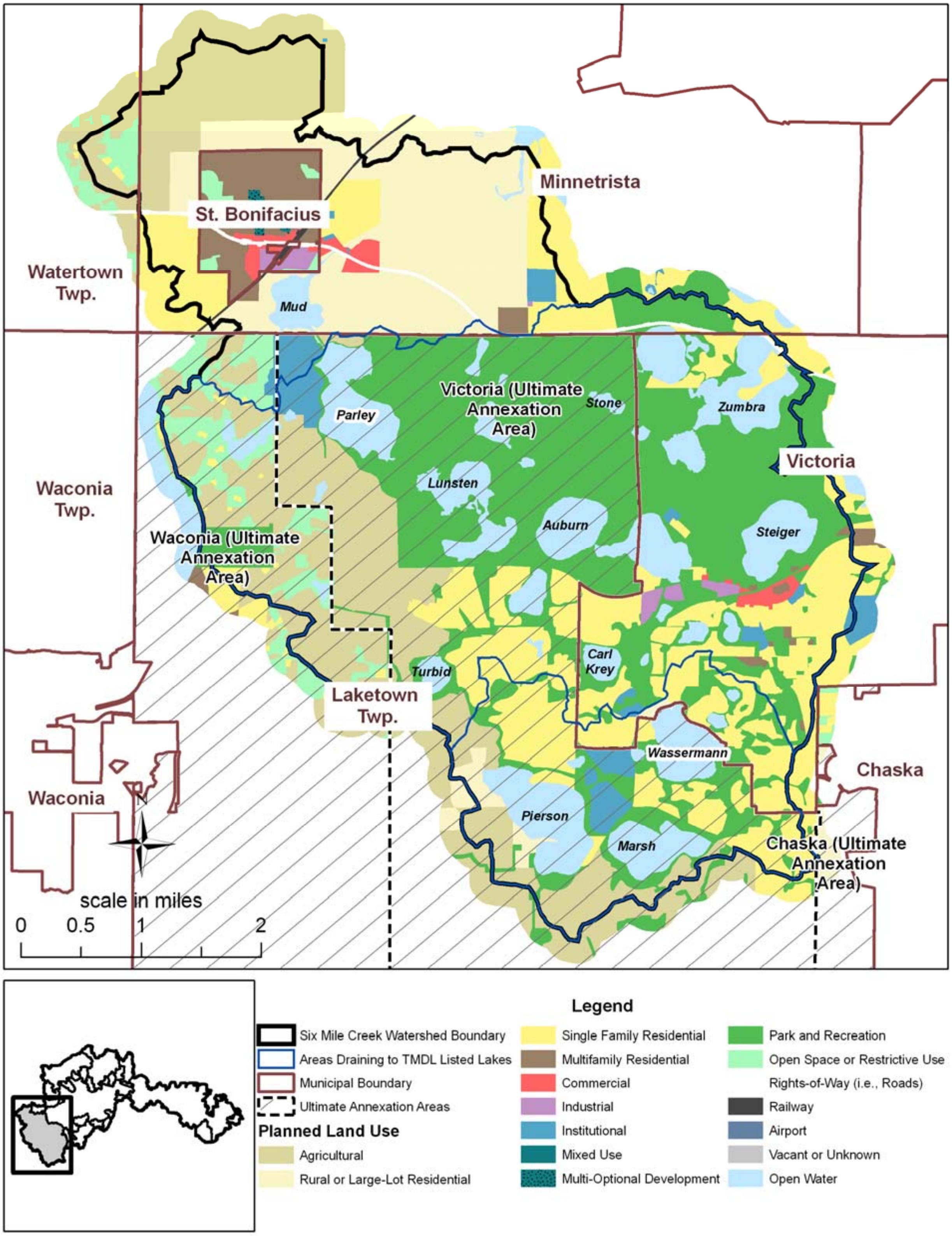


Figure 8. Six Mile Creek Planned Land Use

2020 Regional Planned Land Use - Twin Cities Metropolitan Area. See footnote in Table 8 regarding "Rural or Large-Lot Residential" land use in Hennepin County.

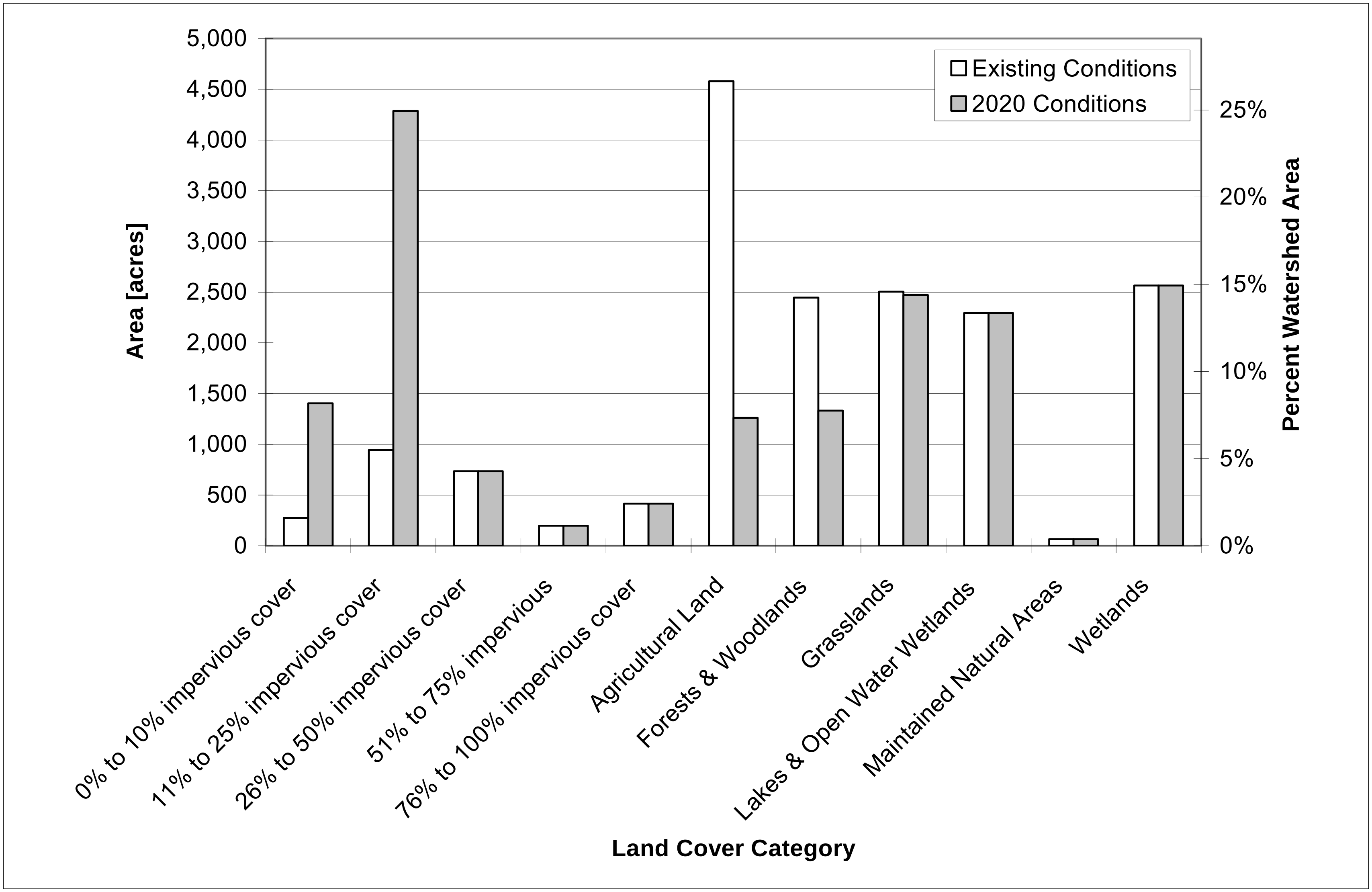


Figure 9. Six Mile Creek Watershed Land Cover

MLCCS Level 3 data; existing conditions from 2002 data, 2020 conditions projected from MLCCS data and projected (2020) land use changes.

Lake Virginia

The Lake Virginia watershed (including Lake Minnewashta) is located along the southern boundary of the MCWD and within the cities of Victoria, Chanhassen, Chaska, and Shorewood (Figure 1). The watershed is 3,990 acres in size (about 6.2 sq. miles), and includes sixteen subwatershed units (designated LMC-1 through LMC-10, representing the Lake Minnewashta drainage area, and LV-1 through LV-6, representing the portion of the Lake Virginia watershed downstream of Lake Minnewashta, Figure 10).

Surface flows in the Lake Virginia and Lake Minnewashta watershed are routed overland primarily though a system of culverts with a few areas served by typical urban storm sewer. Flows received by Lake Minnewashta discharge to Lake Minnewashta Creek, which flows into Lake Virginia. Lake Virginia discharges to Smithtown Bay of Lake Minnetonka through a short channel.

The water levels of Lake Virginia are strongly influenced by Lake Minnetonka backwater conditions when Minnetonka water levels are at or higher than about 926 ft (the bottom elevation of the culvert, which is the high point elevation separating the two lakes). However, the constant inflow of water from Lake Minnewashta Creek ensures that the general flow is in the direction of Lake Virginia to Minnetonka and keeps the water surface of Lake Virginia slightly above that of Minnetonka. If Lake Minnewashta Creek were to stop flowing and Lake Minnetonka were above the run-out of Lake Virginia, it is probable Lake Virginia and Minnetonka would equalize. Due to the backwater conditions on Lake Virginia, the Lake Virginia high water level is related to, but slightly higher than, that of Lake Minnetonka.

Land use and land cover

Land use north and west of Lake Minnewashta is dominated by single family residential (Figure 11). Lake Minnewashta Regional Park lies to the east of the lake. Within the park, land use is dominated by forest, woodland, wetland, and grassland. South of Highway 5, the watershed is also dominated by open space land use types (forest, woodland, and wetland). The area surrounding Lake Virginia is predominantly single family residential. The 2020 projected land use plans indicate some conversion of undeveloped land to single family residential (Figure 12).

The MLCCS land cover classifications were combined into five impervious surface area categories and six vegetative cover type categories (Figure 13). Under 2020 land use conditions, impervious cover is expected to increase slightly, with a decrease in forests and woodlands.

Lake Uses

Lake Virginia has a public access and boat ramp that are maintained by the DNR. Individual private properties along the lake (mostly on the southern shore) have private access points to the lake. Boating, fishing, swimming, water skiing, and tubing are common activities on the lake. In addition to fishing from boats, visitors fish from the shore near the public access.

Watershed Management

The City of Victoria completed a Lake Virginia Stewardship and Management Plan in 2000. A public access and boat ramp are maintained by the DNR. The public DNR access and individual private properties are all used to access the lake.

Based on a survey of lake residents completed for the lake management plan, Eurasian watermilfoil is the top concern. Lakeshore properties have been treated for milfoil by the Lake Virginia Association in the past; these treatments are meant to lessen the problem, as complete eradication is almost impossible. Several goals and recommendations were laid out in the management plan to control exotic species, improve water quality, restore and preserve shoreland habitat, and provide for compatible recreational uses.

Population

Population changes in the cities that intersect the Lake Virginia watershed are expected between now and 2030 (Table 4). Population is expected to increase dramatically in Victoria by 2030 (this takes into account the annexation of portions of Laketown Township to the City of Victoria), and is expected to approximately double in Chanhassen and Chaska. Population is expected to increase slightly in Shorewood.

Table 4. Current population and population forecasts for cities and townships within the Lake Virginia watershed

2030 Regional Development Framework - Revised Forecasts as of December 10, 2008

County	City or Township	Population				% Change 2000 to 2030
		2000	2010	2020	2030	
Carver	City of Chanhassen	20,321	27,500	34,500	38,000	87%
Carver	City of Chaska	17,603	27,600	33,000	35,700	103%
Carver	City of Victoria	4,025	10,700	19,600	28,000	596%
Hennepin	City of Shorewood	7,400	7,850	8,000	8,100	9%

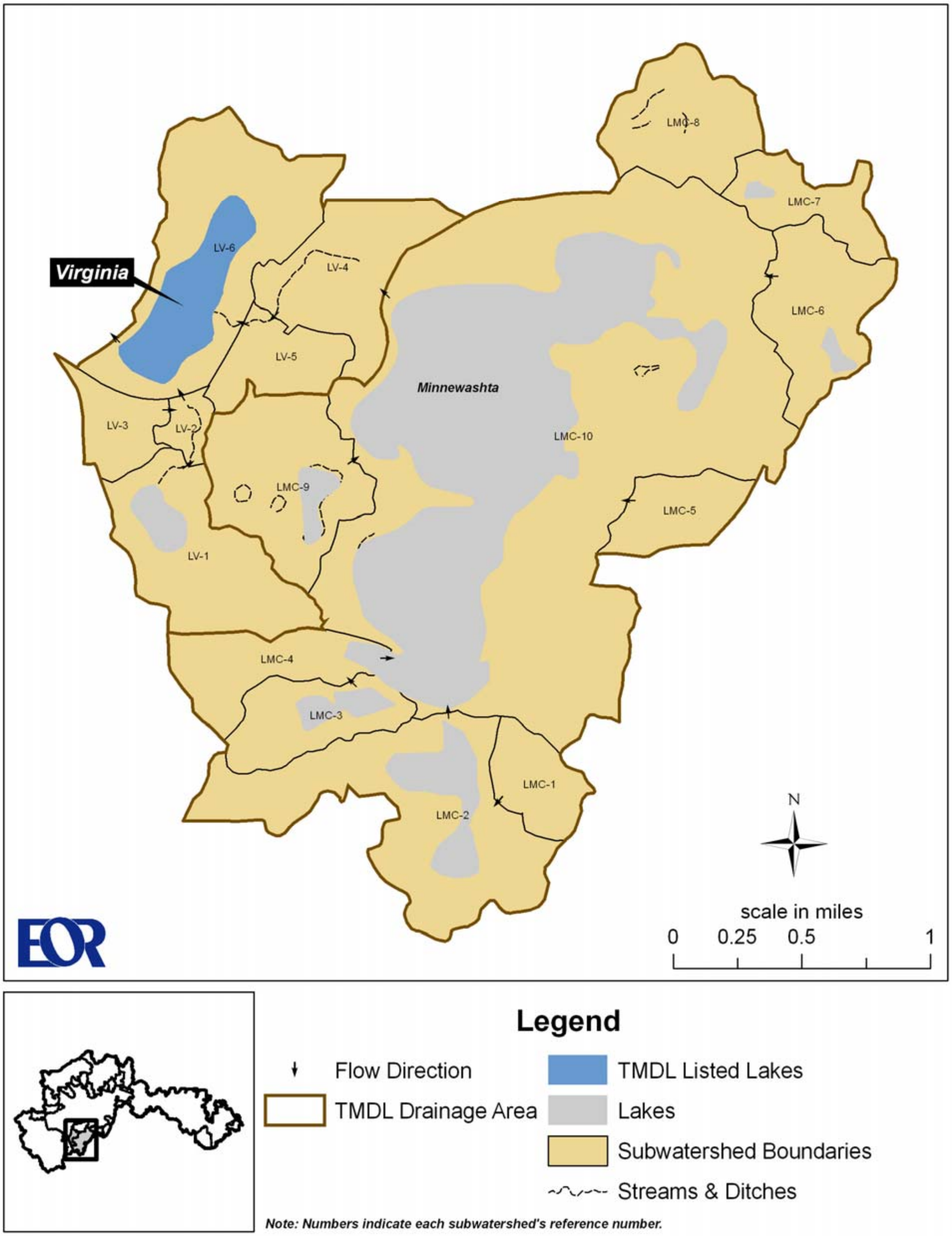


Figure 10. Lake Virginia Subwatersheds and Drainage Direction

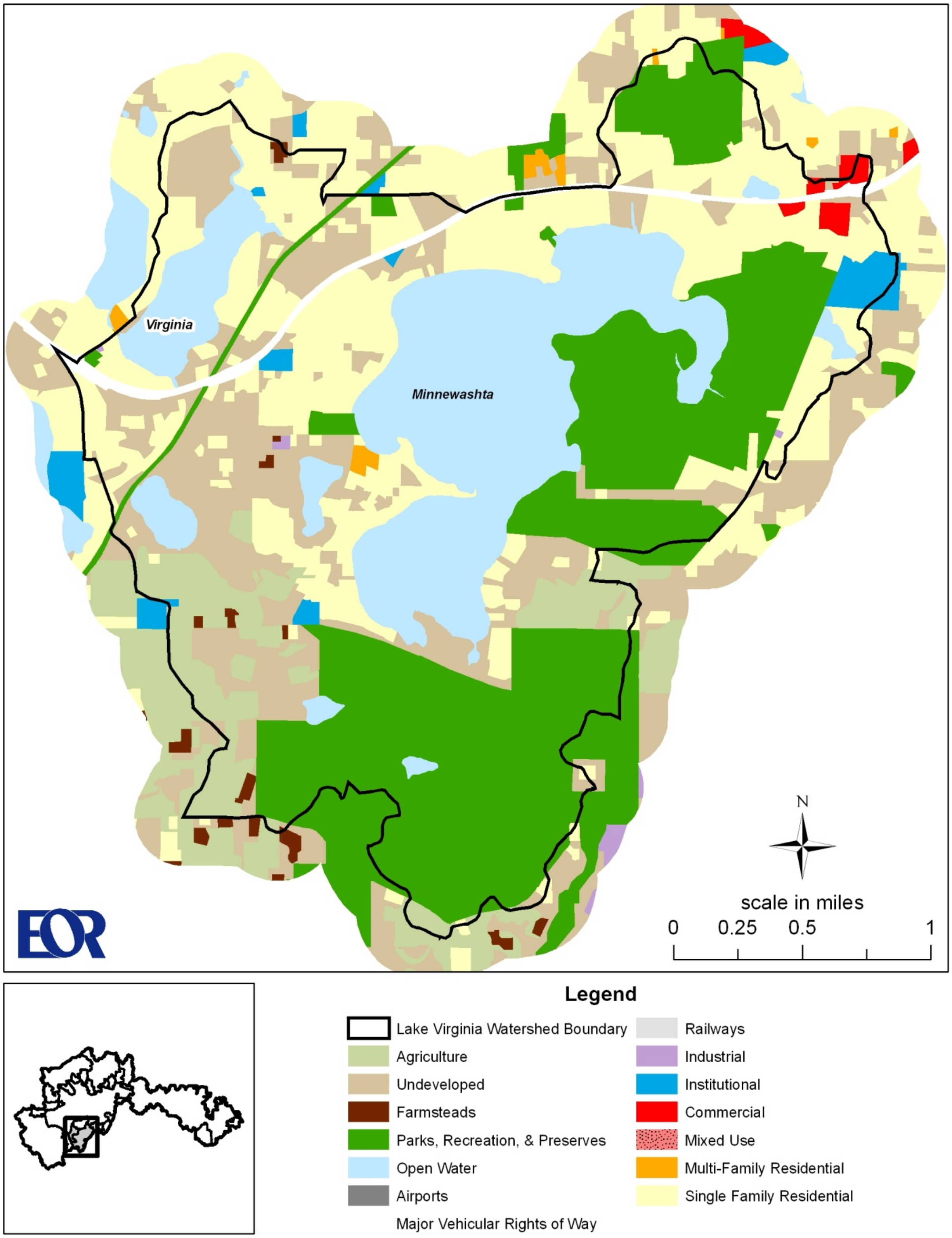


Figure 11. Lake Virginia Land Use (Generalized Land Use 2000 for the Twin Cities Metropolitan Area)

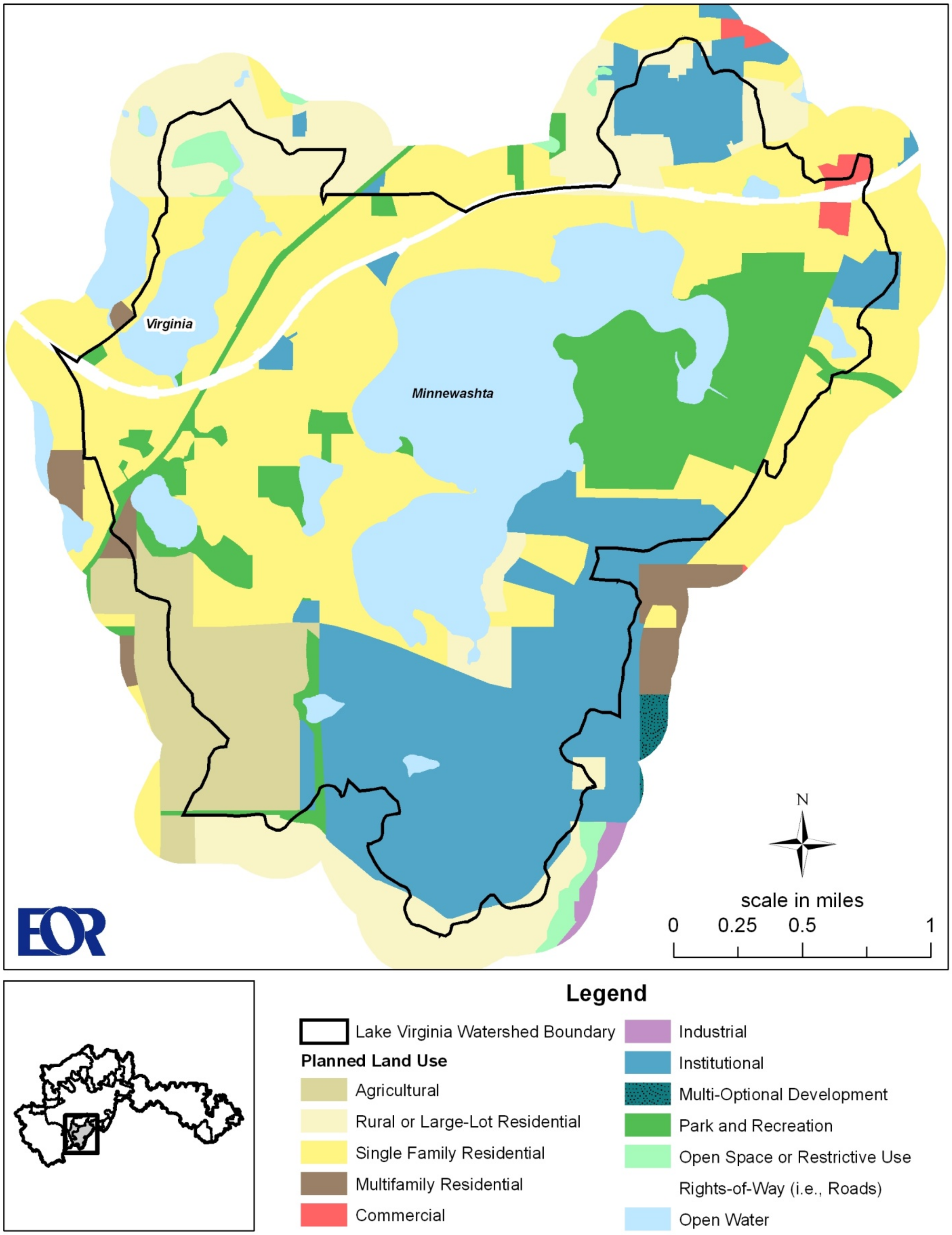


Figure 12. Lake Virginia Planned Land Use (2020 Regional Planned Land Use - Twin Cities Metropolitan Area)

See footnote in Table 8 regarding "Rural or Large-Lot Residential" land use in Hennepin County.

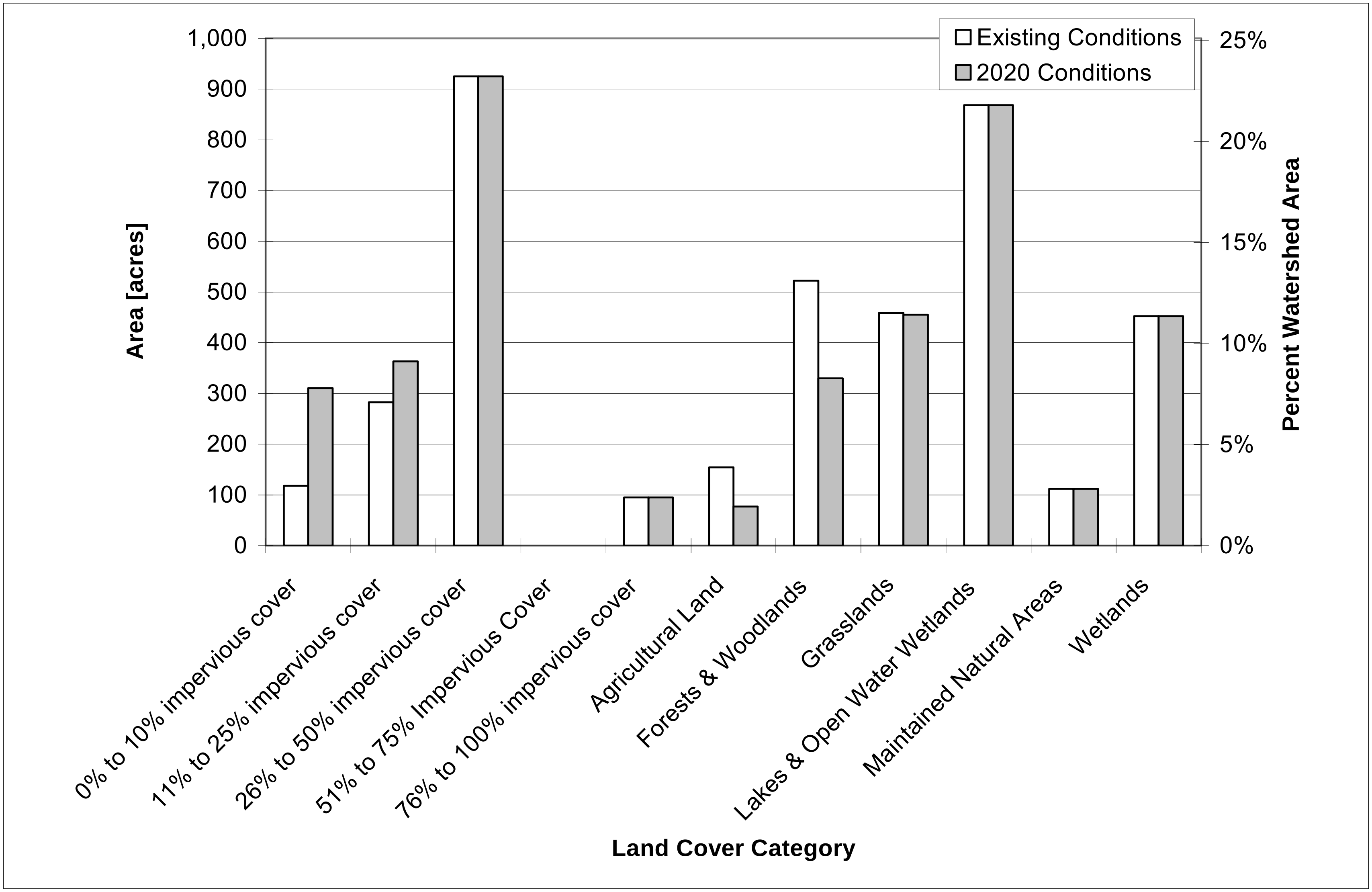


Figure 13. Lake Virginia Watershed Land Cover
MLCCS Level 3 data; existing conditions from 2002 data, 2020 conditions projected from MLCCS data and projected (2020) land use changes.

C. Pollutant Sources

Role of Phosphorus in Lakes

Total phosphorus is often the limiting factor controlling primary production in freshwater lakes. It is the nutrient of focus for this TMDL, and is sometimes referred to as the causal factor. As phosphorus concentrations increase, primary production may also increase, as measured by higher chlorophyll-*a* concentrations. Higher concentrations of chlorophyll lead to lower water transparency. Both chlorophyll-*a* and Secchi transparency are referred to as response factors, since they indicate the ecological response of a lake to excessive nutrient input. Increased chlorophyll-*a* (a measure of algae growth) and transparency (water clarity) directly relate to the perceived aquatic recreation suitability of lakes.

There is often a positive relationship between TP and chlorophyll-*a* in a lake, as is the case with the TMDL study lakes (Figure 14). Similarly, a negative relationship is apparent between TP and Secchi depth (Figure 15).

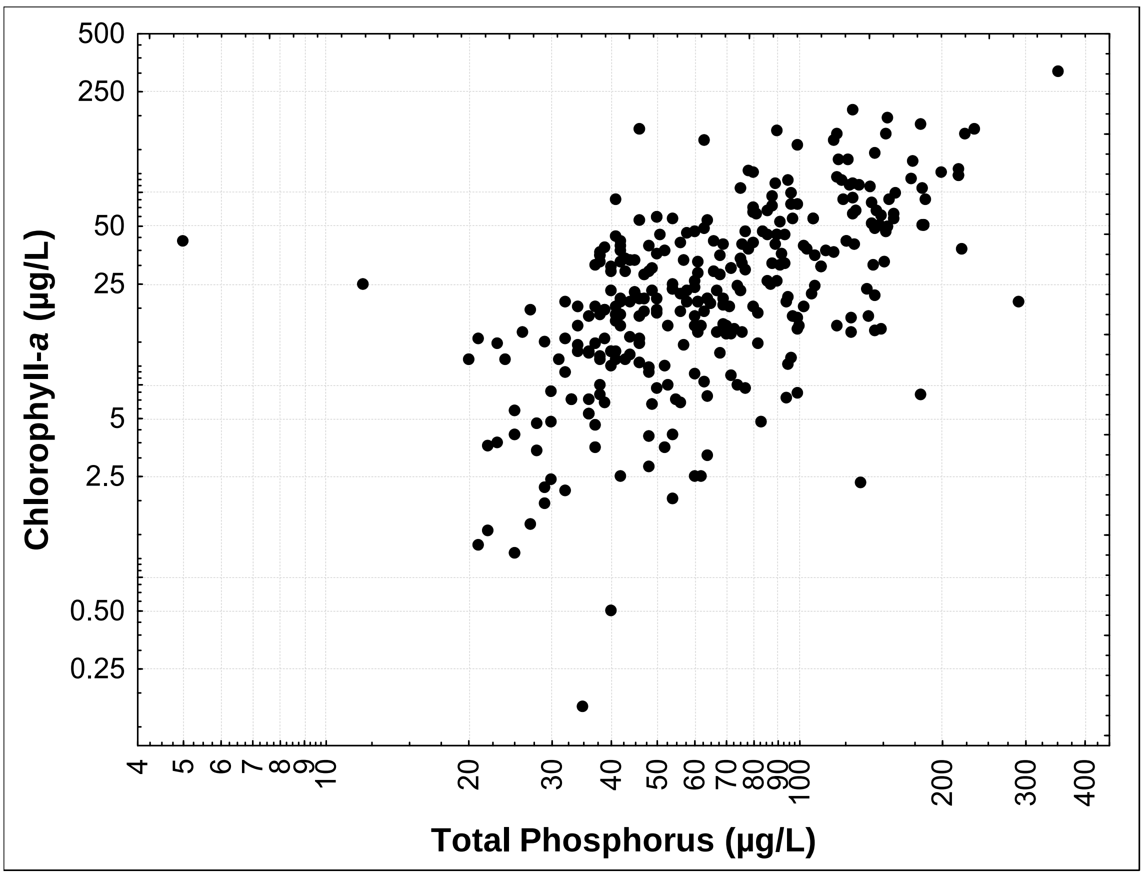


Figure 14. Relationship of Chlorophyll-a to TP in Project TMDL Lakes (2000-2007 data)
Figure includes data from Brownie Lake and Powderhorn Lake, originally part of this TMDL project.

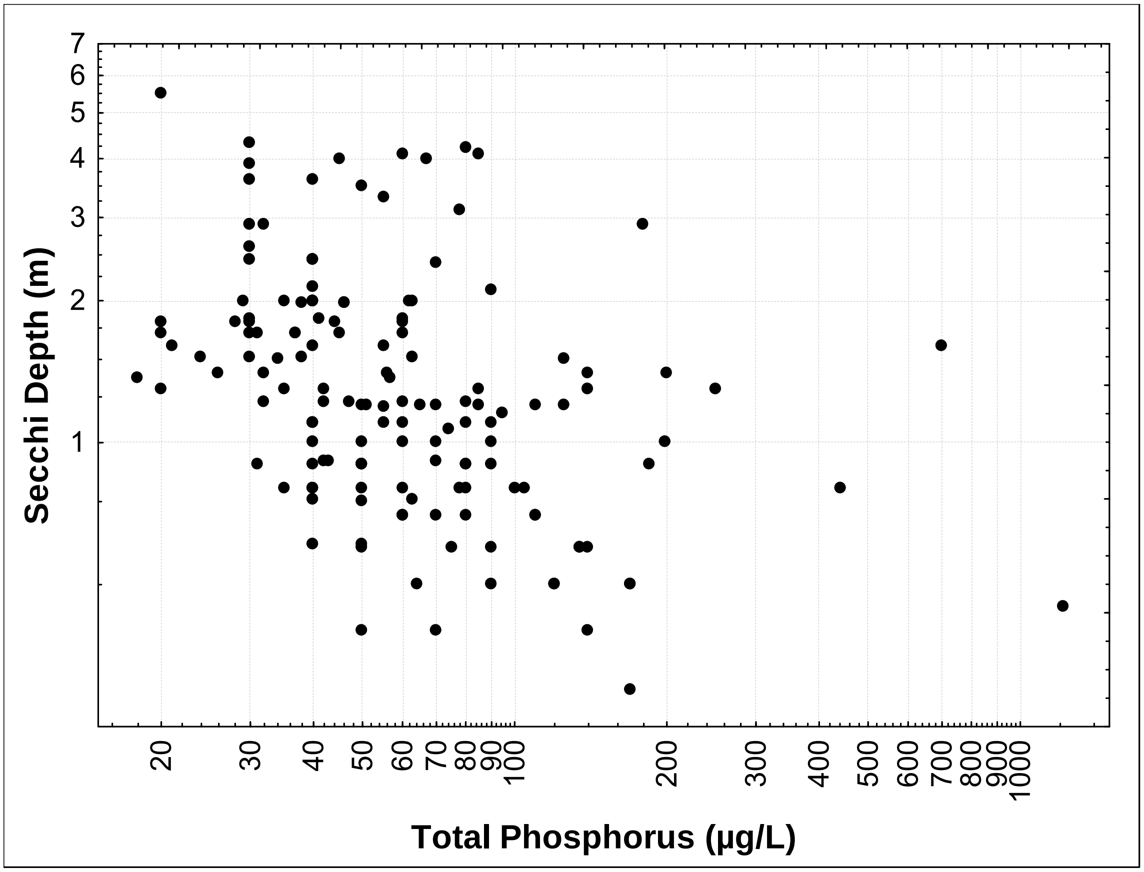


Figure 15. Relationship of Transparency to TP in Project TMDL Lakes (all available data)
Figure includes data from Brownie Lake and Powderhorn Lake, originally part of this TMDL project.

Phosphorus and Shallow Lake Ecology

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

The result of this impact of biological components on the ecological interactions is that shallow lakes normally exhibit one of two alternative stable states (Figure 16): the turbid, phytoplankton-dominated state, and the clear, macrophyte (plant)-dominated state. The clear state is the most preferred, since phytoplankton communities (composed mostly of algae and cyanobacteria) are held in check by diverse and healthy zooplankton and fish communities. Less nutrients are released from the sediments in this state. The roots of the macrophytes stabilize the sediments, lessening the amount of sediment stirred up by the wind. Periodic winter fish kills are desirable, as they control the population of bottom feeders that also stir up bottom sediments and exacerbate internal loading. Bottom feeders also forage in the bottom sediments and release nutrients into the water column through excretion.

Nutrient reduction in a shallow lake does not lead to a linear improvement in water quality (indicated by turbidity in Figure 16). As external nutrient loads are decreased in a lake in the turbid state, slight improvements in water quality may at first occur. At some point, a further decrease in nutrient loads will cause the lake to abruptly shift from the turbid state to the clear state. The general pattern in Figure 16 is often referred to as hysteresis, meaning that, when forces are applied to a system, it does not return completely to its original state nor does it follow the same trajectory on the way back.

