Rice Creek Watershed District Southwest Urban Lakes

Total Maximum Daily Load Study

Image: Island Lake

Minnesota Pollution Control Agency

EOR water ecology community

wq-iw11-19e

Note Regarding Legislative Charge

The science, analysis and strategy development described in this report began before accountability provisions were added to the Clean Water Legacy Act in 2013 (MS114D); thus, this report does not address all of those provisions. When this watershed is revisited (according to the 10-year cycle), the information will be updated according to the statutorily required elements of a Watershed Restoration and Protection Strategy Report.

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<tr><td>Wasteload Allocation</td><td>Categorical wasteload allocations were assigned to construction, industrial, and municipal MS4 stormwater. An individual wasteload allocation was assigned to MnDOT stormwater and to one wastewater discharger (New Brighton Water Treatment Plant)
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<tr><td>Load Allocation</td><td>The load allocation is based on the following sources of phosphorus not requiring NPDES permit coverage, as applicable to each lake:

Loading from upstream lakes
Atmospheric deposition
Internal loading

<table>
<tr><th>Impaired Lake</th><th>Total TP LA (kg/day)</th></tr>
<tr><td>Island Lake, North Basin</td><td>0.025</td></tr>
<tr><td>Island Lake, South Basin</td><td>0.043</td></tr>
<tr><td>Little Lake Johanna</td><td>0.006</td></tr>
<tr><td>Long Lake, South Basin</td><td>1.598</td></tr>
<tr><td>Moore Lake, East</td><td>0.010</td></tr>
<tr><td>Pike Lake</td><td>0.122</td></tr>
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<tr><td>Margin of Safety</td><td>An explicit 5% margin of safety was accounted for in the TMDL for each lake. This MOS is sufficient to account for uncertainties in predicting loads to the lakes and predicting how lakes respond to changes in phosphorus loading.
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<tr><th>Impaired Lake</th><th>Margin of Safety (kg/day)</th></tr>
<tr><td>Island Lake, North Basin</td><td>0.004</td></tr>
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<tr><td>Little Lake Johanna</td><td>0.033</td></tr>
<tr><td>Long Lake, South Basin</td><td>0.110</td></tr>
<tr><td>Moore Lake, East</td><td>0.015</td></tr>
<tr><td>Pike Lake</td><td>0.064</td></tr>
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USEPA/MPCA Required Elements	Summary		TMDL Section (Page #)
	Lake Valentine	0.044	
Seasonal Variation	Critical conditions in these lakes occur in the summer, when TP concentrations peak and clarity is worst. The water quality standards are based on growing season (June – September) averages. The load reductions are designed so that the lakes will meet water quality standards over the course of the growing season.		35
Reasonable Assurance	See Section 5 REASONABLE ASSURANCES		46
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EXECUTIVE SUMMARY

The Clean Water Act (1972) requires that each State develop a plan to identify and restore any waterbody that is deemed impaired by state regulations. A Total Maximum Daily Load Study (TMDL) is required by the Environmental Protection Agency (EPA) as a result of the federal Clean Water Act. A TMDL identifies the pollutant that is causing the impairment and how much of that pollutant can enter the waterbody and still meet water quality standards.

This TMDL study includes seven lakes located in the southwest region of the Rice Creek Watershed District within the Mississippi River – Twin Cities Major Watershed (HUC 07010206) that are on the 2012 EPA's 303(d) list of impaired waters due to excess nutrients.

Information from multiple sources was used to evaluate the ecological health of each waterbody:

- All available in-lake water quality data over the past ten years
- Sediment phosphorus concentrations
- Fisheries surveys
- Plant surveys
- Stakeholder input

The following phosphorus sources were evaluated for each lake: watershed runoff, loading from upstream lakes, atmospheric deposition, and internal loading. An inventory of phosphorus sources was then used to develop a lake response model for each lake and these models were used to determine the phosphorus reductions needed for the lakes to meet water quality standards. A summary of the TMDLs and necessary reductions is below.

Impaired Lake	Loading Capacity (TMDL) (kg/day)	Wasteload Allocation (kg/day)	Load Allocation (kg/day)	Margin of Safety (kg/day)	Total Reduction Needed (%)
Island Lake, North Basin	0.073	0.044	0.025	0.004	48%
Island Lake, South Basin	0.078	0.031	0.043	0.004	46%
Little Lake Johanna	0.653	0.614	0.006	0.033	55%
Long Lake, South Basin	2.201	0.493	1.598	0.110	36%
Moore Lake, East	0.299	0.274	0.010	0.015	25%
Pike Lake	1.288	1.102	0.122	0.064	47%
Lake Valentine	0.871	0.702	0.125	0.044	29%

1. PROJECT OVERVIEW

1.1. Purpose

This Total Maximum Daily Load (TMDL) study addresses aquatic recreation use impairments due to excess nutrients (phosphorus) in seven lakes located in the southwest portion of the Rice Creek Watershed District (RCWD) within the Mississippi River – Twin Cities Watershed (07010206) in east-central Minnesota (Figure 1). The goal of this TMDL is to provide wasteload allocations (WLAs) and load allocations (LAs) and to quantify the pollutant reductions needed to meet the state water quality standards. These TMDLs for nutrients are being established in accordance with section 303(d) of the Clean Water Act, because the State of Minnesota has determined that these lakes exceed the state established standards for nutrients.

This TMDL is based largely on a previous study completed in 2009 funded by RCWD that assessed the water quality of and pollutant loading to 24 lakes in the southwest portion of the RCWD, in relation to state standards. Throughout this TMDL, there will be references to methods and analyses from the *2009 Southwest Urban Lakes Study*, which can be accessed online from the Reports & Plans section of the Rice Creek Watershed District website (www.ricecreek.org).

1.2. Impaired Waters

This TMDL study includes seven lakes located in the southwest region of the Rice Creek Watershed District within the Mississippi River – Twin Cities Major Watershed (HUC 07010206) that are on the 2012 EPA's 303(d) list of impaired waters due to excess nutrients (Table 1; Figure 1). Long Lake is on the 2012 list of impaired waters as one basin but was analyzed as two basins in the *2009 Southwest Urban Lakes Study*. The north basin is clearly distinct and separate from the south basin and is in line with Rice Creek and thus has a very short hydraulic residence time. As such it should not be expected to achieve lake nutrients standards (40 µg/L TP). An analysis conducted as part of the TMDL project confirms this. Based on a request from RCWD to the MPCA, the two basins are being considered separately for the purposes of assessment for the draft 2014 EPA's 303(d) list of impaired waters. A TMDL was included in this study for the south basin only, which will remain on the impaired list. The north basin is not expected to be on the 2014 impaired waters list, but may very well be assessed in the future as part of Rice Creek based on stream nutrient standards. Thus, it is important that local implementation efforts continue, regardless of the north basin not being addressed in this study.

Table 1. Southwest Rice Creek Watershed Impaired Lakes

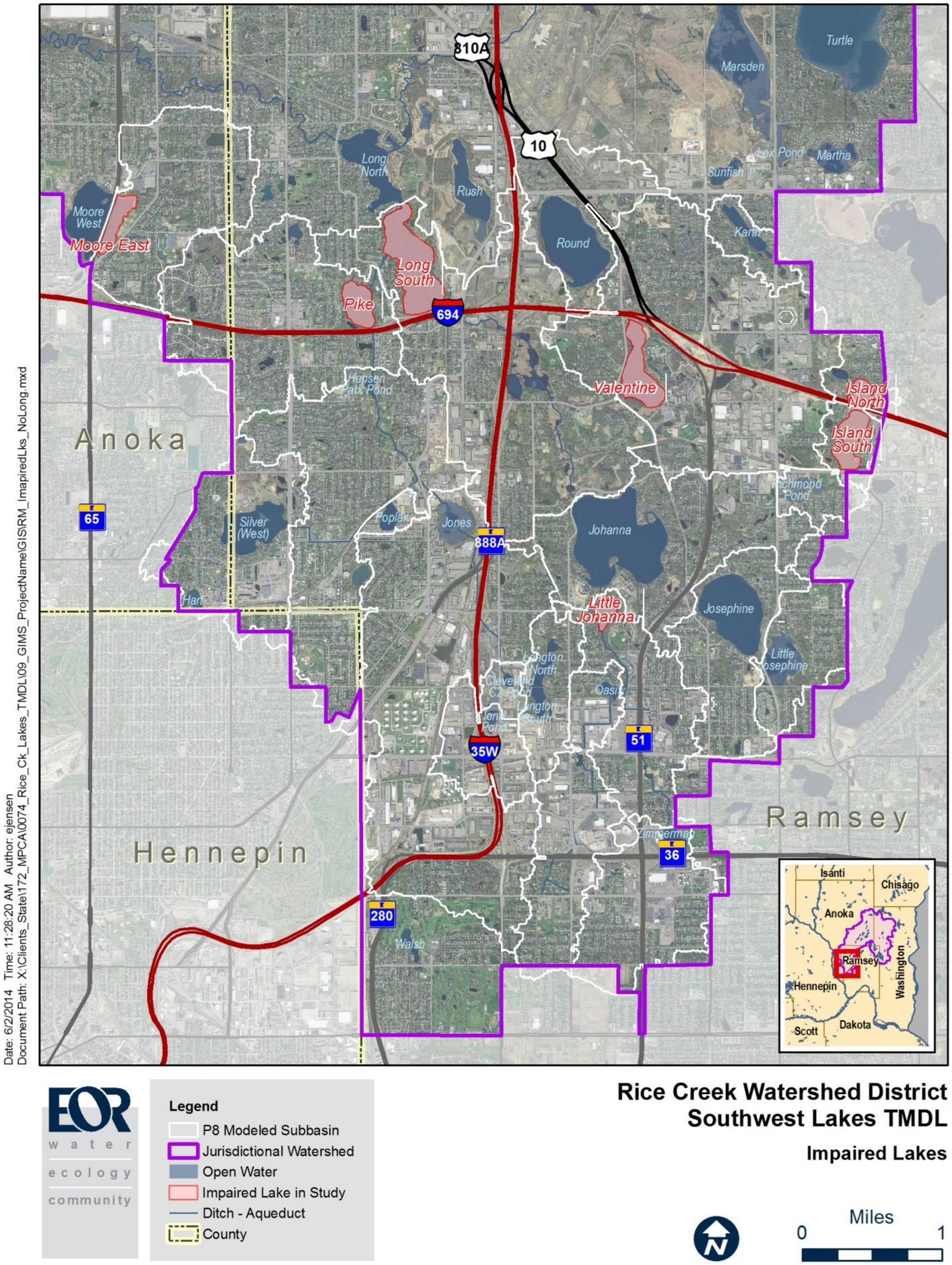
Lake Name	Lake ID	Year Listed	Target Start/ Completion
Island Lake, North Basin	**62-0075-02**	2002	2012/2015
Island Lake, South Basin	**62-0075-01**	2002	2012/2015
Little Lake Johanna	**62-0058-00**	2004	2012/2015
Long Lake, South Basin	**62-0067-00**	2002	2012/2017
Moore Lake, East	**02-0075-01**	2002	2012/2015
Pike Lake	**62-0069-00**	2002	2012/2015
Lake Valentine	**62-0071-00**	2002	2012/2015

A number of other TMDLS have been conducted in the Rice Creek Watershed. These include the Hardwood Creek biota and dissolved oxygen TMDL and nutrient TMDLs for Peltier Lake, Centerville Lake, the Lino Lakes chain of lakes, Bald Eagle Lake, Golden Lake, and Silver Lake. Of these waterbodies only Silver Lake has a hydrologic connection to this study. Specifically, its watershed is upstream of Pike Lake and, thus, is taken into account in the Pike Lake TMDL calculations.

1.3. Priority Ranking

MPCA's projected schedule for TMDL completions (Table 1), as indicated on the 2012 EPA 303(d) list of impaired waters, implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

Figure 1. Impaired lakes in the Southwest portion of the Rice Creek Watershed District addressed by this TMDL



2. APPLICABLE WATER QUALITY STANDARDS

2.1. Designated Use

Minnesota Rule Chapter 7050 designates uses for waters of the state. The impaired lakes in this TMDL are designated as Class 2B waters for aquatic recreation use (Minnesota Rule 7050.0140, subp 3): "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."

2.2. Water Quality Standards

Total phosphorus is often the limiting factor controlling primary production in freshwater lakes: as in-lake phosphorus concentrations increase, algal growth increases resulting in higher chlorophyll-a concentrations and lower water transparency. In addition to meeting phosphorus limits, chlorophyll-a and Secchi transparency depth standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. Rule 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2005). Clear relationships were established between the causal factor total phosphorus and the response variables chlorophyll-a and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the chlorophyll-a and Secchi standards will likewise be met. The impaired lakes are located within the North Central Hardwood Forests (NCHF) Ecoregion. The applicable water quality standards are listed in Table 2.

In the NCHF Ecoregion, a separate water quality standard was developed for shallow lakes which tend to have poorer water quality than deeper lakes in this ecoregion. According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 feet, or if the littoral zone (area where depth is less than 15 feet) covers at least 80% of the lake's surface area. Island Lake North, Island Lake South, Pike Lake, and Lake Valentine are shallow according to this definition.

To be listed as impaired (Minnesota Rule 7050.0150 subp 5), the summer growing season (June-September) monitoring data must show that the standards for both total phosphorus (the causal factor) and either chlorophyll-a or Secchi transparency (the response variables) 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 it 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 Determination of Impairment: 303(b) Report and 303(d) List* (MPCA 2012).

Table 2. Lake Eutrophication Standards, North Central Hardwood Forests Ecoregion

Lake Type	TP (ppb)	Chl-a (ppb)	Secchi (m)
North Central Hardwood Forests – General Including: Little Johanna, Long South, Moore East	< 40	< 14	> 1.4
North Central Hardwood Forests – Shallow Lakes Including: Island North, Island South, Pike, Valentine	< 60	< 20	> 1.0

3. WATERSHED AND WATERBODY CHARACTERISTICS

The impaired lakes included in this study are located within the southwest portion of the Rice Creek Watershed District (RCWD) within the Mississippi River – Twin Cities Watershed (HUC 07010206), a tributary to the Mississippi River in east-central Minnesota (Figure 1).

3.1. Lakes

The physical characteristics of the impaired lakes are listed in Table 3.

Table 3. Impaired lake physical characteristics

Lake	Surface area (ac)	Littoral area (% total area)	Maximum depth (feet)	Mean depth (m)	Fetch (km)	Watershed area (incl. lake area) (ac)	Watershed area : Surface area
Island North	18.6	100%	9	0.86	0.44	256	14: 1
Island South	43.6	100%	9	1.43	0.71	128	3: 1
Little Lake Johanna	17.3	67%	28	3.04	0.41	1,703	98: 1
Long Lake, South Basin	118.9	44%	24	3.44	1.24	12,986	109: 1
Moore East	29.5	79%	22	1.65	0.82	638	22: 1
Pike	37.2	91%	16	1.87	0.59	5,215	141: 1
Valentine	63.9	100%	14	1.05	1.05	2,540	40: 1

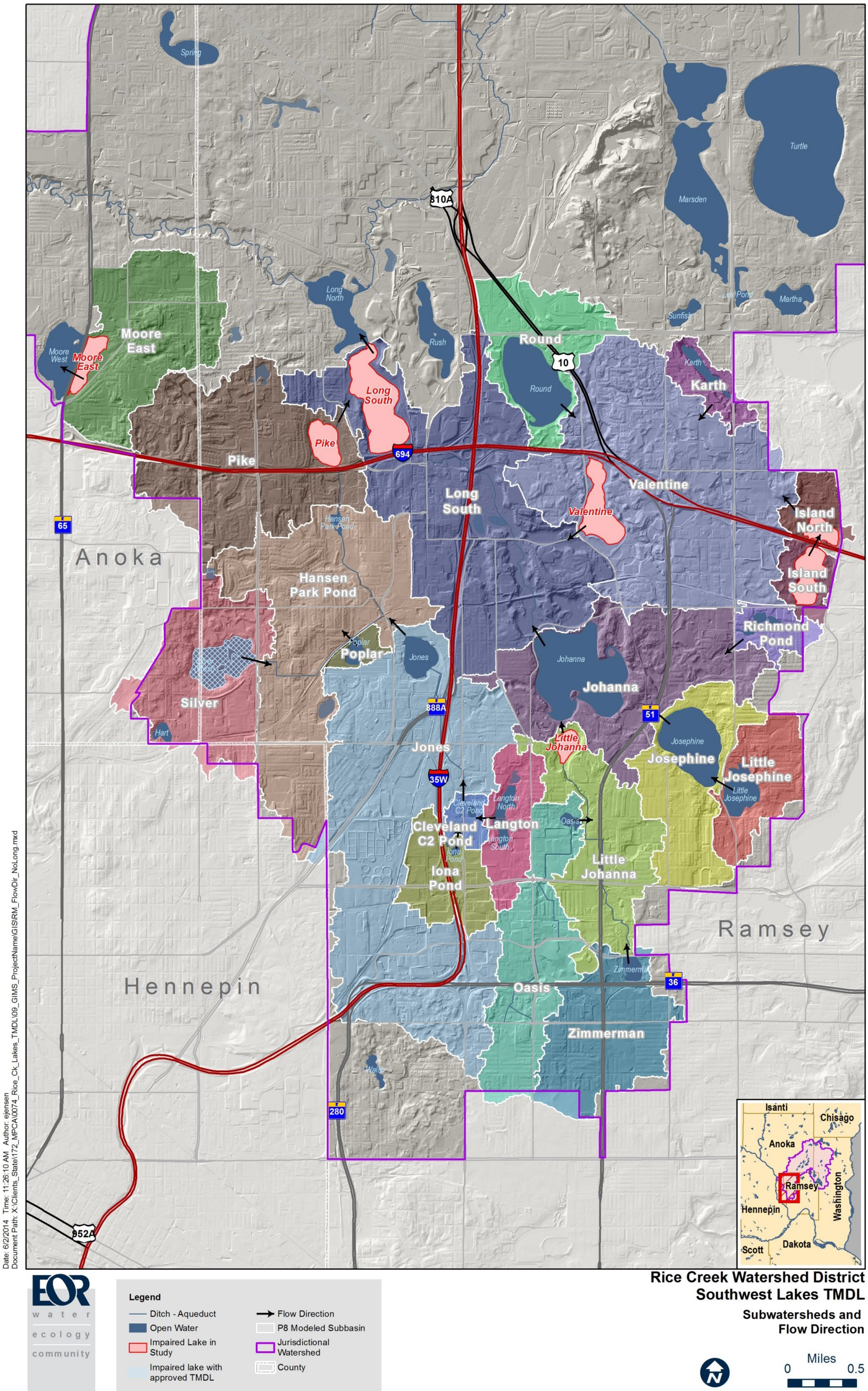
3.2. Subwatersheds

The subwatersheds for each lake were delineated using ArcHydro, LiDAR elevations, known stream paths (both open-channel and pipes), and known watershed boundaries by the RCWD (Houston Engineering 2012). In addition, landlocked areas identified by cities at the 2013 stakeholder meeting were also excluded from the subwatershed areas. These included:

- 127.27 acres in the Pike Lake subwatershed, and
- 42.9 acres in the Moore East Lake subwatershed.

All watershed runoff from the impaired lake subwatersheds covered by the TMDLs in this study are located within an MS4 boundary and therefore all watershed runoff will receive a wasteload allocation (see Section 4.1.2). However, the Pike Lake TMDL does not include allocations for the subwatershed area upstream of Silver Lake since that lake already has an approved TMDL with associated allocations. The impaired lake subwatershed boundaries and dominant flow directions are shown in Figure 2.

Figure 2. Impaired lake subwatershed boundaries and dominant flow direction



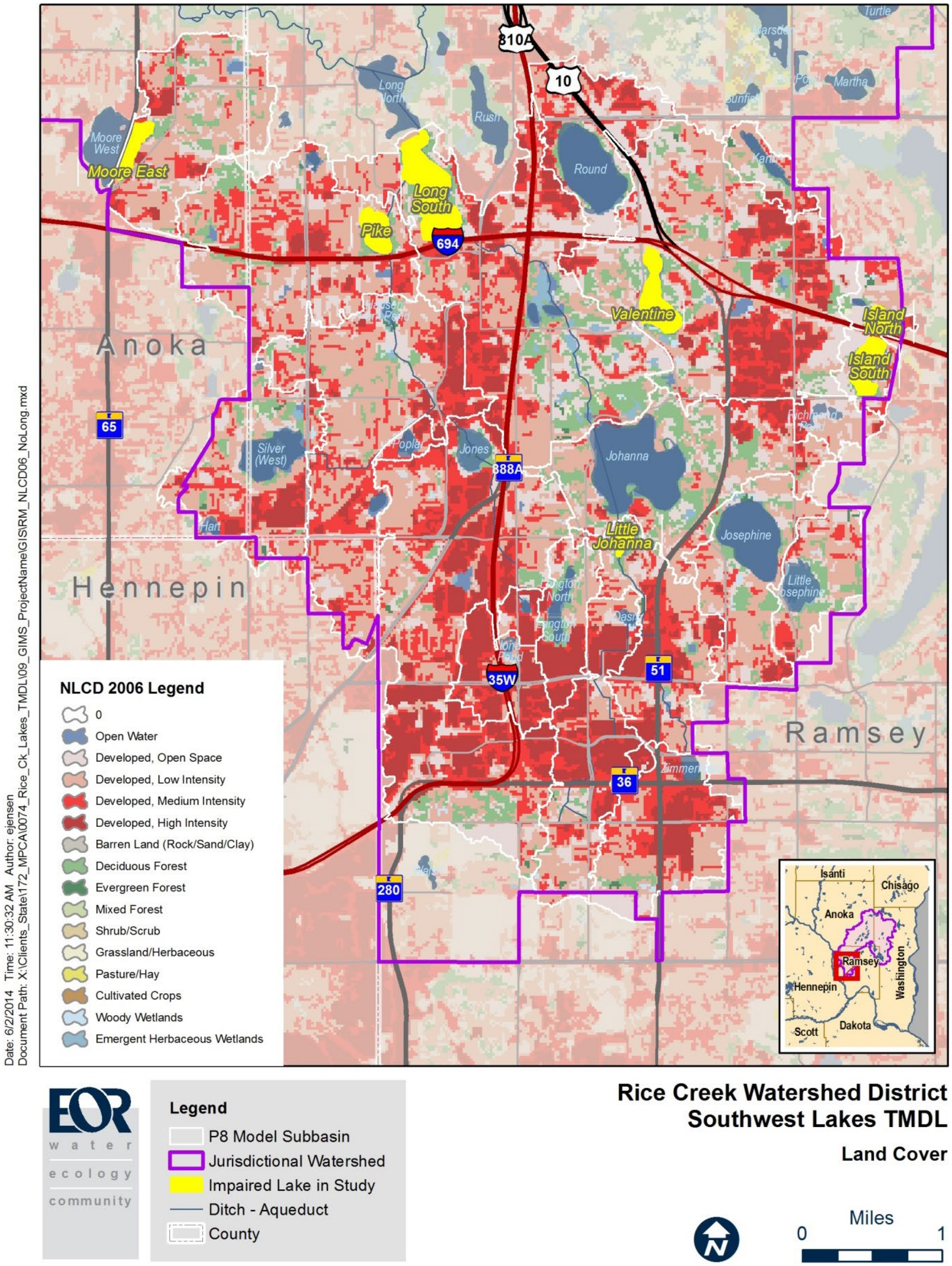
3.3. Land Cover

Land cover in the impaired lake watersheds (excluding the watershed area of other upstream impaired lakes) was assessed using the Multi-Resolution Land Characteristics Consortium 2006 National Land Cover Dataset (http://www.mrlc.gov/nlcd2006.php). Most of the impaired lake subwatersheds are highly developed (Table 4).

Table 4. Impaired Lake Subwatershed Land Cover (NLCD 2006)

Lake	Developed	Forest	Grassland/ Pasture	Open Water	Wetlands	Cropland
Island North	72%	11%	1.1%	15%	1%	0%
Island South	62%	9%	0%	29%	0%	0%
Little Johanna	94%	4%	0%	2%	1%	0%
Long South	71%	13%	0.1%	13%	3%	0%
Moore East	86%	9%	0%	4%	1%	0%
Pike	91%	5%	0%	3%	1%	0%
Valentine	81%	9%	0%	9%	1%	0%

Figure 3. Impaired lake watershed land cover (NLCD 2006)



3.4. Water Quality

The 10-year growing season mean TP, Chl-*a*, and Secchi for each impaired lake are listed in Table 5 as calculated in the *2009 Southwest Urban Lakes Study*. Refer to the *2009 Southwest Urban Lakes Study* individual lake Management Action Plan appendices for complete summaries of lake conditions, including: in-lake water quality, fisheries, and macrophytes.

Table 5. 10-year growing season mean TP, Chl-*a*, and Secchi, 1998-2007
(Table 11 in the 2009 Southwest Urban Lakes Study)

	10-year Growing Season Mean (June – September)					
	TP		Chl-*a*		Secchi	
Lake Name	(µg/L)	CV	(µg/L)	CV	(m)	CV
NCHF General	**< 40**	**--**	**< 14**	**--**	**> 1.4**	**--**
Little Johanna	80	33%	25	65%	1.5	51%
Long, South Basin	54	34%	25	47%	1.4	49%
Moore East	44	21%	18	47%	1.7	36%
NCHF Shallow	**< 60**	**--**	**< 20**	**--**	**> 1.0**	**--**
Island, North Basin	102	35%	25	57%	1.3	40%
Island, South Basin	86	26%	34	51%	1.1	48%
Pike	91	24%	53	40%	0.8	32%
Valentine	70	32%	18	75%	1.7	31%

CV = coefficient of variation, defined in BATHTUB as the standard error divided by the mean

3.5. Pollutant Source Summary

3.5.1. Phosphorus

A key component to developing a nutrient TMDL is understanding the sources contributing to the impairment. This section provides a brief description of the potential sources in the watershed contributing to excess nutrients in the seven lakes addressed in this TMDL. The latter sections of this report discuss the major pollutant sources that have been quantified using collected monitoring data and water quality modeling. The information presented here and in the following sections (as well as the *2009 Southwest Urban Lakes Study* that this TMDL was based on) together provides information necessary to both assess the existing contributions of pollutant sources and target pollutant load reductions.

Phosphorus in lakes often originates on land. Phosphorus from sources such as phosphorus-containing fertilizer, manure, and the decay of organic matter can adsorb to soil particles. Wind and water action erode the soil, detaching particles and conveying them in stormwater runoff to nearby waterbodies where the phosphorus becomes available for algal growth. Organic material such as leaves and grass clippings can leach dissolved phosphorus into standing water and runoff or be conveyed directly to waterbodies where biological action breaks down the organic matter and releases phosphorus. It should be noted that Minnesota's Phosphorus Lawn Fertilizer Law (Minnesota Statutes 18C.60) continues to serve to restrict the impact of this source of phosphorus.

A summary of the relative distribution of phosphorus loads to each lake is summarized in Table 6 below.