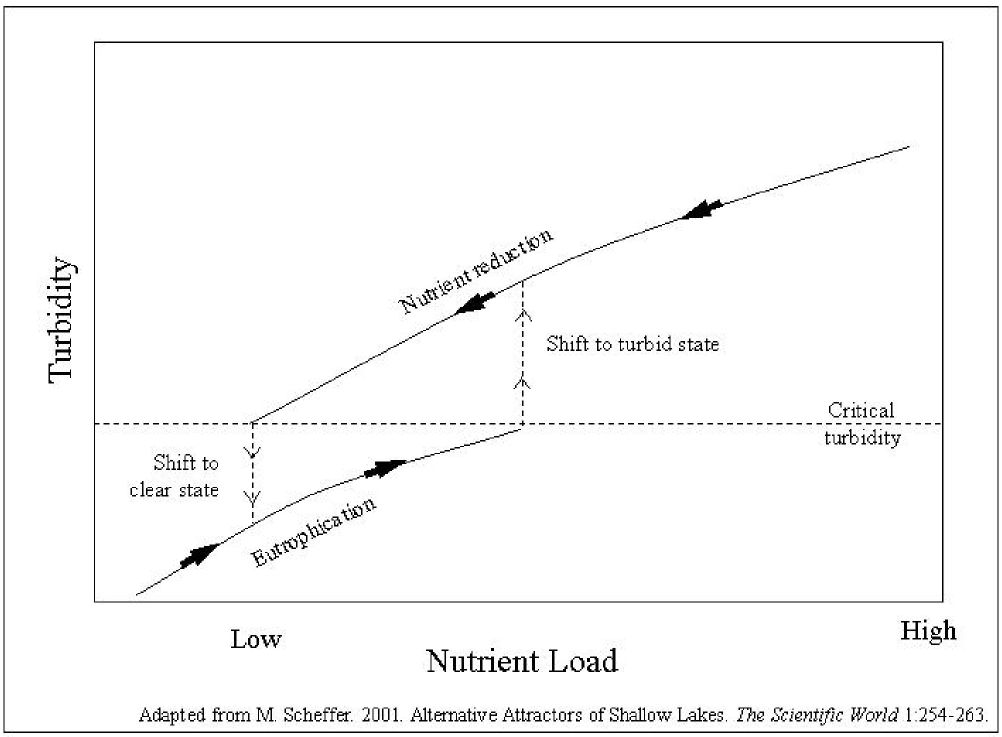


Figure 16. Alternative Stable States in Shallow Lakes

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

- Disturbance to the macrophyte community, for example from wind, benthivorous fish, boat motors, or light availability (influenced by algal density or water depth).

- A decrease in zooplankton grazer density, which allows unchecked growth of sestonic (suspended) algae. These changes in zooplankton density could be caused by an increase in predation, either directly by an increase in planktivorous fish that feed on zooplankton, or indirectly through a decrease in piscivorous fish that feed on the planktivorous fish.

This complexity in the relationships among the biological communities in shallow lakes leads to less certainty in predicting the in-lake water quality of a shallow lake based on the phosphorus load to the lake. The relationships between external phosphorus load and in-lake phosphorus concentration, chlorophyll concentration, and transparency are less predictable than in deeper lakes, and therefore lake response models are less accurate. At a certain in-lake phosphorus concentration, a lake can exist in either of the two stable states and thus have very different chlorophyll concentrations and transparencies.

It is therefore often helpful to use chlorophyll concentrations and transparency as endpoints themselves, instead of the main focus being in-lake phosphorus concentrations. Since TMDLs are load-based, the goals are based on phosphorus loading to the lake, including both external and internal loads. But the overall goal is improved water quality in the lakes, and therefore chlorophyll and transparency (the response factors) should be considered as well.

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

Phosphorus Sources

The phosphorus sources to these impaired lakes consist of the following different types:

- Regulated stormwater runoff
- Non-regulated stormwater runoff
- Point sources
- Internal loading
- Atmospheric deposition
- Groundwater discharge

There are no concentrated animal feeding operations (CAFOs) in the watershed.

Stormwater Runoff

Stormwater runoff is generated in the watershed during precipitation events. The sources of phosphorus in stormwater are many and include: decaying vegetation (leaves, grass clippings, etc.), domestic and wild animal waste, soil and deposited particulates from the air, oil and grease from vehicles, and phosphorus-containing fertilizer. Certain types of stormwater runoff are covered under National Pollutant Discharge Elimination System (NPDES) permits based on where the stormwater originates:

Municipal Separate Storm Sewer Systems

Municipal Separate Storm Sewer Systems (MS4s) are defined by the Minnesota Pollution Control Agency as conveyance systems owned or operated by an entity such as a state, city, town, county, district, or other public body having jurisdiction over disposal of stormwater or other wastes. Stormwater runoff that falls under these permits is regulated as a point source and therefore must be included in the WLA portion of a TMDL (EPA, 2002; see 40 C.F.R. § 130.2(h)). EPA recommends that the WLAs be broken down as much as possible in the TMDL, as information allows. For this TMDL, with one exception, individual WLAs were established for each MS4 community. This will facilitate implementation planning and load reduction goals for the MS4 entities.

Phase I of the NPDES Storm Water Program identified Minneapolis and St. Paul as large MS4 communities, and each city has an individual NPDES permit. Under Phase II of the NPDES Storm Water Program, MS4 communities outside of urbanized areas, with populations greater than 10,000 (or greater than 5,000 if they are located within 0.5 mile of an outstanding value resource or impaired water) are classified as small designated MS4s. MS4 communities within urbanized areas are classified as mandatory MS4s. Under the NPDES Stormwater Program, the MS4 entities are required to obtain a permit and design an MS4 Storm Water Pollution Prevention Program, which outlines a plan to reduce pollutant discharge, protect water quality, and satisfy water quality requirements in the Clean Water Act. A report is submitted each year by the municipality documenting the implementation of the Storm Water Pollution Prevention Program. The municipal stormwater permit holds municipalities responsible for stormwater discharging from the conveyance system within their city limits. The conveyance system includes ditches, roads, storm sewers, stormwater ponds, etc.

The MS4 permits cover only the stormwater runoff that passes through each MS4 community's conveyance system. There are portions of each city that generate stormwater runoff that does not pass through a conveyance system but rather runs off directly to a water body. In the cities that are completely contained within the Metropolitan Urban Service Area (MUSA) boundary, these areas are relatively small. However, there are cities that are not fully contained within the MUSA boundary; these cities, such as several of those in Carver County, have larger expanses of their land area that are not urbanized and that are therefore not covered under the MS4 permit. Future point sources may be included in a WLA. 40 C.F.R. § 130.2(h) states that a WLA is "the portion of a receiving water's loading capacity that is allocated to one of its existing or *future* point sources of pollution" (emphasis added). The MS4-regulated area of the MS4 communities was approximated based on projected 2020 land use; there are certain land uses that in general indicate whether or not the area is regulated by the MS4 permit (more detail is included in *Section 3.A: Pollutant Sources*, see Table 8).

The MS4 entities within the boundaries of this project are either Phase I (City of Minneapolis), Phase II designated (Waconia), or Phase II mandatory MS4s (the remainder), consisting of eight municipalities, one township, two counties, the MN Department of Transportation, and the Minnehaha Creek Watershed District (Table 5, Figure 17 and Figure 18). Laketown Township, although currently in the watershed, will ultimately be fully annexed by the Cities of Waconia, Chaska, and Victoria and therefore will not exist under future/ultimate conditions. The City of Waconia does not currently lie within the watershed boundaries, but after it has annexed portions of Laketown Township it will lie within the Parley Lake watershed. Only one jurisdiction in the watershed, Fort Snelling, is not a regulated MS4 community.

The MS4 permit for the City of Minneapolis applies to stormwater owned or operated by the City of Minneapolis or the Minneapolis Park and Recreation Board (MPRB). In most cases, MPRB stormwater is located within the municipal boundaries of the City of Minneapolis. However, the recently acquired Edward C. Solomon Park (within the Lake Nokomis watershed) is partially located within the city and partially located outside of the city boundary. Since the MS4 permit applies to MPRB stormwater, the area of the park was added to the City of Minneapolis boundary in order to determine the boundary of the regulated MS4.

Table 5. Regulated Municipal Separate Storm Sewer Systems (MS4s)

Name	NPDES Permit #
Carver County	MS400070
Chanhassen City	MS400079
Chaska City	MS400080
Hennepin County	MS400138
Laketown Township	MS400142
Minneapolis City	MN0061018
Minnehaha Creek Watershed District	MS400182
Minnetrista City	MS400106
Mn/DOT Metro District	MS400170
Richfield City	MS400045
Shorewood City	MS400122
Victoria City	MS400126
Waconia City	MS400232

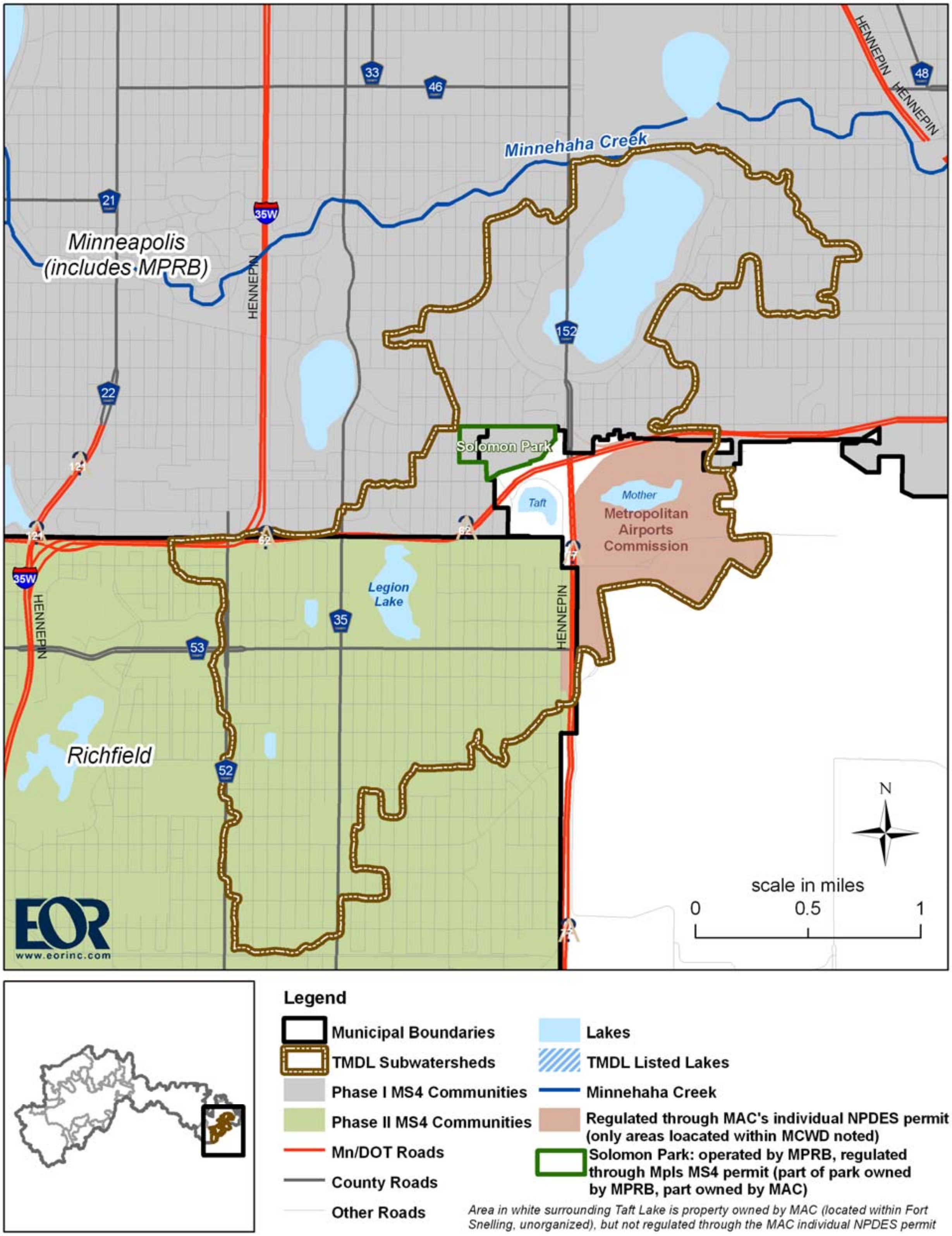


Figure 17. Location of Regulated Sources within the Lake Nokomis watershed
Sources include Municipal Separate Storm Sewer Systems (MS4s) and Metropolitan Airports Commission (MAC) individual permit

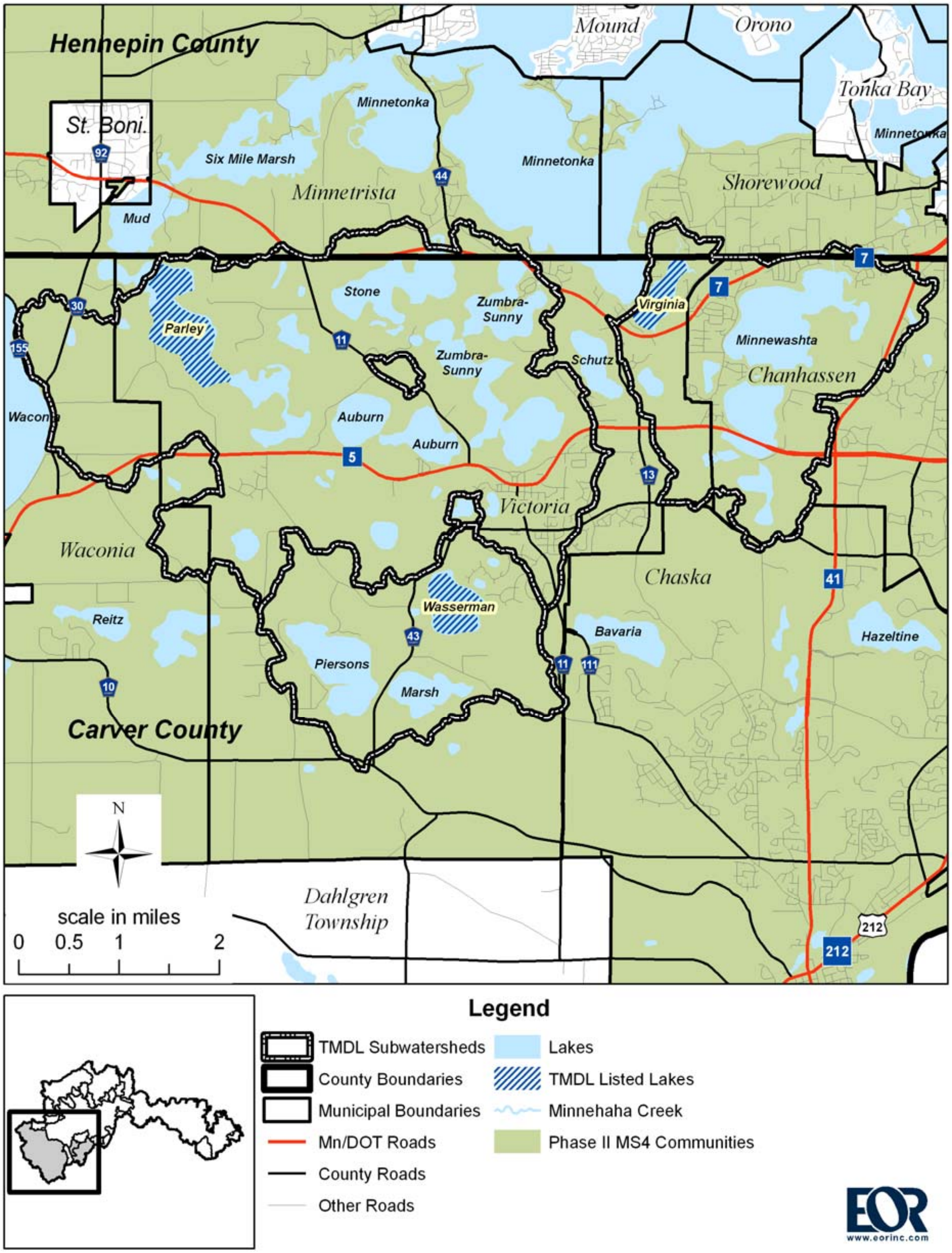


Figure 18. Location of Regulated Municipal Separate Storm Sewer Systems (MS4s) within Watersheds of Lake Virginia, Lake Wassermann, and Parley Lake

Municipal boundaries are those expected after the annexation of Laketown Township by the Cities of Victoria and Waconia (ultimate municipal boundaries).

Construction

Construction sites can contribute substantial amounts of sediment to stormwater runoff. The NPDES Stormwater Program requires that all construction activity disturbing areas equal to or greater than one acre of land must obtain a permit and create a Stormwater Prevention Pollution Plan (SWPPP) that outlines how runoff pollution from the construction site will be minimized during and after construction. Construction stormwater permits cover construction sites throughout the duration of the construction activities, and the level of on-going construction activity varies.

Industrial

The draft Industrial Stormwater General Permit, projected to be re-issued in 2010, 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.

<u>Non-regulated stormwater runoff</u>

Non-regulated stormwater runoff includes watershed runoff that does not originate within the jurisdiction of an MS4 permit. It includes land uses such as agriculture, open space, and rural residential.

<u>Metropolitan Airports Commission</u>

The Metropolitan Airports Commission (MAC) owns and operates the Minneapolis-St. Paul International Airport (MSP). The significant discharges from the facility that are regulated in the NPDES permit (permit # MN0002101) consist of process wastes in combination with stormwater runoff, referred to in the permit as waste/stormwater. A portion of the land operated by MAC is located in the Lake Nokomis watershed (Figure 17). This area, which drains to Mother Lake, is approximately 300 acres and consists of impervious areas, grassland, and Mother Lake itself; industrial activity involving process wastes does not occur anymore in the MAC's Mother Lake drainage area. The impervious areas are used for storage, fire-fighter training, and aircraft taxiing. Soil stockpiling and other construction staging activities occur in an area that is semi-landlocked. Other semi-landlocked areas exist.

<u>Internal Loading</u>

Phosphorus internal loading is the phosphorus that is released from the lake bottom sediments into the water column. Each year, phosphorus settles out of the water column and adsorbs onto particulate matter in the lake sediments and accumulates. This phosphorus may be re-released into the water column, and can occur through various mechanisms:

1) Anoxic conditions in the overlying waters: Water at the sediment-water interface may remain anoxic for a portion of the growing season, and low oxygen concentrations result

in phosphorus release from the sediments. If a lake's hypolimnion remains anoxic for a portion of the growing season, the phosphorus released due to anoxia will be mixed throughout the water column when the lake loses its stratification at the time of fall mixing. Alternatively, in shallow lakes, the periods of anoxia can last for short periods of time; wind mixing can then destabilize the temporary stratification, thus releasing the phosphorus into the water column.

2) Physical disturbance by bottom-feeding fish such as carp and bullhead. This is exacerbated in shallow lakes since bottom-feeding fish inhabit a greater portion of the lake bottom than in deeper lakes. (Sediments located in deep water do not contain as much of the benthic feeders' food sources as do sediments in shallow waters/lakes, such as aquatic plants, insects, crayfish, and dead fish.)
3) Physical disturbance due to wind mixing. This is more common in shallow lakes than in deeper lakes. In shallower depths, wind energy can vertically mix the lake at numerous instances throughout the growing season.
4) Phosphorus release from decaying curlyleaf pondweed (*Potamogeton crispus*). This is more common in shallow lakes since shallow lakes are more likely to have nuisance levels of curlyleaf pondweed.

<u>Atmospheric Deposition</u>

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly to the lake surface as the particulates settle out of the atmosphere. Atmospheric deposition is usually a minimal source of phosphorus to a lake; however; if a lake has a very low watershed to lake area ratio, atmospheric deposition can represent a substantial portion of the total phosphorus load to a lake.

<u>Groundwater Discharge</u>

Phosphorus may enter a lake through groundwater discharge to a lake. The concentration of phosphorus in groundwater is usually below the lake's water quality standard, and usually doesn't play a significant role in the eutrophication of a lake. However, in a lake with a lot of groundwater interaction, the phosphorus from groundwater can play a role in the phosphorus budget. Site-specific data are needed to estimate the role of groundwater in a lake's phosphorus budget; phosphorus loads due to groundwater were not estimated as part of this project.

2. WATER QUALITY STANDARDS

Designated Uses

The four listed lakes are all classified as Class 2B, 3C, 4A, 4B, 5, and 6 waters. The most protective of these classes is Class 2 waters, which are protected for aquatic life and recreation. MN Rules Chapter 7050.0140 Water Use Classification for Waters of the State reads:

> Subp. 3. Class 2 waters, aquatic life and recreation. Aquatic life and recreation includes all waters of the state that support or may support fish, other aquatic life, bathing, boating, or other recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life or their habitats or the public health, safety, or welfare.

Water Quality Standards

Water quality standards are established to protect the designated uses of the state's waters. Amendments to Minnesota's Rule 7050, approved in May 2008, include eutrophication standards for lakes (Table 6). Eutrophication standards were developed for lakes in general, and for shallow lakes in particular. Standards are less stringent for shallow lakes, due to higher rates of internal loading in shallow lakes and different ecological characteristics.

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

According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 ft, or if the littoral zone (area where depth is less than 15 ft) covers at least 80% of the lake's surface area. Parley Lake is shallow according to this definition; the remaining three lakes are not.

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

Parameter	Eutrophication Standard, General	Eutrophication Standard, Shallow Lakes
TP (µg/l)	TP < 40	TP < 60
Chlorophyll-*a* (µg/l)	chl < 14	chl < 20
Secchi depth (m)	SD > 1.4	SD > 1.0
Lakes the standards apply to	Nokomis, Virginia, Wassermann	Parley

TMDL Endpoints

MPCA lake TMDL protocol allows for setting site-specific standards and standards based on natural background conditions *(Lake nutrient TMDL protocols and submittal requirements*, MPCA March 2007). A request is being made to set site-specific standards for Lake Nokomis (Table 7). This request (Appendix C) is being considered by the MPCA and EPA, and the process could take up to two years. Instead of waiting for the final decision regarding the site-specific standard, this TMDL will consider both the eutrophication standards and the requested site-specific standards as dual endpoints for Lake Nokomis. The TMDL will be calculated based on both of these endpoints, to allow for either to be implemented after the standards are finalized.

Table 7. Requested Site-Specific Standards for Lake Nokomis

Parameter	Eutrophication Standard, General	Requested Site-Specific Standard
TP (µg/l)	TP < 40	TP < 50
Chlorophyll-*a* (µg/l)	chl < 14	chl < 20
Secchi depth (m)	SD > 1.4	SD > 1.4

3. TMDL DERIVATION APPROACH

This section presents the overall approach to estimating the components of the TMDL. The pollutant sources were first identified, categorized, and estimated (*Section A: Pollutant Sources*). The loading capacity (TMDL) of each lake was then estimated (*Section B: Calculation of TMDL Components*) using an in-lake phosphorus response model and was divided among wasteload allocations (WLAs) and load allocations (LAs).

- Loading capacity (=TMDL): the total amount of pollutant that the water body can assimilate and still maintain water quality standards.
- Wasteload allocations (WLAs): the pollutant load that is allocated to point sources, including regulated MS4 entities, construction, and industrial stormwater covered under an NPDES permit. A source can receive a WLA for a current or future regulated (that will come under regulation in the foreseeable future) pollutant source.
- Load allocations (LA): the pollutant load that is allocated to non-NPDES-regulated sources, including non-regulated MS4 stormwater runoff, atmospheric deposition, and internal loading.

A. Pollutant Sources

The pollutant sources identified were stormwater runoff, internal loading, and atmospheric deposition. Methods to quantify the existing loads are presented in this section.

The pollutant sources were estimated using a combination of monitoring data and modeling approaches. If additional monitoring and/or evaluation become available, the new information may be used to refine the existing load estimates.

Stormwater Runoff

The phosphorus load from stormwater runoff was calculated using the Simple Method, described in Appendix A. This approach uses stormwater runoff volume and total phosphorus event mean concentrations, which differ according to land use and land cover, to calculate phosphorus loads from stormwater runoff. The loads were summarized separately for each city and/or MS4 community.

The Simple Method was selected based on its ability to compare loads from different land uses and levels of imperviousness. Additionally, the data needs of the model fit well with the amount of available data in the watershed to serve as input. Output from the watershed modeling serves as input into the lake response models.

Best management practices (BMPs) that already exist within the watersheds were not factored in when estimating the total watershed load to each lake. Each MS4 community is involved in accounting for all of the BMPs that are in place. In the TMDL implementation plan, estimated load reductions attributed to the BMPs will be presented.

Municipal Separate Storm Sewer Systems (MS4)

For Parley Lake, Lake Virginia, and Wassermann Lake, 2020 regional planned land use data was used to approximate the areas that are and are not regulated by the MS4 permit. Regulated land uses are considered to be those having stormwater conveyances owned by the MS4. Only those land uses that are regulated under the MS4 permit were considered to be part of regulated stormwater runoff (Table 8). Parks and recreation were included in the regulated MS4 boundary since the majority of the parks are surrounded by MS4-regulated land uses such as residential, and therefore would also likely be regulated by the MS4 permit. One exception was Carver Park Reserve in the Parley Lake watershed; this entire area was included as non-regulated stormwater runoff.

The percent distribution of areas that are and are not regulated by the MS4 permit was applied to the total stormwater runoff load and used to apportion it into stormwater runoff regulated by the MS4 permit and stormwater runoff that is not regulated. Although the 2020 regional planned land use distribution is different from the land use distribution in the existing land use data, the 2020 regional planned land use data were used to approximate the break-down of existing loading into regulated and non-regulated stormwater. This allowed the existing loads to be comparable to the TMDL allocations so that percent reductions needed could be estimated by regulated MS4.

Table 8. Land Use Categories Regulated by MS4 Permit

Land Use Description (2020 regional planned land use categories)	Regulated Stormwater
Agricultural	N
Commercial	Y
Industrial	Y
Institutional	Y
Multi-Family Residential	Y
Open Space	N
Park & Recreation[1]	Y
Roadway	Y
Rural / Rural Residential[2]	Y / N
Single-Family Residential	Y
Water	N

[1]Although park and recreation is often open space, it was included as part of regulated stormwater runoff because in these watersheds parkland is often dispersed throughout residential and other developed areas that are regulated by the MS4 permit. An exception is Carver Park, in the Parley Lake watershed, which was considered unregulated stormwater runoff.

[2]The types of land use within the “Rural / Rural Residential” category differ between Carver County and Hennepin County. The “Rural / Rural Residential” areas within the portion of Hennepin County in the Lake Virginia watershed (0 - 1 units per acre) are similar to the areas identified as “Single-Family Residential” in Carver County (1.2 - 4.0 units per acre). These areas were categorized in this study to be likely regulated by the MS4 permit. The “Rural / Rural Residential” areas within the portion of Hennepin County in the Parley Lake watershed (1 unit per 10 acres) and the areas within Carver County categorized as “Rural / Rural Residential” (1 unit per 2.5 acres minimum or 1 unit per 10 acres) were categorized in this study to be unlikely regulated by the MS4 permit.

Based on the fully developed conditions of the Lake Nokomis watershed, it was assumed that the entire drainage from the City of Minneapolis and the City of Richfield is regulated by the MS4 permit, and that land use is not expected to change in the Lake Nokomis watershed.

Stormwater runoff was further divided according to individual MS4 permit:

- Road authorities: The jurisdiction of the MS4s that are road authorities (Mn/DOT, Hennepin County, and Carver County) was determined by using the average right-of-way (ROW) width for each road length. The ROW widths were provided by the permittees. The load estimates resulting from the watershed modeling (Appendix A) were summed up for areas within each road authority's jurisdiction (ROW). Land within the ROW may be categorized as land uses besides roadway or major vehicular rights of way due to the scale at which the land use data was developed.

- The MS4 permits of the road authorities apply only to area within the urbanized area as defined by the U.S. Census; the urbanized area boundary from 2000 was used (see Figure 34, Figure 43, and Figure 50 for the urbanized areas within the Parley, Virginia, and Wassermann Lake watersheds, respectively).

- Watershed district: MCWD's jurisdiction covers the portion of Six Mile Creek that is Judicial Ditch-2 (JD-2), in the Parley Lake watershed. The area of JD-2 was determined by estimating the ditch width using aerial photography and using the aerial coverage of the ditch to represent MCWD's MS4 jurisdiction.

- Municipalities: The jurisdiction of the municipalities was determined by using the municipal boundaries and subtracting out the area that was determined to be under the jurisdiction of the road authorities and the watershed district.

Metropolitan Airports Commission (MAC)

The load from stormwater runoff from the area covered by the MAC NPDES permit was approximated using the same method that was used to estimate stormwater runoff from the MS4 entities (the Simple Method).

Non-regulated Stormwater Runoff

Fort Snelling is the only jurisdiction within the project area that is not covered under an MS4 permit. In addition to Fort Snelling, the land areas within MS4 communities that were estimated to not be regulated by the MS4 permit were included in the non-regulated stormwater runoff category. The load from these areas was calculated using the same method as the load covered under the MS4 permits (the Simple Method), but its allocation will be contained under the loading allocations since it is not a regulated source.

A relatively limited number of livestock facilities exist in the project area and these occur in the Parley Lake and Wassermann Lake watersheds and have a total of approximately 600 animal units. Loads from any manure runoff from the livestock facilities themselves were not specifically estimated in the Simple Method methodology.

Internal Loading

Internal loading was estimated as part of the lake modeling approach (Appendix B). Internal loading is a non-regulated source.

Atmospheric Deposition

Atmospheric deposition was estimated with the default loading rate (30 kg/km^2-yr) in the lake model used to calculate the TMDL (Appendix B). Atmospheric deposition is a non-regulated source.

B. Calculation of TMDL Components

The pollutant sources were estimated using a combination of monitoring data and modeling approaches. If additional monitoring and/or evaluation become available, the new information may be used to refine the existing load estimates. These future changes would not affect the actual TMDL components (including the WLA and LA), but rather would change the amount of load reductions needed to meet the allocations.

Loading Capacity

To link phosphorus loads with in-lake water quality and to calculate the loading capacity for each lake, in-lake models were developed using Bathtub (Version 6.1, 2004). A publicly available model, Bathtub was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). Bathtub has been used successfully in many lake studies in Minnesota and throughout the United States. Bathtub is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. Bathtub's time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. Bathtub has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of Bathtub is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and (if appropriate) groundwater; and outputs through the lake outlet, groundwater (if appropriate), water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments. Bathtub allows choice among several different mass balance phosphorus models. For deep lakes in Minnesota, the option of the Canfield-Bachmann lake formulation has proven to be appropriate in most cases. For shallow Minnesota lakes, other options have often been more useful. Bathtub's in-lake water quality predictions include two response variables, chlorophyll-*a* concentration and Secchi depth, in addition to total phosphorus concentration. Empirical relationships between in-lake total phosphorus, chlorophyll-*a*, and Secchi depth form the basis for predicting the two response variables. Among the key empirical model parameters is the ratio of the inverse of Secchi depth (the inverse being proportional to the light extinction coefficient) to the chlorophyll-*a* concentration. The ratio's default value in the model is 0.025 meters squared per milligram (m^2/mg); however, the experience of MPCA staff supports a lower value, as low as 0.015 m^2/mg, as typical of Minnesota lakes in general.

Nutrient inputs to the model consisted of stormwater runoff (estimated using the Simple Method, see Appendix A), atmospheric deposition (aerial loading rate, see Appendix B), and internal loading (mass balance approach, see Appendix B). The models were calibrated to existing water quality data, and then were used to determine the phosphorus loading capacity of each lake. The modeling approach is detailed in Appendix B. The loading capacity of each lake is the TMDL; the TMDL is then split into wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS).

The TMDL was first determined in terms of annual loads. In-lake water quality models predict annual averages of water quality parameters based on annual loads. Symptoms of nutrient enrichment normally are the most severe during the summer months. The state eutrophication standards are based on a growing season average and were established with this seasonal variability in mind.

The annual loads were converted to daily loads by dividing the annual loads by 365.

Margin of Safety

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

An implicit MOS was incorporated into all of the TMDLs for this study and is based on conservative assumptions related to the lake response model's prediction of the loading capacity of shallow lakes (as well as lakes that do not meet the MPCA's definition of shallow lakes, but still have a substantial proportion of littoral zone and so largely function ecologically the same way). The basis and reasoning for this is as follows:

- Shallow lakes that are impaired can be depended on to be in a turbid-water state, not a clear-water state.
- A lake water quality model calibrated for a shallow lake in a turbid-water state will ultimately determine a loading capacity that also reflects a turbid-water state.
- A shallow lake's state will switch from turbid-water to clear-water when its P load is reduced to the loading capacity as determined above.
- Shallow lakes can tolerate larger P loads in a clear-water state while still maintaining acceptable chlorophyll-a and Secchi transparency, than they can in a turbid-water state. This is largely because zooplankton graze phytoplankton (algae) more effectively in clear water. (The meaning of "acceptable" for chlorophyll-a and Secchi transparency is "meeting the state's water quality standards".)
- A shallow lake's loading capacity as determined above (i.e., for a turbid-water state) is therefore an underestimate. In other words, the amount of phosphorus calculated to be allowed to enter the lake is lower than what it would need to be in order to meet the in-lake water quality standards.

Wasteload Allocations

Municipal Separate Storm Sewer Systems (MS4)

The land use categories used to approximate areas regulated by the MS4 permit (Table 8 in *Section 3.A*) were also used to separate stormwater runoff into WLAs and LAs.

Individual WLAs were set for each regulated MS4 source, including regulated stormwater runoff from the municipalities, the road authorities (Hennepin County, Carver County, and Mn/DOT), and MCWD. The loading goals were based on a single target watershed runoff phosphorus concentration (150 µg/L) for the entire watershed of each TMDL lake, multiplied by the estimated volume of watershed runoff under modeled (Simple Method model) ultimate land use conditions[1](Appendix A). In some of the watersheds, a phosphorus concentration higher than 150 µg/L was sufficient for the lake to meet its in-lake water quality goals; therefore the target phosphorus concentration was adjusted accordingly. The TP concentration of 150 µg/L is derived from the concept of "irreducible pollutant concentrations," which is the concentration of a pollutant in stormwater that represents what has typically been shown to be achieved with current technology for stormwater treated with stormwater ponds and wetlands (Schueler 1996). Further basis for using this 150 µg/L value as a component of calculating allowable loads is provided below:

- The Minnesota Stormwater Manual (in Appendix N: Three-Tiered BMP Performance Range for TSS and TP; MPCA 2005) presents a summary of BMP performance data. The average TP outflow concentration of stormwater ponds ranges from 110 to 130 µg/L, the average TP outflow concentration of stormwater wetlands ranges from 130 to 200 µg/L, and the average TP outflow concentration of media filters ranges from 100 to 110 µg/L. 150 µg/L falls in the middle of these ranges.
- In the EPA's Stormwater Best Management Practice Guide (Appendix E: Quantifying Pollutant Removal) the median TP effluent concentration of BMPs ranges from 50 µg/L to 200 µg/L. 150 µg/L falls within this range as well.
- The average concentration of stormwater runoff in the City of Minneapolis (NPDES monitoring data summarized in the MPRB annual water resources monitoring reports) is 0.43 mg/L. Many water quality standards are based on achieving EPA's Nationwide Urban Runoff Program (NURP) standards, which on an average basis are expected to reduce phosphorus loads by 65%. Applying NURP guidelines to the runoff would yield a concentration of 153 µg/L.

It is important to make clear that this concentration was used to calculate the WLAs, but it is the actual load-based WLA that is the target for this TMDL. Since loads are the product of concentrations and volumes, the WLA can be achieved partly or wholly through volume control, even if the TP concentration in runoff is above 150 µg/L.

[1] Modeled ultimate land use conditions are slightly different from 2020 regional planned land use data. The 2020 regional planned land use data were used to approximate land uses that are regulated by the MS4 stormwater permit and then to separate the watershed loading goals into WLA and LA. The modeled ultimate land use conditions, as described in Appendix A, were used to initially set the overall watershed loading goal (before it was divided between WLA and LA).