Table 6. Phosphorus load distribution by impaired lake

Lake	Direct Drainage Urban Runoff + Upstream Ponds		Upstream Lakes		Atmospheric Deposition		Excess Internal Loading	
	kg/yr	% total	kg/yr	% total	kg/yr	% total	kg/yr	% total
Island North	28	**57%**	10	**20%**	2.3	**5%**	8.7	**18%**
Island South	21	**43%**	0	**0%**	5.3	**11%**	22.4	**46%**
Little Johanna	421	**84%**	0	**0%**	2.1	**0%**	79.9	**16%**
Long South	388	**31%**	758	**61%**	14.4	**1%**	83.1	**7%**
Moore East	134	**97%**	0	**0%**	3.6	**3%**	0.0	**0%**
Pike	844	**93%**	0	**0%**	4.5	**0%**	62.6	**7%**
Valentine	370	**87%**	48	**11%**	7.8	**2%**	0.0	**0%**

3.5.1.1. Permitted Sources of Phosphorus

The regulated sources of phosphorus within the watersheds of the eutrophication impairments addressed in this TMDL study include regulated stormwater from municipal separate storm sewer systems (MS4), construction sites, and industrial sites. Phosphorus loads from regulated

MS4, construction, and industrial stormwater runoff were accounted for using the P8 model as described in Section 4.1.1.

Urban Watershed Runoff

All of the impaired lake subwatersheds are located within the U.S. Census urbanized area. Consequently, a key source of phosphorus in the TMDL project area is from developed land covers and impervious surfaces. A reconnaissance level P8 Urban Catchment Model was chosen to estimate the flows for all subwatersheds and the phosphorus load from just the impaired lake direct drainage areas. Phosphorus loads from upstream lakes were estimated based on monitored in-lake phosphorus concentrations as described in *Section 3.5.1.2: Upstream Lakes* below.

The P8 model predicts loads generated from urban watersheds based primarily on their size and level of imperviousness and is a strong tool for predicting build-up and wash-off of phosphorus from impervious surfaces in urban watersheds. The P8 model allows the user to account for the degree to which impervious surfaces are connected throughout the watershed and, ultimately, to the receiving waterbody. The portion of the impervious surfaces directly connected to the receiving waterbody was set at 85% for each of the watersheds in the study area. The other 15% of the area is indirectly connected to the receiving waterbody through pervious areas such as lawns or natural areas. A P8 model was developed for the project area as part of the *2009 Southwest Urban Lakes Study*. This model was updated in 2013 using the 2012 RCWD revised subwatershed boundaries that were delineated using ArcHydro, LiDAR elevations, known stream paths (both open-channel and pipes), and known watershed boundaries (Houston Engineering 2012).

The P8 model was run using the 1995 water year (October 1994 through September 1995). This water year represents an average year for the Minneapolis-St. Paul area in terms of total precipitation and distribution of storm events for the 1998-2007 period. In addition, the P8 model was constructed with a particle file calibrated for a nearby watershed district with a similar number of ponds and developed land cover (Barr 2000) that is more representative of the phosphorus loading from the TMDL project area than the default NURP50 particle file. This particle file also implicitly accounts for water quality treatment provided by small ponds or other BMPs, such as street sweeping, throughout the watersheds. However, the P8 model framework can be used during the implementation phase to estimate the load reductions from and effectiveness of potential BMPs in the watershed.

The P8 model assumptions are summarized in Appendix B. The urban runoff phosphorus loads from the direct drainage of each impaired lake are summarized in Table 7.

Table 7. Direct drainage area urban runoff phosphorus loads to the impaired lakes

Impaired Lake	Direct Drainage Area (ac)	Urban Runoff Load (kg/yr)
Island North	110	28
Island South	85	21
Little Johanna	552	152
Long South	1,535	388
Moore East	609	134
Pike	899	193
Valentine	1,612	370

3.5.1.2. Non-permitted Sources of Phosphorus

Upstream Lakes

Upstream lakes and ponds can contribute significant phosphorus loads to downstream impaired lakes. The upstream lakes and ponds directly discharging to each impaired lake are listed in Table 8. Flows from all upstream lakes were estimated in P8. Where available, observed in-lake phosphorus concentrations were used to determine the lake phosphorus load. For upstream ponds and smaller lakes (Oasis, Zimmerman, and Hansen Park Pond), P8 was used to estimate the fraction of phosphorus removed by the waterbodies from the contributing watershed urban runoff before being discharged downstream to the impaired lakes.

Table 8. Upstream lake phosphorus loads to the impaired lakes

Impaired Lake	Upstream Lake	Upstream Lake TP Conc. (ppb)	Individual Upstream Lake Load (kg/yr)	Total Upstream Lake Load (kg/yr)
Island North	Island South	84	10	10
Island South	None	N/A	0	0
Little Johanna	Oasis	*	152	269
	Zimmerman	*	117	
Long South	Johanna	31	111	758
	Pike	91	489	
	Valentine	70	158	
Moore East	None	N/A	0	0
Pike	7th Street Pond	*	651	651
Valentine	Island North	100	24	48
	Karth	54	6	
	Round	46	18	

* Upstream lake TP concentration unknown, load determined in P8

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters. Average phosphorus atmospheric deposition loading rates were assumed to be 30 mg/m^2 of TP per year for an average rainfall year for the Upper Mississippi River Basin (MPCA 2004). This rate was applied to the lake surface area to determine the total atmospheric deposition load per year to the impaired lakes (Table 9).

Table 9. Atmospheric deposition phosphorus loads to impaired lakes [MPCA 2004]

Impaired Lake	Atmospheric Deposition (kg/yr)
Island North	2.3
Island South	5.3
Little Johanna	2.1
Long South	14.4
Moore East	3.6
Pike	4.5
Valentine	7.8

Internal Loading

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments or macrophytes and is released back into the water column. Internal loading can occur via:

1. *Chemical release from the sediments*
   Caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (>9). If a lake's hypolimnion (bottom area) 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. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently.
2. *Physical disturbance of the sediments*
   Caused by bottom-feeding fish behaviors (such as carp and bullhead), motorized boat activity, and wind mixing. This is a known problem in Island North, Island South, Little Johanna, Long South Basin, and Pike Lakes.
3. *Decaying plant matter*
   Specifically curly-leaf pondweed (*Potamogeton crispus*). While curly-leaf pondweed is present in many of the impaired lakes, the population densities are not at nuisance levels.

The potential total internal loading due to the anoxic release of phosphorus from the sediments of each lake was estimated in this study based on the expected release rate (RR) of phosphorus from the lakebed sediment, the lake anoxic factor (AF), and the lake area. Lake sediment samples were taken and tested for bicarbonate dithionite extractable phosphorus (BD-P), which analyzes iron-bound phosphorus. Phosphorus release rates were calculated using statistical regression equations developed using measured release rates and sediment P concentrations from a large set of North American (NA) lakes (Nürnberg 1988; Nürnberg 1996; Table 10.

Because some amount of internal loading is explicit in the BATHTUB lake water quality model and uncertainty exists around the amount of internal loading estimated by the Nurnberg regression equations, the estimated total sediment phosphorus release rates per anoxic day converted to day were used as a reference point for calibrating each impaired lake BATHTUB model to observed in-lake phosphorus concentrations (see *Section 4.1.1.4*). Moreover, the internal loading rates estimated by the Nurnberg regression equations represents the total potential sediment release rate while the calibrated internal loading rates from the BATHTUB model represents the excess sediment release rate beyond the average background release rate accounted for by the model development lake dataset. For Island Lake South and Island Lake North, the calibrated BATHTUB release rates were slightly greater than the estimated sediment phosphorus release rates using the Nurnberg regression equations (Table 10). For all other lakes, the calibrated BATHTUB release rates were very small or zero, indicating that most or all of the internal loading in these lakes was accounted for by average background release rates from the model development lake dataset.

Internal loading due to physical disturbance by carp is a known problem in Island North, Island South, Little Johanna, Long South Basin, and Pike Lakes. To explicitly account for the amount of implicit internal load including in the BATHTUB model, an additional internal load was added to the existing load and loading capacity (Table 10). This was done to allocate reductions to internal load in lakes known to be infested by and actively managed for carp.

Table 10. Internal phosphorus load assumptions and summary (Nurnberg 1988, 1996)

Lake	Lake Type	Sediment Sample Depth	Iron-P	Anoxic Factor	Estimated Total Sediment P Release Rate NA Lakes Dataset		BATHTUB Calibrated Excess Release Rate	Additional Sediment P Release Rate for lakes with carp	Total Sediment P Release Rate	Total Existing Internal Load
		(feet)	(mg/kg dry)	(days)	(mg/m^2-anoxic day)	(mg/m^2-calendar day)	(mg/m^2-day)	(mg/m^2-day)	(mg/m^2-day)	(kg/yr)
Island North	Shallow	9	120	66	1.07	0.195	0.205	0.111	0.316	**8.7**
Island South	Shallow	9	120	63	1.07	0.184	0.347	0	0.347	**22.4**
Little Johanna	General	28	1,200	68	15.88	2.96	0	3.130	3.130	**79.9**
Long South	General	24	1,300	54	17.26	2.57	0.14	0.333	0.473	**83.1**
Moore East	General	22	220	50	2.44	0.334	0	0	0	**0**
Pike	Shallow	16	1,200	65	15.88	2.83	0	1.14	1.14	**62.6**
Valentine	Shallow	14	360	58	4.36	0.69	0	0	0	**0**

4. TMDL DEVELOPMENT

This section presents the overall approach to estimating the components of the TMDL. The pollutant sources were first identified and estimated in *Section 3.5 Phosphorus Pollutant Source Summary*. The loading capacity (TMDL) of each lake was then estimated using an in-lake phosphorus response model and was divided among wasteload allocations (WLAs) and load allocations (LAs). A TMDL for a waterbody that is impaired as the result of excessive loading of a particular pollutant can be described by the following equation:

$$\text{TMDL} = \text{LC} = \sum \text{WLA} + \sum \text{LA} + \text{MOS} + \text{RC}$$

Where:

Loading capacity (LC): the greatest pollutant load a waterbody can receive without violating water quality standards;

Wasteload allocation (WLA): the pollutant load that is allocated to point sources, including wastewater treatment facilities, regulated construction stormwater, and regulated industrial stormwater, all covered under NPDES permits for a current or future permitted pollutant source;

Load allocation (LA): the pollutant load that is allocated to sources not requiring NPDES permit coverage, including non-regulated stormwater runoff, atmospheric deposition, and internal loading;

Margin of Safety (MOS): an accounting of uncertainty about the relationship between pollutant loads and receiving water quality;

Reserve Capacity (RC): the portion of the loading capacity attributed to the growth of existing and future load sources.

4.1. Phosphorus

4.1.1. Loading Capacity

The modeling software Bathtub (Version 6.1) was selected to link phosphorus loads with in-lake water quality. Bathtub was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker, 1999) and is publicly available. It 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 summer (June through September) mean lake surface water quality. This time-scale is appropriate because watershed phosphorus loads are determined on an annual basis, symptoms of nutrient enrichment are normally the most severe during the summer months, and Minnesota lake eutrophication standards are based on growing season means. 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.

These impaired lakes were originally modeled in BATHTUB as part of the *2009 Southwest Urban Lakes Study*. However, the original models were not developed to the level of detail necessary for a TMDL. Therefore, these lakes were re-modeled for this TMDL project using updated inputs, model segmentation, and calibration procedures as described below.

4.1.1.1. System Representation in Model

In typical applications of Bathtub, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. For this study, the direct drainage area and outflow from an upstream pond or lake for which TP concentration is known was defined as a separate tributary for each lake (i.e., segment).

4.1.1.2. Model Inputs

The input required to run the Bathtub model includes lake morphometry (Table 3), observed lake water quality (Table 5), atmospheric deposition rates (Table 9), precipitation rates, evaporation rates, and watershed runoff flow and phosphorus loads (Table 11). Ten-year (1998-2007) growing season (June through September) means of total phosphorus, chlorophyll-*a*, and Secchi depth were calculated to facilitate model verification and calibration. Recent long-term average conditions are appropriate for modeling the loading capacities of lakes.

Precipitation rates were determined from 1998-2007 average annual precipitation data downloaded from the Minnesota Climatology Working Group - 'Closest Station' Climate Data Retrieval website (http://climate.umn.edu/hidradius/radius.asp) sponsored by the State Climatology Office - MN DNR Division of Ecological and Water Resources and the University of Minnesota, using the center of Long Lake as the target location.

Evaporation rates were estimated from 1998-2007 annual average pan evaporation multiplied by a 0.8 coefficient using data downloaded from the Minnesota Climatology Working Group - Monthly Pan Evaporation Data from U of M - St. Paul Campus (1972-2012) website (http://climate.umn.edu/img/wxsta/pan-evaporation.htm) sponsored by the State Climatology Office - MN DNR Division of Ecological and Water Resources and the University of Minnesota.

As described in *Section 3.5.1.1*, P8 was used to estimate the urban watershed runoff flow and phosphorus loads to the impaired lakes (Table 11). The P8 model was run using the 1995 water year (October 1994 through September 1995). This water year represents an average year for the Minneapolis-St. Paul area in terms of total precipitation and distribution of storm events for the 1998-2007 period. Advective outflow from the calibrated BATHTUB models was used for the outflow from Island Lake South Basin, Pike Lake, and Valentine Lake.

Table 11. Tributary flows and phosphorus loads to the impaired lakes

Impaired Lake	Tributary	Flow Weighted Mean TP (ppb)	Flow (ac-ft/yr)
Island North	Direct drainage	256	88
	Island Lake South outflow	84	93
Island South	Direct drainage	256	68
Little Johanna	Direct drainage	240	517
	Oasis pond outflow	195	639
	Zimmerman pond outflow	179	536
Long South	Direct drainage	244	1,300
	Pike Lake outflow	91	4,398
	Lake Valentine outflow	70	1,845
	Lake Johanna outflow	31	2,926
Moore East	Direct drainage	244	448
Pike	Direct drainage	250	633
	Hansen Park pond outflow	142	3,745
Valentine	Direct drainage	251	1,207
	Karth Lake outflow	54	94
	Round Lake outflow	46	317
	Island Lake North outflow	100	191

4.1.1.3. Selection of BATHTUB models

BATHTUB allows a choice among several different phosphorus sedimentation models. The Canfield-Bachmann Lakes phosphorus sedimentation model best predicted the in-lake phosphorus concentration for Island Lake North and Island Lake South. The Canfield-Bachmann Reservoirs phosphorus sedimentation model best predicted the observed in-lake phosphorus concentrations for all other impaired lakes in the study.