TMDL allocations for Parley Lake and Lake Wassermann are presented under two scenarios. Portions of Laketown Township are currently located within these two watersheds, but the township will ultimately be fully annexed by the Cities of Victoria, Waconia, and Chaska (although Chaska is not in the Parley Lake watershed) in the future. TMDL allocations were given to Laketown Township for both the existing township boundaries and ultimate boundaries. The first set of allocations is based on the existing township and municipal boundaries (based on the most recent Laketown Township annexation to the City of Victoria on December 15, 2006, as presented in the City of Victoria's Comprehensive Plan 2008), and the WLAs were split up according to the distribution (by area) of the land uses likely to be regulated by the MS4 permit (Table 8) within Laketown Township and the Cities of Victoria and Waconia. The second set of allocations is based on the ultimate municipal boundaries, in which Laketown Township is fully annexed by the Cities of Victoria and Waconia. A transfer rate (in lbs TP/acre-year) is provided for when land is annexed from Laketown Township to either the City of Victoria or the City of Waconia; this rate will be used to transfer WLA from Laketown Township to the appropriate city as land is annexed. The rate is different for each city because the relative distribution of land uses (which determines which areas are regulated by the MS4 permit) is different in each jurisdiction. Both sets of allocations use projected 2020 land use data to approximate the break-down into WLAs and LA (see *Section 3. A: Municipal Separate Storm Sewer Systems*).

Specifics of how WLAs were calculated for each lake are included in Section 4 where the TMDL calculations are presented for each lake.

Metropolitan Airports Commission

The WLA for the MAC was developed using the same approach that was used to calculate the WLA for the MS4 entities, based on a single target watershed runoff phosphorus concentration (150 µg/L), multiplied by the estimated volume of watershed runoff under ultimate land use conditions (Appendix A). This target concentration was used to calculate the WLA, but it is the actual load-based WLA that is the target for this TMDL. The WLA can be achieved partly or wholly through volume control, even if the TP concentration in runoff is above 150 µg/L.

Under consideration for the MAC area within the Mother Lake drainage area is the transition from the individual NPDES permit to coverage under the NPDES general industrial permit. If this were to happen, the individual WLA provided to MAC in the Lake Nokomis TMDL would be transferred to the WLA for industrial stormwater activities. Industrial storm water activities are considered in compliance with provisions of the TMDL if they obtain an industrial stormwater general permit (permit #MNR050000) or general sand and gravel permit (NPDES and SDS Permit MNG49 for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production Facilities) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

Construction

The construction stormwater wasteload allocations were calculated based on the estimated area of the watershed under permitted construction activity over the past six years (2003 through 2008). Project areas of permits were summed up by municipality and presented as an annual average percent of total municipal area that has been issued a construction stormwater permit.

All of the municipalities within the lakes' watersheds (Table 9) were used to determine the average percent for each of the TMDL lakes.

Table 9. Percent of area under construction stormwater permits, by city

City	City Area (ac)	Total Project Area (ac) 2003-2008 Average Annual	% of City Area
Chanhassen	14,495	154	1.1%
Chaska	9,215	248	2.7%
Minneapolis	36,763	287	0.8%
Minnetrista	19,714	103	0.5%
Richfield	4,524	21	0.5%
Shorewood	8,537	16	0.2%
Victoria	5,454	94	1.7%
Waconia	20,393	159	0.8%

The following averages were used:

- Lake Nokomis: Minneapolis and Richfield (weighted average based on area within watershed = 0.6%)
- Parley: Victoria, Minnetrista, and Waconia (weighted average based on area within watershed = 1.6%)
- Virginia: Chanhassen, Chaska, Shorewood, and Victoria (weighted average based on area within watershed = 1.1%)
- Wassermann: Victoria (1.7%)

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

<u>Industrial</u>

Industrial stormwater permits that discharge within the boundaries of this project are not individually listed here. There are several industrial stormwater permits in the vicinity of the Lake Nokomis watershed, but none of these permits will have phosphorus benchmarks in the new industrial stormwater permit (projected to be reissued in 2010). There is one facility with a *No Exposure Exclusion from NPDES / SDS Stormwater Permit for Industrial Activity*, issued to HEI Inc (ID# A00022567) in Victoria in January of 2009. The certification is a temporary exclusion from an industrial storm water permit and must be re-certified every five years.

A small portion of the TMDL was set aside for regulated industrial stormwater sources (existing and future); the industrial stormwater WLA was calculated as 0.5% of the total WLA. The Lake Wassermann watershed does not contain any land use zoned for industrial; the industrial stormwater WLA was lowered to 0.1% of the total WLA for that watershed. Industrial storm water activities are considered in compliance with provisions of the TMDL if they obtain an industrial stormwater general permit or general sand and gravel permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

Load Allocations

One load allocation was set for each lake. The load allocation includes phosphorus sources from stormwater runoff not regulated by an MS4 permit (see Table 8), internal loading, atmospheric deposition, and any other unidentified loads. The loading goal for the non-regulated stormwater runoff was calculated in the same way that the goal for the regulated stormwater was calculated: the target runoff concentration of 150 µg/L was multiplied by the estimated volume of watershed runoff under modeled (Simple Method model) ultimate land use conditions (Appendix A). Although the target concentration was used to calculate the allocations, it is the actual load-based allocation that is the target for this TMDL. The LA can be achieved partly or wholly through volume control, even if the TP concentration in runoff is above 150 µg/L.

Unidentified loads may include loads from feedlots or related animal agriculture, excessive channel erosion in the watershed, and lake shoreline erosion. In cases where evidence suggests that these sources exist in the watershed, the sources will be targeted in the implementation plan.

Due to the modeling approach and available data, the internal load estimate for each lake cannot be separated from the load due to unidentified sources. To estimate the internal/unidentified loading goal, the pollutant reductions still needed after the watershed load reductions were taken into account were assigned to the internal/unidentified load. The load from atmospheric deposition is assumed to remain constant, with no reductions possible from that source.

Trading or Transfer of Allocations

Trading of load reductions between the WLAs and the LA may be a possibility in the future under certain conditions. A trade can only be done among loads for an individual lake (i.e., load cannot be traded from one lake within this TMDL to another water body). Other conditions and considerations will apply as well and will be established separate from this TMDL report.

As development occurs within the watershed, the Census Bureau-defined Urban Area may expand. If this occurs, it may be necessary to transfer WLA from one MS4 to another. For example, a segment of state-owned highway may come under permit coverage as the Urban Area expands. In the event that additional stormwater discharges come under permit coverage within the watershed, WLA will be transferred to these new entities based on the process used to set wasteload allocations in the TMDL. MS4s will be notified and will have an opportunity to comment on the reallocation.

In regards to MAC owned land if their individual NPDES permit is expanded to include land not currently covered under the permit then the corresponding allocation for that land would be transferred from whatever jurisdiction it had been in to MAC’s WLA.

Reserve Capacity

Reserve capacity, an allocation for future growth, was not explicitly calculated for this TMDL, but rather was included as part of the WLAs and LAs. The watershed WLAs and LAs were developed based on the volume of runoff under modeled ultimate land use conditions (see Appendix A). Therefore each category receives a WLA or LA based on how much it can develop in the future (or is currently developed for those areas in the watershed that are currently fully developed).

4. LAKE ASSESSMENTS AND TMDL CALCULATIONS

Lake assessments and the TMDL calculations are included for each lake.

In these assessments, the available monitoring data are presented in the figures. To quantify the existing water quality conditions, data from the last ten years (1998-2007) were used. This is the time period (the most recent ten years) that the MPCA uses to assess lakes for nutrient impairments (MPCA 2007). The growing season means (GSM) for TP, chlorophyll-*a*, and Secchi depth (clarity) were calculated using data from June through September.

Carlson's Trophic State Index (TSI) values are reported for each lake. This TSI uses algal biomass as a way to describe trophic status, and the values range from approximately zero to 100. The TSI is a way to compare trophic status among lakes and to compare predictions of algal biomass based on TP, chlorophyll, and Secchi depth within a lake.

A. Lake Nokomis

Lake Nokomis is located in the City of Minneapolis, and its watershed includes areas within Minneapolis, Richfield, Fort Snelling, and the Minneapolis-St. Paul Metropolitan Airport. Lake Nokomis was originally a wetland and was dredged from 1914 to 1917 to reduce the area of surface water and increase the area of the adjacent parkland. It currently has a surface area of 200 acres and a watershed area of 2,634 acres (4.1 square miles). Its mean depth is approximately 14 feet and its maximum depth is 33 feet. Approximately 66% of the lake is littoral (having a depth of 15 feet or less) (Figure 19).

A large portion of the Lake Nokomis watershed is semi-landlocked, in that a substantial amount of the runoff from subwatersheds MC-155 through MC-161 (Figure 2) evaporates and/or infiltrates into natural depressions.

Minnehaha Creek used to flow into Lake Nokomis during storm events exceeding the 10-year 24-hour return event (MCWD 2003). An inflatable weir was installed to prevent flow from Minnehaha Creek from entering Lake Nokomis; the weir became operational in 2003. At all other times, the flow is reversed and Lake Nokomis flows into Minnehaha Creek. MCWD is responsible for operation and maintenance of the weir.

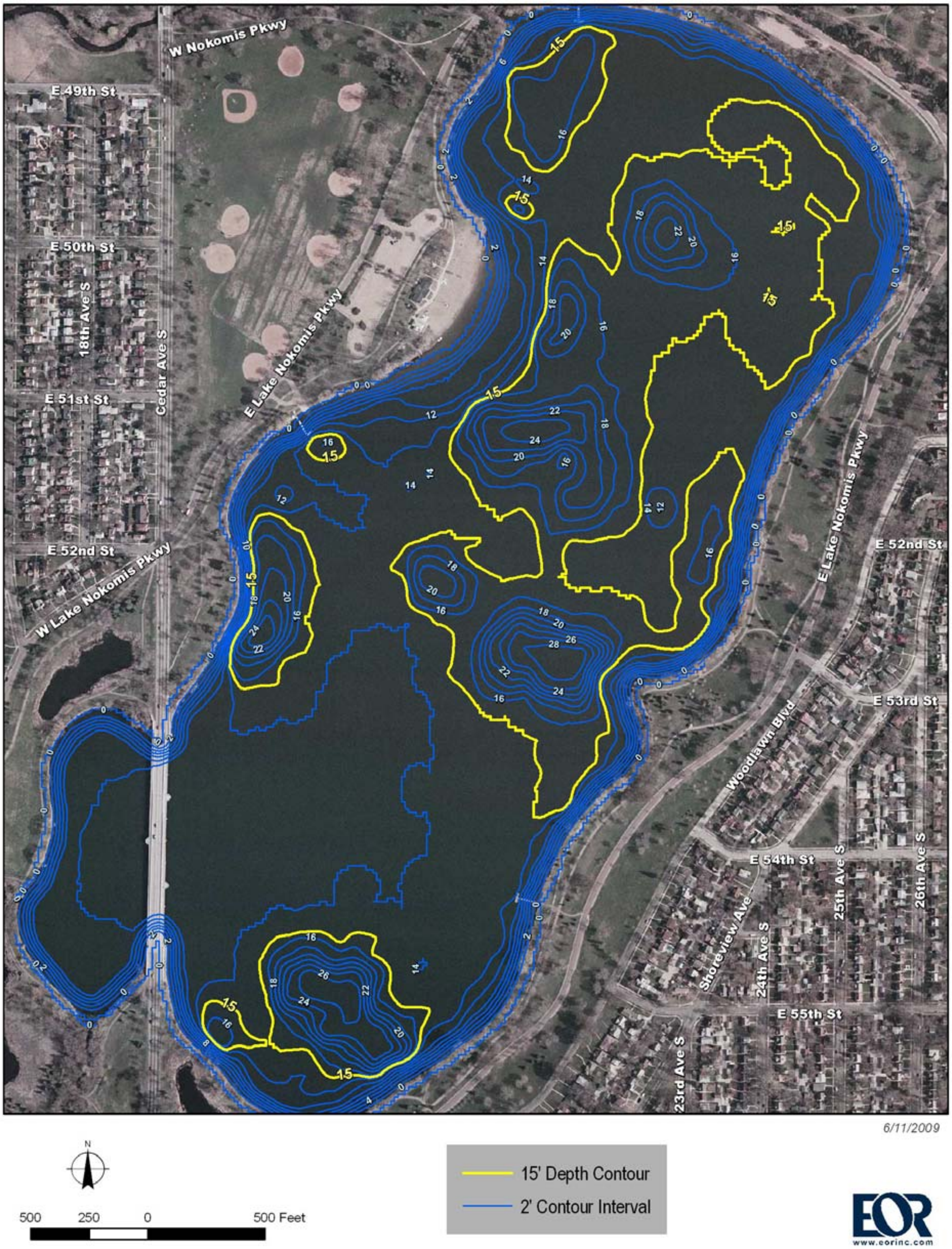


Figure 19. Lake Nokomis Bathymetry, MCWD 2009

Water Quality Assessment

Lake Nokomis is a eutrophic lake, with relatively better transparency compared to TP and chlorophyll-*a*, as indicated by the TSI values (Table 10). The lake is currently almost meeting the Secchi depth standard, but not the TP nor the chlorophyll-*a* standards.

Table 10. Lake Nokomis water quality data summary

Parameter	1998 – 2007 average*	TSI	Standard	Requested site-specific standard
Total Phosphorus	61 µg/l	63	40 µg/l	50 µg/l
Chlorophyll-*a*	29 µg/l	64	14 µg/l	20 µg/l
Secchi Depth	1.3 m	56	1.4 m	1.4 m

*Average of annual GSM (June – September)

In-lake water quality has fluctuated since 1992 (Figure 20 through Figure 22), with no trend of either improving or deteriorating water quality.

66% of the lake's surface area is littoral, and there are several deep spots (approximately 30 feet deep) in the lake that have the potential to thermally stratify during the growing season. Data from one of these holes from 2005 show that this area did thermally stratify and that dissolved oxygen levels dropped to below 2 mg/L in the hypolimnion during a portion of the growing season (Figure 23). High total phosphorus concentrations in the deep hypolimnetic samples (Figure 24) suggest that phosphorus was released from the sediments to the hypolimnion, where it built up to high concentrations until being mixed with the epilimnion during a mixing event that occurred in mid to late August. This internal load can contribute a substantial amount of phosphorus to the lake's annual phosphorus load.

In the more shallow portions of the lake (less than 15 feet), any thermal stratification is unlikely to remain stable throughout the growing season, and the water column likely mixes frequently, classifying these areas as polymictic. Short periods of thermal stratification and low dissolved oxygen concentrations near the sediment-water interface can lead to phosphorus release from the sediments. Subsequent wind-driven mixing events can lead to the mixing of the phosphorus with the entire the water column. High winds can also directly resuspend bottom sediments, which releases phosphorus into the water column.

The fish community was sampled in 2005 and indicated a high density of black bullhead. The number per gill net (130 per net) was 22 times greater than the number per gill net sampled in 2001 (6 per net). Black bullhead are benthivorous fish that forage on the lake bottom, disturbing the sediments and releasing phosphorus into the water column. The black bullhead are likely another source of internal phosphorus loading in the lake.

Other fish found during the survey include walleye, tiger muskellunge, black crappie, bluegill, yellow perch, and carp. The lake has been stocked with tiger muskellunge (fry and fingerling) and walleye (fingerling and yearling).

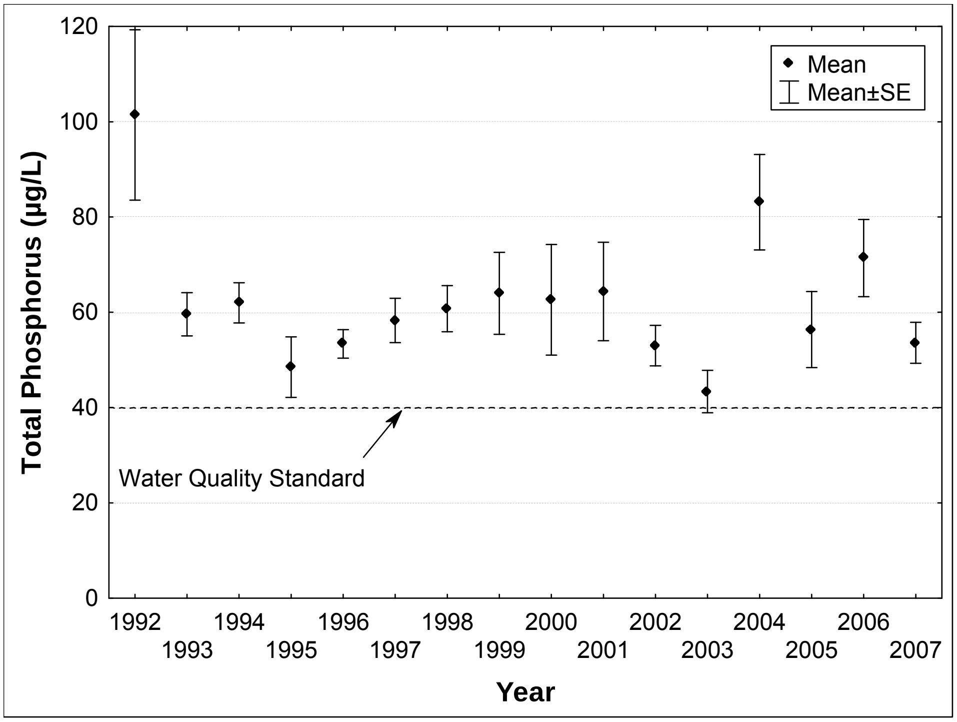


Figure 20. Lake Nokomis Growing Season Mean TP

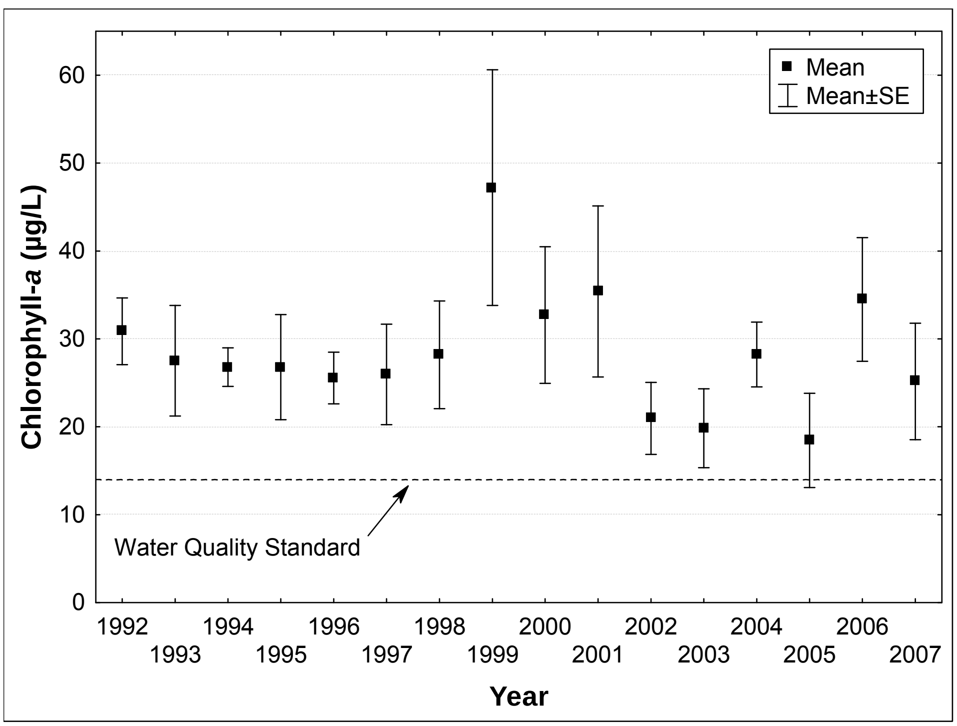


Figure 21. Lake Nokomis Growing Season Mean Chlorophyll-a

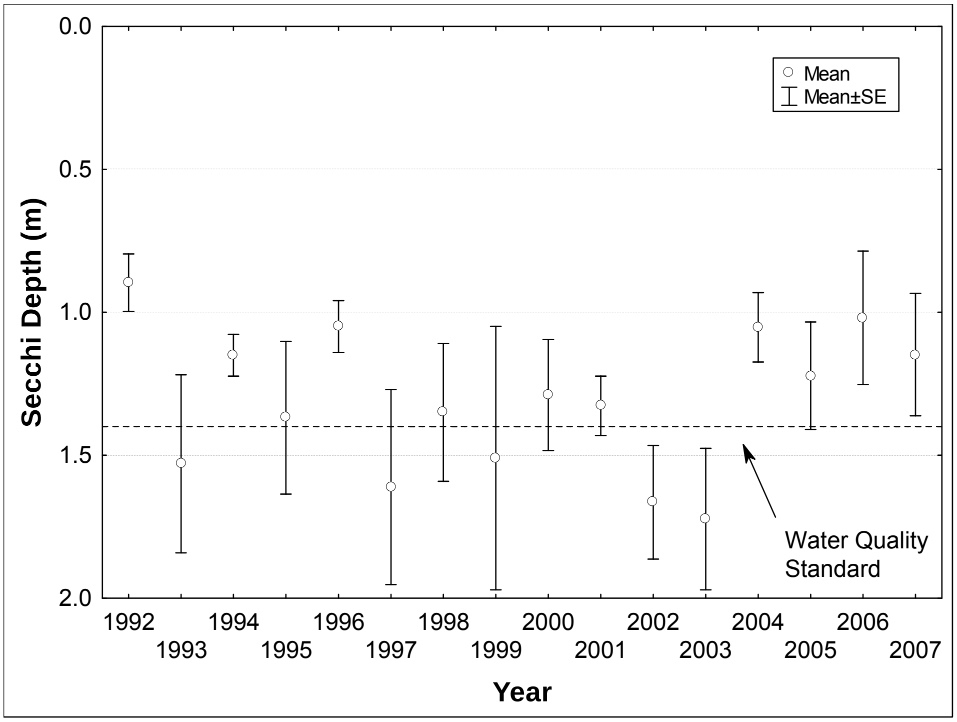


Figure 22. Lake Nokomis Growing Season Mean Secchi Depth

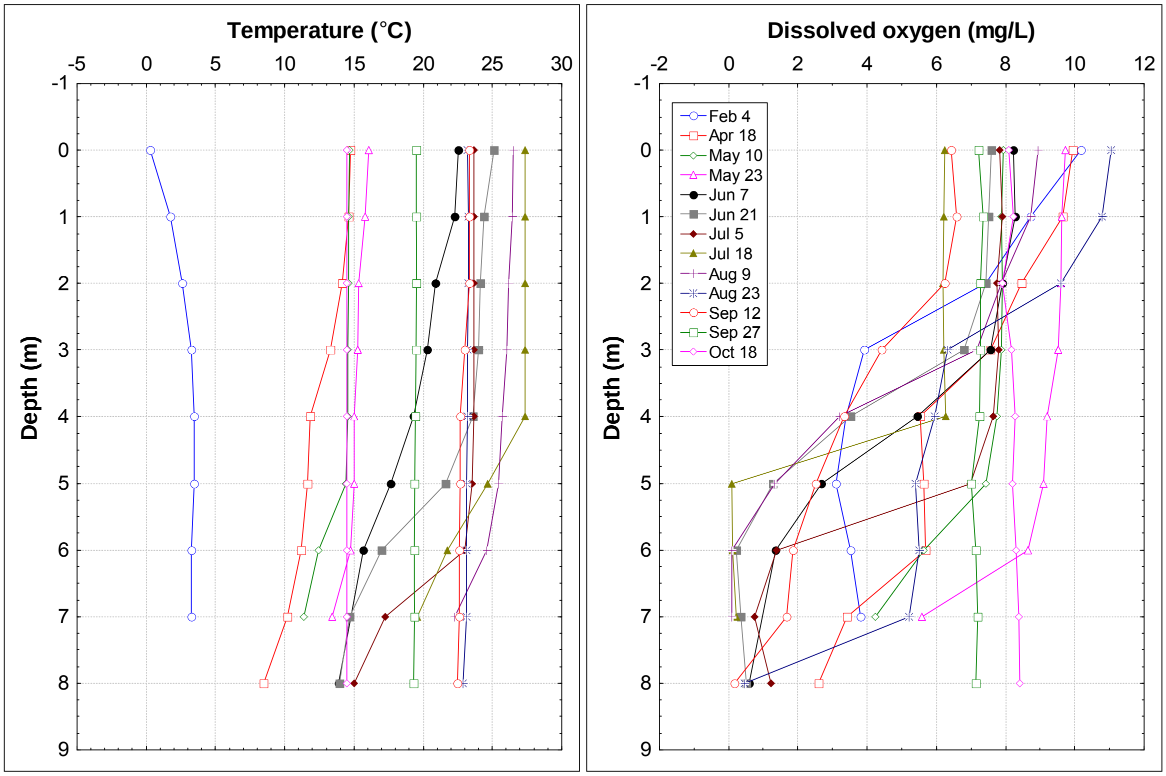


Figure 23. Lake Nokomis Temperature and Dissolved Oxygen, 2005

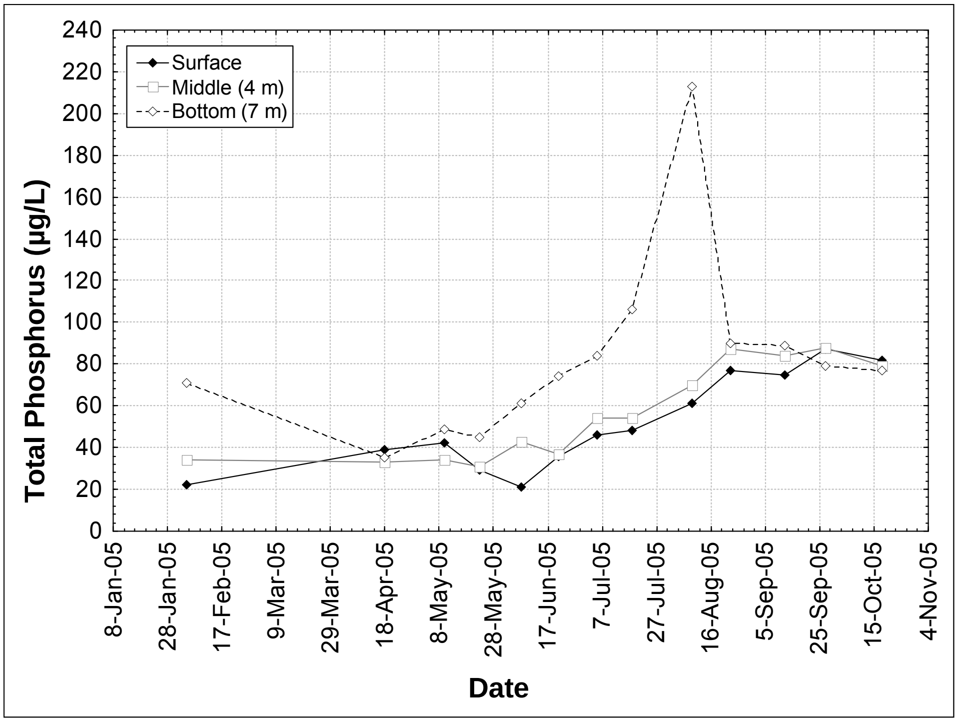


Figure 24. Lake Nokomis Surface vs. Bottom TP, 2005

Water Quality Standards

A range of total phosphorus water quality goals already exists for Lake Nokomis (Table 11), ranging from 32 µg/L to 50 µg/L. The Blue Water Commission's ultimate goal of 32 µg/l is aggressive and may not be achievable in such a highly urbanized setting. The state standards currently serve as the water quality goals for Lake Nokomis: 40 µg/L total phosphorus, 14 µg/L chlorophyll-*a*, and 1.4 m Secchi depth.

Table 11. Lake Nokomis TP Goals

Source	TP Goal (µg/L)
Blue Water Commission	45/32
MCWD, 2007	50
State standard	40

The MCWD, City of Minneapolis, and MPRB have requested that a site-specific standard be established for Lake Nokomis (*Appendix C: Site-Specific Standards Request*). Since the decision of whether or not to approve the requested site-specific standard will not be made before the completion of this study, TMDL equations and allocations will be developed for both the state standards and the proposed site-specific standards (Table 12). Until a site-specific standard is approved by the EPA, the TMDL for the state standard will be in effect. If the site-specific standard is approved, the TMDL for that standard will subsequently be in effect.

Table 12. Lake Nokomis Standards

Source	TP Std (µg/l)	Chl Std (µg/l)	Secchi Std (m)
State standard	40	14	1.4
Site specific standard, requested	50	20	1.4

TMDL Determination

The Lake Nokomis watershed was divided into three portions (see subwatershed drainage directions in Figure 2):

1) Legion Lake drainage: Subwatersheds MC-155 through MC-158 drain to Legion Lake and are semi-landlocked.
2) Mother-Taft Lake drainage: Subwatersheds MC-159 through MC-161 drain to the Mother-Taft Lake wetland complex and are semi-landlocked.
3) Lake Nokomis direct drainage: Subwatersheds MC-162 through MC-167 are downstream of the semi-landlocked drainage areas and drain directly to Lake Nokomis

See Appendix A: Stormwater Runoff Load Estimates for more details regarding the watershed load estimates. The approach described in *Section 3.B Calculation of TMDL Components* was followed.

Under consideration for the MAC area within the Mother Lake drainage area is the transition from the individual NPDES permit to coverage under the NPDES general industrial permit. If this were to happen, the individual WLA provided to MAC in the Lake Nokomis TMDL would be transferred to the WLA for industrial stormwater activities.

<u>State Eutrophication Standard</u>

The assimilative capacity (or TMDL) of Lake Nokomis was calculated to be 490 lbs/yr, or 1.34 lbs/day TP. The loads were divided between the total WLA and LA as follows:

TMDL = WLA + LA
490 lbs/yr = 330 lbs/yr + 160 lbs/yr
1.34 lbs/day = 0.90 lbs/day + 0.44 lbs/day

The regulated MS4 entities within the Lake Nokomis watershed are the City of Minneapolis, the City of Richfield, Hennepin County, and Mn/DOT Metro District (Table 13). Fort Snelling is not a regulated MS4. The entire watershed falls within the urbanized area, and therefore the entire area of Hennepin County's and Mn/DOT's ROW is regulated by the MS4 permit (Figure 25). A portion of the Minneapolis-St. Paul Metropolitan Airport is within the Lake Nokomis watershed and is regulated under the MAC's NPDES permit.

The WLA was further broken down into individual WLAs that cover regulated MS4 stormwater. The LA includes internal loading, atmospheric deposition, and non-regulated stormwater runoff (Table 14).

An overall load reduction of 57% is needed for Lake Nokomis. The percent reductions required by the permitted sources range from 7% to 65% (Table 16), and the reductions are spread throughout the watershed (Figure 26). The runoff from subwatersheds MC-159 through MC-161 does not need any reductions; the average loading rate from these subwatersheds is lower than the other subwatersheds due to a higher proportion of natural areas.

Requested Site-Specific Standard

The assimilative capacity (or TMDL) of Lake Nokomis under the requested site-specific standard was calculated to be 742 lbs/yr, or 2.03 lbs/day TP. The loads were divided between the total WLA and LA as follows:

TMDL = WLA + LA
742 lbs/yr = 463 lbs/yr + 279 lbs/yr
2.03 lbs/day = 1.27 lbs/day + 0.765 lbs/day

The regulated MS4 entities within the Lake Nokomis watershed are the City of Minneapolis, the City of Richfield, Hennepin County, and Mn/DOT Metro District (Table 13). Fort Snelling is not a regulated MS4. The entire watershed falls within the urbanized area, and therefore the entire area of Hennepin County's and Mn/DOT's ROW is regulated by the MS4 permit (Figure 25). A portion of the Minneapolis-St. Paul Metropolitan Airport is within the Lake Nokomis watershed and is regulated under the MAC's NPDES permit.

The WLA was broken down into individual WLAs that cover MS4 stormwater. The breakdown was determined by proportionally adjusting the percent reductions required under the state standard goal scenario. The proportion used was the ratio of the total percent reduction required under the site-specific standard scenario divided by the total percent reduction required under the state standard scenario, or 35% / 57% = 0.614. After the percent reductions were adjusted, the WLAs and LA were adjusted accordingly.

The LA includes internal loading, atmospheric deposition, and non-regulated stormwater runoff (Table 15).

An overall load reduction of 35% is needed for Lake Nokomis. The percent reductions required by the permitted sources range from 5% to 40% (Table 17), and the reductions are spread throughout the watershed (Figure 26). The runoff from subwatersheds MC-159 through MC-161 does not need any reductions; the average loading rate from these subwatersheds is lower than the other subwatersheds due to a higher proportion of natural areas.

Table 13. Regulated Areas within the Lake Nokomis Watershed

MS4/Jurisdiction	MS4-Regulated Area (ac)	Non-MS4-Regulated Area (ac)
Fort Snelling	0	56
City of Minneapolis (includes MPRB)	878	0
City of Richfield	1234	0
Hennepin County	50	0
Mn/DOT Metro District	98	0
Metropolitan Airports Commission	318	0
Total:	*2238*	*56*

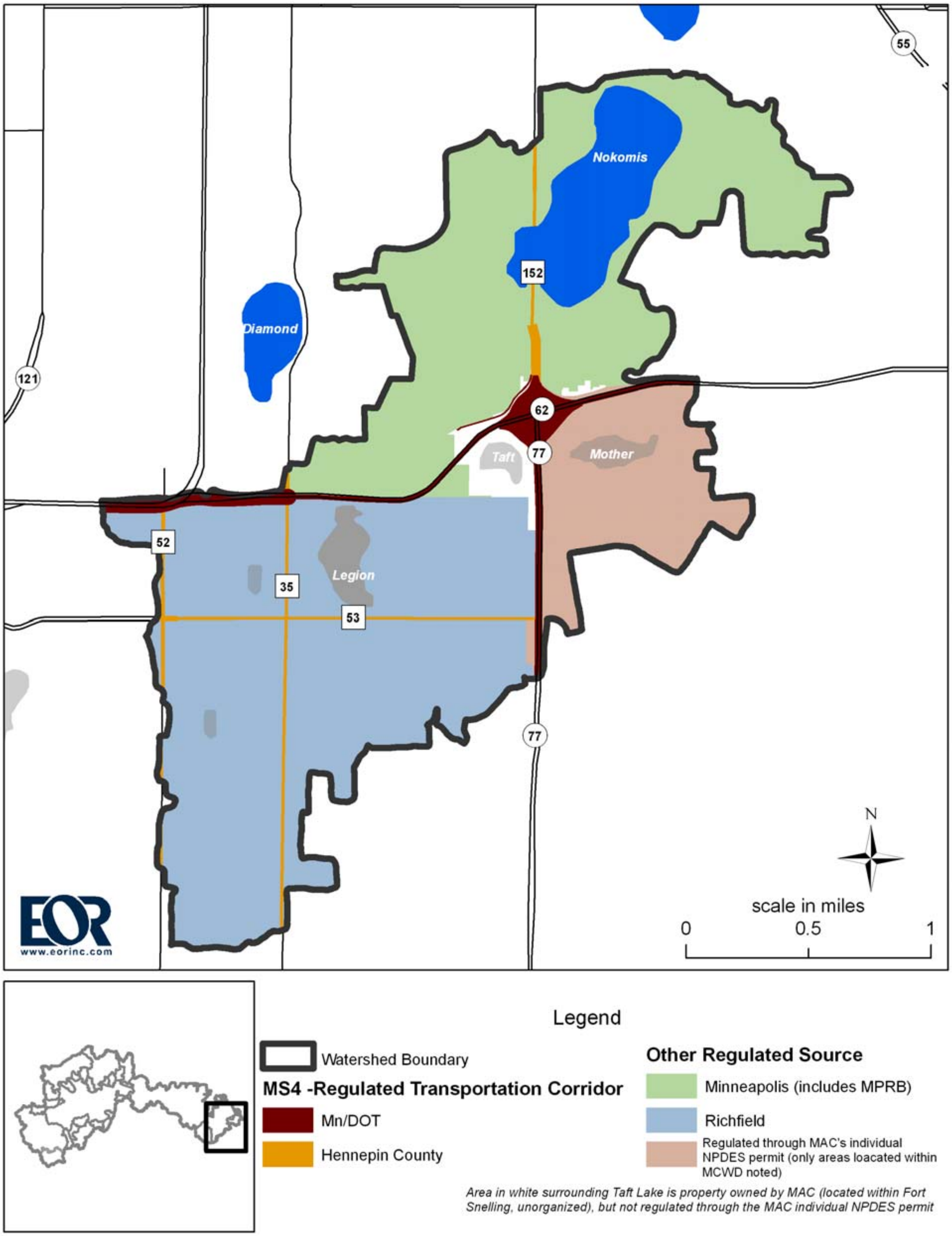


Figure 25. MS4-Regulated Road Authorities within the Lake Nokomis Watershed

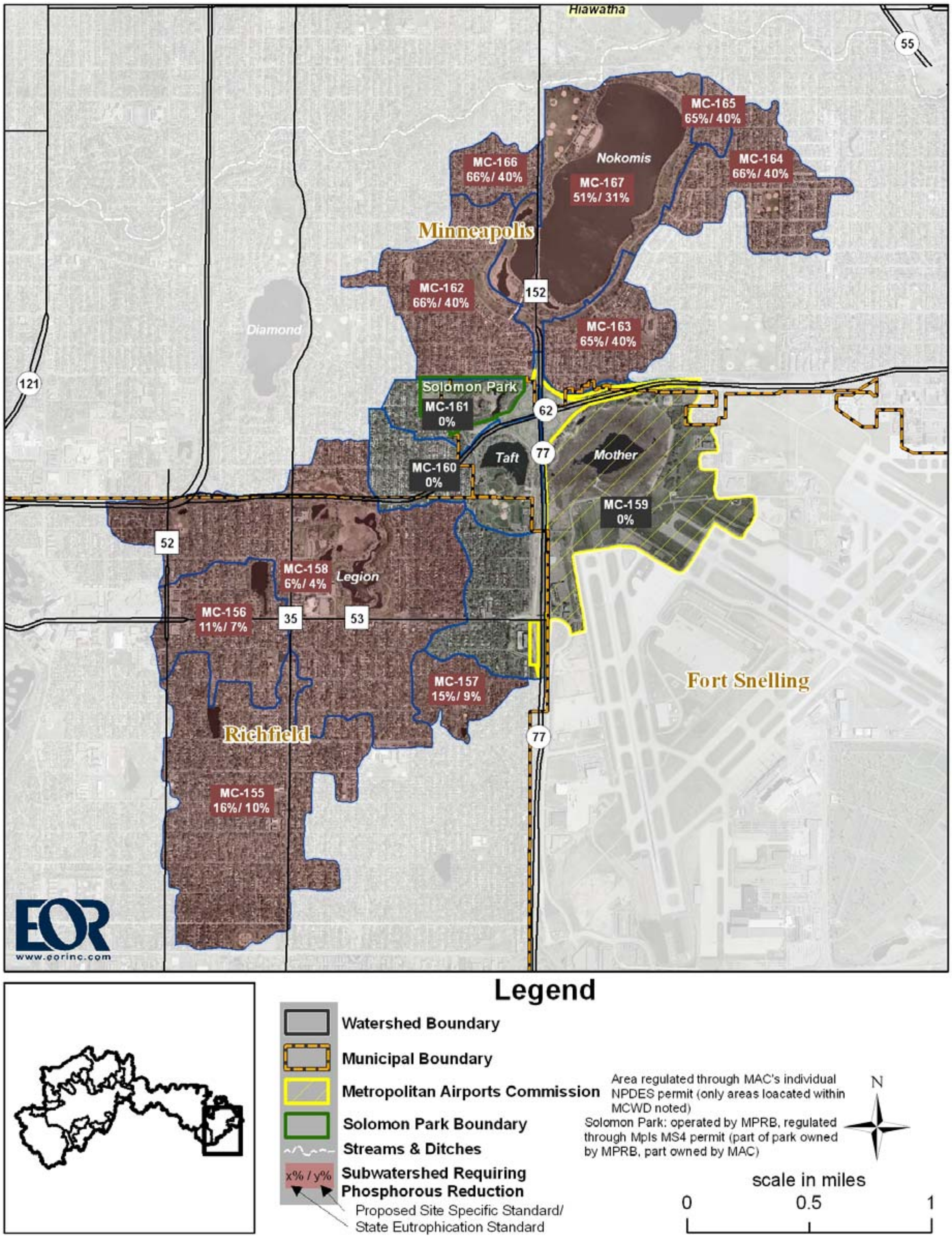


Figure 26. Lake Nokomis Subwatersheds Needing Phosphorus Reductions

Percent reductions by subwatersheds are presented to be used for prioritizing locations for implementation. The values may differ from the percent reductions provided by source in Table 16 and Table 17 since they are averaged over different areas.

Table 14. Lake Nokomis TMDL Allocations, State Eutrophication Standard
Daily WLAs are presented with three significant digits to avoid needing to adjust allocations for differences due to rounding.

Source		TMDL	
		lbs/yr	lbs/day
Load Allocation (internal load, atmospheric deposition, non-MS4 stormwater runoff from Fort Snelling)		160	0.437
Wasteload Allocation (regulated stormwater runoff)		330	0.904
MS4 or other source	NPDES Permit #		
City of Minneapolis	*MN0061018*	*188*	*0.516*
City of Richfield	*MS400045*	*103*	*0.281*
Hennepin County	*MS400138*	*8.1*	*0.0223*
Mn/DOT Metro District	*MS400170*	*10*	*0.0277*
Metropolitan Airports Commission	*MN0002101*	*17*	*0.0467*
Construction stormwater	*Various*	*2.0*	*0.00542*
Industrial site stormwater	*No current regulated sources*	*1.6*	*0.00452*
Total TMDL		490	1.34

Table 15. Lake Nokomis TMDL Allocations, Requested Site-Specific Standard
Daily WLAs are presented with three significant digits to avoid needing to adjust allocations for differences due to rounding.

Source		TMDL	
		lbs/yr	lbs/day
Load Allocation (internal load, atmospheric deposition, non-MS4 stormwater runoff from Fort Snelling)		279	0.765
Wasteload Allocation (regulated stormwater runoff)		463	1.27
MS4 or other source	NPDES Permit #		
City of Minneapolis	*MN0061018*	*310*	*0.851*
City of Richfield	*MS400045*	*108*	*0.295*
Hennepin County	*MS400138*	*11*	*0.0303*
Mn/DOT Metro District	*MS400170*	*11*	*0.0296*
Metropolitan Airports Commission	*MN0002101*	*18*	*0.0481*
Construction stormwater	*Various*	*2.8*	*0.00761*
Industrial site stormwater	*No current regulated sources*	*2.3*	*0.00634*
Total TMDL		742	2.03

Table 16. Lake Nokomis Percent Load Reductions, State Eutrophication Standard
Load estimates from MS4s include construction and industrial stormwater loads within the MS4 boundaries.

Source	Existing Load (lbs/yr)	Allowable Load (lbs/yr)	% Reduction
Internal Load	411	105	75%
Atmospheric deposition	54	54	0%
Non-regulated stormwater runoff (Fort Snelling)	2.0	2.0	0%
City of Minneapolis	509[1]	190	63%
City of Richfield	118	104	12%
Hennepin County	16	8	48%
Mn/DOT Metro District	12	10	15%
Metropolitan Airports Commission	19	17	7%
Total:	*1,141*	*490*	*57%*

[1]Does not take into account the treatment ponds/wetlands adjacent to the lake. The estimated load reductions from these BMPs will be credited to the load reduction goals in the implementation plan.

Table 17. Lake Nokomis Percent Load Reductions, Requested Site-Specific Standard
Load estimates from MS4s include construction and industrial stormwater loads within the MS4 boundaries.

Source	Existing Load (lbs/yr)	Allowable Load (lbs/yr)	% Reduction
Internal Load	411	223	46%
Atmospheric deposition	54	54	0%
Non-regulated stormwater runoff (Fort Snelling)	2.0	2.0	0%
City of Minneapolis	509[1]	314	38%
City of Richfield	118	109	7%
Hennepin County	16	11	30%
Mn/DOT Metro District	12	11	9%
Metropolitan Airports Commission	19	18	5%
Total:	*1,141*	*742*	*35%*

[1]Does not take into account the treatment ponds/wetlands adjacent to the lake. The estimated load reductions from these BMPs will be credited to the load reduction goals in the implementation plan.

B. Parley Lake

Parley Lake is located in Laketown Township, and its watershed is located in Laketown Township, the City of Victoria, and the City of Minnetrista. The Cities of Victoria and Waconia have plans to annex the portions of Laketown Township that contain the watershed; therefore, under ultimate conditions, the watershed will include portions of the City of Waconia in addition to the other municipalities (Figure 6). Wassermann Lake and its watershed are fully contained within the Parley Lake watershed; Wassermann Lake is located upstream of Parley Lake along Six Mile Creek.

Parley Lake has a surface area of 256 acres and a watershed area of 12,406 acres (19 square miles). Its mean depth is approximately 7 feet and its maximum depth is 18 feet. Approximately 95 % of the lake is littoral (having a depth of 15 feet or less) (Figure 27).

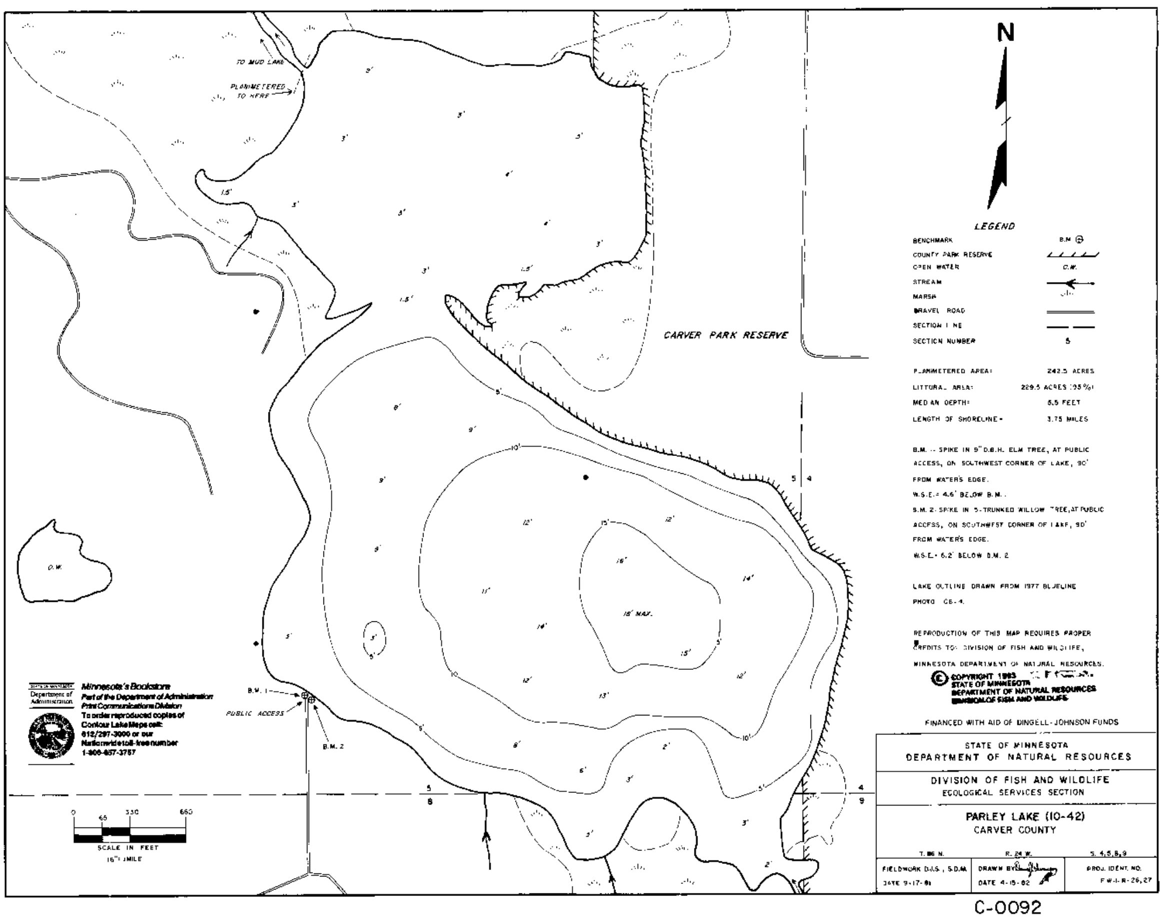


Figure 27. Parley Lake Bathymetry, MDNR 1981

Water Quality Assessment

In-lake monitoring data are available sporadically for TP, chl-*a* and SD from 1984 through 2006 (Figure 28 through Figure 30). Parley Lake is a eutrophic to hypereutrophic lake, with relatively higher TP and chlorophyll concentrations compared to transparency, as indicated by the TSI values (Table 18).

Table 18. Parley Lake water quality data summary

Parameter	1998 – 2007 average*	TSI	Standard
Total Phosphorus	93 µg/l	70	60 µg/l
Chlorophyll-*a*	105 µg/l	76	20 µg/l
Secchi Depth	0.83 m	63	1.0 m

*Average of annual GSM (June – September)

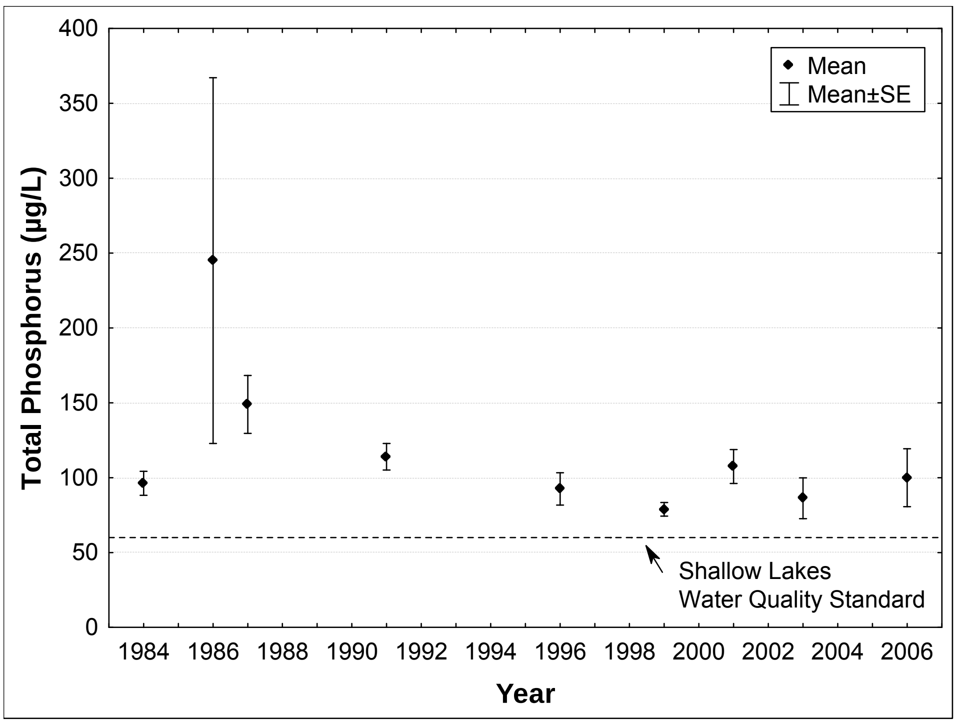


Figure 28. Parley Lake Growing Season Mean TP

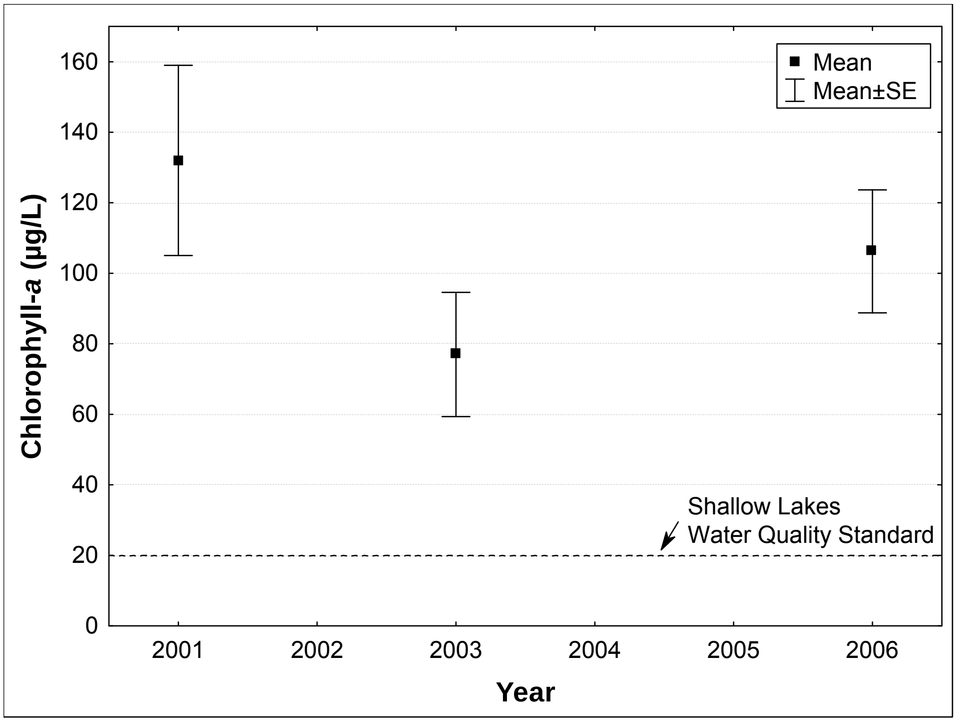


Figure 29. Parley Lake Growing Season Mean Chlorophyll-*a*

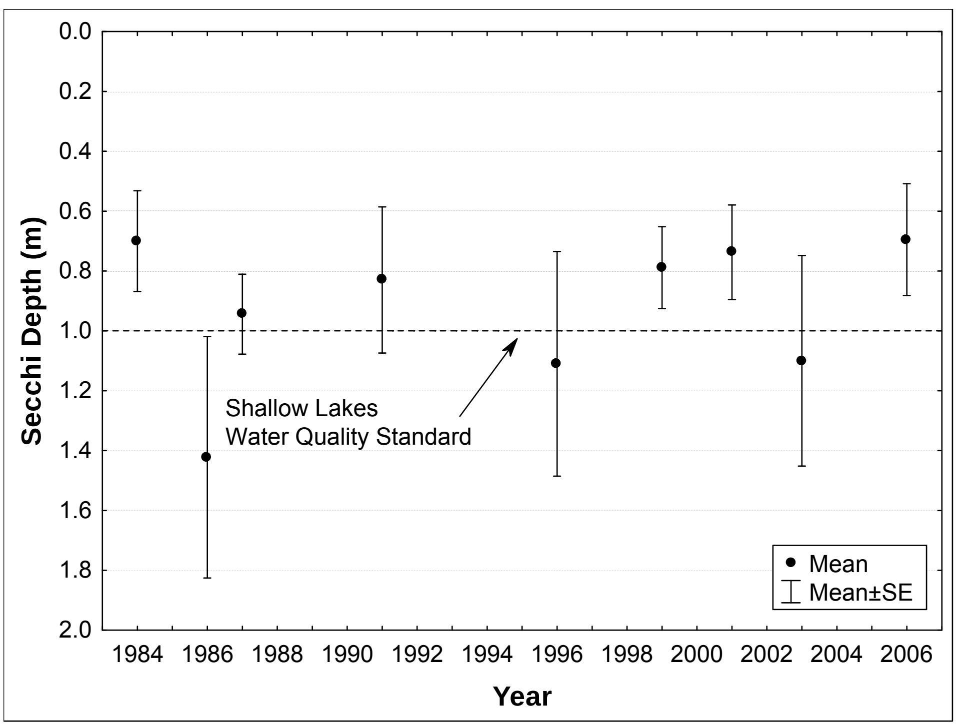


Figure 30. Parley Lake Growing Season Mean Secchi Depth

Lunsten Lake, a shallow lake directly upstream of Parley Lake, is monitored by the MCWD. Although there are not a lot of data available, the existing data show an average in-lake TP concentration of 50 µg/L (Table 19). The west arm of Auburn Lake, located less than 1,000 ft upstream of Lunsten Lake, has an average in-lake TP of 33 µg/l (2002-2007). Since the water quality of the west arm of Auburn Lake is relatively good, the portion of Parley Lake's watershed that flows through Auburn Lake will not be focused on in the implementation strategy; the focus will be downstream of Auburn Lake.

Table 19. Lunsten Lake Total Phosphorus Data

Year	TP average (µg/l)	# samples
2006	72	2
2007	46	4
2008	33	5
3-yr average = 50 µg/l		

The seasonal pattern of TP concentrations in Parley Lake in 2001, 2003, and 2006 (Figure 31), along with the observed dense population of curly-leaf pondweed, suggests that the senescence of curly-leaf pondweed in early summer likely contributes to the high in-lake TP concentrations seen in July. In 2006 there was also a large increase in the chlorophyll concentrations towards the end of June, with a smaller increase in 2003 (Figure 32). The load from curly-leaf pondweed is included in the internal load portion of the total load to the lake.

The second jump in phosphorus and chlorophyll concentrations towards the end of the summer is likely due to internal loading from the sediments. The bottom layer of the lake becomes intermittently stratified during the growing season, with low oxygen concentrations (Figure 33) and likely phosphorus release.

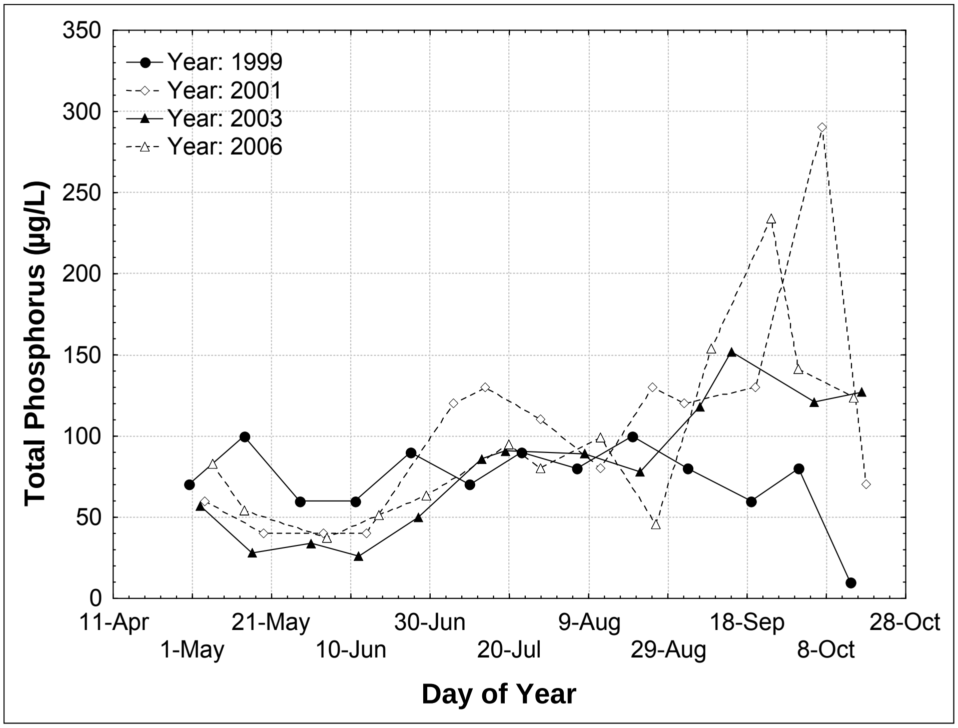


Figure 31. Parley Lake Seasonal Pattern in TP

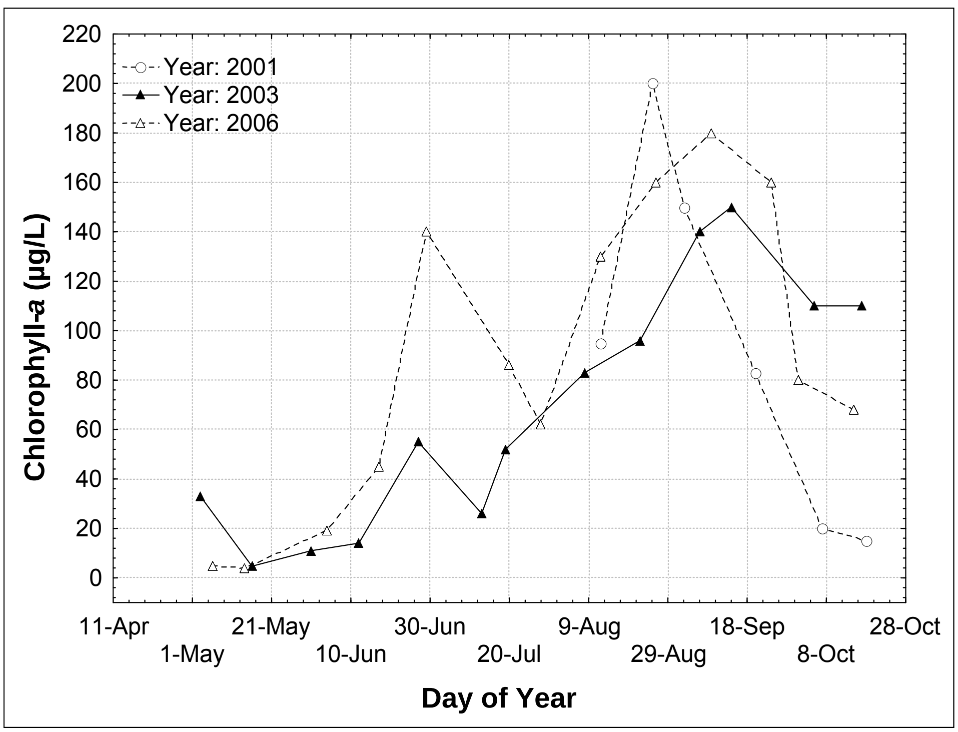


Figure 32. Parley Lake Seasonal Pattern in Chlorophyll

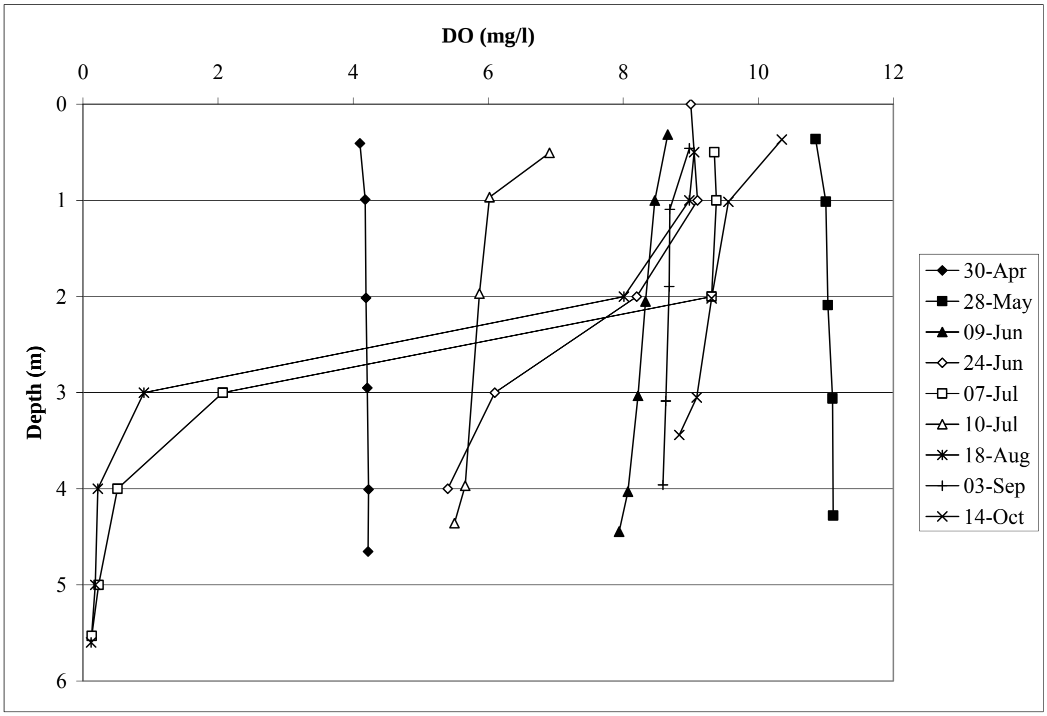


Figure 33. Parley Lake DO Depth Profiles, 2003

In a 2004 fish survey, bowfin (dogfish) and common carp were sampled in higher than typical numbers compared to lakes with similar physical and chemical characteristics. Carp may be contributing to the internal loading in Parley Lake. Bluegill, black bullhead, black crappie, and yellow perch were also found in large numbers. Northern pike and walleye abundance and size was moderate for this type of lake. Walleye fry have been stocked in the lake.

Water Quality Standards

A range of water quality goals already exists for Parley Lake (Table 20). Approximately 95% of the lake is classified as littoral, classifying this lake as a shallow lake. The state standards for shallow lakes will serve as the water quality goals for Parley Lake: 60 µg/L total phosphorus, 20 µg/L chlorophyll-*a*, and 1.0 m Secchi depth.

Table 20. Parley Lake TP Goals

Source	TP Goal (µg/l)
MCWD, 2007	50
State standard	60

TMDL Determination

The Parley Lake watershed was divided into three portions: the subwatersheds that drain to Auburn Lake before eventually draining to Parley Lake (SMC-1 through SMC-29 in Figure 5), the subwatersheds that drain to Lunsten Lake before eventually draining to Parley Lake (SMC-30 through SMC-37 in Figure 5), and the subwatersheds downstream of Lunsten Lake that drain to Parley Lake (SMC-38 through SMC-47 in Figure 5). The approach described in *Section 3.B*

Calculation of TMDL Components was followed, with the following adjustments to the approach:

- Auburn Lake West's existing in-lake TP concentration is 33 µg/L, and it is predicted to increase to above 40 µg/L by 2020 (MCWD 2003). The load from Auburn Lake West's subwatersheds (SMC-1 through SMC-29) was held at existing conditions for the TMDL allocations; this will prevent Auburn Lake West from worsening and from itself becoming impaired. Loads to Auburn Lake West are not allowed to increase in order to be in compliance with the TMDL allocations.
- For subwatersheds that are relatively undeveloped and that have relatively low existing imperviousness and average runoff TP concentration (less than 150 µg/L TP), the loads were held at existing conditions for the TMDL allocations (SMC-30, 31, 36, 37, 39, 43-47). Reductions in TP loading from these subwatersheds are not warranted (due to their current low loading rates), but, in order to restore Parley Lake, loads should not be allowed to increase.
- There were several subwatersheds with an existing average TP concentration in runoff slightly above 150 µg/L (SMC-32, 38, 41, and 42). These subwatersheds are undergoing development and the runoff concentrations are predicted to increase, along with increases in runoff volume. For these subwatersheds, instead of calculating the loading goal based on runoff volumes under modeled ultimate land use conditions and 150 µg/L TP in runoff (which would allow an increase in TP load), the load was held at existing conditions. However, loads from feedlots with runoff concerns were not directly incorporated into the watershed load estimates. Instead of not requiring any reductions in some of the subwatersheds in the region of SMC-32 through SMC-43, the load reductions from this region were averaged out, leading to a required reduction of 10%.
- For the remaining subwatersheds (SMC-33, 34, 35, 40), the approach described in *Section 3.B Calculation of TMDL Components* was followed, basing the loading goal on runoff volumes under modeled ultimate land use conditions and 150 µg/L TP in runoff.
- Reductions in internal loading in Parley Lake are required. Since loads from unidentified sources were not independently estimated, unidentified sources that exist in the area modeled using the Simple Method (as opposed to the area that drains to Auburn Lake West, since that load was estimated using observed in-lake TP data) are included as part of the internal load.
- The load to Lake Auburn West is attenuated by the sedimentation within the lake, and therefore the load to the lake is greater than the load that leaves the lake and eventually reaches Parley Lake. The average attenuation by the lake is 68%; this attenuation percentage was applied to the modeled existing load from the Lake Auburn West watershed to determine the actual load from the Lake Auburn West outlet to Parley Lake. This attenuated load was taken into account for both the existing load and the loading goal from the Lake Auburn West watershed.
- Subwatersheds SMC-1 through SMC-5 are included in both the Wassermann Lake TMDL and the Parley Lake TMDL. To restore Wassermann Lake, reductions in the watershed load are needed and are required under the Wassermann Lake TMDL. However, due to the high water quality of Auburn Lake West in the Parley Lake

watershed, loads upstream of Auburn Lake (including the Wassermann Lake watershed) do not need to be reduced in order to restore Parley Lake.

The assimilative capacity (or TMDL) of Parley Lake was calculated to be 1,270 lbs/yr, or 3.48 lbs/day TP. The loads were divided between the total WLA and LA as follows:

TMDL = WLA + LA
1,270 lbs/yr = 175 lbs/yr + 1,097 lbs/yr
3.48 lbs/day = 0.48 lbs/day + 3.00 lbs/day

The regulated MS4 entities within the Parley Lake watershed are the City of Minnetrista, the City of Victoria, the City of Waconia (under future/ultimate municipal boundaries only), Laketown Township (under existing municipal boundaries only), MCWD, Carver County, and Mn/DOT Metro District. The WLAs only cover those portions of the MS4 entities that are regulated by the MS4 permit (Table 21). The MS4-regulated areas within municipalities were determined by land use (see *Section 3.B: Calculation of TMDL Components: Wasteload Allocations*), and the road authority areas that are regulated by the MS4 permit were determined by the urbanized area boundary (Figure 34).

The WLA was further divided into individual WLAs for MS4 stormwater (Table 22 and Table 23). The LA includes loads from non-regulated MS4 stormwater runoff, internal loading, unidentified loads, and atmospheric deposition (Table 22 and Table 23).

WLAs are presented for both the existing Laketown Township boundaries (Table 22) and future/ultimate municipal boundaries (Table 23). The first set of WLAs are to be used when this TMDL is approved. **As portions of Laketown Township become annexed to the City of Victoria, Laketown Township's WLA will be transferred to the city based on the rate of 0.036 lbs/acre-year (9.9 x 10^{-5} lbs/acre-day). As portions of Laketown Township become annexed to the City of Waconia, Laketown Township's WLA will be transferred to the city based on the rate of 0.086 lbs/acre-year (2.4 x 10^{-4} lbs/acre-day).** (Table 24 includes details of these calculations.) The rate is different for each city because the relative distribution of land uses (which determines which areas are regulated by the MS4 permit) is different in each jurisdiction.

An overall load reduction of 44% is needed for Parley Lake (Table 25). The greatest required percent reduction is for internal loading (61% reduction). Averaged over the whole watershed, the watershed percent load reductions are low since the majority of the watershed flows through Auburn Lake West, a good quality lake. The watershed load reductions needed for Parley Lake are all downstream of Auburn Lake West (Figure 35).