4.1.1.4. Model Calibration

The models were calibrated to existing water quality data according to Table 12, and then were used to determine the phosphorus loading capacity (TMDL) of each lake. When the predicted in-lake total phosphorus concentration was *lower* than the average observed (monitored) concentration, an explicit additional load was added to calibrate the model. It is widely recognized that Minnesota lakes in agricultural and urban regions have histories of high phosphorus loading and/or very poor water quality. For this reason, it is reasonable that internal loading may be higher than that of the lakes in the data set used to derive the Canfield-Bachmann lakes formulation. It is also possible that the watershed model loading estimates did not account for certain hot spots of phosphorus loading such as above average application of lawn fertilizer runoff and/or pet waste. When the predicted in-lake total phosphorus concentration was *higher* than the average monitored concentration; the phosphorus sedimentation rate calibration coefficient was increased to calibrate the model.

Table 12. Model calibration summary for the impaired lakes

Impaired Lake	BATHTUB TP Sedimentation Model	Calibration Mode	Calibration Factor
Island North	Canfield & Bachmann, Lakes	Added Internal Load	0.205 mg/m^2-day
Island South	Canfield & Bachmann, Lakes	Added Internal Load	0.347 mg/m^2-day
Little Johanna	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	1.51
Long South	Canfield & Bachmann, Reservoirs	Added Internal Load	0.14 mg/m^2-day
Moore East	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	2.405
Pike	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	1.097
Valentine	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	1.625

4.1.1.5. Determination of lake loading capacity (TMDL) and reductions needed to meet standards

Using the calibrated existing conditions model as a starting point, the tributary phosphorus concentrations were reduced until the model indicated that the total phosphorus state standard was met, to the nearest tenth of a whole number. First, upstream impaired lake phosphorus concentrations were assumed to meet lake water quality standards. Next, the direct drainage flow weighted mean TP concentration was reduced to no less than 150 ppb until the in-lake phosphorus concentration met the lake water quality standard. A flow weighted mean concentration goal of 150 ppb was chosen to represent reasonable baseline loading conditions from the highly developed watershed. If further reductions were needed, any added internal loads were reduced until the in-lake phosphorus concentration met the lake water quality standard.

4.1.2. Load Allocations

The LA includes all sources of phosphorus that do not require NPDES permit coverage: internal loading (sediment release), atmospheric deposition, and lake outflow from an upstream impaired lake with a watershed runoff WLA. The LA for internal loading (sediment release), atmospheric deposition, and lake outflow from an upstream impaired lake were determined based on the load estimates described in Section 3.5.1.2 Non-permitted Sources of Phosphorus.

4.1.3. Wasteload Allocations

All of the watershed runoff in the impaired lake subwatersheds covered by this TMDL are within a regulated MS4 boundary and receive a WLA (see Section 3.2). The remainder of the loading capacity (TMDL) after subtraction of the MOS, atmospheric deposition, and internal loading was used to determine the WLA for each impaired lake on an areal basis. Note that the MOS was distributed proportionately among internal loading and watershed runoff based on existing loads relative to the loading capacity, but not to atmospheric deposition and lake outflow from an upstream impaired lake.

4.1.3.1. Regulated Construction Stormwater

Construction stormwater is regulated by NPDES permits for any construction activity disturbing a) one acre or more of soil, b) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre, or c) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges from sites where there is construction activities reflects the number of construction sites $\geq$ 1 acre expected to be active in the impaired lake subwatershed at any one time.

A categorical WLA was assigned to all construction activity in each impaired lake subwatershed. First, the average annual fraction of the impaired lake subwatershed area under construction activity over the past 5 years was calculated based on MPCA Construction Stormwater Permit data from January 1, 2007 to October 6, 2012 (Table 13), area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load component to determine the construction stormwater WLA. The watershed runoff load component is equal to the total TMDL (loading capacity) minus the sum of the non-watershed runoff load components (atmospheric load, internal load, upstream lakes, and MOS).

Table 13. Average Annual NPDES/SDS Construction Stormwater Permit Activity by County (1/1/2007-10/6/2012)

County	Average Annual Construction Activity Area	
	(ac)	(% county area)
Anoka	754	0.26%
Hennepin	1,529	0.39%
Ramsey	564	0.52%

4.1.3.2. Regulated Industrial Stormwater

Industrial stormwater is regulated by NPDES permits if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired lake subwatershed for which NPDES industrial stormwater permit coverage is required.

A categorical WLA was assigned to all industrial activity in each impaired lake subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area. Industrial NPDES permitted facilities in the TMDL project area are listed in Table 14.

Table 14. NPDES/SDS Industrial Stormwater Multi-Sector General Permitted Facilities

Impaired Lake Subwatershed	Facility Name	Permit ID
Little Johanna	First Transit Inc – 55872 – ISW	MNR05355K
Long South	First Student Inc – 11730 – ISW	MNR053555
	Wolkerstorfer Co Inc – SW	MNR0537GR
Pike	Bell Lumber & Pole Co – SW	MNR053424
	Rebarfab Inc – ISW	MNR0535F8
	Remmele Engineering Inc – Plant 10 – ISW	MNR0535W4
	Fedex Freight Inc – SMN – ISW	MNR0535DN
	Fedex Freight Inc – MSP – ISW	MNR0535FS
	International Paper – Twin Cities Recycling – ISW	MNR0533WL
	Koch Trucking Trailer Shop – ISW	MNR05379N
	Lakeville Motor Express ISW	MNR05353C
	Lubrication Technologies Inc – Roseville – SW	MNR0534C5
Valentine	International Paper – Container Division – ISW	MNR05363F
	PACE Industries – St. Paul Division ISW	MNR05377X

4.1.3.3. MS4 Regulated Stormwater

Stormwater from municipal separate storm sewer systems (MS4s) - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES permits for all mandatory, designated, or petition MS4s. All MS4s in the project area are mandatory MS4s, which is based on the U.S. Census definition of an urbanized area: a land area comprising one or more places ("central places") and the adjacent densely settled surrounding area ("urban fringe") that together have a residential population of at least 50,000 and a density of at least 1,000 people per square mile. The definition also includes any other public storm sewer system located fully or partially within an urbanized area.

All of the impaired lake subwatershed areas covered by this TMDL are located within the U.S. Census Bureau Urban Area and are regulated as a mandatory MS4. Regulated MS4 stormwater in the impaired lake subwatersheds is summarized in Table 15 and Figure 4. MS4 permits for state (MnDOT) and county road authorities apply to roads within the U.S. Census Bureau Urban Area.

A categorical WLA was assigned to all municipal MS4s and the Rice Creek Watershed District (RCWD) MS4, which has jurisdiction over several ditches in the watershed, within the impaired lake watersheds based on a request from the individual municipal MS4s during a stakeholder meeting at the start of the project. The cities and RCWD have a history of cooperating together on phosphorus reduction projects to meet pollutant reduction goals for other impaired lakes and streams in the Rice Creek Watershed District as part of other EPA approved TMDL projects. The cities and RCWD prefer a categorical WLA because they recognize that they all should invest in the most effective BMPs to reduce phosphorus loading to impaired lakes in the watershed, even if the best project sites do not fall directly within their city boundary. In addition, a categorical approach is fully consistent with the approach and level of rigor used in the *2009 Southwest Urban Lakes Study* which is the basis for this TMDL.

Per their request, an individual WLA was assigned to MnDOT road right-of-ways located within the impaired lake watersheds. The area of MnDOT road right-of-ways in each impaired lake subwatershed are summarized in Table 16.

Table 15. Regulated MS4 stormwater in the impaired lake subwatersheds

Impaired Lake	Permit Number	MS4 Community
Island North	MS400121 MS400193 MS400170 MS400191	Shoreview City MS4 Rice Creek WD MS4 MNDOT Metro District MS4 Ramsey County Public Works MS4
Island South	MS400121 MS400193 MS400170 MS400191	Shoreview City MS4 Rice Creek WD MS4 MNDOT Metro District MS4 Ramsey County Public Works MS4
Little Johanna	MS400002 MS400018 MS400047 MS400212 MS400193 MS400170 MS400191	Arden Hills City MS4 Falcon Heights City MS4 Roseville City MS4 University of Minnesota MS4 Rice Creek WD MS4 MNDOT Metro District MS4 Ramsey County Public Works MS4
Long South	MS400002 MS400038 MS400047 MS400121 MS400193 MS400170 MS400191	Arden Hills City MS4 New Brighton City MS4 Roseville City MS4 Shoreview City MS4 Rice Creek WD MS4 MNDOT Metro District MS4 Ramsey County Public Works MS4
Moore East	MS400019 MS400038 MS400193 MS400170 MS400066 MS400191	Fridley City MS4 New Brighton City MS4 Rice Creek WD MS4 MNDOT Metro District MS4 Anoka County MS4 Ramsey County Public Works MS4

Impaired Lake	Permit Number	MS4 Community
Pike	MS400002	Arden Hills City MS4
	MS400010	Columbia Heights City MS4
	MS400019	Fridley City MS4
	MS400038	New Brighton City MS4
	MS400047	Roseville City MS4
	MS400051	St Anthony Village City MS4
	MS400193	Rice Creek WD MS4
	MS400170	MNDOT Metro District MS4
	MS400066	Anoka County MS4
	MS400138	Hennepin County MS4
	MS400191	Ramsey County Public Works MS4
Valentine	MS400002	Arden Hills City MS4
	MS400121	Shoreview City MS4
	MS400193	Rice Creek WD MS4
	MS400170	MNDOT Metro District MS4
	MS400191	Ramsey County Public Works MS4

Table 16. MnDOT road right-of-way regulated area by impaired lake subwatershed

Impaired Lake Subwatershed	MnDOT road right-of-way regulated area (acres)
Island North	9.2
Island South	8.1
Little Johanna	154.4
Long South	214.1
Moore East	9.1
Pike	307.9
Valentine	216.5

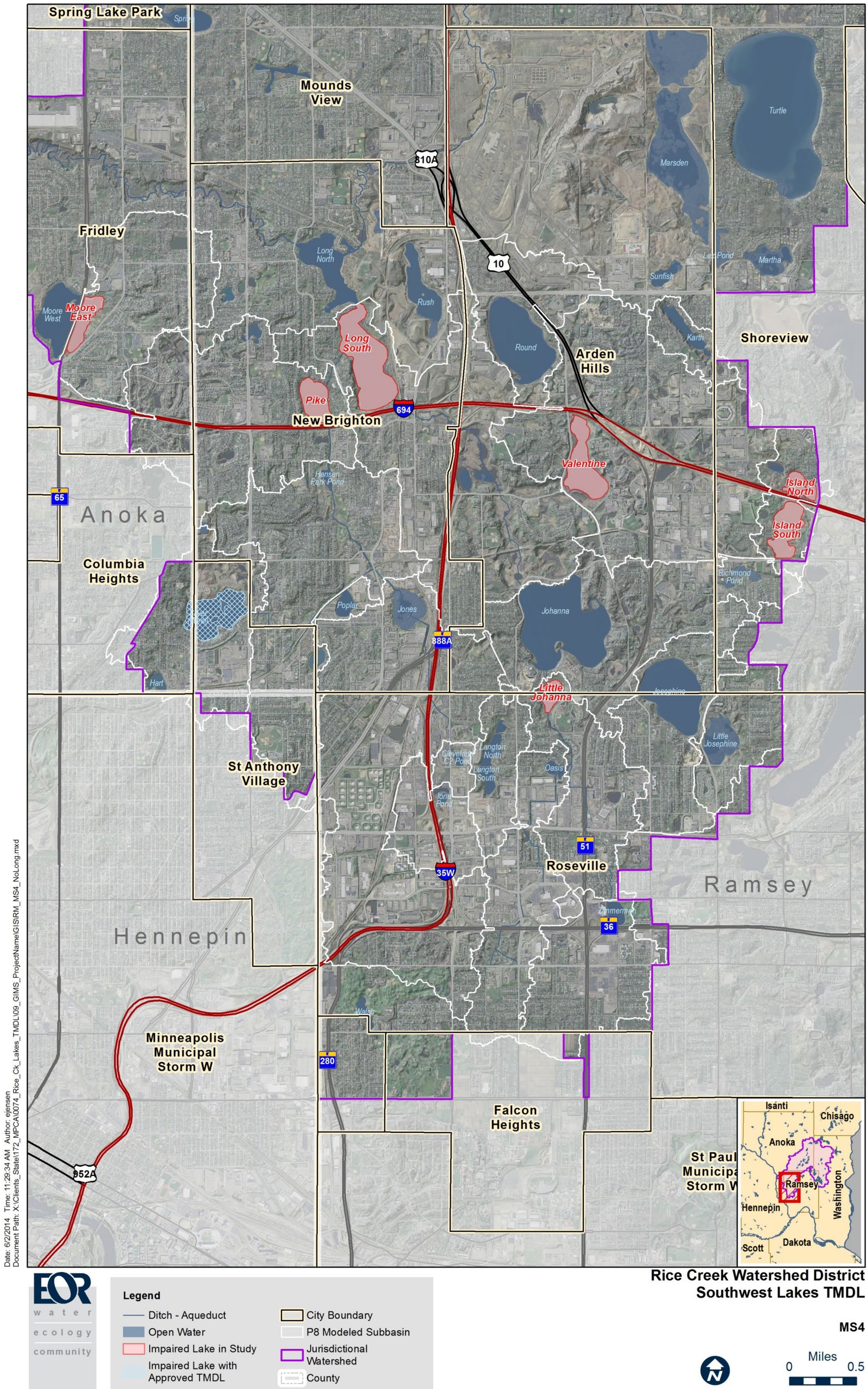


Figure 4. Location of MS4s within the project area

4.1.3.4. NPDES Permitted Feedlots

There are no NPDES-permitted feedlots in the watershed.