Table 21. MS4-Regulated Areas within the Parley Lake Watershed, Future (Ultimate) Municipal Boundaries

MS4	MS4-Regulated Area (ac)		Non-MS4-Regulated Area (ac)	
	Lake Auburn West Watershed (SMC-1 - 29)	Downstream Auburn W (SMC-30 - 47)	Lake Auburn West Watershed (SMC-1 - 29)	Downstream Auburn W (SMC-30 - 47)
City of Minnetrista	11	1	278	17
City of Victoria	3,229	501	4374	2,506
City of Waconia	0	184	0	1,121
MCWD	0	7	0	0
Carver County	28	0	45	19
Mn/DOT Metro District	7	0	53	25
Total:	*3,275*	*693*	*4,750*	*3,688*

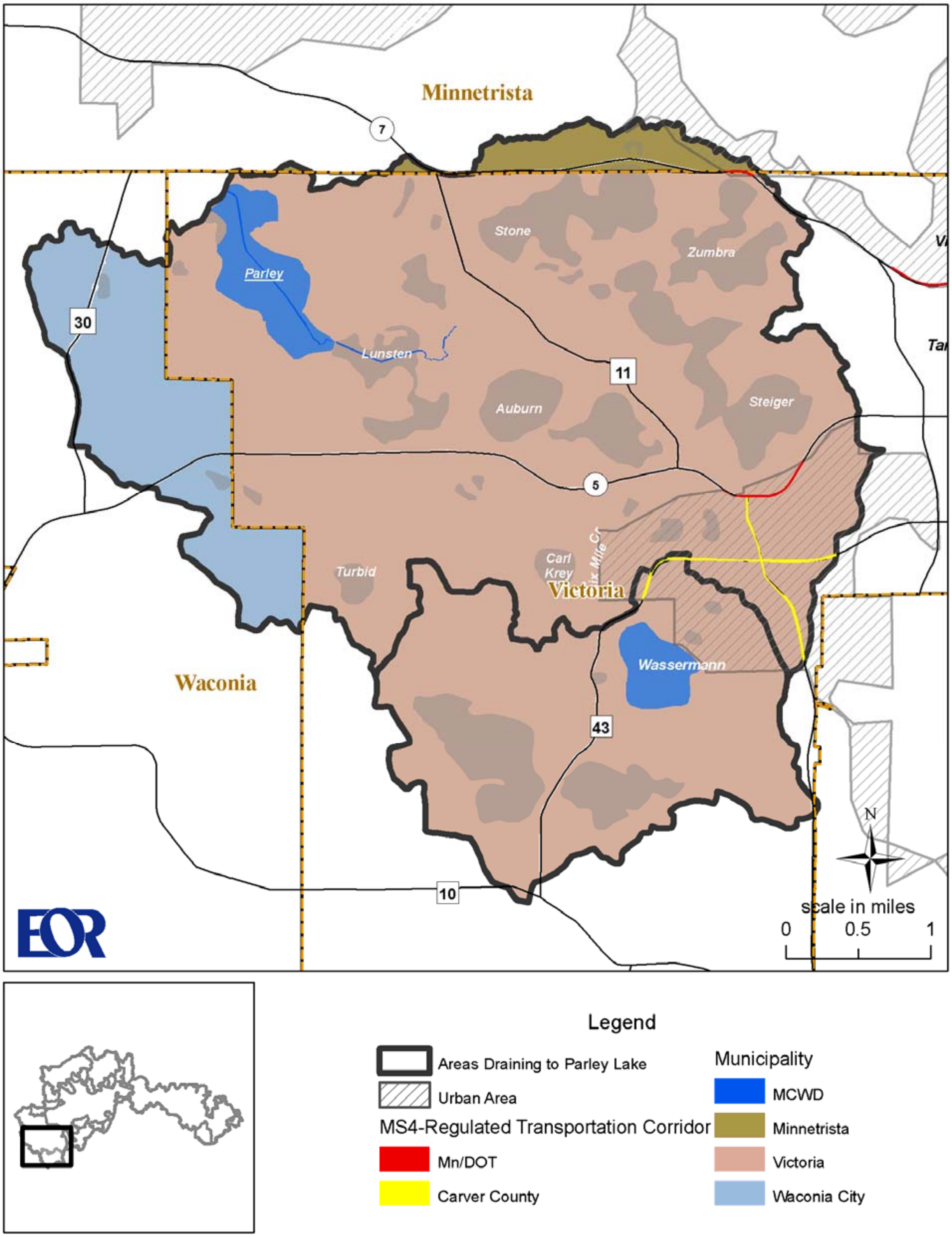


Figure 34. MS4-Regulated Road Authorities within the Parley Lake Watershed, Future (Ultimate) Municipal Boundaries

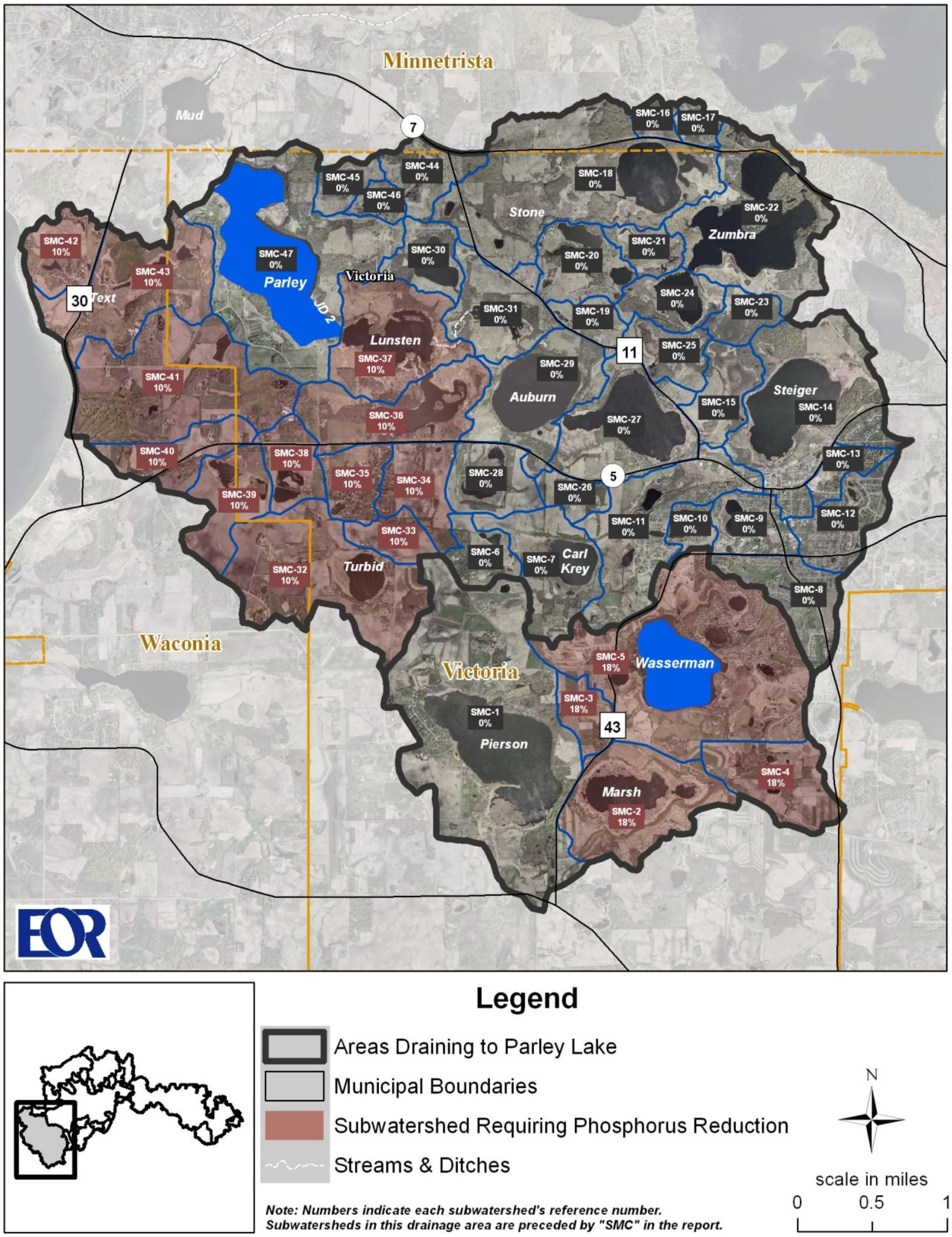


Figure 35. Parley Lake Subwatersheds Needing Phosphorus Reductions, Future (Ultimate) Municipal Boundaries

Reductions for the Wassermann Lake watershed (SMC-1 through SMC-5) are for meeting the Wassermann Lake TMDL allocations. Load reductions for SMC-32 through SMC-43 are presented as an average needed percent reduction over the area.

Percent reductions by subwatersheds are presented to be used for prioritizing locations for implementation. The values may differ from the percent reductions provided by source in Table 25 since they are averaged over different areas.

Table 22. Parley Lake TMDL Allocations, Existing Municipal Boundaries

Municipal boundaries are based on the most recent Laketown Township annexation to the City of Victoria on December 15, 2006, as presented in the City of Victoria's Comprehensive Plan 2008.

Individual daily WLAs are presented with three significant digits to avoid needing to adjust allocations for differences due to rounding.

Source		TMDL	
		lbs/yr	lbs/day
Load Allocation (internal load, unidentified loads, atmospheric deposition, non-regulated stormwater runoff)		1,097	3.00
Wasteload Allocation (regulated stormwater runoff)		175	0.48
MS4 or other source	NPDES Permit #		
City of Victoria	*MS400126*	*103*	*0.282*
City of Minnetrista	*MS400106*	*0.54*	*0.00148*
Laketown Township	*MS400142*	*61*	*0.167*
Carver County	*MS400070*	*4.6*	*0.0126*
Mn/DOT Metro District	*MS400170*	*1.6*	*0.00442*
MCWD	*MS400182*	*0.54*	*0.00148*
Construction stormwater	*Various*	*2.8*	*0.00765*
Industrial site stormwater	*No current regulated sources*	*0.87*	*0.00240*
Total TMDL		1,272	3.48

Table 23. Parley Lake TMDL Allocations, Future (Ultimate) Municipal Boundaries

Individual daily WLAs are presented with three significant digits to avoid needing to adjust allocations for differences due to rounding.

Source		TMDL	
		lbs/yr	lbs/day
Load Allocation (internal load, unidentified loads, atmospheric deposition, non- regulated stormwater runoff)		1,097	3.00
Wasteload Allocation (regulated stormwater runoff)		175	0.48
MS4 or other source	NPDES Permit #		
City of Victoria	*MS400126*	*148*	*0.405*
City of Minnetrista	*MS400106*	*0.54*	*0.00148*
City of Waconia	*MS400232*	*16*	*0.0436*
Carver County	*MS400070*	*4.6*	*0.0126*
Mn/DOT Metro District	*MS400170*	*1.6*	*0.00442*
MCWD	*MS400182*	*0.54*	*0.00148*
Construction stormwater	*Various*	*2.8*	*0.00765*
Industrial site stormwater	*No current regulated sources*	*0.87*	*0.00240*
Total TMDL		1,272	3.48

Table 24. WLA Transfer Rate, Parley Lake TMDL

	Laketown Twp		City of Victoria
	Future annex to Waconia	Future annex to Victoria	
Regulated area (ac) within existing municipal boundaries	186	2080	2073
WLA (lbs/yr), future (ultimate) municipal boundaries	16	148	
WLA (lbs/yr), existing municipal boundaries	16	74	74

Laketown Twp to Waconia transfer rate = 16 lbs/186 acres-yr = 0.086 lbs/ac-yr, or 2.4×10^{-4} lbs/ac-day

Laketown Twp to Victoria transfer rate = 74 lbs/2080 acres-yr = 0.036 lbs/ac-yr, or 9.9×10^{-5} lbs/ac-day

Table 25. Parley Lake Percent Load Reductions, Future (Ultimate) Municipal Boundaries

Load estimates from MS4s include construction and industrial stormwater loads within the MS4 boundaries. Reductions for MS4 entities apply only to the MS4-regulated portions. Load reductions are not needed for SMC-1 through SMC-29 (Figure 35 and Figure 36) for the Parley Lake TMDL, which is reflected in the % reduction values in this table. However, for the Wassermann Lake TMDL load reductions are needed in SMC-2 through SMC-5; those reductions are reflected in the % reduction values in the load reduction table for the Wassermann Lake TMDL (Table 37) and are also included in Figure 35.

Source	Existing Load[1] (lbs/yr)	Allowable Load[2] (lbs/yr)	% Reduction
Internal/unidentified load	1,591	620	61%
Atmospheric deposition	69	69	0%
Non-regulated stormwater runoff	416	408	2%
City of Victoria (including parts currently Laketown Twp.)	170[2]	151	11%
City of Minnetrista	0.55	0.55	0%
City of Waconia (currently Laketown Twp.)	16[3]	16	0%
Carver County	4.7	4.7	0%
Mn/DOT Metro District	1.6	1.6	0%
MCWD	0	0	0%
Total:	*2,269*	*1,271*	*44%*

[1]Takes into account attenuation by Auburn Lake West
[2]Includes drainage in entire watershed
[3]Existing load based on land use and land cover, summed up according to future/ultimate municipal boundaries

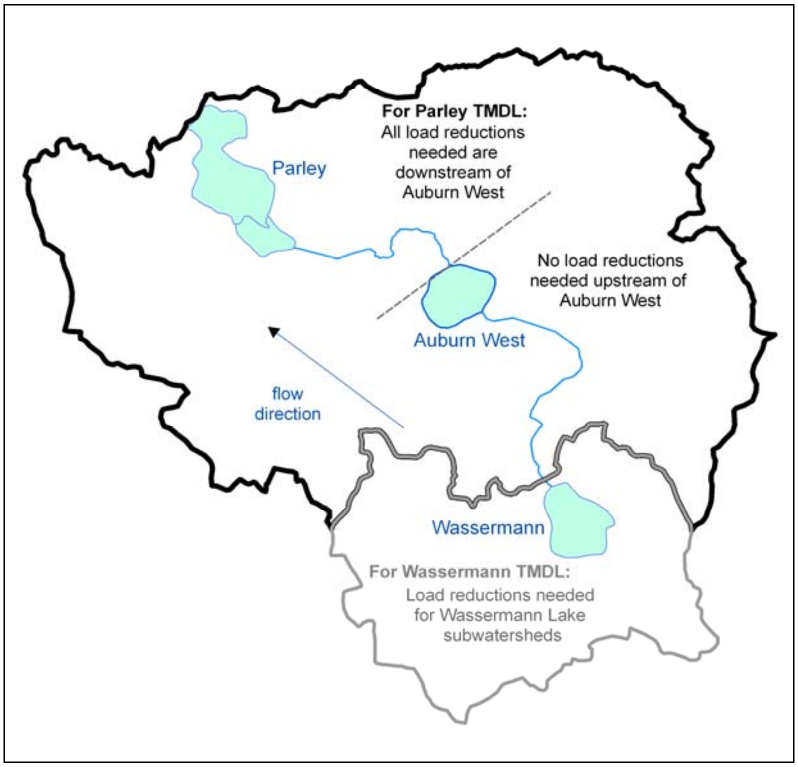


Figure 36. Relationship between Parley Lake and Wassermann Lake TMDLs

C. Lake Virginia

Lake Virginia is located in the City of Victoria, and its watershed includes areas within Victoria, Shorewood, Chanhassen, and Chaska. It currently has a surface area of 111 acres and a watershed area of 3,881 acres (6 square miles). Its mean depth is approximately 11 feet and its maximum depth is 34 feet. Approximately 73% of the lake is littoral (having a depth of 15 feet or less) (Figure 37).

Eurasian watermilfoil has been in the lake since the early 1990s and grows around the entire lake (Lake Virginia Stewardship and Management Plan 2000), and chemical treatments for milfoil have been applied to the lake in the past.

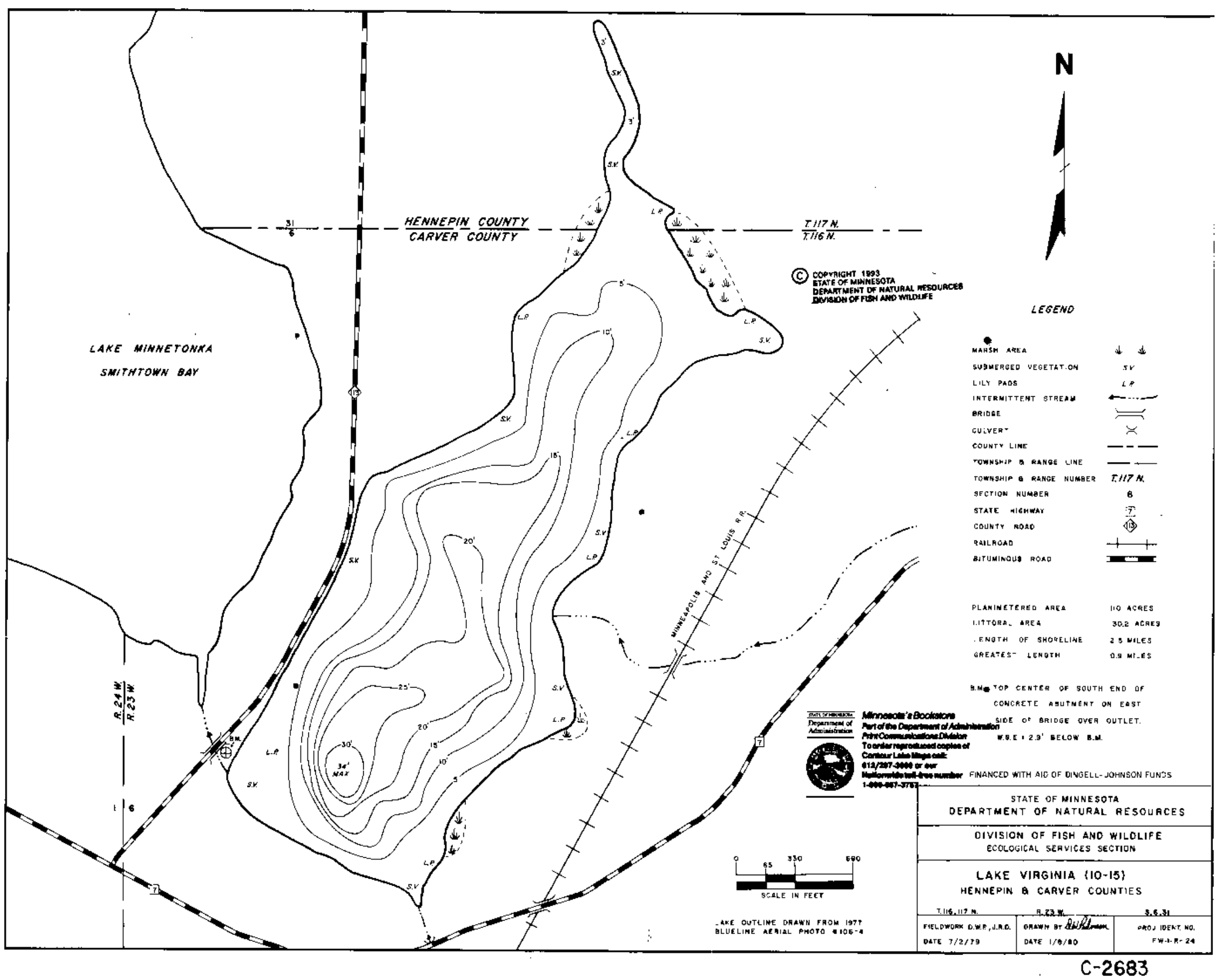


Figure 37. Lake Virginia Bathymetry, MDNR 1979

Littoral area appears to be misrepresented in figure text; actual littoral area is 76.5 ac.

Water Quality Assessment

Lake Virginia is mildly eutrophic, with slightly higher chl-*a* levels compared to transparency, as indicated by the TSI values (Table 26).

Table 26. Lake Virginia water quality data summary

Parameter	1998 – 2007 average*	TSI	Standard
Total Phosphorus	47 µg/l	60	40 µg/l
Chlorophyll-*a*	26 µg/l	63	14 µg/l
Secchi Depth	1.3 m	56	1.4 m

*Average of annual GSM (June – September)

In-lake monitoring data are available from 1999 through 2007 (Figure 38 through Figure 40). Water quality did not vary much within this time period.

DO depth profile data were collected from 2006 through the present and show that the deep portion of the lake stratifies during the growing season, with low DO in the hypolimnion during the majority of the growing season (Figure 41). Hypolimnetic (from the bottom of the water column) water samples show increasing concentrations of TP over the course of the growing season (Figure 42), suggesting that phosphorus is being released from the sediments into the water column during the periods of low DO in the hypolimnion.

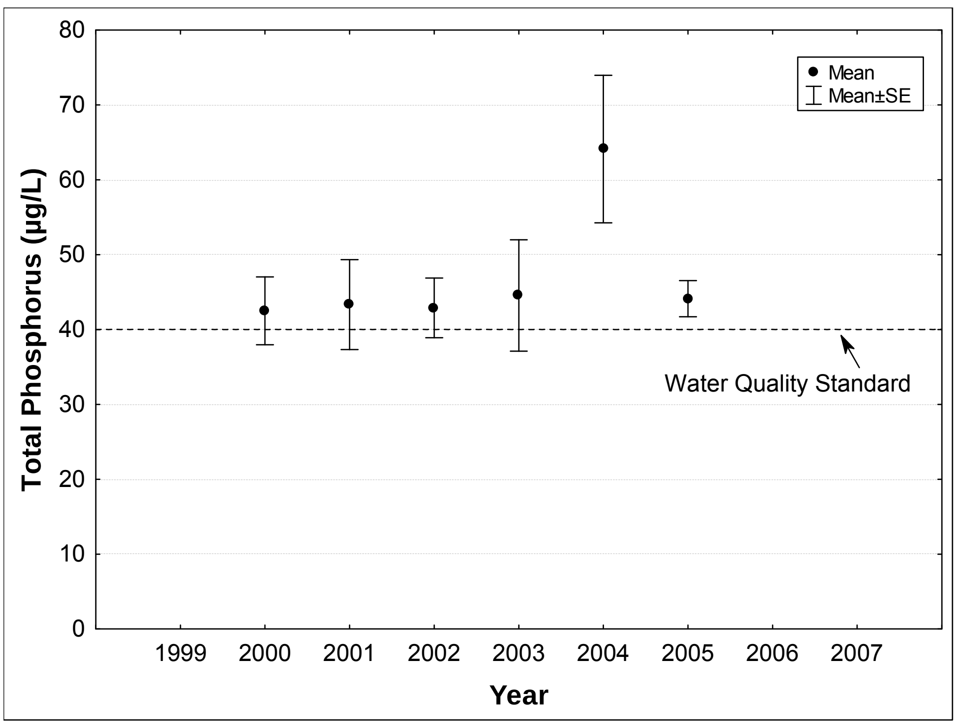


Figure 38. Lake Virginia Growing Season Mean TP

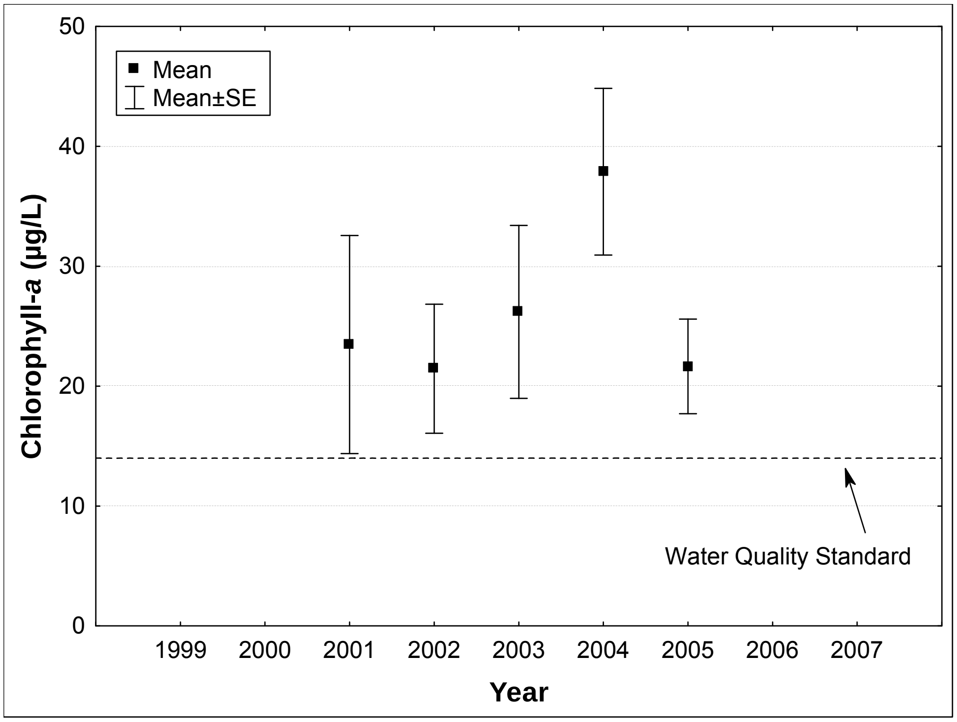


Figure 39. Lake Virginia Growing Season Mean Chlorophyll-a

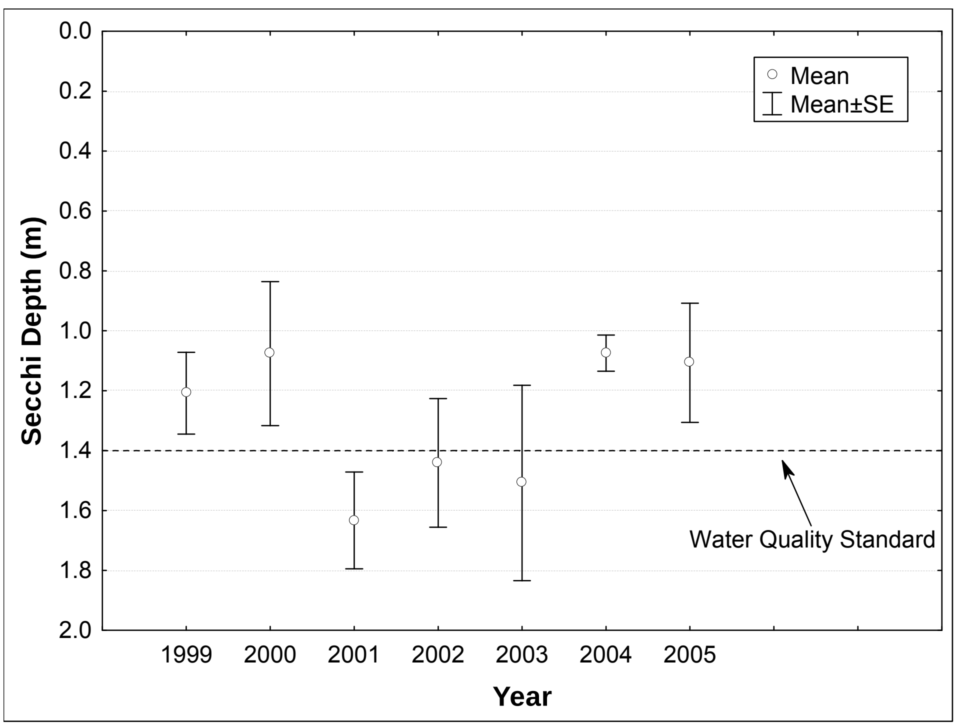


Figure 40. Lake Virginia Growing Season Mean Secchi Transparency

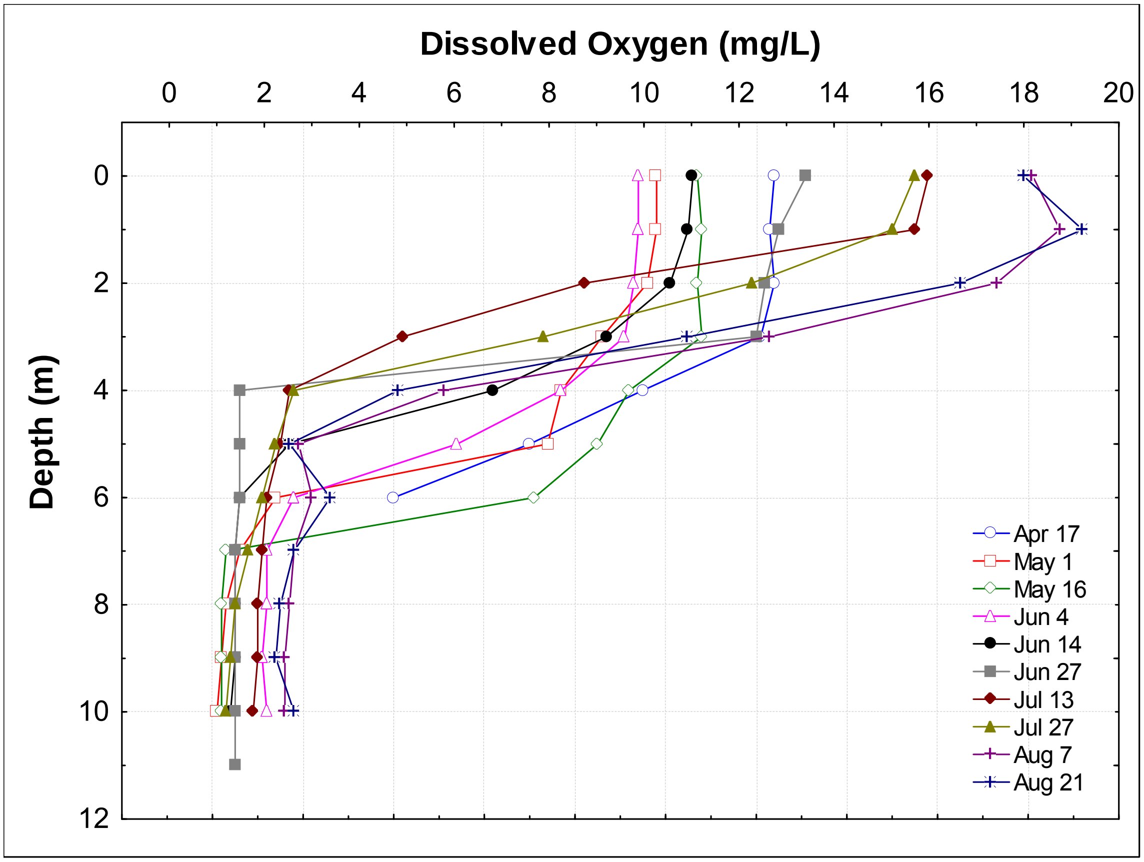


Figure 41. Lake Virginia 2006 DO Depth Profiles

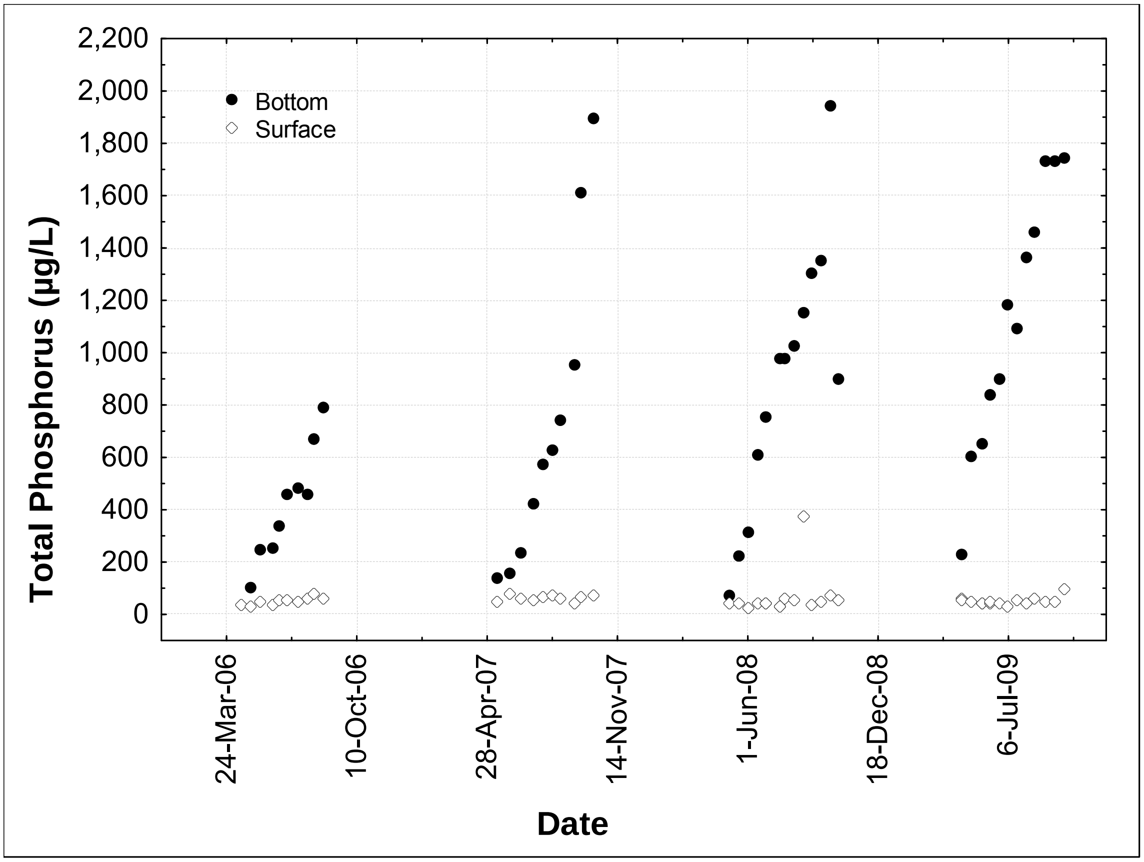


Figure 42. Lake Virginia Bottom TP Concentrations

Based on a 2003 fish survey, northern pike were sampled in higher than typical numbers compared to lakes with similar physical and chemical characteristics. Bluegill were the most abundant fish, also sampled at numbers higher than typical. Other fish captured include walleye, black crappie, yellow perch, sunfish, black bullhead, and yellow bullhead. Walleye fry were stocked in Lake Virginia in 2001. Lake users observed that carp are abundant in the lake.

Water Quality Standards

A range of water quality goals already exists for Lake Virginia (Table 27). The state standards will serve as the water quality goals: 40 µg/L total phosphorus, 14 µg/L chlorophyll-*a*, and 1.4 m Secchi depth.

Table 27. Lake Virginia TP Goals

Source	TP Goal (µg/l)
Lake Virginia Stewardship and Management Plan*	23-32
MCWD, 2007	40
State standard	40

*Chlorophyll-*a* goal: 10 - 20 µg/l; Secchi depth goal: 2.1 - 3.0 m

TMDL Determination

The Lake Virginia watershed was divided into two portions: the subwatersheds that drain to Lake Minnewashta before eventually draining to Lake Virginia (LMC-1 through LMC-10 in Figure 10), and the subwatersheds downstream of Lake Minnewashta that drain to Lake Virginia (LV-1 through LV-6 in Figure 10). The approach described in *Section 3.B Calculation of TMDL Components* was followed, with the following adjustments to the approach:

- Due to the high water quality of Lake Minnewashta (average growing season TP surface concentration is 16 µg/L), reductions in the Lake Minnewashta drainage area are not warranted for the Lake Virginia TMDL. Load reductions in the Lake Minnewashta watershed would likely not translate into measurable improvements to the Lake Minnewashta water quality, and therefore the load reductions would not improve the in-lake water quality of Lake Virginia. The TMDL allocations for the Lake Minnewashta watershed are therefore based on existing loads.
- The load from LV-1 was also held at existing conditions for the TMDL allocations. This subwatershed is relatively undeveloped and the existing imperviousness and average TP concentration in runoff is relatively low (less than 150 µg/L TP). Reductions in TP loading from this subwatershed are not warranted (due to its current low loading rates), but, in order to restore Lake Virginia and avoid degrading Lake Minnewashta, loads should not be allowed to increase.
- Due to the fact that the existing in-lake TP concentration of Lake Virginia is not far from the standard (47 µg/L vs. 40 µg/L), the target TP concentration of 150 µg/L for the subwatersheds downstream of Lake Minnewashta (LV-1 through LV-6) was not necessary. Instead, a target concentration of 190 µg/L was used for those subwatersheds.
- The load to Lake Minnewashta is attenuated by the sedimentation within the lake, and therefore the load to the lake is greater than the load that leaves the lake and eventually reaches Lake Virginia. The average attenuation by Lake Minnewashta is 87.4%; this attenuation percentage was applied to the modeled existing loads from the Lake Minnewashta watershed to determine the actual load to Lake Virginia. These attenuated loads were taken into account for both the existing loads and the loading goals from the Lake Minnewashta watershed.

The assimilative capacity (or TMDL) of Lake Virginia was calculated to be 306 lbs/yr, or 0.84 lbs/day TP. The loads were divided between the total WLA and LA as follows:

$$\text{TMDL} = \text{WLA} + \text{LA}$$
$$306 \text{ lbs/yr} = 133 \text{ lbs/yr} + 173 \text{ lbs/yr}$$
$$0.84 \text{ lbs/day} = 0.37 \text{ lbs/day} + 0.47 \text{ lbs/day}$$

The regulated MS4 entities within the Lake Virginia watershed are the City of Chanhassen, the City of Chaska, the City of Shorewood, the City of Victoria, Carver County, and Mn/DOT Metro District. The WLAs only cover those portions of the MS4 entities that are regulated by the MS4 permit (Table 28). The MS4-regulated areas within municipalities were determined by land use (see *Section 3.B: Calculation of TMDL Components: Wasteload Allocations*), and the road authority areas that are regulated by the MS4 permit were determined by the urbanized area boundary (Figure 43).

The WLAs for the MS4 entities include loads from the Lake Minnewashta watershed, which are held at existing conditions, and loads from the direct Lake Virginia watershed, which are required to be reduced to the equivalent of 190 µg/L TP. (As with the other lakes, this target concentration was used to calculate the WLAs, but it is the actual load-based WLA that is the target for this TMDL. The WLA can be achieved partly or wholly through volume control, even if the TP concentration in runoff is above 190 µg/L). The WLA was further divided into individual WLAs for MS4 stormwater (Table 29). The LA includes the loads from non-regulated MS4 stormwater runoff, internal loading, and atmospheric deposition (Table 29).