4.1.3.5. Municipal and Industrial Wastewater Treatment Systems

There is one NPDES-permitted industrial wastewater discharger in the project area. The New Brighton Water Treatment Plant permit (MNG640068) authorizes filter backwash discharges from two discharge points upstream of Pike Lake. Monitoring indicates annual average effluent total phosphorus concentrations consistently below the lake standard (60 µg/L). The WLA is based on a product of the total annual volume discharge (0.624 million gallons), the lake standard and a 50 percent added uncertainty factor. The result is 0.21 kg/year, which is 0.04 percent of the total loading capacity for Pike Lake.

4.1.4. Margin of Safety

An explicit 5% margin of safety (MOS) was accounted for in the TMDL for each impaired lake. This MOS is sufficient to account for uncertainties in predicting phosphorus loads to lakes and predicting how lakes respond to changes in phosphorus loading. This explicit MOS is considered to be appropriate based on the generally good agreement between the water quality models' predicted and observed values.

4.1.5. Seasonal Variation and Critical Conditions

In-lake water quality varies seasonally. In Minnesota lakes, the majority of the watershed phosphorus load often enters the lake during the spring. During the growing season months (June through September) in lakes, phosphorus concentrations may not change drastically if major runoff events do not occur. However, chlorophyll-a concentration may still increase throughout the growing season due to warmer temperatures fostering higher algal growth rates. In shallow lakes, the phosphorus concentration more frequently increases throughout the growing season due to the additional phosphorus load from internal sources. This can lead to even greater increases in chlorophyll-a since not only is there more phosphorus but temperatures are also higher. This seasonal variation is taken into account in the TMDL by using the eutrophication standards (which are based on growing season averages) as the TMDL goals. The eutrophication standards were set with seasonal variability in mind. 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).

Critical conditions in these lakes occur during the growing season, which is when the lakes are used for aquatic recreation. Similar to the manner in which the standards take into account seasonal variation, since the TMDL is based on growing season averages, the critical condition is covered by the TMDL.

4.1.6. Future Growth Considerations

Potential changes in population and land use over time in the Rice Creek Watershed could result in changing sources of pollutants. Possible changes and how they may or may not impact TMDL allocations are discussed below.

4.1.6.1. Load Transfer

Because MS4-permitted land areas can be subject to change the MPCA's Stormwater Program has outlined for TMDLs in general the potential circumstances in which transfer of watershed runoff allocations may need to occur and how load is transferred between and/or within the WLA and LA categories. These scenarios are described below, though not all are applicable to the specific TMDLs in the watershed boundaries of this project.

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded Urban Area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL (see Section 1). One transfer rate was defined for each impaired lake as the total wasteload allocation (kg/yr) divided by the watershed area downstream of any upstream impaired waterbody (acres). In the case of a load transfer, the amount transferred from LA to WLA will be based on the area (acres) of land coming under permit coverage multiplied by the transfer rate (kg/ac-yr). The MPCA will make these allocation shifts. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment. Individual transfer rates for each lake TMDL are listed in Table 17.

Table 17. Transfer rates for any future MS4 discharger in the impaired lake watersheds

Lake name	WLA transfer rates (kg/ac-yr)	WLA transfer rates (kg/ac-day)
Island North	0.13	0.00035
Island South	0.09	0.00024
Little Johanna	0.13	0.00036
Long South	0.05	0.00014
Moore East	0.16	0.00043
Pike	0.10	0.00027
Valentine	0.11	0.00031

4.1.7. TMDL Summaries

The individual impaired lake TMDL and allocations are summarized in the following tables. The TMDL was allocated among phosphorus sources according to the methodology described in Section 4.1.1 – 4.1.4, with load reductions determined based on the following:

1. No load reduction was assigned to atmospheric loading.
2. Upstream impaired lake phosphorus concentrations were assumed to meet lake water quality standards.
3. The growing season mean phosphorus concentration of upstream ponds that were not assessed for aquatic recreational use as lakes were reduced to 90 ppb.
4. The direct drainage flow weighted mean TP concentration was reduced to no less than 150 ppb until the in-lake phosphorus concentration met the lake water quality standard. A flow weighted mean concentration goal of 150 ppb was chosen to represent reasonable baseline loading conditions from the highly developed watershed.
5. If further reductions were necessary, internal load was reduced until the in-lake phosphorus concentration met the lake water quality standard.

Equal reductions were assigned to MS4 and MnDOT WLAs. There was no reduction assigned to the MnDOT WLAs for Island Lake North, Island Lake South, and Moore Lake East due to the very small regulated road right-of-way area in those subwatersheds.

4.1.7.1. Island Lake North Basin

Table 18. Island Lake North Basin TMDL and Allocations

Island North Load Component		Existing	Goal		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Categorical MS4 stormwater (See Table 16)	25.4	14.0	0.038	11.4	45%
	Construction stormwater (MNR100001)	0.1	0.1	0.0003	0	0%
	Industrial stormwater (MNR50000)	0.1	0.1	0.0003	0	0%
	MnDOT stormwater (MS400170)	2.0	2.0	0.0054	0.0	0%
	Total WLA	**27.6**	**16.2**	**0.044**	**11.4**	
Load Allocations	Internal Load	8.7	0.0	0.0000	8.7	100%
	Atmospheric	2.3	2.3	0.0063	0.0	0%
	Upstream Impaired Lake: Island South	9.7	6.8	0.019	2.9	30%
	Total LA	**20.7**	**9.1**	**0.025**	**11.6**	
MOS			**1.3**	**0.0036**		
TOTAL		**48.3**	**26.6**	**0.073**	**23.0**	**48%**

4.1.7.2. Island Lake South Basin

Table 19. Island Lake South Basin TMDL and Allocations

Island South Load Component		Existing	Goal		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Categorical MS4 stormwater (See Table 16)	19.9	9.7	0.027	10.2	51%
	Construction stormwater (MNR100001)	0.06	0.06	0.00016	0	0%
	Industrial stormwater (MNR50000)	0.06	0.06	0.00016	0	0%
	MnDOT stormwater (MS400170)	1.3	1.3	0.0036	0.0	0%
	Total WLA	**21.3**	**11.1**	**0.031**	**10.2**	
Load Allocations	Internal Load	22.4	10.2	0.028	12.2	54%
	Atmospheric	5.3	5.3	0.015	0.0	0%
	Total LA	**27.7**	**15.5**	**0.043**	**12.2**	
MOS			**1.4**	**0.004**		
TOTAL		**49.0**	**28.0**	**0.078**	**22.4**	**46%**

4.1.7.3. Little Lake Johanna

Table 20. Little Lake Johanna TMDL and Allocations

Little Johanna Load Component		Existing (kg/yr)	Goal (kg/yr)	Goal (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Categorical MS4 stormwater (See Table 16)	380.6	201.6	0.552	179.0	47%
	Construction stormwater (MNR100001)	1.2	1.2	0.003	0.0	0%
	Industrial stormwater (MNR50000)	1.2	1.2	0.003	0.0	0%
	MnDOT stormwater (MS400170)	38.0	20.1	0.055	17.9	47%
	Total WLA	**421.0**	**224.1**	**0.614**	**196.9**	
Load Allocations	Internal Load	79.9	0.0	0.000	79.9	100%
	Atmospheric	2.1	2.1	0.006	0.0	0%
	Total LA	**82.0**	**2.1**	**0.006**	**79.9**	
MOS			**11.9**	**0.033**		
TOTAL		**503.0**	**238.1**	**0.653**	**276.8**	**55%**

4.1.7.4. Long Lake South Basin

Table 21. Long Lake South Basin TMDL and Allocations

Long South Load Component		Existing	Goal		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Categorical MS4 stormwater (See Table 16)	307.5	167.4	0.459	140.1	46%
	Construction stormwater (MNR100001)	0.9	0.9	0.002	0.0	0%
	Industrial stormwater (MNR50000)	0.9	0.9	0.002	0.0	0%
	MnDOT stormwater (MS400170)	19.9	10.8	0.030	9.1	46%
	Total WLA	**329.1**	**180.0**	**0.493**	**149.1**	
Load Allocations	Internal Load	83.1	0.0	0.000	83.1	100%
	Atmospheric	14.4	14.4	0.039	0.0	0%
	Upstream Lake: Lake Johanna	110.9	110.9	0.304	0.0	0%
	Upstream Impaired Lake: Lake Valentine	157.9	135.4	0.371	22.5	14%
	Upstream Impaired Lake: Pike Lake	489.5	322.7	0.884	166.8	34%
	Total LA	**855.8**	**583.4**	**1.598**	**272.4**	
MOS			**40.2**	**0.110**		
TOTAL		**1,184.9**	**803.6**	**2.201**	**421.5**	**36%**

4.1.7.5. Moore Lake East

Table 22. Moore Lake East TMDL and Allocations

Moore East Load Component		Existing (kg/yr)	Goal (kg/yr)	Goal (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Categorical MS4 stormwater (See Table 16)	131.3	97.5	0.267	33.8	26%
	Construction stormwater (MNR100001)	0.3	0.3	0.0008	0.0	0%
	Industrial stormwater (MNR50000)	0.3	0.3	0.0008	0.0	0%
	MnDOT stormwater (MS400170)	1.9	1.9	0.0052	0.0	0%
	Total WLA	**133.8**	**100.0**	**0.274**	**33.8**	
Load Allocations	Atmospheric	3.6	3.6	0.010	0.0	0%
	Total LA	**3.6**	**3.6**	**0.010**	**0.0**	
MOS			**5.5**	**0.015**		
TOTAL		**137.4**	**109.1**	**0.299**	**33.8**	**25%**

4.1.7.6. Pike Lake

Table 23. Pike Lake TMDL and Allocations

Pike Lake Load Component		Existing	Goal		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Categorical MS4 stormwater (See Table 16)	685.5	371.1	1.016	314.4	46%
	Construction stormwater (MNR100001)	2.0	2.0	0.005	0.0	0%
	Industrial stormwater (MNR50000)	2.0	2.0	0.005	0.0	0%
	MnDOT stormwater (MS400170)	49.9	27.0	0.074	22.9	46%
	New Brighton Water Treatment Facility (MNG640068)	0.2	0.2	0.001	0.0	0%
	Total WLA	**739.6**	**402.3**	**1.102**	**337.3**	
Load Allocations	Internal Load	62.6	0.0	0.000	62.6	100%
	Atmospheric	4.5	4.5	0.012	0.0	0%
	Upstream Impaired Lake: Silver	41.8	39.8	0.109	2.0	5%
	Total LA	**109.0**	**44.3**	**0.122**	**64.6**	
MOS			**23.5**	**0.064**		
TOTAL		**848.6**	**470.2**	**1.288**	**401.9**	**47%**

4.1.7.7. Lake Valentine

Table 24. Lake Valentine TMDL and Allocations

Lake Valentine Load Component		Existing (kg/yr)	Goal (kg/yr)	Goal (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Categorical MS4 stormwater (See Table 16)	332.7	229.5	0.629	103.2	31%
	Construction stormwater (MNR100001)	1.3	1.3	0.004	0.0	0%
	Industrial stormwater (MNR50000)	1.3	1.3	0.004	0.0	0%
	MnDOT stormwater (MS400170)	34.8	24.0	0.066	10.8	31%
	Total WLA	**370.1**	**256.1**	**0.702**	**114.0**	
Load Allocations	Atmospheric	7.8	7.8	0.021	0.0	0%
	Upstream Lake: Karth	6.2	6.2	0.017	0.0	0%
	Upstream Lake: Round	17.8	17.8	0.049	0.0	0%
	Upstream Impaired Lake: Island North	23.9	14.0	0.038	9.9	41%
	Total LA	**55.7**	**45.8**	**0.125**	**9.9**	
MOS			**15.9**	**0.044**		
TOTAL		**425.8**	**317.8**	**0.871**	**123.9**	**29%**

4.1.8. TMDL Baseline

The TMDLs are based on data from the ten year period 1998-2007. Any activities implemented during or after the mid-point of that time period, specifically 2003, which lead to a reduction in phosphorus loads to the lake may be considered as progress towards meeting a WLA or LA.

5. REASONABLE ASSURANCES

5.1. Non-regulatory

Non-regulatory load reductions for these lakes pertain to the LA category and within that category specifically in-lake phosphorus sources. RCWD takes a lead role for their lakes using the information gained from all available nutrient loading studies, evaluating the feasibility of options for addressing these sources, seeking or providing funding and implementing actions. Identification of options for all the lakes in this study are provided in the associated Management Action Plans completed for each lake as part of the 2009 Southwest Lakes Study.

TMDLs have been completed and approved for nearby Bald Eagle Lake, Golden Lake, Silver Lake, Peltier-Centerville Lakes, and Hardwood Creek. Many of the partners involved in the pollutant reductions and implementation efforts of these TMDLs are also involved in the Rice Creek Watershed District Southwest Urban Lakes TMDL, providing additional reasonable assurance that these partners are capable of working together to achieve the pollutant reductions and implementation efforts required by this TMDL project.

5.2. Regulatory

Regulatory load reductions for these lakes pertain to the WLA category and specifically stormwater. Regulatory actions fall under federal, state and local (RCWD) jurisdiction.

The MPCA is responsible for applying federal and state regulations to protect and enhance water quality within the Rice Creek watershed. The MPCA oversees all regulated MS4 entities in stormwater management accounting activities. All regulated MS4s in the watershed fall under the category of Phase II. MS4 NPDES/SDS permits require regulated municipalities to implement BMPs to reduce pollutants in stormwater runoff to the Maximum Extent Practicable (MEP).