An overall load reduction of 20% is needed for Lake Virginia. The percent reductions required by the MS4 entities range from 16% for Shorewood to 37% for Victoria (Table 30). Percent reductions by subwatershed vary from 0% in the Lake Minnewashta subwatersheds to up to 50% in the Lake Virginia subwatersheds (Figure 44).

Table 28. MS4-Regulated Areas within the Lake Virginia Watershed

MS4	MS4-Regulated Area (ac)		Non-MS4-Regulated Area (ac)	
	Lake Minnewashta Watershed	Lake Virginia Watershed	Lake Minnewashta Watershed	Lake Virginia Watershed
City of Chanhassen	1715	209	782	0
City of Chaska	0	0	13	0
City of Shorewood	220	88	6	21
City of Victoria	100	397	194	65
Carver County	0	0	8	1
Mn/DOT Metro District	22	19	17	5
Total:	*2057*	*713*	*1020*	*92*

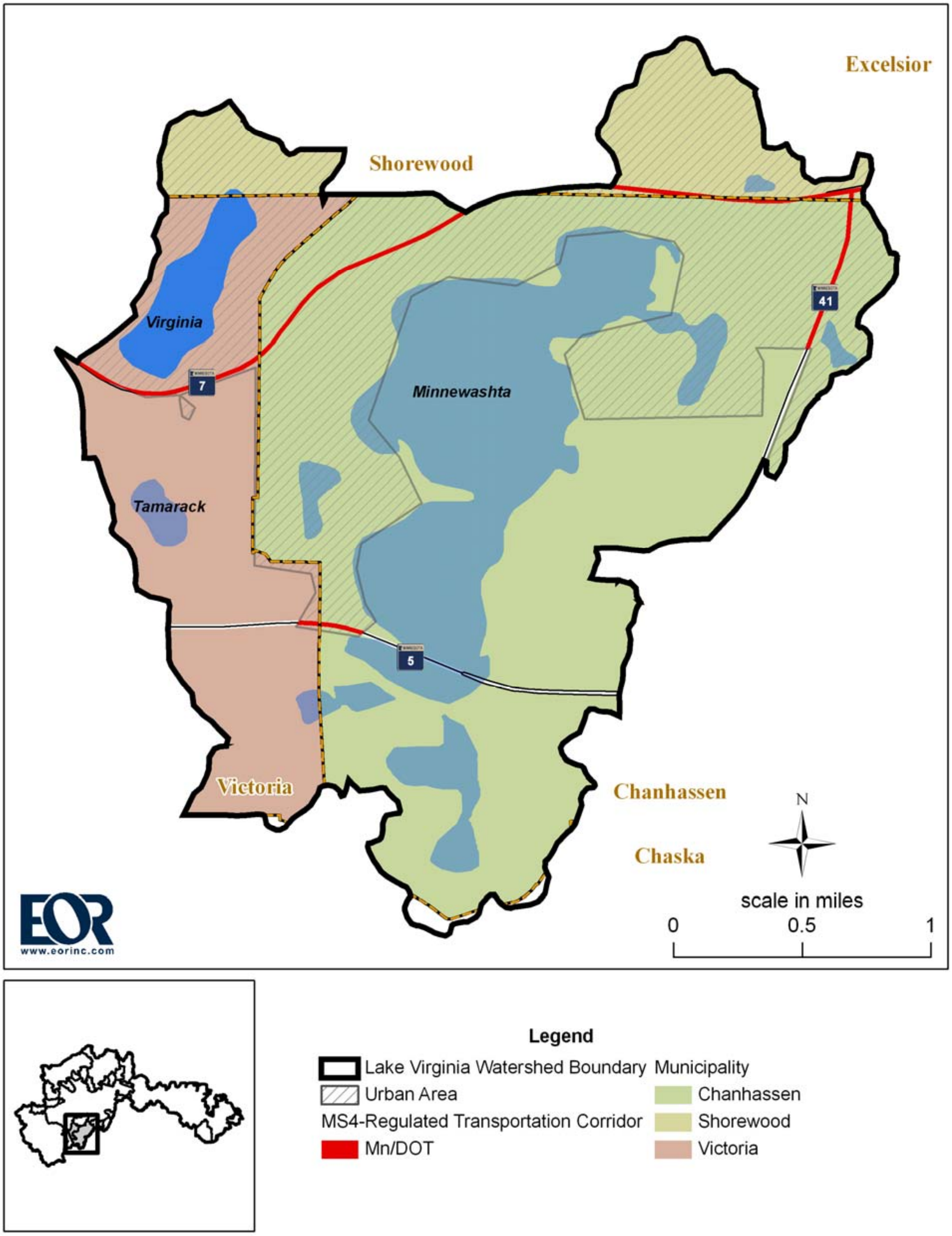


Figure 43. MS4-Regulated Road Authorities within the Lake Virginia Watershed

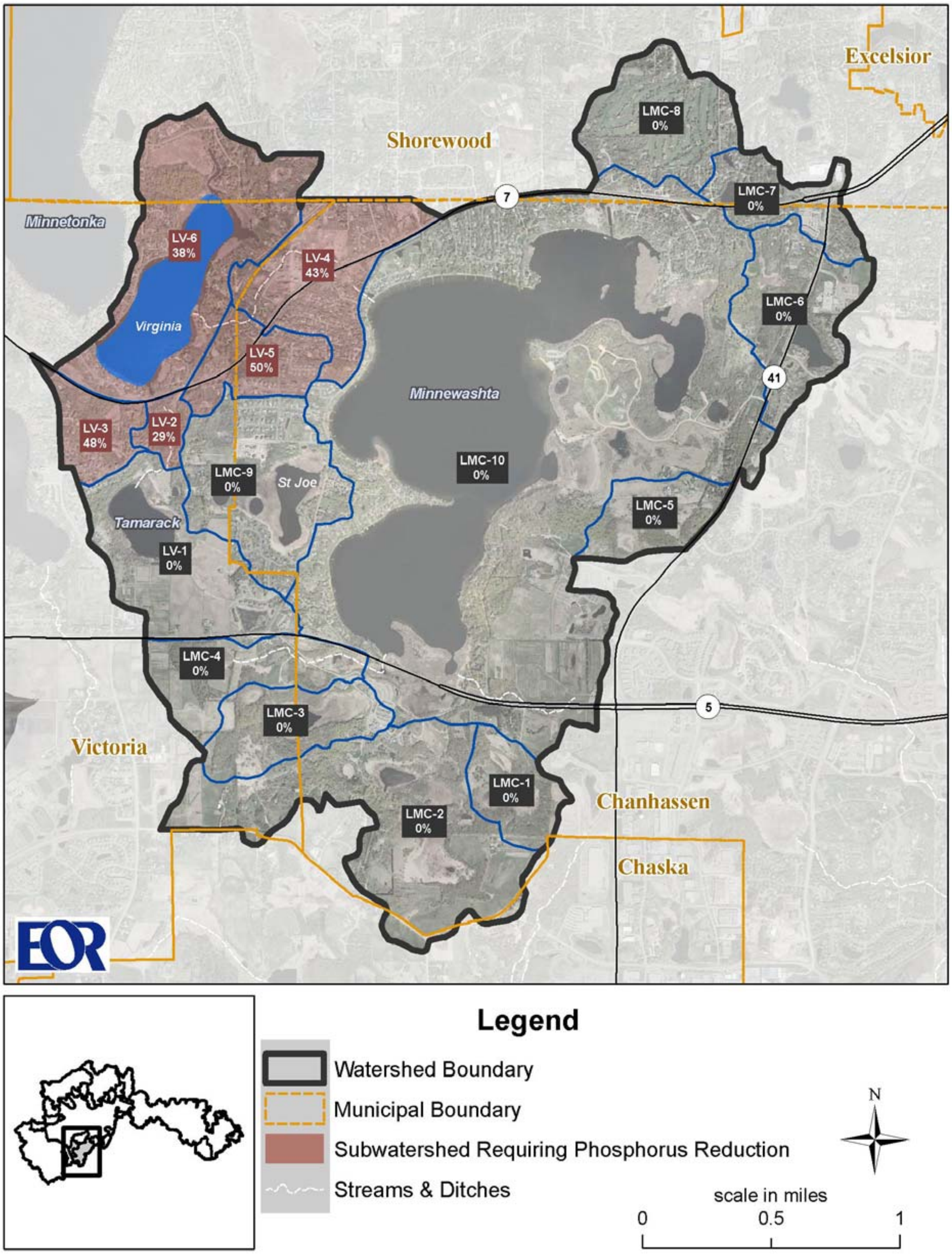


Figure 44. Lake Virginia Subwatersheds Needing Phosphorus Reductions
Percent reductions by subwatersheds are presented to be used for prioritizing locations for implementation. The values may differ from the percent reductions provided by source in Table 30 since they are averaged over different areas.

Table 29. Lake Virginia TMDL Allocations

Source		TMDL	
		lbs/yr	lbs/day
Load Allocation (internal load, ISTS, atmospheric deposition, non-regulated stormwater runoff)		173	0.47
Wasteload Allocation (regulated stormwater runoff)		132	0.37
MS4 or other source	NPDES Permit #		
City of Chanhassen	*MS400079*	*59*	*0.16*
City of Shorewood	*MS400122*	*18.3*	*0.05*
City of Victoria	*MS400126*	*46*	*0.13*
Mn/DOT Metro District	*MS400170*	*7.6*	*0.021*
Construction stormwater	*Various*	*1.3*	*0.0036*
Industrial site stormwater	*No current regulated sources*	*0.59*	*0.0016*
Total TMDL		306	0.84

Table 30. Lake Virginia Percent Load Reductions.

Load estimates from MS4s include construction and industrial stormwater loads within the MS4 boundaries. Reductions for MS4 entities apply only to the MS4-regulated portions.

Source	Existing Load[1] (lbs/yr)	Allowable Load[2] (lbs/yr)	% Reduction
Internal load/unidentified load[3]	123	117	5%
Atmospheric deposition	30	30	0%
Non-regulated stormwater runoff	33	26	22%
City of Chanhassen	90	60	33%
City of Shorewood	22	19	16%
City of Victoria	74	47	37%
Mn/DOT Metro District	11	7.7	29%
Total:	*383*	*306*	*20%*

[1]Takes into account attenuation by Lake Minnewashta
[2]Includes drainage in entire watershed
[3]Includes unidentified loads such as ISTS and instream erosion

D. Wassermann Lake

Wassermann Lake is located in Laketown Township, and its watershed is located in Laketown Township and the City of Victoria. Based on an Orderly Annexation Agreement approved in 1976 with Laketown Township, the City of Victoria has plans to annex the portion of Laketown Township that contains the watershed; therefore the entire watershed will be in the City of Victoria under future/ultimate municipal boundaries (Figure 6). The lake has a surface area of 163 acres and a watershed area of 2,729 acres (4.3 square miles). Its mean depth is approximately 10 feet and its maximum depth is 41 feet. Approximately 73% of the lake is littoral (having a depth of 15 feet or less) (Figure 45).

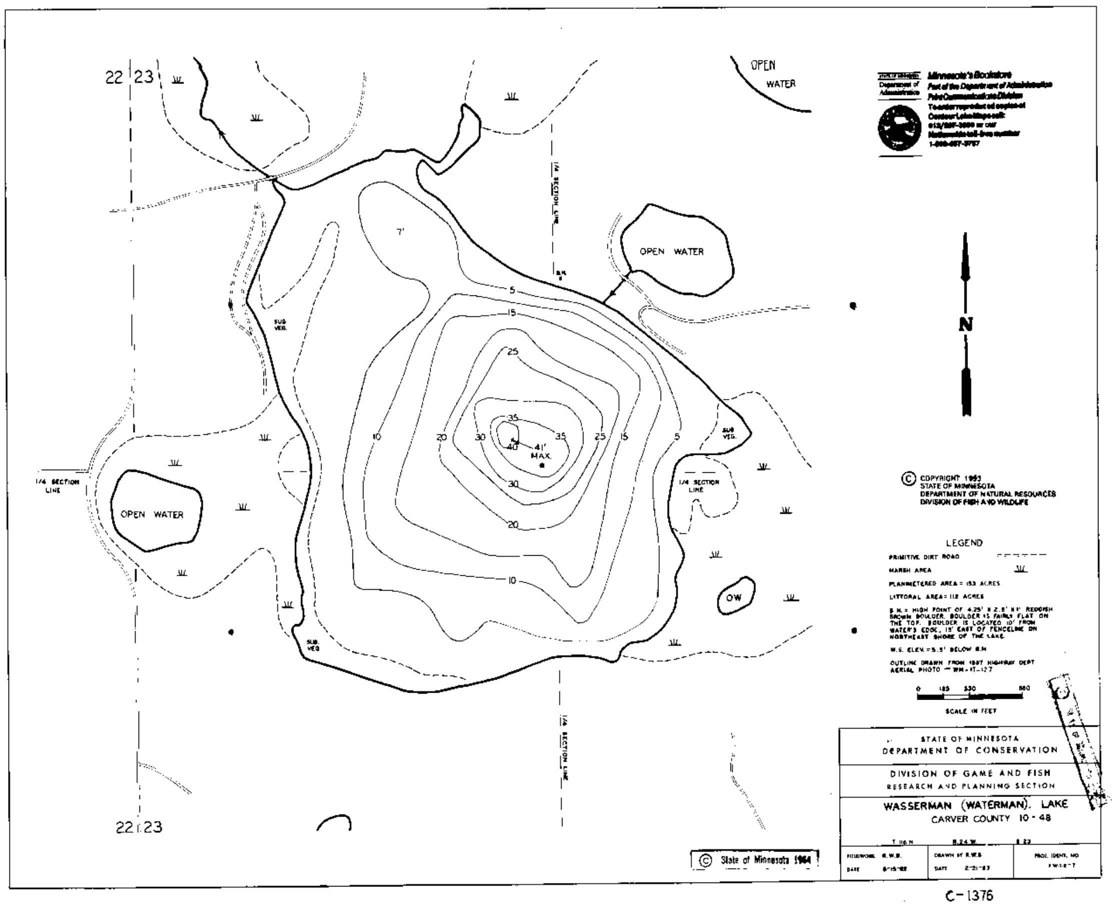


Figure 45. Wassermann Lake Bathymetry, MDNR 1962

Water Quality Assessment

In-lake monitoring data are available sporadically from 1983 through 2006 (Figure 46 through Figure 48) for TP, chl-*a*, and SD.

Wassermann Lake is a eutrophic to hypereutrophic lake, with TP, chl-*a*, and transparency having similar TSI values (Table 31).

Depth profile monitoring data from 2001 indicate that DO began to be depleted in the hypolimnion as early as May, and the lake remained stratified through the last monitoring date on September 20 (Figure 49), indicating that internal loading is a likely phosphorus source in this lake. Additionally, as evidenced by the 1999 and 2005 DNR fish surveys, as well as anecdotal information, there is a substantial carp population in the lake, which likely increases the internal loading rate.

Table 31. Wassermann Lake water quality data summary

Parameter	1998 – 2007 average*	TSI	Standard
Total Phosphorus	77 µg/l	67	40 µg/l
Chlorophyll-*a*	32 µg/l	65	14 µg/l
Secchi Depth	0.82 m	63	1.4 m

*Average of annual GSM (June – September)

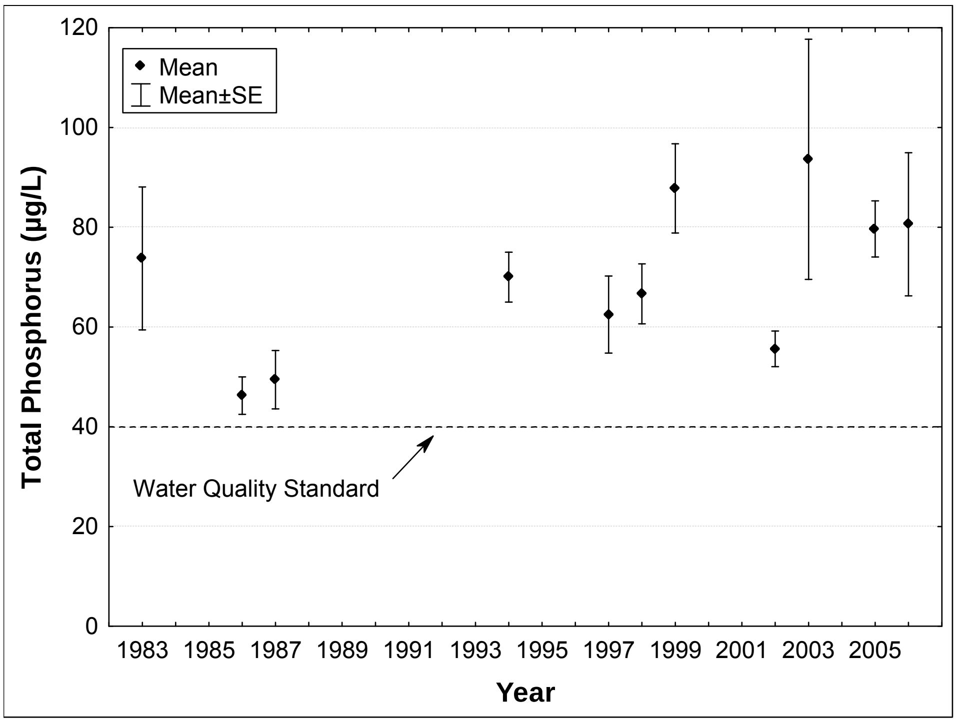


Figure 46. Wassermann Lake Growing Season Mean TP

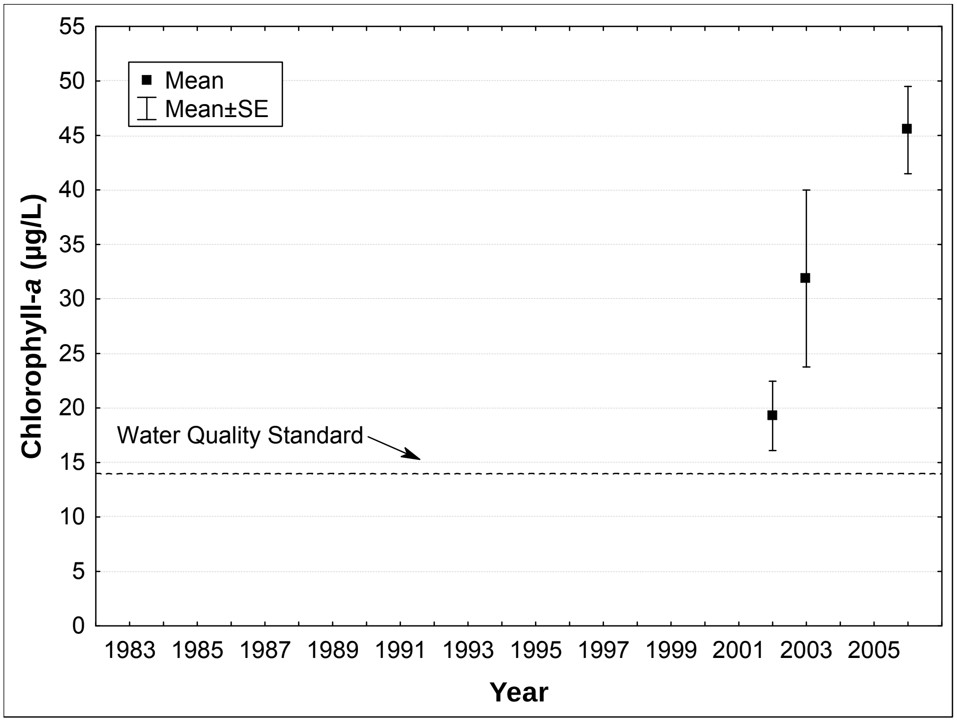


Figure 47. Wassermann Lake Growing Season Mean Chlorophyll-a

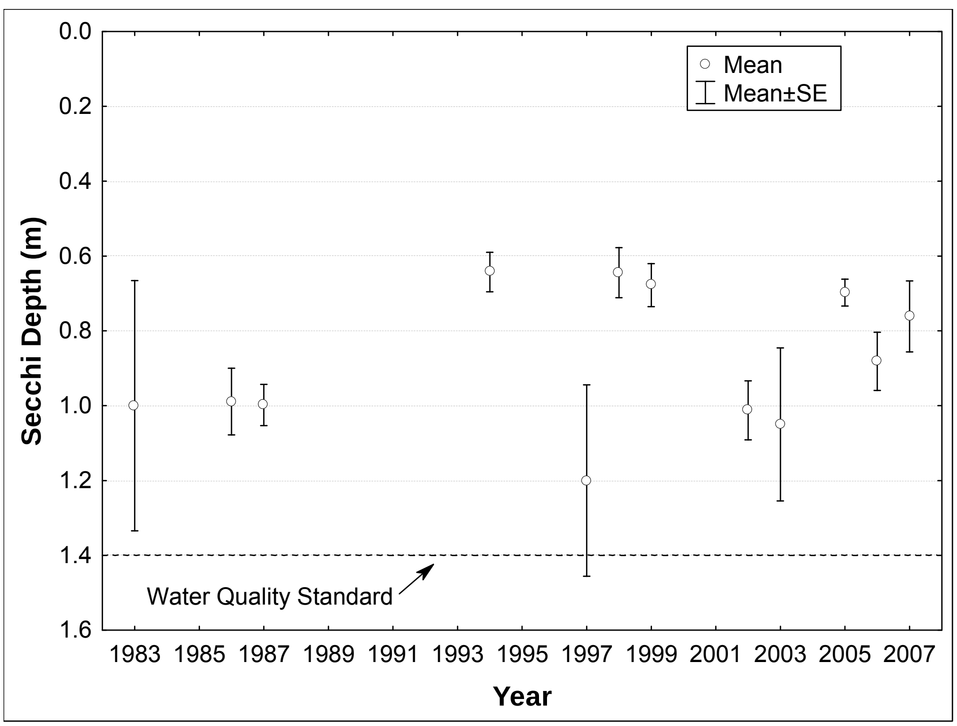


Figure 48. Wassermann Lake Growing Season Mean Secchi Depth

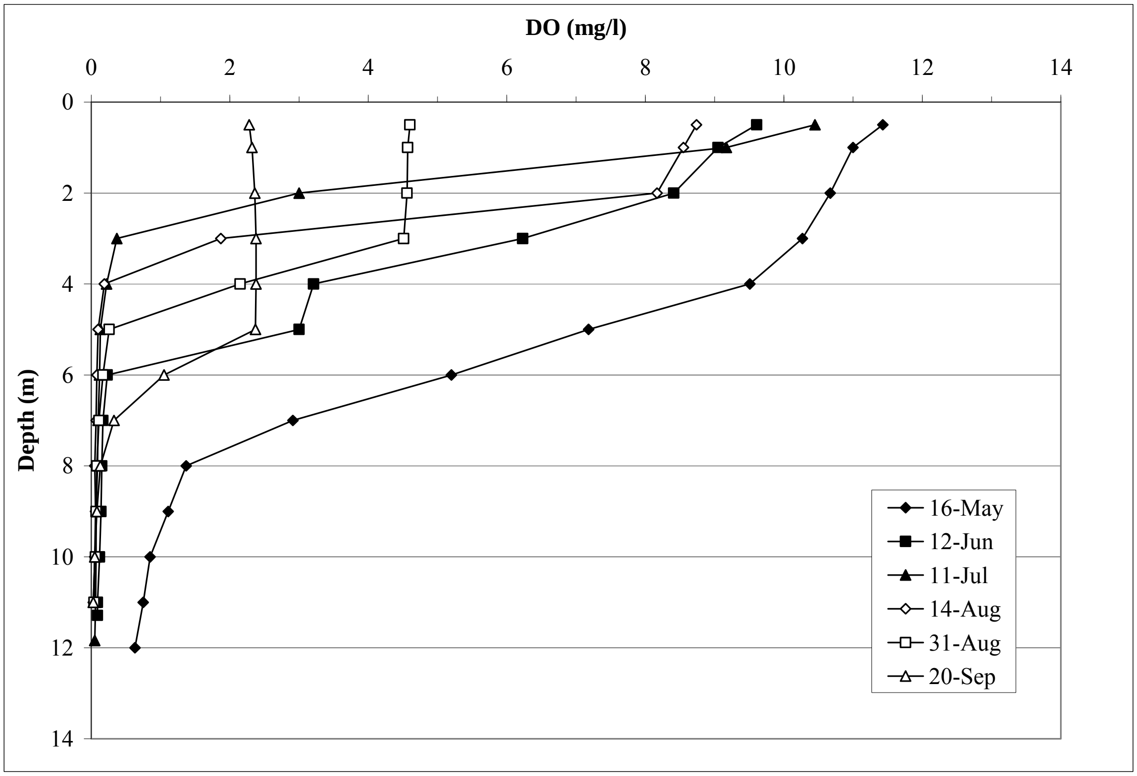


Figure 49. Wassermann Lake DO-Depth profiles, 2001

In a 2005 DNR fish survey, black crappie were sampled in higher than typical numbers (over six times the 75th percentile) compared to lakes with similar physical and chemical characteristics. There was an influx of young fish seen in this survey, as compared to the 1999 survey. Other fish caught include hybrid or tiger muskellunge, northern pike, bluegill, largemouth bass, and yellow perch. Hybrid muskellunge are stocked triennially (two fish per littoral acre).

According to local residents, Eurasian watermilfoil has been a problem for about the last five years, and it is now evident around the entire lakeshore.

Water Quality Standards

A range of water quality goals already exists for Wassermann Lake (Table 32). The state standards will serve as the water quality goals for Wassermann Lake: 40 µg/L total phosphorus, 14 µg/L chlorophyll-*a*, and 1.4 m Secchi depth.

Table 32. Wassermann Lake TP Goals

Source	TP Goal (µg/l)
MCWD, 2007	50
State standard	40

TMDL Determination

The Wassermann Lake watershed was divided into two portions: the subwatershed that drains to Pierson Lake before eventually draining to Wassermann Lake (SMC-1 in Figure 5), and the subwatersheds downstream of Pierson Lake that drain to Wassermann Lake (SMC-2 through SMC-5 in Figure 5). The approach described in *Section 3.B Calculation of TMDL Components* was followed, with the following adjustments to the approach:

- Pierson Lake's existing in-lake TP concentration is 36 µg/L, and it is predicted to increase to 43 µg/L by 2020 (MCWD 2003). The load from the Pierson Lake subwatershed (SMC-1) was held at existing conditions for the TMDL allocations; this will prevent Pierson Lake from worsening and from itself becoming impaired.
- SMC-2 and SMC-3 are relatively undeveloped and the existing imperviousness and average TP concentration in runoff is relatively low (less than 150 µg/L TP). Reductions in TP loading from these subwatersheds are not warranted (due to their current low loading rates), but, in order to restore Wassermann Lake, loads should not be allowed to increase. However, loads from feedlots with runoff concerns were not directly incorporated into the watershed load estimates. To cover this possibility, the load reductions needed in the Wassermann Lake watershed were averaged out over SMC-2 through SMC-5, leading to a required reduction of 18% in those subwatersheds.
- The existing average TP concentration in subwatersheds SMC-4 and SMC-5 is above 150 µg/L (171 and 195 µg/L, respectively), and runoff volumes are predicted to increase substantially due to projected development. The loading goals for these subwatersheds were calculated based on the existing runoff volume and the target runoff TP concentration of 150 µg/L.
- The load to Pierson Lake is attenuated by the sedimentation within the lake, and therefore the load to the lake is greater than the load that leaves the lake and eventually reaches Wassermann Lake. The average attenuation by Pierson Lake is 60%; this attenuation percentage was applied to the modeled existing load from the Pierson Lake watershed to determine the actual load from SMC-1 to Wassermann Lake. This attenuated load was taken into account for both the existing load and the loading goal from the Pierson Lake watershed.

The assimilative capacity (or TMDL) of Wassermann Lake was calculated to be 283 lbs/yr, or 0.78 lbs/day TP. The loads were divided between the total WLAs and LA as follows:

$$\text{TMDL} = \text{WLA} + \text{LA}$$
$$283 \text{ lbs/yr} = 125 \text{ lbs/yr} + 158 \text{ lbs/yr}$$
$$0.78 \text{ lbs/day} = 0.34 \text{ lbs/day} + 0.43 \text{ lbs/day}$$

The regulated MS4 entities within the Wassermann Lake watershed are the City of Victoria, Laketown Township (under existing conditions only), and Carver County. The WLAs only cover those portions of the MS4 entities that are regulated by the MS4 permit (Table 33). The MS4-regulated areas within municipalities were determined by land use (see *Section 3.B: Calculation of TMDL Components: Wasteload Allocations*), and the road authority areas that are regulated by the MS4 permit were determined by the urbanized area boundary (Figure 50).

The WLA was further divided into individual WLAs for MS4 stormwater (Table 34 and Table 35). The LA includes the loads from non- regulated MS4 stormwater runoff, internal loading, unidentified loads, and atmospheric deposition (Table 34 and Table 35).

WLAs are presented for both the existing Laketown Township boundaries (Table 34) and future/ultimate municipal boundaries (Table 35). The first set of WLAs are to be used when this TMDL is approved; the average WLA per unit area within the MS4-regulated portions of the watershed is 0.072 lbs TP/acre-year. **As portions of Laketown Township become annexed to the City of Victoria, Laketown Township's WLA will be transferred to the city based on the rate of 0.072 lbs/acre-year (2.0 x 10^{-4} lbs/acre-day).** (Table 36 includes details of this calculation.)

An overall load reduction of 62% is needed for Wassermann Lake (Table 37). The greatest required percent reduction is for internal loading (88% reduction required). Internal loading within Wassermann Lake is high, and this high reduction will be needed in order to restore the lake. Load reductions by subwatershed vary from 0% in SMC-1 (due to the relatively high quality of Pierson Lake) to an average of 18% in the remaining subwatersheds (Figure 51).

Table 33. MS4-Regulated Areas within the Wassermann Lake Watershed, Future (Ultimate) Municipal Boundaries

MS4	MS4-Regulated Area (ac)		Non-MS4-Regulated Area (ac)	
	Pierson Watershed (SMC-1)	Downstream Pierson (SMC-2 through 5)	Pierson Watershed (SMC-1)	Downstream Pierson (SMC-2 through 5)
City of Victoria	488	1204	703	303
Carver County	0	5	9	17
Total:	*488*	*1209*	*712*	*320*

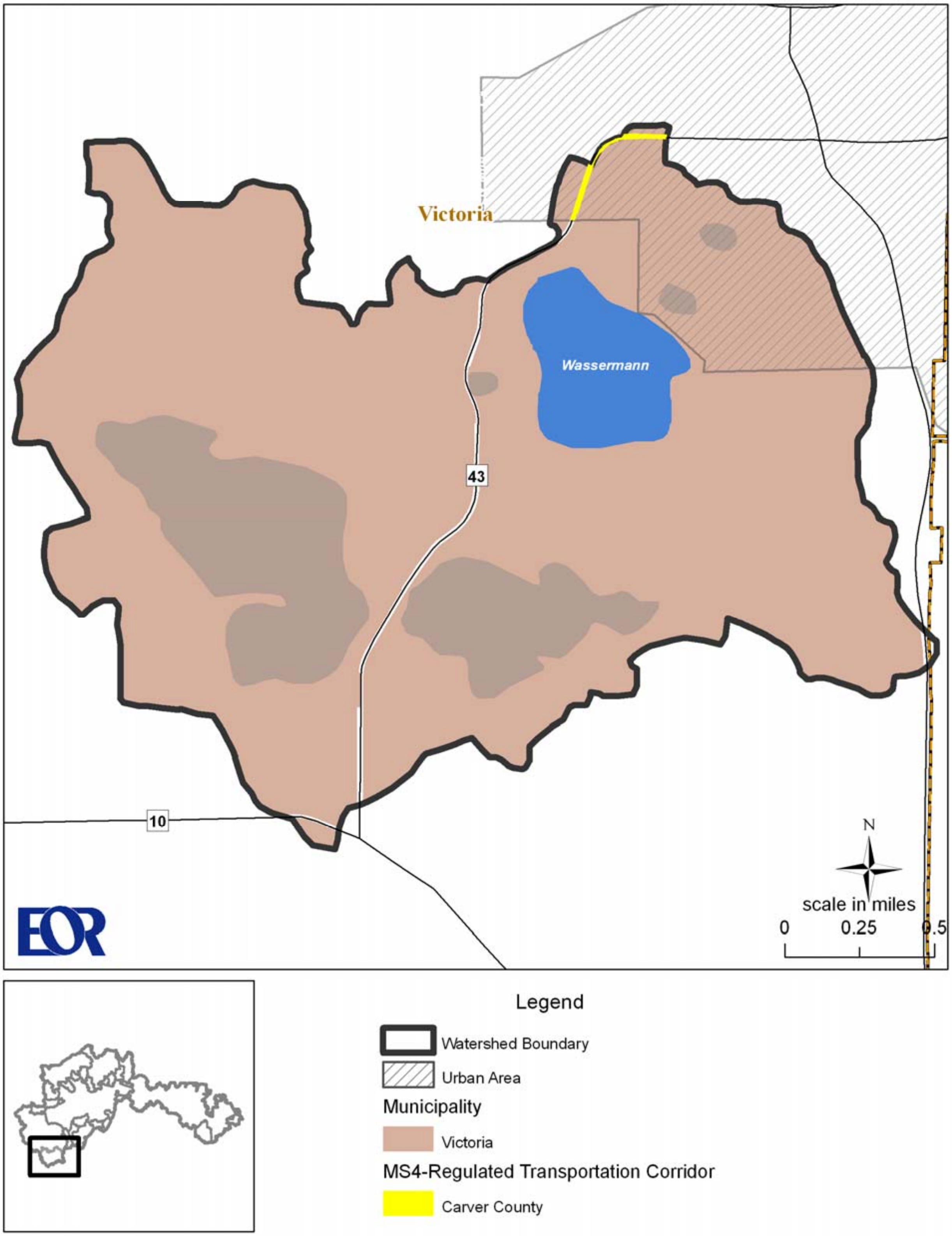


Figure 50. MS4-Regulated Road Authorities within the Wassermann Lake Watershed, Future (Ultimate) Municipal Boundaries

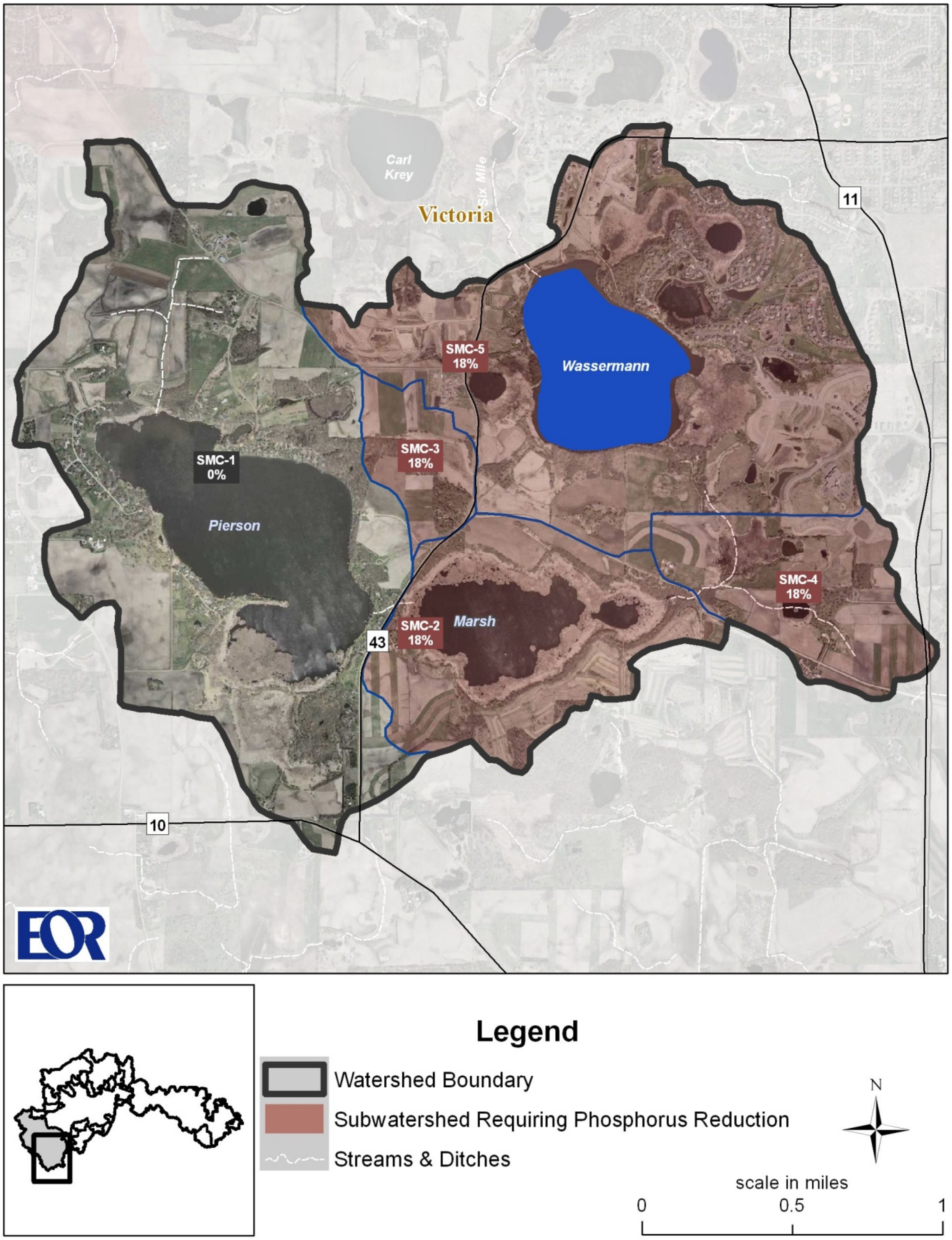


Figure 51. Wassermann Lake Subwatersheds Needing Phosphorus Reductions, Future (Ultimate) Municipal Boundaries

Load reductions for SMC-2 through SMC-5 are presented as an average needed percent reduction over the area.