All owners or operators of regulated MS4s (also referred to as “permittees”) are required to satisfy the requirements of the MS4 general permit. The MS4 general permit requires the permittee to develop a Stormwater Pollution Prevention Program (SWPPP) that addresses all permit requirements, including the following six minimum control measures:

- Public education and outreach
- Public participation
- Illicit Discharge Detection and Elimination (IDDE) Program
- Construction-site runoff controls;
- Post-construction runoff controls; and
- Pollution prevention and municipal good housekeeping measures

A SWPPP is a management plan that describes the MS4 permittee’s activities for managing stormwater within their jurisdiction or regulated area. In the event a TMDL study has been completed, approved by U.S. EPA prior to the effective date of the general permit, and assigns a wasteload allocation to an MS4 permittee, that permittee must document the WLA in their application and provide an outline of the best management practices to be implemented in the current permit term to address any needed reduction in loading from the MS4.

MPCA requires applicants submit their application materials and SWPPP document to MPCA for review. Prior to extension of coverage under the general permit, all application materials are placed on 30-day public notice by the MPCA, to ensure adequate opportunity for the public to comment on each permittee's stormwater management program. Upon extension of coverage by the MPCA, the permittees are to implement the activities described within their SWPPP, and submit annual reports to MPCA by June 30 of each year. These reports document the implementation activities which have been completed within the previous year, analyze implementation activities already installed, and outline any changes within the SWPPP from the previous year.

The MPCA has assigned nutrient loads for the TMDLs of this study to the regulated MS4s. The pollutant load allocations for each MS4 entity are outlined in section 4.0 of the TMDL. The MS4 General Permit, which became effective August 1, 2013, requires permittees to develop compliance schedules for any TMDL that received U.S. EPA-approval prior to the effective date of the General Permit. This schedule must identify BMPs that will be implemented over five-year permit term, timelines for their implementation, an assessment of progress, and a long term strategy for continued progress toward ultimately achieving those WLAs. Because this TMDL will be approved after the effective date of the General Permit, MS4s will not be required to report on WLAs contained in this TMDL until the effective date of the next General Permit, expected in 2018.

Reasonable assurance that the WLAs calculated for this TMDL will be implemented is provided by regulatory actions. According to 40 CFR 122.44(d)(1)(vii)(B), NPDES permit effluent limits must be consistent with assumptions and requirements of all WLAs in an approved TMDL. MPCA's stormwater program and its NPDES permit program are the state programs responsible for ensuring that implementation activities are initiated and maintained, and effluent limits are consistent with the WLAs calculated from the TMDLs. The NPDES program requires construction and industrial sites to create SWPPPs which summarize how stormwater will be minimized from construction and industrial sites.

Regulatory action also stems for RCWD requirements. In 2008 the RCWD adopted a new set of rules under which the district reviews projects within the watershed. RCWD has a long history of regulatory programs and has successfully implemented these new rules since adoption.

Specific rules expected to contribute to water quality improvement in the southwest area of the watershed include stormwater management (Rule C), erosion control (Rule D), wetland alteration (Rule F), and drainage systems (Rule I). Rule C requires volume control and water quality treatment for the first 1.1 inches of stormwater runoff from properties or roads being developed or redeveloped. Rule D requires that bare soils associated with construction projects be stabilized to prevent erosion associated with stormwater runoff. The RCWD also protects wetlands through Rule F and the implementation of the Wetland Conservation Act. The RCWD maintains permit review and inspection programs to ensure compliance of these rules.

RCWD takes a significant lead role for their lakes for implementing reductions to address the WLAs. As with LA sources they use information gained from all available nutrient loading studies, evaluate the feasibility of options for addressing these sources, seek or provide funding and implement actions. They have a proven track record at securing funding from a variety of sources.

6. MONITORING PLAN

6.1. Lake Monitoring

The RCWD maintains a comprehensive lake monitoring program, utilizing both in-house monitoring capabilities, and the Citizen Assisted Monitoring Program (CAMP), administered by Metropolitan Council Environmental Services. Water quality parameters include total phosphorus, chlorophyll-a, and clarity for all lakes and for some makes may also include depth profiles of temperature and dissolved oxygen.

Additional RCWD lake monitoring activities could, depending on available resources, include:

- Periodic plant surveys in each lake to assess changes in abundance and distribution of both native and invasive plant species
- Rough fish surveys to categorize impacts on internal phosphorus loading and native plant distribution

All water quality data will be submitted to the State's water quality database (EQuIS). Data will be also incorporated into the RCWD's *State of the Lakes* report.

6.2. Watershed and BMP Monitoring

The RCWD also maintains a watershed monitoring program. This program will continue to monitor concentrations of phosphorus flowing into the lakes for the various subwatersheds identified in this study. Water samples will be collected approximately every two weeks throughout the growing season and analyzed for total phosphorus. Data will be used to assess changes in watershed phosphorus loading over time, and in response to management practices. Data may also be used to further refine and calibrate the watershed loading model (P8) used in the TMDL. All water quality data will be submitted to the State's water quality database (EQuIS). Data will be also incorporated into the RCWD's *Stream Monitoring* report.

When technically feasible, assessment of individual BMPs will also be conducted. For example, if a large stormwater BMP were installed, pre- and post-outflow water quality and/or quantity monitoring may evaluate the effectiveness of the BMP.

7. IMPLEMENTATION STRATEGY

Lake Management Action Plans have been completed for each lake as part of the *2009 Southwest Urban Lakes Study*. These plans are already being actively used and provide the following:

- Detailed watershed background information
- Historic water quality and loading summaries
- Public input summaries
- Watershed management recommendations, including:
  - Field reconnaissance results identifying likely regional, local and site-specific retrofit opportunities
  - Summaries of potential BMP locations
  - Other actions to reduce external loading, including education needs and strategic partnerships
- Internal loading lake management recommendations, specifically carp management
- Recommended data and information collection

The RCWD conducts their work using adaptive management principles. This means learning from the results of actions taken via monitoring and evaluation and correcting course as needed.

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

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

The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [Minn. Statutes 2007, section 114D.25]. A detailed analysis of the cost to implement this TMDL was not conducted. However, as a rough approximation one can use some general results from BMP cost studies across the U.S. For example, a USEPA summary of several studies of predominantly developed urban landscapes showed a median cost of approximately $2,200 per pound total phosphorus removed per year (Foraste et al., 2012). Multiplying that by the needed 2,284 pound reduction for all the lakes in this study provides a total cost of approximately $5M.

8. PUBLIC PARTICIPATION

Stakeholder and public input was sought during the development of the original *2009 Southwest Urban Lakes Study*. Two public input meetings for each lake were conducted during the development of the lake Management Action Plans (MAPs). The first series of meetings, held in the summer of 2008, solicited input from citizens and LGU staff and officials regarding water quality concerns to further define impairments. At the second series of public meetings, held in January 2009, draft MAPs were reviewed, impairments described, and in-lake and watershed management strategies were summarized. Input received during the meetings as well as comments from LGU in response to draft MAPs were incorporated into the final MAPs.

Following the launch of the formal TMDL development, two stakeholder input meetings were held in June 2013 and in May 2014 to refine contributing areas to the impaired lakes, discuss load allocation strategies, and to discuss phosphorus reduction strategies. In addition an informal opportunity to comment on the draft TMDL report was provided. The following stakeholders were invited to meetings and were provided with an opportunity for comment:

- City of Arden Hills
- City of Blaine
- City of Circle Pines
- City of Columbia Heights
- City of Falcon Heights
- City of Fridley
- City of Lauderdale
- City of Lexington
- City of Lino Lakes
- City of Mounds View
- City of New Brighton
- City of Roseville
- City of Shoreview
- City of St. Anthony
- Anoka County
- Hennepin County
- Ramsey County
- MNDOT Metro
- University of Minnesota – Twin Cities, St. Paul Campus
- Rice Creek WD

In addition, an opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from September 22 – October 21, 2014.

9. LITERATURE CITED

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10. Appendix A: BATHTUB Input and Output Summary Tables

Table 25. Model calibration summary for the impaired lakes

Impaired Lake	BATHTUB TP Sedimentation Model	Calibration Mode	Calibration Factor
Island North	Canfield & Bachmann, Lakes	Added Internal Load	0.205 mg/m^2-day
Island South	Canfield & Bachmann, Lakes	Added Internal Load	0.347 mg/m^2-day
Little Johanna	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	1.51
Long South	Canfield & Bachmann, Reservoirs	Added Internal Load	0.14 mg/m^2-day
Moore East	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	2.405
Pike	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	1.097
Valentine	Canfield & Bachmann, Reservoirs	Increased TP Sedimentation Rate Calibration Factor	1.625

Table 26. Island Lake North Basin Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	**1**	**Island North**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	102.0	0.25	79.9%	102.0	0.35	80.0%

Table 27. Island Lake North Basin Calibrated Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**		**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	0.4436	0.1079	7.28E-04	0.25	0.24
2	1	1	Island South outflow	0.5188	0.1132	8.01E-04	0.25	0.22
PRECIPITATION				0.0752	0.0647	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				0.9624	0.2211	1.53E-03	0.18	0.23
***TOTAL INFLOW				1.0376	0.2858	1.53E-03	0.14	0.28
ADVECTIVE OUTFLOW				1.0376	0.2339	1.53E-03	0.17	0.23
***TOTAL OUTFLOW				1.0376	0.2339	1.53E-03	0.17	0.23
***EVAPORATION					0.0519	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				**Predicted TOTAL P**	**Outflow & Reservoir Concentrations**					
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	27.6	61.1%	9.55E+01	92.1%	0.35	256.2	62.3
2	1	1	Island South outflow	9.7	21.5%	6.87E+00	6.6%	0.27	86.0	18.8
PRECIPITATION				2.3	5.0%	1.27E+00	1.2%	0.50	34.9	30.0
INTERNAL LOAD				5.6	12.4%	0.00E+00		0.00		
TRIBUTARY INFLOW				37.4	82.6%	1.02E+02	98.8%	0.27	169.1	38.8
***TOTAL INFLOW				45.3	100.0%	1.04E+02	100.0%	0.22	158.4	43.6
ADVECTIVE OUTFLOW				23.8	52.7%	5.65E+01		0.32	102.0	23.0
***TOTAL OUTFLOW				23.8	52.7%	5.65E+01		0.32	102.0	23.0
***RETENTION				21.4	47.3%	5.00E+01		0.33		

Overflow Rate (m/yr)	3.1	Nutrient Resid. Time (yrs)	0.1451
Hydraulic Resid. Time (yrs)	0.2755	Turnover Ratio	6.9
Reservoir Conc (mg/m3)	102.0	Retention Coef.	0.473

Table 28. Island Lake North Basin TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:	**1**	**Island North**					
	Predicted Values--->			**Observed Values--->**			
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3		60.0	0.21	59.9%	102.0	0.35	80.0%

Table 29. Island Lake North Basin TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**	**1.00 years**		
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km²**	**hm³/yr**	**(hm3/yr)²**	**-**	**m/yr**
1	1	1	Direct drainage	0.4436	0.1079	7.28E-04	0.25	0.24
2	1	1	Island South outflow	0.5188	0.1132	8.01E-04	0.25	0.22
PRECIPITATION				0.0752	0.0647	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				0.9624	0.2211	1.53E-03	0.18	0.23
***TOTAL INFLOW				1.0376	0.2858	1.53E-03	0.14	0.28
ADVECTIVE OUTFLOW				1.0376	0.2339	1.53E-03	0.17	0.23
***TOTAL OUTFLOW				1.0376	0.2339	1.53E-03	0.17	0.23
***EVAPORATION					0.0519	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				**Predicted TOTAL P**		**Outflow & Reservoir Concentrations**				
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**(kg/yr)²**	**%Total**	**CV**	**mg/m³**	**kg/km²/yr**
1	1	1	Direct drainage	10.8	46.2%	1.46E+01	75.9%	0.35	100.0	24.3
2	1	1	Island South outflow	6.8	29.1%	3.34E+00	17.4%	0.27	60.0	13.1
PRECIPITATION				2.3	9.7%	1.27E+00	6.6%	0.50	34.9	30.0
INTERNAL LOAD				3.5	15.1%	0.00E+00		0.00		
TRIBUTARY INFLOW				17.6	75.3%	1.79E+01	93.4%	0.24	79.5	18.3
***TOTAL INFLOW				23.4	100.0%	1.92E+01	100.0%	0.19	81.7	22.5
ADVECTIVE OUTFLOW				14.0	60.1%	1.45E+01		0.27	60.0	13.5
***TOTAL OUTFLOW				14.0	60.1%	1.45E+01		0.27	60.0	13.5
***RETENTION				9.3	39.9%	9.10E+00		0.32		

Overflow Rate (m/yr)	3.1	Nutrient Resid. Time (yrs)	0.1656
Hydraulic Resid. Time (yrs)	0.2755	Turnover Ratio	6.0
Reservoir Conc (mg/m3)	60.0	Retention Coef.	0.399

Table 30. Island Lake South Basin Calibrated Model Predicted & Observed Values

Segment:	1	Island South				
	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	86.0	0.36	74.2%	86.0	0.26	74.2%

Table 31. Island Lake South Basin Calibrated Model Water and Phosphorus Balances

Overall Water Balance					Averaging Period =	1.00 years		
				Area	Flow	Variance	CV	Runoff
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	0.3423	0.0832	4.33E-04	0.25	0.24
PRECIPITATION				0.1765	0.1518	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				0.3423	0.0832	4.33E-04	0.25	0.24
***TOTAL INFLOW				0.5188	0.2350	4.33E-04	0.09	0.45
ADVECTIVE OUTFLOW				0.5188	0.1132	4.33E-04	0.18	0.22
***TOTAL OUTFLOW				0.5188	0.1132	4.33E-04	0.18	0.22
***EVAPORATION					0.1218	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				Predicted TOTAL P	Outflow & Reservoir Concentrations					
				Load		Load Variance			Conc	Export
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	21.3	43.5%	5.69E+01	89.0%	0.35	256.4	62.3
PRECIPITATION				5.3	10.8%	7.01E+00	11.0%	0.50	34.9	30.0
INTERNAL LOAD				22.4	45.7%	0.00E+00		0.00		
TRIBUTARY INFLOW				21.3	43.5%	5.69E+01	89.0%	0.35	256.4	62.3
***TOTAL INFLOW				49.0	100.0%	6.39E+01	100.0%	0.16	208.5	94.4
ADVECTIVE OUTFLOW				9.7	19.9%	1.68E+01		0.42	86.0	18.8
***TOTAL OUTFLOW				9.7	19.9%	1.68E+01		0.42	86.0	18.8
***RETENTION				39.3	80.1%	4.92E+01		0.18		