Percent reductions by subwatersheds are presented to be used for prioritizing locations for implementation. The values may differ from the percent reductions provided by source in Table 37 since they are averaged over different areas.

Table 34. Wassermann Lake TMDL Allocations, Existing Municipal Boundaries

Municipal boundaries are based on the most recent Laketown Township annexation to the City of Victoria on December 15, 2006, as presented in the City of Victoria's Comprehensive Plan 2008.
Individual daily WLAs are presented with three significant digits to avoid needing to adjust allocations for differences due to rounding. Reductions for MS4 entities apply only to the MS4-regulated portions.

Source		TMDL	
		lbs/yr	**lbs/day**
Load Allocation (internal load, unidentified loads, atmospheric deposition, non-MS4 stormwater runoff)		158	0.43
Wasteload Allocation		125	0.34
MS4 or other source	NPDES Permit #		
City of Victoria	*MS400126*	*65*	*0.177*
Laketown Township	*MS400142*	*57*	*0.157*
Carver County	*MS400070*	*1.23*	*0.00337*
Construction stormwater	*Various*	*2.13*	*0.00584*
Industrial site stormwater	*No current regulated sources*	*0.125*	*0.000343*
Total TMDL		283	0.78

Table 35. Wassermann Lake TMDL Allocations, Future (Ultimate) Municipal Boundaries

Individual daily WLAs are presented with three significant digits to avoid needing to adjust allocations for differences due to rounding. Reductions for MS4 entities apply only to the MS4-regulated portions.

Source		TMDL	
		lbs/yr	**lbs/day**
Load Allocation (internal load, unidentified loads, atmospheric deposition, non- regulated stormwater runoff)		158	0.43
Wasteload Allocation (regulated stormwater runoff)		125	0.34
MS4 or other source	NPDES Permit #		
City of Victoria	*MS400126*	*122*	*0.334*
Carver County	*MS400070*	*1.23*	*0.00337*
Construction stormwater	*Various*	*2.13*	*0.00584*
Industrial site stormwater	*No current regulated sources*	*0.125*	*0.000343*
Total TMDL		283	0.78

Table 36. WLA Transfer Rate, Wassermann Lake TMDL

	Laketown Township	**City of Victoria**
Regulated area (ac) within existing municipal boundaries	1210	506
% regulated area within existing municipal boundaries	71%	29%
WLA, future (ultimate) municipal boundaries	0	122
WLA, existing municipal boundaries	87	35
Transfer rate = 87 lbs/1210 acres-yr = 0.072 lbs/ac-yr, or 2.0×10^{-4} lbs/ac-day		

Table 37. Wassermann Lake Percent Load Reductions, Future (Ultimate) Municipal Boundaries
Load estimates from MS4s include construction and industrial stormwater loads within the MS4 boundaries.

Source	Existing Load[1] (lbs/yr)	Allowable Load[2] (lbs/yr)	% Reduction
Internal/unidentified load	505	63	88%
Atmospheric deposition	44	44	0%
Non-regulated stormwater runoff	55	51	7.2%
City of Victoria	147[3]	124	16%
Carver County	2.5	1.3	48%
Total:	753	283	62%

[1]Takes into account attenuation by Pierson Lake
[2]Includes drainage in entire watershed
[3]Existing load based on land use and land cover, summed up according to future/ultimate municipal boundaries

5. SEASONAL VARIATION AND CRITICAL CONDITIONS

Seasonal variation is accounted for through the use of annual loads in the in-lake water quality model used and developing targets for the summer period where 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, the seasonal variation is accounted for in annual loads. The nutrient standards set by the MPCA – which are a growing season concentration average, rather than an individual sample (i.e., daily) concentration value – were set with this concept in mind. 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 other seasons.

The critical condition for lakes is the summer growing season, which in Minnesota is when phosphorus concentrations peak and clarity is at its worst. Lake goals focus on summer-mean total phosphorus, Secchi transparency and chlorophyll-a concentrations. Consequently, the lake response models have focused on the summer growing season (June through September) as the critical condition. Likewise, the load reductions in this TMDL are designed so that the lakes will meet the water quality standards over the course of the growing season.

6. REASONABLE ASSURANCES

As part of an implementation strategy, reasonable assurances provide a level of confidence that the TMDL allocations will be implemented by federal, state, or local authorities. Implementation of the MCWD Lakes TMDL will be accomplished by both state and local action on many fronts. State implementation of the TMDL will be through action on NPDES permits for stormwater. In addition, potential state funding of TMDL implementation projects includes Clean Water Legacy Act grants and the Clean Water Partnership program. At the federal level, funding can be provided through Section 319 grants that provide cost share dollars to implement voluntary activities in the watershed.

The MCWD recently updated its overall watershed management plan. This plan is well-poised to evaluate and implement TMDL recommendations through a locally driven process. In addition, the MCWD also has cost-share and grant programs to assist with funding water quality improvement projects within the overall watershed. The MCWD rules are also in place and watershed permitting is expected to continue into the future. The MCWD also reviews and provides comments, when appropriate, on municipal Storm Water Pollution Prevention Programs (SWPPPs) and will continue to review and comment as relates to applicable TMDL studies within the watershed.

The regulated Phase II MS4s within the watershed must review the adequacy of their SWPPP to ensure that it meets the TMDL's WLA set for stormwater sources. If the SWPPP from any regulated MS4 does not meet the applicable requirements, schedules, and objectives of the TMDL, the MS4 will be required to modify their SWPPP, as appropriate, within 18 months after the TMDL is approved by the US EPA.

The NPDES Phase I stormwater permit for Minneapolis and MPRB is currently being rewritten. The draft permit requires the city to estimate phosphorus loads to their lakes and evaluate their local surface water management plan to determine if it will meet the WLA; this requirement is similar to the existing NPDES Phase II stormwater permit.

Local water plans for each of the cities within the lakes' watersheds can also be used to identify implementation actions specific to their city with associated costs and schedule. This will allow the cities to implement measures to protect the lakes.

7. STAKEHOLDER PARTICIPATION

City, County, Agency, and Park District participation

The following project partners and stakeholders were invited at various stages to provide input into the project approach and to review draft documents:

- Board of Water and Soil Resources
- Carver County
- Carver SWCD
- City of Chanhassen
- City of Chaska
- City of Golden Valley
- City of Minneapolis
- City of Richfield
- City of Shorewood
- City of St. Louis Park
- City of Victoria
- City of Waconia
- Hennepin County
- Laketown Township
- Metropolitan Council Environmental Services
- Minneapolis Park & Recreation Board
- Minnesota Department of Natural Resources
- Minnesota Department of Transportation
- Three Rivers Park District
- Metropolitan Airports Commission

Public meetings

A series of meetings was held to provide information to the public about the project and to solicit input regarding background information and implementation recommendations. The lakes were grouped geographically, and one or two meetings were held for each group of lakes. These meetings followed a lengthy public participation process completed previously as part of the Hydrologic, Hydraulic and Pollutant Loading Study (HHPLS) in 2003 for the MCWD. This study integrated land cover and land use, topography, soils, major storm sewer infrastructure, and other data into a comprehensive XP-SWMM and PLOAD model of the entire Minnehaha Creek/Lake Minnetonka watershed.

In the HHPLS, a series of meetings was held with regional teams throughout the Minnehaha Creek watershed. A total of nine meetings were held for each regional team, during which background information on water resources management, lakes, modeling, water quality, and water quantity was provided. Participants provided input on the water resources issues in their areas, issues were prioritized, and management strategies were presented and discussed. The resulting models have been used by a variety parties for a variety of tasks, and are continually updated with new information. For the complete discussion of the stakeholder meetings, see *Volume III: Public Involvement* of the HHPLS.

The public participation meetings for the TMDL were grouped as follows:

1) Carver County lakes: Lake Virginia, Wassermann Lake, Parley Lake
2) Lake Nokomis

Lake Virginia, Wassermann Lake, Parley Lake

A public meeting for the three Carver County Lakes was held on January 25, 2005 at the Victoria City Hall. In addition to project staff, ten stakeholders participated in the meeting. Three of the participants represented public agencies, and seven were homeowners/landowners in the vicinity of the lakes. A second public meeting was held on September 29, 2009. Attendees were primarily stakeholders.

Lake Nokomis

Public meetings for the Lake Nokomis TMDL were held on September 30, 2009 and October 7, 2009. The same presentation was presented for both public meetings. The meeting agenda also included materials on Brownie Lake and Powderhorn Lake, two lakes that were initially part of the TMDL study but were subsequently removed from the study as a result of their meeting water quality standards. Attendees were primarily neighborhood homeowners.

Public Comment

The draft TMDL report was placed on public notice from September 27 to October 27, 2010, for public review and comment.

8. IMPLEMENTATION STRATEGY

A. Implementation Approach

The approach to implementation will include and augment, where needed, actions and strategies in the MCWD Comprehensive Watershed Management Plan (MCWD Plan), approved by the MN Board of Water and Soil Resources and adopted by the MCWD Board of Managers in 2007. The MCWD Plan outlines a framework for water resource management including requirements for local government units. In addition, the MCWD has also adopted rules that regulate activities in the watershed and strive to prevent pollution.

The implementation strategy differs among the lakes based on setting. For the Carver County lakes (Wassermann, Parley, and Virginia), the focus will be on new development and rural BMPs. For Lake Nokomis, the focus will be on redevelopment and retrofits. The strategies identified here are general and will be explored fully in the MCWD Lakes TMDL Implementation Plan, which is in progress.

The implementation plan will incorporate load reduction activities identified by the MCWD in their Capital Improvement Plan (CIP) and by local government units in their local water management plans. When these activities are not enough to meet the TMDL, additional activities will be identified in the implementation plan.

A key component of the implementation plan to be completed will be a process for adaptive management, whereby an ongoing assessment process will be implemented to evaluate the impact (effectiveness) of implementation activities on lake water quality and then tailor future implementation actions. Also, new findings or development of new practices may suggest better implementation strategies which can be factored into the plan.

The Clean Water Legacy Act requires that a TMDL include an overall approximation of the cost to implement a TMDL. It is estimated that it will cost approximately $6 million to $12 million to restore the four impaired lakes in this study ($2.2 - 2.6M for Wassermann, $0.5 – 1.1M for Virginia, $2.7 – 3.8M for Parley and $1.1 – 4.5M for Nokomis). These estimates are considered preliminary and have not all been subject to review by the entities who will be involved in implementation efforts, so they are subject to change.

MCWD Pollutant Reduction Activities

The MCWD Plan outlines numerous projects and programs that will reduce the pollutant loads to the impaired waters. These projects and programs are contained within an adopted CIP. It is anticipated that these projects and programs will be conducted per the implementation schedule and contribute significantly to water quality improvement in the impaired lakes. In addition, the MCWD has adopted rules that require water quality treatment for developments and other land disturbing activities.

Local Government Unit Pollutant Reduction Activities

The MCWD Plan outlines required pollutant load reductions for the majority of member communities based on previous studies in the MCWD. Each member community is required by MN Statute and Rule to comply with the requirements set forth within the MCWD Plan. The majority of the communities included in this study have local water plans approved by the MCWD; the rest are expected to be completed in 2010. After approval, communities begin implementing projects and programs that will achieve the pollutant load reductions as required by the MCWD. The pollutant load reductions for each community are outlined within Appendix C of the MCWD Plan, which includes the general and specific requirements for local government units.

B. Watershed-wide Activities

MCWD Rules

The existing MCWD Rules, adopted in 2005, include a stormwater management rule (Rule N) that requires water quality treatment to achieve District water quality standards. Rule N requires that facilities, including wet detention ponds and other systems using BMPs in addition to or in place of ponding, shall be designed to reduce phosphorus loading at the downgradient site boundary by at least 50 percent on an annual average removal basis.

The complete watershed rules can be found on the Minnehaha Creek Watershed District Website (http://www.minnehahacreek.org/rules.php). The MCWD will continue to permit new development and redevelopments into the foreseeable future. The stormwater management rule (Rule N) is currently under revision and is expected to be adopted in 2010.

Enforcement of P-free fertilizer laws

Minnesota Statute (Chapter 18C) has been updated to include the Phosphorus Lawn Fertilizer Law (SF 1555), which went into effect in 2004 and restricts the use of fertilizer containing phosphorus in non-cropped land. Since this is a recent law, its full effect has not yet been observed. A similar ordinance went into effect in the City of Minneapolis in 2001.

Education Program

A targeted education program could be used to provide information to residents near the lakes on good housekeeping practices such as keeping lawn clippings and leaves off of impervious areas, fertilizer management, the importance of aquatic macrophytes in the health of shallow lakes, and how homeowners can protect the lake. This education program could be coordinated by the MCWD in conjunction with the municipalities.

C. Carver County Lakes

MCWD Pollutant Reduction Activities

The MCWD has identified projects and programs within the Carver County lakes' watersheds for implementation between 2007 and 2018. Each of these projects is identified below. Detailed descriptions of each project can be found in the MCWD Plan, available at http://www.minnehahacreek.org/Draft509Plan.php#download. During implementation plan development, each project will be evaluated and refined based on information contained within the TMDL and through the stakeholder involvement process.

Parley Lake

The MCWD Plan identifies the following projects for the Parley Lake watershed.

- Parley Lake internal load management project
- Parley Lake tributary wetland restoration
- Steiger Lake wet detention pond
- Auburn Lake internal load management project
- Turbid/Lunsten Lake corridor restoration
- Two regional infiltration projects
- Stone Lake internal load management
- Auburn West internal load management project
- Parley Lake aquatic vegetation management

Wassermann Lake

The MCWD Plan identifies the following projects for the Wassermann Lake watershed.

- Wassermann Lake internal load management project
- Wassermann Lake aquatic vegetation management
- Marsh/Wassermann wetland restoration and stream stabilization
- Regional infiltration project

Lake Virginia

The MCWD Plan identifies the need for four regional infiltration projects within the Lake Virginia watershed.

Local Government Unit Pollutant Reduction Activities

The MCWD Plan requires a 25% reduction in pollutant loads from existing agricultural lands, a 15% reduction from existing residential land uses, and a 10% reduction in pollutant loads from all other existing developed land uses. This will require communities to implement water quality practices through the development process, retrofit best management practices into existing land uses, and use additional pollutant prevention practices. Load reductions in addition to the MCWD Plan requirements may be needed. Municipalities can pursue partnering with MCWD on projects, either through expanding projects already in the MCWD's CIP or through new projects to fund via MCWD's low impact development cost-share program.

The following implementation activities can be used to achieve the pollutant load reduction requirements of the TMDL.

Municipal Water Quality Ordinance

Each community could develop a water quality ordinance that would achieve the objectives of the MCWD Plan that requires reduction in pollutant loads from existing conditions.

Agricultural Best Management Practices

The Carver Soil and Water Conservation District (SWCD) currently has numerous programs that address agricultural BMPs. Communities can work with the SWCD by providing additional incentive programs and by identifying known pollutant sources or issues in the watershed. Agricultural BMPs that can be used to reduce phosphorus loadings include precision fertilizer application, manure management, conservation tillage, grassed swales, and buffer strips.

Other

In addition, the following activities should be considered to assist in achieving the TMDL:

- Retrofitting best management practices in urban areas
- Wetland restoration
- Lake shoreline restoration
- Stream restoration and stabilization
- Internal load reduction projects
- Education programs

D. Lake Nokomis

The City of Minneapolis lakes will require a different set of implementation strategies to address the lake impairments, primarily due to the urban nature of these lakes.

MCWD Pollutant Reduction Activities

The MCWD has identified one project in their plan that will address the TMDL for Lake Nokomis: Lake Nokomis Internal Load Management. This project was scheduled to take place in 2007. A detailed description of this project can be found in the MCWD Plan, available at http://www.minnehahacreek.org/Draft509Plan.php#download. No other implementation activities are identified in the MCWD Plan for Lake Nokomis. During implementation plan development, this project will be evaluated and refined based on information contained within the TMDL and through the stakeholder involvement process.

Local Government Unit Pollutant Reduction Activities

The MCWD Plan requires a 25% reduction in pollutant loads from existing agricultural lands, a 15% reduction from existing residential land uses, and a 10% reduction in pollutant loads from all other existing developed land uses. This will require communities to implement water quality practices through the development process, retrofit best management practices into existing land uses, and use additional pollutant prevention practices. Load reductions in addition to the MCWD Plan requirements may be needed. Municipalities can pursue partnering with MCWD on projects, either through expanding projects already in the MCWD's CIP or through new projects to fund via MCWD's low impact development cost-share program.

The following implementation activities can be used to achieve the pollutant load reduction requirements of the TMDL.

Municipal Water Quality Ordinance

The cities with contributing drainage area could develop a water quality ordinance that would in part achieve the objectives of the MCWD Plan that requires reduction in pollutant loads from existing conditions. This ordinance should be applicable to redevelopment sites.

Retrofitting BMPs

Opportunities within the City of Minneapolis should be identified for retrofits including small and large scale water quality treatment practices. Projects similar to efforts in another Minneapolis watershed (Powderhorn Lake) to install 150 rain gardens could be implemented in the Lake Nokomis watershed. In addition, opportunities for water quality treatment should be investigated on all public and private property located in key areas.

E. Construction and Industrial Stormwater

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

Industrial storm water activities are considered in compliance with provisions of the TMDL if they obtain an industrial stormwater general permit or general sand and gravel permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

9. MONITORING

Existing Monitoring Data

Lake Nokomis

Lake Nokomis is monitored as part of the MPRB's annual in-lake monitoring program. The following lists detail some of the parameters that are monitored on an annual basis. Additional parameters are included in the monitoring; these details can be found in the MPRB's annual water resources reports.

Monitored twice per month from May through September; once each in the winter, March/April, and October:

- Dissolved oxygen, temperature, pH, conductivity
- Secchi transparency
- Surface water sampling: TP, SRP (soluble reactive phosphorus), TN, chlorophyll-a

Plankton sampling:

- Phytoplankton: Monitored twice per month from May through September; once each in the winter, March/April, and October
- Zooplankton: Monitored once per month from May through September; once each in March/April, and October

Aquatic macrophyte surveys:

- A macrophyte survey was completed in Lake Nokomis by MPRB in August of 2005.

DNR Fisheries surveys the fisheries in Lake Nokomis every six years. The last fisheries survey was completed in 2007.

Parley Lake

Parley Lake is included in the MCWD's annual monitoring program, consisting of the following monitoring parameters, monitored on a bi-weekly basis from ice-out (usually in April) to fall mixing (usually in October):

- Dissolved oxygen, temperature, pH, specific conductivity at one meter depth increments
- Secchi transparency
- Surface water sampling: TP, SRP, TN, chlorophyll-a
- Thermocline sampling (if stratification exists): TP, SRP
- Bottom water sampling: TP, SRP

The following are included in the MCWD's stream monitoring program:

- Lunsten Lake outlet (CSI01): Continuous (15-minute intervals) flow gauging from May through October.
- Auburn Lake West outlet (CSI09): Weekly flow gauging from April through October
- Water quality sampling at both of the above stream sites:
- DO, temperature, specific conductivity, pH: weekly
- TP and SRP: weekly
- TSS: biweekly
- Chloride and TN: monthly

DNR Fisheries surveys the fisheries in Parley Lake every six years. The last fisheries survey was completed in 2004.

Lake Virginia

Lake Virginia is included in the MCWD's annual monitoring program, consisting of the following monitoring parameters, monitored on a bi-weekly basis from ice-out (usually in April) to fall mixing (usually in October):

- Dissolved oxygen, temperature, pH, specific conductivity at one meter depth increments
- Secchi transparency
- Surface water sampling: TP, SRP (soluble reactive phosphorus), TN, chlorophyll-a
- Thermocline sampling (if stratification exists): TP, SRP
- Bottom water sampling: TP, SRP

The following are included in the MCWD's stream monitoring program:

- Lake Minnewashta Creek outlet from Lake Minnewashta (CSI11): Weekly flow gauging from April through October
- Water quality sampling at the above stream site:
- DO, temperature, specific conductivity, pH: weekly
- TP and SRP: weekly
- TSS: biweekly
- Chloride and TN: monthly

DNR Fisheries surveys the fisheries in Lake Virginia every six years. The last fisheries survey was completed in 2003.

Wassermann Lake

Wassermann Lake is included in the MCWD's annual monitoring program, consisting of the following monitoring parameters, monitored on a bi-weekly basis from ice-out (usually in April) to fall mixing (usually in October):

- Dissolved oxygen, temperature, pH, specific conductivity at one meter depth increments

- Secchi transparency
- Surface water sampling: TP, SRP (soluble reactive phosphorus), TN, chlorophyll-a
- Thermocline sampling (if stratification exists): TP, SRP
- Bottom water sampling: TP, SRP

The following are included in the MCWD's stream monitoring program:

- Six Mile Creek inlet to Wassermann Lake (CSI11): Weekly flow gauging from April through October
- Water quality sampling at the above stream site:
- DO, temperature, specific conductivity, pH: weekly
- TP and SRP: weekly
- TSS: biweekly
- Chloride and TN: monthly

DNR Fisheries surveys the fisheries in Wassermann Lake every six years. The last fisheries survey was completed in 2005.

Monitoring Plan

Lake Nokomis

The water quality sampling (DO, temperature, pH, conductivity, Secchi transparency, and surface water sampling) will be continued on an annual basis by the MPRB. Fisheries surveys will continue every six years by DNR Fisheries.

Parley Lake

The water quality monitoring (DO, temperature, pH, conductivity, Secchi transparency, and water quality sampling) will be continued on an annual basis by the MCWD.

Flow and water quality monitoring at the existing stream monitoring sites should continue in order to be able to individually track the loads originating from upstream of Lunsten Lake, from within Lunsten Lake (internal loading), from the watershed downstream of Lunsten Lake, and from within Parley Lake (internal loading). The smaller tributaries to Parley Lake should also be monitored to determine their contribution and to isolate any sources stemming from channelization of those tributaries.

Fisheries surveys will continue every six years by DNR Fisheries.

Lake Virginia

The water quality monitoring (DO, temperature, pH, conductivity, Secchi transparency, and water quality sampling) will be continued on an annual basis by the MCWD. Fisheries surveys will continue every six years by DNR Fisheries.

Wassermann Lake

The water quality monitoring (DO, temperature, pH, conductivity, Secchi transparency, and water quality sampling) will be continued on an annual basis by the MCWD.

Flow and water quality monitoring at the Six Mile Creek inlet monitoring site should continue in order to be able to determine the portion of the total load to the lake that originates upstream, isolating it from the direct load to the lake and the internal load.

Fisheries surveys will continue every six years by DNR Fisheries.

Other Recommendations

There are additional actions that could contribute to the body of knowledge on these lakes. These actions are recommended as conditions allow and are *not* requirements as part of the monitoring plan for this TMDL study.

Parley Lake, Lake Virginia, and Wassermann Lake

Plankton and aquatic macrophyte data are not currently collected for these lakes, but could be useful in determining lake management practices. Biological monitoring is helpful to track the ecological interactions within the lake, providing information regarding the causes of the existing water quality conditions. If changes are seen in the transparency, TP, or chlorophyll concentrations within the lake, biological sampling (including fish, plankton, and macrophytes) can be used to understand what happened and to identify actions to improve the water quality.

If funding allows, aquatic macrophyte surveys should be completed twice during the growing season. A plant survey during June would capture invasives that tend to dominate from late May to mid June, and a second macrophyte survey in August would provide the opportunity to capture more native plant communities. If only one survey is possible, then it should be completed in June, especially if it is thought that curly-leaf pondweed is present in the lakes (Parley Lake). Plant community data will provide information on whether or not the lake is switching from the turbid state to the clear state.

Lake Nokomis

MPRB conducts plankton sampling and aquatic macrophyte surveys on Lake Nokomis. This biological monitoring is helpful to track the ecological interactions within the lake, providing information regarding the causes of the existing water quality conditions. If changes are seen in the transparency, TP, or chlorophyll concentrations within the lake, biological sampling (including fish, plankton, and macrophytes) can be used to understand what happened and to identify actions to improve the water quality. If it is thought that curly-leaf pondweed is present in the lake, a June survey of aquatic macrophytes would help track the abundance of curly-leaf pondweed. This plant tends to dominate from late May to mid June and can contribute substantially to internal loading.

Three large wetlands/ponds with a total surface area of 9.1 acres were installed near the lake in 2001. They have modeled phosphorus removal rates of 65% and treat a total of 307 acres. It is not known how much phosphorus they are removing; water quality in the lake improved for two years after the wetlands were installed, but has since worsened (Figure 20 through Figure 22). A study designed to investigate the effectiveness of the wetland and ponding treatment system and its impact on Lake Nokomis would clarify the role of the system in the lake's water quality and would provide information for future projects (on other lakes) to help increase the likelihood that other projects will succeed.

10. REFERENCES

Blue Water Commission. 1998. Report and Recommendations for the Management of Lake Nokomis and Lake Hiawatha.

EPA 2002. Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on those WLAs. Memorandum from Robert H. Wayland (Office of Wetlands, Oceans and Watersheds) and James H. Hanlon (Office of Wastewater Management). Environmental Protection Agency Office of Water. November 22, 2002.

EPA 2004. Stormwater Best Management Practice Design Guide: Volume 1 General Considerations. EPA/600/R-04/121 September 2004.

MCWD 2007. Minnehaha Creek Watershed District Comprehensive Water Resources Management Plan.

MCWD 2003. Hydrologic, Hydraulic, and Pollutant Loading Study.

MCWD 1997. Water Resources Management Plan

MCWD 1998. Lakes Nokomis and Hiawatha Diagnostic-Feasibility Study

MPCA 2007. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List. Minnesota Pollution Control Agency, Environmental Outcomes Division.

MPCA 2007. Lake nutrient TMDL protocols and submittal requirements. Minnesota Pollution Control Agency, Lakes TMDL Protocol Team

MPCA 2005. Minnesota Stormwater Manual, Version 2. Minnesota Pollution Control Agency.

MPCA 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Minnesota Pollution Control Agency. Prepared by Barr Engineering.

MPRB 2005. Water Resources Report. Minneapolis Park & Recreation Board Environmental Operations, October 2006.

Schueler, T.R. 1996. Irreducible Pollutant Concentrations Discharged from Stormwater Practices, Technical Note #75 from Watershed Protection Techniques 2(2): 369-372; p 37-40, Center for Watershed Protection.

Walker, W. W., 1999. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. Prepared for Headquarters, U.S. Army Corps of Engineers, Waterways

Experiment Station Report W-96-2. http://wwwalker.net/bathtub/, Walker 1999 (October 30, 2002).

11. APPENDIX A. STORMWATER RUNOFF LOAD ESTIMATES

Approach

The EPA's Simple Method was used to calculate pollutant loads from the watersheds draining to each lake. The surface area of the lake itself was not included in these load estimates; the load that is generated on the surface area of each lake (atmospheric deposition) was estimated independently in the lake model.

These watershed runoff estimates were used as input to the lake response models (using Bathtub, see Appendix B).

Volume

First, the runoff coefficient (Rvu) for each land cover type was derived using the following equation:

$$Rvu = 0.05 + (0.009 * \%Imp)$$

%Imp = Percent of impervious cover, derived from the MLCCS land cover classification (MCWD 2003)

Volume of runoff (in acre-feet/year) was calculated using the following equation:

$$Volume = (P * P_j * Rvu * A) / 12$$

P = Precipitation (inches/year)
P_j = Ratio of storms producing runoff (default = 0.9), used in calibration
Rvu = Runoff coefficient for each land cover type
A = Area of land cover type (acres)

Annual precipitation was derived from the MN Hydrology Guide (annual normal precipitation 1961-1990); annual precipitation was 29.5 inches for the lakes in Minneapolis and 28.8 inches for the Carver County lakes. Volumes for the lakes' watersheds in Carver County were calibrated to the long-term mean annual runoff, estimated from the MN Hydrology Guide (average annual runoff 1961-1990):

- Lakes Wassermann and Parley – 4.2 inches
- Lake Virginia – 4.3 inches

Volumes for the Lake Nokomis watershed were calibrated to runoff data from sites within Minneapolis and St. Paul. Runoff volumes from these sites are more representative of the highly urbanized watersheds in Minneapolis than the larger scale data from the MN Hydrology Guide. Table 38 reflects runoff data presented in the MPRB's annual Water Resources Reports (values are volume-weighted averages of all monitoring sites). An equation describing the relationship between runoff depth and precipitation was used to estimate a long-term average runoff depth of 8.3 inches. The Simple Method approach was calibrated to this depth of runoff over the watershed area.

Table 38. Minneapolis-St. Paul Runoff Monitoring Data

Year	Precip (in)	Runoff Depth (in)
2006	27.57	7.3
2005	33.41	13.2
2004	27.39	6.2
2003	22.73	7.3
2002	38.45	10.5
2001	34.23	7.3
long term[1]	29.5	8.3[2]

[1]Long-term precipitation reported in MN Hydrology Guide
[2]Based on: runoff depth = 0.2759(precip) + 0.1941

A large portion of the Lake Nokomis watershed is semi-landlocked, in that a substantial amount of the runoff from subwatersheds MC-155 through MC-161 (Figure 2) evaporates and/or infiltrates into natural depressions and therefore does not reach Lake Nokomis. Appendix D (*Legion Lake and the Mother-Taft Wetland Complex Inputs to Lake Nokomis Watershed*) describes the approach used to estimate how much volume and TP on an average annual basis reaches Lake Nokomis from these subwatersheds. The following conclusions from Appendix D were incorporated into the Lake Nokomis TMDL allocations:

- 26% of the flow originating in MC-155 through -158 reaches Nokomis
- 48% of the flow originating in MC-159 through -161 reaches Lake Nokomis
- The Mother-Taft wetland complex has a phosphorus removal rate of 59%

TP Loads

Pollutant loads were then calculated using event mean concentrations and summed to determine the total pollutant load:

Pollutant Load = Volume * EMC
(EMC = Event mean concentration for each land cover or land use type)

The EMCs were determined differently for the Carver County lakes and Lake Nokomis. For the Carver County lakes, land use (Metropolitan Council 2000 and 2020 land use) and land cover (MLCCS, as described in MCWD 2003) were both used to assign EMCs (Table 39). Land use refers to the traditional planning approach to describing the way in which land is being used, such as single family residential. Land cover refers to an actual description of the land surface, such as grassland. The land cover classification used in modeling a single family residential area would be "11% to 25% impervious cover with perennial grasses and sparse trees." Land cover mapping allows for more detailed, accurate description of land within the study area. The land cover data specifies whether or not impervious surfaces exist within the mapped area. The following were the guidelines used when assigning an EMC to a mapped area:

- For mapped areas with natural land covers (i.e. do not contain impervious surfaces), the land cover category was used to assign an EMC (Table 39).

- For mapped areas that contain impervious surfaces, the land use category was used to assign an EMC (Table 39).
- Since land use classification is generally on a coarser scale than the land cover data used in the modeling, at times a land use category that inherently should not have impervious surfaces, such as open water, will contain impervious surfaces in its coverage. These land use categories are agriculture, open water, railways, undeveloped, open space, and vacant or undetermined. In these instances, land cover data was used to infer land use on a more detailed scale than that provided by the land use database. For example, the land use category for open water may cover developed areas adjacent to open water. For these land use categories, when the impervious coverage was between 4% and 25%, it was assumed that the land use was single family residential, and the appropriate EMC was used. When the impervious coverage was greater than 25%, it was assumed that the land use was multiple family residential.

These EMCs were derived from a literature search of upper Midwest data and were calibrated to monitoring data within the MCWD for the HHPLS (MCWD 2003). Land use categories in the 2000 generalized land use database (used for existing conditions) differ slightly from land use categories in the 2020 regional planned land use database.

Table 39. TP Event Mean Concentrations (EMCs) Associated with Land Cover and Land Use

Land Cover (from MLCCS database)	Phosphorus (mg/l)
Cropland	0.32
Forest/Shrub/Grassland	0.04
Open Water	0.01
Wetlands	0.01-0.04*
Land Use (categories from 2000 generalized land use database and 2020 regional planned land use database)	**Phosphorus (mg/L)**
Airports	0.28
Commercial	0.28
Extractive	0.28
Farmsteads	0.46
Industrial	0.28
Institutional	0.28
Mixed Use / Multiple Use	0.30
Multi-Family Residential	0.32
Park and Recreation	0.04
Public Industrial	0.28
Public/Semi Public	0.28
Public/Semi Public Not Developed	0.28

Rural Residential	0.46
Roadway / Major Vehicular Rights of Way	0.28
Single Family Residential	0.46
Vacant/Agricultural	0.32

*Varied based on wetland type.

Since monitoring data were available from the Minneapolis and St. Paul monitoring sites (as presented in MPRB's annual Water Resources Reports), these data were used to estimate the TP concentration in runoff from impervious surfaces for the Lake Nokomis watershed (Table 40). These monitoring data are from highly developed areas, with a large percentage of residential land use. The average TP from these data (0.44 mg/l) was within the range of estimates used in the Carver County lake models for runoff from residential land use (0.32 mg/l for multi-family residential and 0.46 mg/l for single family residential).

EMCs for natural areas (pervious surfaces) in the Lake Nokomis watershed were based on land cover (same method as for the Carver County lakes).

Table 40. MPRB Runoff TP Monitoring Data

Year	TP (mg/l)*
2001	0.55
2002	0.34
2003	0.49
2004	0.32
2005	0.36
2006	0.58
Average	*0.44*

*Flow-weighted mean concentration

Since the MPRB's monitoring data are collected from storm sewers, the data already take into account certain types of BMPs in the watershed, such as street sweeping, rain gardens, and the phosphorus-free fertilizer ordinance. They do not account for BMPs installed downstream of the monitoring locations, such as a wetland restoration adjacent to a lake or a shoreline restoration project. Each MS4 community is involved in accounting for all of the BMPs that are in place that were not taken into account using these EMCs. In the TMDL implementation plan, the estimated load reductions attributed to the BMPs will be credited to the load reduction goals, lessening the additional load reduction that will still need to be achieved to meet the loading goals.

Ultimate Conditions

An ultimate conditions watershed runoff volume and load was estimated for the lakes in Carver County, based on an ultimate land use scenario, as defined in MCWD's Comprehensive Water Resources Management Plan (MCWD 2007). This calculation was not completed for Lake Nokomis since it is assumed that its watershed is fully developed.