Overflow Rate (m/yr)	0.6	Nutrient Resid. Time (yrs)	0.4430
Hydraulic Resid. Time (yrs)	2.2295	Turnover Ratio	2.3
Reservoir Conc (mg/m3)	86.0	Retention Coef.	0.801

Table 32. Island Lake South Basin TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Island South**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	60.0	0.34	59.9%	86.0	0.26	74.2%

Table 33. Island Lake South Basin TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**		**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	0.3423	0.0832	4.33E-04	0.25	0.24
PRECIPITATION				0.1765	0.1518	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				0.3423	0.0832	4.33E-04	0.25	0.24
***TOTAL INFLOW				0.5188	0.2350	4.33E-04	0.09	0.45
ADVECTIVE OUTFLOW				0.5188	0.1132	4.33E-04	0.18	0.22
***TOTAL OUTFLOW				0.5188	0.1132	4.33E-04	0.18	0.22
***EVAPORATION					0.1218	0.00E+00	0.00	

Overall Mass Balance Based Upon				**Predicted**		**Outflow & Reservoir Concentrations**				
Component:				**TOTAL P**						
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	8.3	29.7%	8.65E+00	55.2%	0.35	100.0	24.3
PRECIPITATION				5.3	18.9%	7.01E+00	44.8%	0.50	34.9	30.0
INTERNAL LOAD				14.4	51.4%	0.00E+00		0.00		
TRIBUTARY INFLOW				8.3	29.7%	8.65E+00	55.2%	0.35	100.0	24.3
***TOTAL INFLOW				28.0	100.0%	1.57E+01	100.0%	0.14	119.1	54.0
ADVECTIVE OUTFLOW				6.8	24.3%	7.03E+00		0.39	60.0	13.1
***TOTAL OUTFLOW				6.8	24.3%	7.03E+00		0.39	60.0	13.1
***RETENTION				21.2	75.7%	1.38E+01		0.18		
	Overflow Rate (m/yr)			0.6		Nutrient Resid. Time (yrs)			0.5410	
	Hydraulic Resid. Time (yrs)			2.2295		Turnover Ratio			1.8	
	Reservoir Conc (mg/m3)			60.0		Retention Coef.			0.757	

Table 34. Little Lake Johanna Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	**1**	**Little Johanna**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	80.0	0.29	71.5%	80.0	0.33	71.6%

Table 35. Little Lake Johanna Calibrated Model Water and Phosphorus Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Direct drainage	2.2330	0.6322	2.50E-02	0.25	0.28
2	1	1	Oasis pond outflow	2.3822	0.7816	3.82E-02	0.25	0.33
3	1	1	Zimmerman pond outflow	2.2050	0.6552	2.68E-02	0.25	0.30
PRECIPITATION				0.0699	0.0601	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				6.8202	2.0690	9.00E-02	0.14	0.30
***TOTAL INFLOW				6.8901	2.1291	9.00E-02	0.14	0.31
ADVECTIVE OUTFLOW				6.8901	2.0809	9.00E-02	0.14	0.30
***TOTAL OUTFLOW				6.8901	2.0809	9.00E-02	0.14	0.30
***EVAPORATION					0.0482	0.00E+00	0.00	

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

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Direct drainage	151.8	35.9%	2.88E+03	38.5%	0.35	240.2	68.0
2	1	1	Oasis pond outflow	152.2	36.0%	2.90E+03	38.7%	0.35	194.7	63.9
3	1	1	Zimmerman pond outflow	117.0	27.7%	1.71E+03	22.9%	0.35	178.6	53.1
PRECIPITATION				2.1	0.5%	1.10E+00	0.0%	0.50	34.9	30.0
TRIBUTARY INFLOW				421.1	99.5%	7.49E+03	100.0%	0.21	203.5	61.7
***TOTAL INFLOW				423.2	100.0%	7.49E+03	100.0%	0.20	198.8	61.4
ADVECTIVE OUTFLOW				166.4	39.3%	3.13E+03		0.34	80.0	24.2
***TOTAL OUTFLOW				166.4	39.3%	3.13E+03		0.34	80.0	24.2
***RETENTION				256.8	60.7%	5.07E+03		0.28		

Overflow Rate (m/yr)	29.8	Nutrient Resid. Time (yrs)	0.0402
Hydraulic Resid. Time (yrs)	0.1022	Turnover Ratio	24.9
Reservoir Conc (mg/m3)	80.0	Retention Coef.	0.607

Table 36. Little Lake Johanna TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Little Johanna**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	40.0	0.23	42.1%	80.0	0.33	71.6%

Table 37. Little Lake Johanna TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**	**1.00**	**years**	
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	2.2330	0.6322	2.50E-02	0.25	0.28
2	1	1	Oasis pond outflow	2.3822	0.7816	3.82E-02	0.25	0.33
3	1	1	Zimmerman pond outflow	2.2050	0.6552	2.68E-02	0.25	0.30
PRECIPITATION				0.0699	0.0601	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				6.8202	2.0690	9.00E-02	0.14	0.30
***TOTAL INFLOW				6.8901	2.1291	9.00E-02	0.14	0.31
ADVECTIVE OUTFLOW				6.8901	2.0809	9.00E-02	0.14	0.30
***TOTAL OUTFLOW				6.8901	2.0809	9.00E-02	0.14	0.30
***EVAPORATION					0.0482	0.00E+00	0.00	

Overall Mass Balance Based Upon				**Predicted**		**Outflow & Reservoir Concentrations**				
Component:				**TOTAL P**						
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	65.7	42.7%	5.40E+02	53.5%	0.35	104.0	29.4
2	1	1	Oasis pond outflow	46.9	30.4%	2.75E+02	27.2%	0.35	60.0	19.7
3	1	1	Zimmerman pond outflow	39.3	25.5%	1.93E+02	19.1%	0.35	60.0	17.8
PRECIPITATION				2.1	1.4%	1.10E+00	0.1%	0.50	34.9	30.0
TRIBUTARY INFLOW				152.0	98.6%	1.01E+03	99.9%	0.21	73.4	22.3
***TOTAL INFLOW				154.1	100.0%	1.01E+03	100.0%	0.21	72.4	22.4
ADVECTIVE OUTFLOW				83.2	54.0%	5.70E+02		0.29	40.0	12.1
***TOTAL OUTFLOW				83.2	54.0%	5.70E+02		0.29	40.0	12.1
***RETENTION				70.8	46.0%	5.45E+02		0.33		
	Overflow Rate (m/yr)			29.8		Nutrient Resid. Time (yrs)			0.0552	
	Hydraulic Resid. Time (yrs)			0.1022		Turnover Ratio			18.1	
	Reservoir Conc (mg/m3)			40.0		Retention Coef.			0.460	

Table 38. Long Lake South Basin Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment:		**1**	**Long Lake South**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	54.0	0.20	55.3%	54.0	0.34	55.3%

Table 39. Long Lake South Basin Calibrated Model Water and Phosphorus Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Direct drainage	6.2138	1.5901	1.58E-01	0.25	0.26
2	1	1	Pike Lake outflow	21.1054	5.3791	1.81E+00	0.25	0.25
3	1	1	Valentine Lake outflow	10.2770	2.2560	3.18E-01	0.25	0.22
4	1	1	Johanna Lake outflow	14.4735	3.5790	8.01E-01	0.25	0.25
PRECIPITATION				0.4810	0.4137	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				52.0697	12.8042	3.09E+00	0.14	0.25
***TOTAL INFLOW				52.5507	13.2179	3.09E+00	0.13	0.25
ADVECTIVE OUTFLOW				52.5507	12.8860	3.09E+00	0.14	0.25
***TOTAL OUTFLOW				52.5507	12.8860	3.09E+00	0.14	0.25
***EVAPORATION					0.3319	0.00E+00	0.00	

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

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Direct drainage	387.6	32.7%	1.88E+04	48.3%	0.35	243.8	62.4
2	1	1	Pike Lake outflow	489.5	41.3%	1.74E+04	44.7%	0.27	91.0	23.2
3	1	1	Valentine Lake outflow	157.9	13.3%	1.81E+03	4.6%	0.27	70.0	15.4
4	1	1	Johanna Lake outflow	110.9	9.4%	8.92E+02	2.3%	0.27	31.0	7.7
PRECIPITATION				14.4	1.2%	5.21E+01	0.1%	0.50	34.9	30.0
INTERNAL LOAD				24.6	2.1%	0.00E+00		0.00		
TRIBUTARY INFLOW				1146.0	96.7%	3.89E+04	99.9%	0.17	89.5	22.0
***TOTAL INFLOW				1185.0	100.0%	3.89E+04	100.0%	0.17	89.7	22.5
ADVECTIVE OUTFLOW				695.7	58.7%	3.05E+04		0.25	54.0	13.2
***TOTAL OUTFLOW				695.7	58.7%	3.05E+04		0.25	54.0	13.2
***RETENTION				489.3	41.3%	2.37E+04		0.31		

Overflow Rate (m/yr)	26.8	Nutrient Resid. Time (yrs)	0.0754
Hydraulic Resid. Time (yrs)	0.1284	Turnover Ratio	13.3
Reservoir Conc (mg/m3)	54.0	Retention Coef.	0.413

Table 40. Long Lake South Basin TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Long Lake South**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	40.0	0.17	42.1%	54.0	0.34	55.3%

Table 41. Long Lake South Basin TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**		**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	6.2138	1.5901	1.58E-01	0.25	0.26
2	1	1	Pike Lake outflow	21.1054	5.3791	1.81E+00	0.25	0.25
3	1	1	Valentine Lake outflow	10.2770	2.2560	3.18E-01	0.25	0.22
4	1	1	Johanna Lake outflow	14.4735	3.5790	8.01E-01	0.25	0.25
PRECIPITATION				0.4810	0.4137	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				52.0697	12.8042	3.09E+00	0.14	0.25
***TOTAL INFLOW				52.5507	13.2179	3.09E+00	0.13	0.25
ADVECTIVE OUTFLOW				52.5507	12.8860	3.09E+00	0.14	0.25
***TOTAL OUTFLOW				52.5507	12.8860	3.09E+00	0.14	0.25
***EVAPORATION					0.3319	0.00E+00	0.00	

Overall Mass Balance Based Upon				**Predicted**		**Outflow & Reservoir Concentrations**				
Component:				**TOTAL P**						
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	195.6	24.3%	4.78E+03	32.7%	0.35	123.0	31.5
2	1	1	Pike Lake outflow	322.7	40.2%	7.55E+03	51.7%	0.27	60.0	15.3
3	1	1	Valentine Lake outflow	135.4	16.8%	1.33E+03	9.1%	0.27	60.0	13.2
4	1	1	Johanna Lake outflow	110.9	13.8%	8.92E+02	6.1%	0.27	31.0	7.7
PRECIPITATION				14.4	1.8%	5.21E+01	0.4%	0.50	34.9	30.0
INTERNAL LOAD				24.6	3.1%	0.00E+00		0.00		
TRIBUTARY INFLOW				764.6	95.1%	1.46E+04	99.6%	0.16	59.7	14.7
***TOTAL INFLOW				803.7	100.0%	1.46E+04	100.0%	0.15	60.8	15.3
ADVECTIVE OUTFLOW				515.3	64.1%	1.36E+04		0.23	40.0	9.8
***TOTAL OUTFLOW				515.3	64.1%	1.36E+04		0.23	40.0	9.8
***RETENTION				288.3	35.9%	8.54E+03		0.32		
	Overflow Rate (m/yr)			26.8		Nutrient Resid. Time (yrs)			0.0823	
	Hydraulic Resid. Time (yrs)			0.1284		Turnover Ratio			12.1	
	Reservoir Conc (mg/m3)			40.0		Retention Coef.			0.359	

Table 42. Moore Lake East Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Moore East**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	44.0	0.39	46.2%	44.0	0.21	46.2%

Table 43. Moore Lake East Calibrated Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**		**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	2.4636	0.5478	1.88E-02	0.25	0.22
PRECIPITATION				0.1195	0.1028	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				2.4636	0.5478	1.88E-02	0.25	0.22
***TOTAL INFLOW				2.5831	0.6506	1.88E-02	0.21	0.25
ADVECTIVE OUTFLOW				2.5831	0.5681	1.88E-02	0.24	0.22
***TOTAL OUTFLOW				2.5831	0.5681	1.88E-02	0.24	0.22
***EVAPORATION					0.0825	0.00E+00	0.00	

Overall Mass Balance Based Upon				**Predicted**		**Outflow & Reservoir Concentrations**				
Component:				**TOTAL P**						
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	133.8	97.4%	2.24E+03	99.9%	0.35	244.2	54.3
PRECIPITATION				3.6	2.6%	3.21E+00	0.1%	0.50	34.9	30.0
TRIBUTARY INFLOW				133.8	97.4%	2.24E+03	99.9%	0.35	244.2	54.3
***TOTAL INFLOW				137.4	100.0%	2.24E+03	100.0%	0.34	211.2	53.2
ADVECTIVE OUTFLOW				25.0	18.2%	1.56E+02		0.50	44.0	9.7
***TOTAL OUTFLOW				25.0	18.2%	1.56E+02		0.50	44.0	9.7
***RETENTION				112.4	81.8%	1.64E+03		0.36		
			Overflow Rate (m/yr)	4.8		Nutrient Resid. Time (yrs)			0.0631	
			Hydraulic Resid. Time (yrs)	0.3471		Turnover Ratio			15.8	
			Reservoir Conc (mg/m3)	44.0		Retention Coef.			0.818	