The following steps were taken to determine the ultimate conditions estimates:

- The Metropolitan Council's 2020 land use data (Regional Planned Land Use - Twin Cities Metropolitan Area) was first used to assign 2020 land use conditions.
- Modeled ultimate development was determined based on the guidelines in MCWD 2007:
- All land use identified as agriculture is converted to developed.
- One half of the other upland area that remains undeveloped in the 2020 land use projections is converted to developed.
- The imperviousness and the TP EMC applied to the land converted to developed is based on the average imperviousness and average TP EMC in the developed land under 2020 land use conditions.
- Volumes and TP loads were then estimated based on the imperviousness and TP EMCs using the Simple Method, as described above.

Results

Table 41 presents the calculated runoff volume and loading estimates by subwatershed, under existing land use conditions. The estimates do not include the surface area of the impaired lakes (they do include the surface area of other surface waters). The subwatersheds in the Parley Lake watershed that show substantial decreases in runoff volume and phosphorus loading from existing to ultimate land use conditions are current agricultural land uses that are located within Carver Park Reserve. The ultimate land use for these areas was considered undeveloped, so that the agricultural land reverts back to the natural landscape.

Table 41. Runoff Volume and Load Estimates, Existing Conditions

Loads are modeled loads that originate in the watershed; values do not take into account attenuation of loads in upstream lakes for Lake Virginia (attenuation by Lake Minnewashta), Lake Wassermann (attenuation by Pierson Lake), or Parley Lake (attenuation by Auburn Lake West).
The subwatersheds in the Parley Lake watershed that show substantial decreases in runoff volume and phosphorus loading from existing to ultimate land use conditions are current agricultural land uses that are located within Carver Park Reserve.

Lake Watershed	Sub-watershed	Area (ac)	Existing Conditions				Ultimate Conditions					
			Volume (ac-ft/yr)	TP (lbs/yr)	TP (µg/L)	TP yield (lbs/ac-yr)	Volume (ac-ft/yr)	TP (lbs/yr)	TP (µg/L)	TP yield (lbs/ac-yr)	Vol % Increase	TP % Increase
Nokomis	MC-155*	435	85	41	178	0.89						
Nokomis	MC-156*	148	31	14	169	0.89						
Nokomis	MC-157*	65	11	5	177	0.79						
Nokomis	MC-158*	549	100	44	160	0.75						
Nokomis	MC-159*	484	138	47	124	0.49						
Nokomis	MC-160*	159	47	19	145	0.59						
Nokomis	MC-161*	85	17	6	137	0.37						
Nokomis	MC-162	203	142	168	435	0.83						
Nokomis	MC-163	113	74	88	434	0.78						
Nokomis	MC-164	165	120	143	439	0.86						
Nokomis	MC-165	24	16	19	434	0.78						
Nokomis	MC-166	55	42	50	439	0.91						
Nokomis	MC-167	148	39	32	304	0.22						
Virginia	LMC-1	76	10	1	46	0.02	10	1	50	0.02	1%	11%
Virginia	LMC-10	1701	818	202	91	0.12	825	212	94	0.12	1%	5%
Virginia	LMC-2	365	50	21	154	0.06	58	25	156	0.07	15%	17%
Virginia	LMC-3	115	22	8	134	0.07	30	13	161	0.11	33%	60%
Virginia	LMC-4	122	17	6	142	0.05	29	17	215	0.14	72%	158%
Virginia	LMC-5	83	11	4	136	0.05	13	7	201	0.09	21%	80%
Virginia	LMC-6	158	46	39	310	0.25	46	39	313	0.25	0%	1%
Virginia	LMC-7	90	42	36	319	0.40	43	39	333	0.43	3%	8%
Virginia	LMC-8	152	23	23	380	0.15	24	25	383	0.16	5%	6%
Virginia	LMC-9	215	65	37	210	0.17	69	46	245	0.21	6%	24%
Virginia	LV-1	215	59	20	126	0.09	74	40	196	0.18	26%	96%
Virginia	LV-2	27	4	4	352	0.13	5	6	416	0.21	32%	56%
Virginia	LV-3	65	18	19	389	0.30	20	22	412	0.34	7%	14%
Virginia	LV-4	173	57	52	337	0.30	58	56	354	0.32	2%	7%
Virginia	LV-5	87	23	26	401	0.29	25	28	413	0.32	6%	9%

Lake Watershed	Sub-watershed	Area (ac)	Existing Conditions				Ultimate Conditions					
			Volume (ac-ft/yr)	TP (lbs/yr)	TP (µg/L)	TP yield (lbs/ac-yr)	Volume (ac-ft/yr)	TP (lbs/yr)	TP (µg/L)	TP yield (lbs/ac-yr)	Vol % Increase	TP % Increase
Virginia	LV-6	236	72	61	312	0.26	74	67	333	0.28	2%	10%
Wassermann/Parley	SMC-01	1201	475	115	89	0.10	569	244	158	0.20	20%	113%
Wassermann/Parley	SMC-02	393	190	22	43	0.06	212	47	81	0.12	11%	111%
Wassermann/Parley	SMC-03	94	13	5	150	0.06	13	5	140	0.05	0%	0%
Wassermann/Parley	SMC-04	238	46	22	171	0.09	69	55	294	0.23	49%	157%
Wassermann	SMC-05**	803	206	109	195	0.14	265	196	272	0.24	29%	79%
Parley	SMC-05**	965	382	114	110	0.12	441	201	167	0.21	16%	76%
Parley	SMC-06	105	26	12	171	0.11	35	29	307	0.28	37%	147%
Parley	SMC-07	265	105	14	51	0.05	122	43	131	0.16	17%	201%
Parley	SMC-08	201	55	58	388	0.29	60	64	395	0.32	9%	11%
Parley	SMC-09	130	60	37	229	0.29	60	40	241	0.30	2%	7%
Parley	SMC-10	58	31	11	129	0.19	33	14	156	0.24	7%	31%
Parley	SMC-11	192	69	44	232	0.23	86	56	239	0.29	26%	29%
Parley	SMC-11a	194	46	10	80	0.05	57	26	165	0.13	25%	159%
Parley	SMC-12	180	56	56	370	0.31	67	75	407	0.41	20%	32%
Parley	SMC-13	71	29	28	356	0.39	30	31	381	0.43	3%	10%
Parley	SMC-14	578	308	97	116	0.17	310	98	117	0.17	1%	1%
Parley	SMC-15	146	38	7	65	0.05	36	3	32	0.02	-7%	-54%
Parley	SMC-16	43	15	7	178	0.17	15	7	178	0.17	0%	0%
Parley	SMC-17	46	21	17	306	0.37	21	17	307	0.37	0%	0%
Parley	SMC-18	791	261	41	57	0.05	282	67	87	0.08	8%	65%
Parley	SMC-19	77	7	5	272	0.06	7	2	127	0.03	0%	-53%
Parley	SMC-20	181	49	11	82	0.06	49	8	60	0.04	0%	-26%
Parley	SMC-21	83	26	2	24	0.02	26	2	24	0.02	0%	0%
Parley	SMC-22	524	313	71	83	0.14	318	79	91	0.15	2%	12%
Parley	SMC-23	85	14	1	38	0.02	14	1	38	0.02	0%	0%
Parley	SMC-24	139	60	2	14	0.02	60	2	13	0.01	0%	-12%
Parley	SMC-25	118	27	6	82	0.05	25	4	51	0.03	-6%	-41%
Parley	SMC-26	71	15	12	308	0.17	19	21	399	0.30	32%	71%
Parley	SMC-27	362	230	38	61	0.11	232	41	65	0.11	1%	7%
Parley	SMC-28	163	73	15	75	0.09	83	32	139	0.19	14%	112%
Parley	SMC-29	329	184	18	36	0.05	186	20	40	0.06	1%	12%
Parley	SMC-30	127	52	4	30	0.03	52	4	30	0.03	0%	0%
Parley	SMC-31	21	5	0	16	0.01	5	0	16	0.01	0%	0%

Lake Watershed	Sub-watershed	Area (ac)	Existing Conditions				Ultimate Conditions					
			Volume (ac-ft/yr)	TP (lbs/yr)	TP (µg/L)	TP yield (lbs/ac-yr)	Volume (ac-ft/yr)	TP (lbs/yr)	TP (µg/L)	TP yield (lbs/ac-yr)	Vol % Increase	TP % Increase
Parley	SMC-31a	126	17	5	102	0.04	17	4	92	0.03	0%	-9%
Parley	SMC-31b	88	12	1	36	0.01	12	1	36	0.01	0%	0%
Parley	SMC-32	533	113	50	162	0.09	189	144	281	0.27	68%	190%
Parley	SMC-33	89	14	13	341	0.15	23	25	397	0.28	61%	87%
Parley	SMC-34	164	32	30	341	0.18	38	42	409	0.26	20%	43%
Parley	SMC-35	121	26	22	309	0.18	35	34	353	0.28	36%	56%
Parley	SMC-36	313	111	15	50	0.05	118	22	68	0.07	6%	45%
Parley	SMC-37	346	143	7	18	0.02	143	7	17	0.02	0%	0%
Parley	SMC-38	127	27	13	177	0.10	48	39	293	0.30	81%	200%
Parley	SMC-39	191	44	11	90	0.06	80	54	246	0.28	81%	396%
Parley	SMC-40	165	33	23	250	0.14	53	46	324	0.28	58%	105%
Parley	SMC-41	584	91	46	188	0.08	168	138	302	0.24	85%	197%
Parley	SMC-42	153	24	11	171	0.07	39	29	274	0.19	58%	154%
Parley	SMC-43	406	110	33	112	0.08	150	82	201	0.20	36%	144%
Parley	SMC-44	136	32	5	62	0.04	33	7	73	0.05	2%	21%
Parley	SMC-45	73	14	1	24	0.01	14	1	22	0.01	0%	0%
Parley	SMC-46	48	12	1	25	0.02	12	1	25	0.02	0%	0%
Parley	SMC-47	567	125	30	88	0.05	151	63	155	0.11	21%	112%

*MC-155 through MC-161: The volumes and loads presented take into account the volume and load attenuation provided by Legion Lake and the Mother-Taft Lake wetland complex, as described in Appendix D.

**SMC-05: The estimate presented as part of the Wassermann watershed is for the Wassermann Lake model; it does not include the surface area of Wassermann Lake itself. The estimate presented as part of the Parley watershed includes the surface area of Wassermann Lake.

12. APPENDIX B. IN-LAKE MODELING

Approach

In-lake models were developed using Bathtub (Version 6.1, 2004), an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers. Models used long-term averages for the input data, due to the lack of detailed annual loading and water balance data for each of the lakes.

The Bathtub models are linked to the Simple Method model in that the watershed runoff loading estimates from the Simple Method model were used as input to the Bathtub models. In the goal conditions model (TMDL), the watershed inputs were calculated using a target runoff TP concentration multiplied by the modeled volume of runoff from the Simple Method.

To estimate the internal/unidentified loading goal, the pollutant reductions still needed (estimated using the Bathtub model) after the watershed load reductions were taken into account were assigned to the internal/unidentified load. The load from atmospheric deposition is assumed to remain constant, with no reductions possible from that source.

Model Inputs

Annual precipitation and evaporation

Annual precipitation and evaporation were derived from the MN Hydrology Guide; annual precipitation was 29.5 inches for the lakes in Minneapolis and 28.8 inches for the Carver County lakes. Annual evaporation was 36.1 inches for the lakes in Minneapolis and 36.2 inches for the Carver County lakes.

Atmospheric deposition

Atmospheric deposition (both wet and dry) on to the surface area of each lake was assumed to be 30 mg/m^2-yr, the default rate in Bathtub. This rate is within the range reported in the report, “Detailed Assessment of Phosphorus Sources to Minnesota Watersheds” (MPCA 2004).

Watershed runoff volume and load

The watershed load was based on the watershed runoff estimate derived using the Simple Method (Appendix A). In cases where there was a major lake upstream of the lake in question (Parley, Virginia, Wassermann), the Simple Method was used only to estimate the watershed load between the upstream lake and the lake in question. The load passing through the upstream lake was derived from in-lake monitoring concentration data of the upstream lake, multiplied by the Simple Method’s estimated volume.

Internal loading

An average rate of internal loading is implicit in Bathtub. The model is based on empirical data, and these data sets did not contain direct estimates of internal loading, but rather describe relationships between external loading and the in-lake water quality. In cases where the observed in-lake TP concentration was greater than the initial modeled concentration, and where internal loading is suspected to be higher than average in that lake, an additional internal load was added. This represents the internal load that is *in addition* to the average expected amount of internal load. Because of this approach, the internal load estimate, and the internal load goal, represent only the amount of internal load above the load implicitly assumed in the model. Due to the modeling approach and available data, the internal load estimate for each lake cannot be separated from the load due to unidentified sources. The internal load for each lake is presented as combined with unidentified loads.

Model Calibration

The models were calibrated to 10-year growing season (June through September) means of the modeled parameters (TP, chlorophyll-*a*, and Secchi depth). Data from 1998 through 2007 (where available) were used.

For TP calibration, the Canfield and Bachmann lakes model (option 8) was used for the Carver County lakes models. This model is often the best predictor of in-lake TP concentrations in this region. However, the model overpredicted in-lake TP concentrations in Lake Nokomis; the Canfield and Bachmann reservoir model better predicted in-lake TP concentrations and was used for Lake Nokomis.

If the predicted in-lake TP concentration was lower than the observed, and if internal loading was suspected to be relatively high in that lake, an additional internal load was added to calibrate the TP model.

After the TP model was calibrated, the most appropriate chlorophyll-*a* model was selected, based on which model best predicted the observed concentration (models used are presented in Table 42). The default model was used in all but one of the chlorophyll models. Where there were enough monitoring data to calculate the 1/Secchi vs. chlorophyll-*a* slope, this value was used in model calibration. Lastly, the Secchi depth model was chosen in a similar fashion. The default Secchi model was used in all models (Table 42).

The calibration coefficients for chlorophyll-*a* and Secchi depth were adjusted to calibrate the chlorophyll-*a* concentration to the nearest whole number and the Secchi depth to the nearest tenth. This was done to facilitate the comparison of existing TP loads to TP loads associated with the various goal scenarios. For example, if the observed chlorophyll-*a* concentration was 23 μg/L, and the modeled chlorophyll-*a* concentration was 34 μg/L, although the concentrations appear to be far off, the model still may be calibrated due to high coefficients of variation. But, the TP load reduction needed to achieve a goal of 20 μg/L chlorophyll would appear artificially high if the starting point were 34 μg/L as opposed to 23 μg/L. All of the models (except in one case, noted below under the Parley Lake chlorophyll model calibration) were considered adequately calibrated (based on T1 values in Bathtub) before the calibration coefficients were adjusted. In other words, the models performed well without the need for calibration.

After the model was calibrated to all parameters (TP, chlorophyll-*a*, and Secchi transparency), the water quality goal of each lake was used as an endpoint. For the goal scenario, the watershed load was set at a TP concentration of 150 μg/L, and the internal loading rate was adjusted downward until the model predicted that the in-lake water quality goal would be reached. In some of the watersheds, a phosphorus concentration slightly higher than 150 µg/L was sufficient for the lake to meet its in-lake water quality goals; therefore the target phosphorus concentration was adjusted accordingly.

Lake Model Inputs and Calibrations

The lake modeling inputs are provided in Table 42. Additional detail on some of the inputs is described below.

Lake Nokomis

No additional detail needed.

Parley Lake

The overall watershed TP concentration of 174 µg/L was derived by the following:

- The volume and load from Auburn Lake West was determined by the modeled (Simple Method) volume to Auburn Lake West and the observed in-lake TP concentration in the lake (33 µg/L).
- The watershed TP load to Parley Lake that originates downstream of Auburn Lake West was determined using the Simple Method.

The Parley Lake chlorophyll model was the only model for which the calibration, before the calibration factors were adjusted, did not fall within the expected range due to variability within the data set and model error. The T1 factor for this model was 2.7; this is supposed to be less than 2.0 for a calibrated model. The chlorophyll concentration in Parley Lake is much higher than the Secchi depth would suggest (as judged by the TSI values), and the adjusted calibration factor accounts for this.

Lake Virginia

The overall watershed TP concentration of 63 µg/L was derived by the following:

- The volume and load from the Lake Minnewashta outlet was determined by the modeled (Simple Method) volume to Lake Minnewashta and the observed in-lake TP concentration in Lake Minnewashta
- The watershed TP load to Lake Virginia that originates downstream of Lake Minnewashta was determined using the Simple Method

Wassermann Lake

The overall watershed TP concentration of 81 µg/L was derived by the following:

- The volume and load from the Pierson Lake outlet was determined by the modeled (Simple Method) volume to Pierson Lake and the observed in-lake TP concentration in Pierson Lake (36 µg/L).
- The watershed TP load to Wassermann Lake that originates downstream of Pierson Lake was determined using the Simple Method.

Table 42. Bathtub Input Data

Lake	Precipitation (m)	Evaporation (m)	Lake Area (km^2)	Mean Depth (m)	Drainage Area (km^2)	Flow (hm^3)		Watershed TP Conc (µg/L)	
						Existing	Goal	Existing	Goal
Nokomis	0.75	0.92	0.808	4.3	10.66	1.06	1.06	288	142 / 198*
Parley	0.73	0.92	1.04	2.13	50.23	5.25	5.31	53**	50**
Virginia	0.73	0.92	0.451	3.35	15.71	1.65	1.66	63**	44**
Wassermann	0.73	0.92	0.66	3.05	11.05	1.15	1.15	81**	70**

Lake	TP Model	TP model coefficient	Internal Loading Rate for Model Calibration (mg/m^2-day)		Chl-a Model	Secchi/Chl-*a* Slope (m^2/mg)	Chl-a Model Coefficient	Secchi Model	Secchi Depth Model Coefficient
			Existing	Goal					
Nokomis	Canfield-Bachmann reservoir	1	0.63	0.16 / 0.345*	P, light, T (default)	0.017	1.05	vs. Chl-a & turbidity (default)	0.9
Parley	Canfield-Bachmann lakes	1	1.9	0.74	P, light, T (default)	0.0142	1.71	vs. Chl-a & turbidity (default)	1.2
Virginia	Canfield-Bachmann lakes	1	0.34	0.32	P, light, T (default)	0.0145	1.1	vs. Chl-a & turbidity (default)	0.95
Wassermann	Canfield-Bachmann lakes	1	0.95	0.12	P, light, T (default)	0.0174	1	vs. Chl-a & turbidity (default)	0.9

*Goal scenario input for Lake Nokomis are presented for both the state eutrophication standard and the proposed site-specific standard.
**Takes into account attenuation of watershed loads by upstream lakes. (Loads in Bathtub are input with values for volume and concentration; loads are calculated in the model from the volume and concentration input.)

Lake Model Output

Table 43 and Table 44 show the Bathtub modeling loading summary and the existing and goal scenarios of in-lake water quality. For the water quality standard to be met overall, the TP standard must be met and either the chlorophyll or the Secchi depth standard must also be met (see "Modeled In-Lake WQ under TMDL Scenario" columns in Table 44). For Nokomis, Parley, and Virginia, both the TP and the Secchi depth standard are expected to be met. For Wassermann Lake, the model scenario does not indicate that the chlorophyll or Secchi depth standards will be met. However, it is expected that, as phosphorus loads to the lake decrease, the lake will respond biologically and more of the phosphorus will be taken up by macrophytes instead of algae, increasing the water clarity and meeting the Secchi depth standard. This is not reflected in the Bathtub model since it cannot simulate biological interactions.

Table 43. Bathtub Modeling Phosphorus Loading Summary

Loads vary slightly from the WLAs and LAs provided in Section 4 due to rounding differences.

Lake	Existing Phosphorus Load (lbs/yr)				TMDL Phosphorus Load (lbs/yr)			
	Watershed Load	Additional Internal Load	Atmospheric Deposition	Total	Watershed Load	Additional Internal Load	Atmospheric Deposition	Total
Nokomis*	673	411	54	1,138	332 / 463	104 / 225	54 / 54	490 / 742
Parley	613	1591	69	2,273	585	620	69	1,274
Virginia	229	123	30	382	161	117	30	308
Wassermann	204	505	44	753	178	64	44	286

*Both TMDL scenarios are shown for Lake Nokomis: the state standard and the proposed site-specific standard

Table 44. Existing and Goal Scenario Lake Water Quality

Lake	Existing In-Lake WQ			Modeled In-Lake WQ under TMDL Scenario		
	TP (µg/L)	Chl (µg/L)	Secchi Depth (m)	TP (µg/L)	Chl (µg/L)	Secchi Depth (m)
Nokomis*	61	29	1.3	40 / 50	21 / 25	1.6 / 1.4
Parley	93	105	0.8	60	69	1.1
Virginia	47	26	1.3	40	22	1.4
Wassermann	77	32	0.8	40	18	1.0

*Both TMDL scenarios are shown for Lake Nokomis: the state standard and the proposed site-specific standard

13. APPENDIX C. SITE-SPECIFIC STANDARDS REQUEST

The City of Minneapolis (City), the Minneapolis Park & Recreation Board (MPRB), and the Minnehaha Creek Watershed District (MCWD) are requesting the consideration of site-specific total phosphorus standards for Lake Nokomis. A request was made to the MPCA on August 21, 2009; the MPCA considered the request and the following adapted request will be submitted to the EPA.

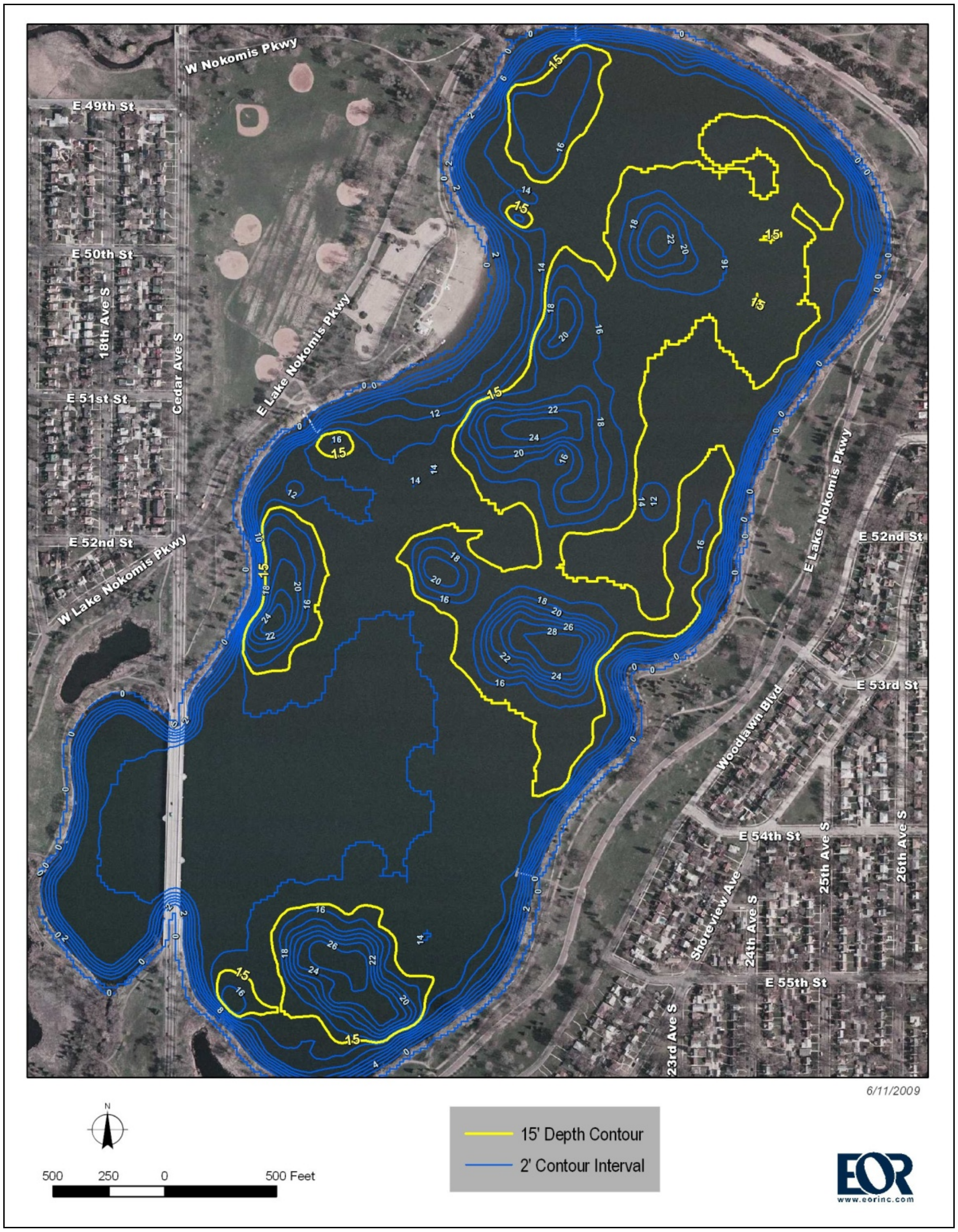


Figure 52. Lake Nokomis Bathymetry, May 2009

Lake Nokomis functions largely as a shallow polymictic lake that mixes many times during the growing season. Mixing potential is increased when higher than normal wind speeds occur along the north-south fetch of the lake. This has the effect of destabilizing the water column and mixing hypolimnetic phosphorus into the surface water where it can be taken up by algae.

Lake Nokomis has a surface area of 200 acres. Its mean depth is approximately 14 feet and its maximum depth is 33 feet. Since the MN state standards are based on whether or not the lake is deep or shallow, the lake's surface area at a depth of 15 feet was examined. (A shallow lake, by state definition, is one that has at least 80% of its area at a depth of 15 feet or less, or has a maximum depth of less than 15 feet.)

Approximately 66% of the lake is littoral (having a depth of 15 feet or less). A large part of the lake that is deeper than 15 feet is only minimally deeper; 84% of the lake has a depth of 16 feet or less (Figure 52). 80% of the lake is shallower than approximately 15.8 feet.

The proposed site-specific standard is a hybrid of the existing standards and the shallow lake standards (Table 45), as Lake Nokomis displays characteristics of both a shallow and a deeper lake. Also, it is acknowledged that a great deal of restoration has been implemented. The primary consideration in proposing a site-specific standard is that the lake must continue to meet its beneficial use (aquatic recreation). Given the heavy recreational use, limiting algal blooms is key and the focus is on the chlorophyll standard. It is the opinion of the MPCA's Water Quality Standards Unit that achieving the chlorophyll standard for shallow lakes (20 µg/l) will meet the beneficial use.

The available dataset suggests that achieving the 20 µg/l chlorophyll standard will result in a TP concentration of approximately 50 µg/l, which is being proposed for the TP site-specific standard. It is expected that additional monitoring over time will help to confirm this relationship. The 10-year Secchi depth average is 1.3 meters, which is just below the Secchi depth standard for deep lakes of 1.4 meters. Since a decrease in chlorophyll concentrations should improve clarity as well, it is proposed that the Secchi depth standard for Lake Nokomis remain at 1.4 meters.

Table 45. Lake Nokomis water quality data summary and requested site-specific standards

Parameter	1998 – 2007 average*	State Standard, Deep Lake	State Standard, Shallow Lake	Proposed Site-Specific Standard
Total Phosphorus (µg/l)	61	40	60	50
Chlorophyll-*a* (µg/l)	29	14	20	20
Secchi Depth (m)	1.3	1.4	1.0	1.4

*Average of annual GSM (June – September)

14. APPENDIX D. LEGION LAKE AND THE MOTHER-TAFT WETLAND COMPLEX INPUTS TO LAKE NOKOMIS WATERSHED

Legion Lake is in the City of Richfield and only intermittently outflows to downstream water bodies. The Mother-Taft wetland complex is located predominantly within Fort Snelling and also intermittently outflows. There are few monitoring data to verify the actual discharges from Legion Lake and the Mother-Taft wetland complex. Observations and anecdotal evidence suggest that Legion Lake contributes to Lake Nokomis only occasionally throughout the year. Without a monitoring history in the area of interest, the model described here represents the most complete picture of this hydrologic system.

Refer to Figure 2 (page 8) for references to subwatersheds and water body locations.

XP-SWMM Model Background and Update

The weir at the outlet of the Taft/Mother Lake wetland complex (in MC-161) was added to the MCWD XP-SWMM model per the plans received from the City of Minneapolis. The starting water elevation in all storage areas was set at the outlet elevation (Table 46). A continuous simulation using the XP-SWMM model previously developed by MCWD was then completed.

In that model, Legion Lake was assigned an infiltration rate that varies between 0 in/hr at 1.5 feet below the outlet to 0.1 in/hr at 3 feet above the outlet. Evidence of infiltration occurring in Legion Lake is noted in the 2003 MCWD Hydrologic, Hydraulic, and Pollutant Loading Study. The rate of infiltration applied to the lake in the original modeling for that study was left as is. Recent monitoring conducted in Legion Lake indicates that infiltration rates in the modeling may be overestimated; however, there is not enough monitoring over a range of dates and hydrologic conditions to warrant updating the model to reflect this monitoring. The infiltration in Legion Lake may be refined in the future based on a larger set of monitoring data.

Table 46. Outlet Elevations

Location	Elevation (ft)
Legion Lake	819.0
Taft/Mother	815.5
Wetland Complex Weir	815.43
Lake Nokomis Weir	815.1

XP-SWMM Model Results

The year 1999 produced 31 inches of rain making it a fairly average year. Items A through H in Table 48 are direct input and output from the model and provide results generated by this modeling exercise. Items I through L show the calculations used to estimate the volume of runoff from Legion Lake that eventually reaches Nokomis. Figure 53 and Figure 54 are presented for additional reference on the flow timing and magnitude at two significant locations.

The XP-SWMM model predicts that 7.5 inches of runoff is generated over the year in watersheds MC-155 through 158, and that 26% of that flow reaches Nokomis (Item K in Table 48). This includes evaporation (Table 47) in the Taft-Mother wetland complex, and infiltration and evaporation in Legion Lake. Of the runoff generated (8.1 inches) within subwatersheds MC-159 through 161, 48% of it reaches Lake Nokomis (Item J in Table 48).

After a small snowmelt occurring in April, Legion Lake contributes five other times during the year. In comparison, the outlet of the Taft wetland complex regularly contributed from the first snowmelt until the end of June.

Table 47. Monthly Evaporation

Month	Evaporation (in)
January	0.32
February	0.35
March	0.85
April	1.8
May	2.95
June	3.95
July	6.9
August	5.9
September	5.3
October	2.95
November	1.3
December	0.38

Table 48. Selected Results from 1999 XP-SWMM Continuous Simulation

Item	1999 XP-SWMM Results	
A	Total Rainfall (in)	31
B	Total Runoff to Legion Lake (in)	7.5
C	Total Richfield Area from model (watersheds 155-158) (ac)	1,196
D	Total Runoff from MC-159 through 161 (in)	8.1
E	Total Runoff to Legion (ac-ft)	752
F	Total Flow from Legion (ac-ft)	**193**
G	Total Runoff from MC-159 through 161 (ac-ft)	491
H	Total Flow from Taft to Nokomis (ac-ft)	331
I	Volume to Taft (ac-ft) [F+G]	684
J	Proportion of flow reaching Nokomis from Taft (%) [H / I]	**48%**
K	Proportion of flow reaching Nokomis from Legion (%) [F / E]	**26%**

Mother/Taft Wetland Treatment

In addition to flow-volume reductions associated with Legion Lake and the Taft-Mother wetland, there are also pollutant reductions associated with settling in these basins. A PondNET model was created to calculate the phosphorus removal that can be expected in this system. All areas and storage volumes were calculated using the values from the XP-SWMM model and an average depth of each pond was assumed to be 2 feet. It was found that a total reduction of 59% of the load is achieved in the treatment system.

Application to TMDL

The following conclusions will be incorporated into the TMDL allocations for Lake Nokomis:

- 26% of the flow originating in MC-155 through -158 reaches Nokomis
- 48% of the flow originating in MC-159 through -161 reaches Lake Nokomis
- The Mother-Taft wetland complex has a phosphorus removal rate of 59%.

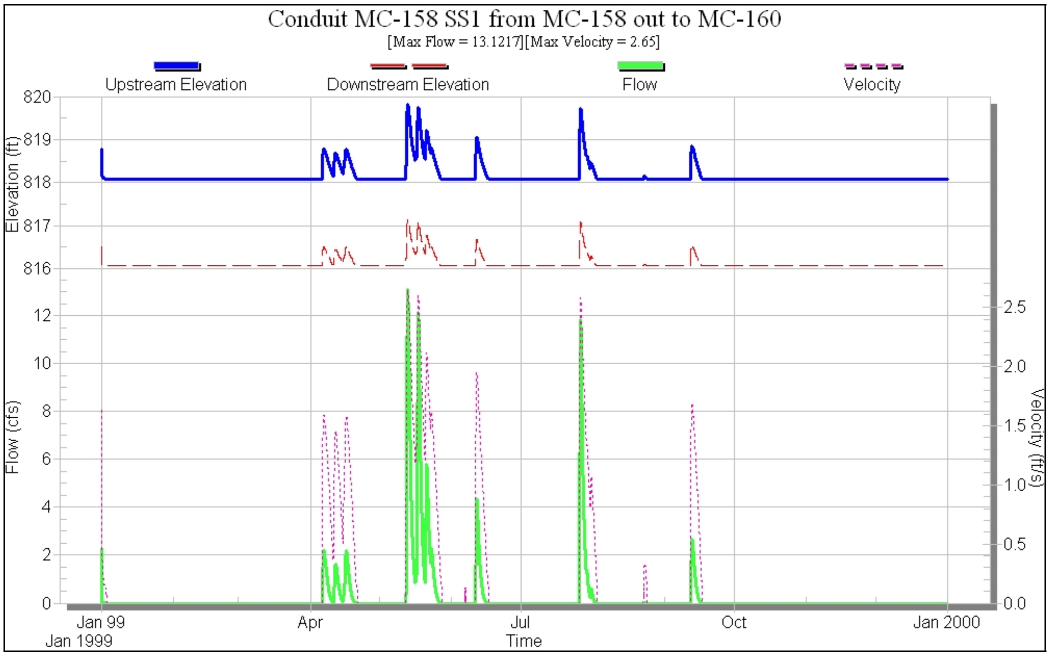


Figure 53. Legion Lake Outflow Hydrograph to Taft – 1999

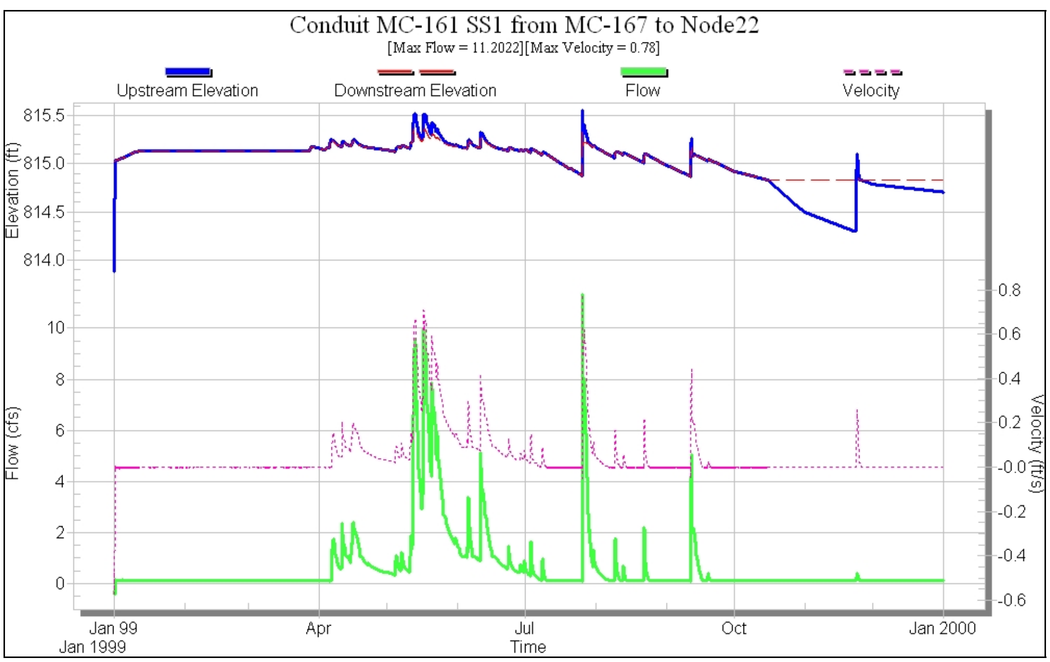


Figure 54. Taft Wetland Complex Outlet to Nokomis – 1999