Table 44. Moore Lake East TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Moore East**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	40.0	0.38	42.1%	44.0	0.21	46.2%

Table 45. Moore Lake East TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**		**1.00 years**	
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	2.4636	0.5478	1.88E-02	0.25	0.22
PRECIPITATION				0.1195	0.1028	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				2.4636	0.5478	1.88E-02	0.25	0.22
***TOTAL INFLOW				2.5831	0.6506	1.88E-02	0.21	0.25
ADVECTIVE OUTFLOW				2.5831	0.5681	1.88E-02	0.24	0.22
***TOTAL OUTFLOW				2.5831	0.5681	1.88E-02	0.24	0.22
***EVAPORATION					0.0825	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				**Predicted TOTAL P**	**Outflow & Reservoir Concentrations**					
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	111.2	96.9%	1.55E+03	99.8%	0.35	203.0	45.1
PRECIPITATION				3.6	3.1%	3.21E+00	0.2%	0.50	34.9	30.0
TRIBUTARY INFLOW				111.2	96.9%	1.55E+03	99.8%	0.35	203.0	45.1
***TOTAL INFLOW				114.8	100.0%	1.55E+03	100.0%	0.34	176.4	44.4
ADVECTIVE OUTFLOW				22.7	19.8%	1.26E+02		0.49	40.0	8.8
***TOTAL OUTFLOW				22.7	19.8%	1.26E+02		0.49	40.0	8.8
***RETENTION				92.0	80.2%	1.11E+03		0.36		

Overflow Rate (m/yr)	4.8	Nutrient Resid. Time (yrs)	0.0688
Hydraulic Resid. Time (yrs)	0.3471	Turnover Ratio	14.5
Reservoir Conc (mg/m3)	40.0	Retention Coef.	0.802

Table 46. Pike Lake Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	1	Pike				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	91.0	0.24	76.2%	91.0	0.24	76.2%

Table 47. Pike Lake Calibrated Model Water and Phosphorus Balances

Note that the 7th Street Pond is referred to the Hansen Park Pond in the rest of the report

Overall Water Balance					Averaging Period =		1.00 years	
				Area	Flow	Variance	CV	Runoff
Trb	Type	Seg	Name	km^2	hm^3/yr	$(hm3/yr)^2$	-	m/yr
1	1	1	Direct drainage	3.6382	0.7740	3.74E-02	0.25	0.21
2	1	1	7th Street pond outflow	17.3167	4.5795	1.31E+00	0.25	0.26
PRECIPITATION				0.1505	0.1294	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				20.9549	5.3535	1.35E+00	0.22	0.26
***TOTAL INFLOW				21.1054	5.4829	1.35E+00	0.21	0.26
ADVECTIVE OUTFLOW				21.1054	5.3791	1.35E+00	0.22	0.25
***TOTAL OUTFLOW				21.1054	5.3791	1.35E+00	0.22	0.25
***EVAPORATION					0.1038	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				Predicted TOTAL P	Outflow & Reservoir Concentrations					
				Load		Load Variance			Conc	Export
Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
1	1	1	Direct drainage	193.4	22.8%	4.67E+03	8.1%	0.35	249.8	53.2
2	1	1	7th Street pond outflow	650.7	76.7%	5.29E+04	91.9%	0.35	142.1	37.6
PRECIPITATION				4.5	0.5%	5.10E+00	0.0%	0.50	34.9	30.0
TRIBUTARY INFLOW				844.0	99.5%	5.76E+04	100.0%	0.28	157.7	40.3
***TOTAL INFLOW				848.5	100.0%	5.76E+04	100.0%	0.28	154.8	40.2
ADVECTIVE OUTFLOW				489.6	57.7%	2.78E+04		0.34	91.0	23.2
***TOTAL OUTFLOW				489.6	57.7%	2.78E+04		0.34	91.0	23.2
***RETENTION				358.9	42.3%	2.05E+04		0.40		

Overflow Rate (m/yr)	35.7	Nutrient Resid. Time (yrs)	0.0302
Hydraulic Resid. Time (yrs)	0.0523	Turnover Ratio	33.1
Reservoir Conc (mg/m3)	91.0	Retention Coef.	0.423

Table 48. Pike Lake TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:	**1**	**Pike**					
	Predicted Values--->			**Observed Values--->**			
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3		60.0	0.23	59.9%	91.0	0.24	76.2%

Table 49. Pike Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Note that the 7th Street Pond is referred to the Hansen Park Pond in the rest of the report

Overall Water Balance					**Averaging Period =**		**1.00 years**	
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	3.6382	0.7740	3.74E-02	0.25	0.21
2	1	1	7th Street pond outflow	17.3167	4.5795	1.31E+00	0.25	0.26
PRECIPITATION				0.1505	0.1294	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				20.9549	5.3535	1.35E+00	0.22	0.26
***TOTAL INFLOW				21.1054	5.4829	1.35E+00	0.21	0.26
ADVECTIVE OUTFLOW				21.1054	5.3791	1.35E+00	0.22	0.25
***TOTAL OUTFLOW				21.1054	5.3791	1.35E+00	0.22	0.25
***EVAPORATION					0.1038	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				**Predicted TOTAL P**		**Outflow & Reservoir Concentrations**				
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	78.2	15.8%	7.64E+02	3.5%	0.35	101.0	21.5
2	1	1	7th Street pond outflow	412.2	83.3%	2.12E+04	96.5%	0.35	90.0	23.8
PRECIPITATION				4.5	0.9%	5.10E+00	0.0%	0.50	34.9	30.0
TRIBUTARY INFLOW				490.3	99.1%	2.20E+04	100.0%	0.30	91.6	23.4
***TOTAL INFLOW				494.8	100.0%	2.20E+04	100.0%	0.30	90.3	23.4
ADVECTIVE OUTFLOW				322.7	65.2%	1.16E+04		0.33	60.0	15.3
***TOTAL OUTFLOW				322.7	65.2%	1.16E+04		0.33	60.0	15.3
***RETENTION				172.2	34.8%	5.76E+03		0.44		

Overflow Rate (m/yr)	35.7	Nutrient Resid. Time (yrs)	0.0341
Hydraulic Resid. Time (yrs)	0.0523	Turnover Ratio	29.3
Reservoir Conc (mg/m3)	60.0	Retention Coef.	0.348

Table 50. Lake Valentine Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**Valentine**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	70.0	0.32	66.3%	70.0	0.32	66.3%

Table 51. Lake Valentine Calibrated Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**		**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km²**	**hm³/yr**	**(hm3/yr)²**	**-**	**m/yr**
1	1	1	Direct drainage	6.5217	1.4767	1.36E-01	0.25	0.23
2	1	1	Karth Lake outflow	0.5486	0.1144	8.18E-04	0.25	0.21
3	1	1	Round Lake outflow	1.9106	0.3871	9.37E-03	0.25	0.20
4	1	1	Island Lake North outflow	1.0376	0.2339	3.42E-03	0.25	0.23
PRECIPITATION				0.2585	0.2223	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				10.0185	2.2121	1.50E-01	0.18	0.22
***TOTAL INFLOW				10.2770	2.4344	1.50E-01	0.16	0.24
ADVECTIVE OUTFLOW				10.2770	2.2560	1.50E-01	0.17	0.22
***TOTAL OUTFLOW				10.2770	2.2560	1.50E-01	0.17	0.22
***EVAPORATION					0.1784	0.00E+00	0.00	

Overall Mass Balance Based Upon				**Predicted**		**Outflow & Reservoir Concentrations**				
Component:				**TOTAL P**						
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**(kg/yr)²**	**%Total**	**CV**	**mg/m³**	**kg/km²/yr**
1	1	1	Direct drainage	370.1	86.9%	1.71E+04	99.5%	0.35	250.6	56.8
2	1	1	Karth Lake outflow	6.2	1.5%	2.77E+00	0.0%	0.27	54.0	11.3
3	1	1	Round Lake outflow	17.8	4.2%	2.30E+01	0.1%	0.27	46.0	9.3
4	1	1	Island Lake North outflow	23.9	5.6%	4.13E+01	0.2%	0.27	102.0	23.0
PRECIPITATION				7.8	1.8%	1.50E+01	0.1%	0.50	34.9	30.0
TRIBUTARY INFLOW				418.0	98.2%	1.72E+04	99.9%	0.31	189.0	41.7
***TOTAL INFLOW				425.7	100.0%	1.72E+04	100.0%	0.31	174.9	41.4
ADVECTIVE OUTFLOW				157.9	37.1%	3.87E+03		0.39	70.0	15.4
***TOTAL OUTFLOW				157.9	37.1%	3.87E+03		0.39	70.0	15.4
***RETENTION				267.8	62.9%	9.97E+03		0.37		
	Overflow Rate (m/yr)			8.7		Nutrient Resid. Time (yrs)			0.0444	
	Hydraulic Resid. Time (yrs)			0.1199		Turnover Ratio			22.5	
	Reservoir Conc (mg/m3)			70		Retention Coef.			0.629	

Table 52. Lake Valentine TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	**1**	**Valentine**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	60.0	0.31	59.9%	70.0	0.32	66.3%

Table 53. Lake Valentine TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water Balance					**Averaging Period =**		**1.00**	**years**
				Area	**Flow**	**Variance**	**CV**	**Runoff**
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Direct drainage	6.5217	1.4767	1.36E-01	0.25	0.23
2	1	1	Karth Lake outflow	0.5486	0.1144	8.18E-04	0.25	0.21
3	1	1	Round Lake outflow	1.9106	0.3871	9.37E-03	0.25	0.20
4	1	1	Island Lake North outflow	1.0376	0.2339	3.42E-03	0.25	0.23
PRECIPITATION				0.2585	0.2223	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				10.0185	2.2121	1.50E-01	0.18	0.22
***TOTAL INFLOW				10.2770	2.4344	1.50E-01	0.16	0.24
ADVECTIVE OUTFLOW				10.2770	2.2560	1.50E-01	0.17	0.22
***TOTAL OUTFLOW				10.2770	2.2560	1.50E-01	0.17	0.22
***EVAPORATION					0.1784	0.00E+00	0.00	

Overall Mass Balance Based Upon				**Predicted**		**Outflow & Reservoir Concentrations**				
Component:				**TOTAL P**						
				Load		**Load Variance**			**Conc**	**Export**
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Direct drainage	288.7	86.3%	1.04E+04	99.5%	0.35	195.5	44.3
2	1	1	Karth Lake outflow	6.2	1.8%	2.77E+00	0.0%	0.27	54.0	11.3
3	1	1	Round Lake outflow	17.8	5.3%	2.30E+01	0.2%	0.27	46.0	9.3
4	1	1	Island Lake North outflow	14.0	4.2%	1.43E+01	0.1%	0.27	60.0	13.5
PRECIPITATION				7.8	2.3%	1.50E+01	0.1%	0.50	34.9	30.0
TRIBUTARY INFLOW				326.7	97.7%	1.05E+04	99.9%	0.31	147.7	32.6
***TOTAL INFLOW				334.5	100.0%	1.05E+04	100.0%	0.31	137.4	32.5
ADVECTIVE OUTFLOW				135.3	40.5%	2.70E+03		0.38	60.0	13.2
***TOTAL OUTFLOW				135.3	40.5%	2.70E+03		0.38	60.0	13.2
***RETENTION				199.1	59.5%	5.72E+03		0.38		

Overflow Rate (m/yr)	8.7	Nutrient Resid. Time (yrs)	0.0485
Hydraulic Resid. Time (yrs)	0.1199	Turnover Ratio	20.6
Reservoir Conc (mg/m3)	60.0	Retention Coef.	0.595

11. Appendix B: P8 Inputs and Assumptions

Table 54. P8 Model Subwatershed Network

Subwatershed Name	Contributing subwatersheds
Hansen Park Pond	Hansen Park Pond Shed, Jones Lake Outflow, SILVER LAKE Outflow
Cleveland C2 Pond	Cleveland C2 Pond Shed (including Oasis Pond Shed), Langton Lake Outflow
Island North	Island North Shed, Island South Lake Outflow
Island South	Island South shed
Johanna	Johanna shed, Little Johanna Outflow, Josephine Lake Outflow, Richmond Pond Outflow
Jones	Jones Shed, Poplar Lake Outflow, Cleveland C2 Outflow
Josephine	Josephine shed, Little Josephine Lake outflow
Karth	Karth shed
Langton	Langton Shed
Little Johanna	Little Johanna Shed, Oasis Lake Outflow, Zimmerman Lake Outflow
Little Josephine	Little Josephine Shed
Long South	Long Lake South Shed, Pike Lake Outflow, Valentine Lake Outflow, Johanna Lake Outflow
Moore East	Moore East Shed
Oasis	Oasis Shed
Pike	Pike Shed, Hansen Park Pond Outflow
Poplar	Poplar Shed
Richmond Pond	Richmond Pond Shed
Round	Round shed
Valentine	Valentine Shed, Karth Lake Outflow, Round Lake Outflow, North Island Lake outflow
Zimmerman	Zimmerman Shed

Table 55. P8 Model Subwatershed Characteristics and Assumptions

Subwatershed	Drainage area (ac)	Pervious CN	Disconnected % Impervious	Connected % Impervious
Hansen Park Pond	1153.95	65	0.0695	0.3936
Cleveland C2 Pond	321.61	75	0.1286	0.7285
Island North	109.60	73	0.0714	0.4045
Island South	84.59	73	0.0714	0.4045
Johanna	710.34	69	0.0779	0.4415
Jones	1788.71	66	0.0810	0.4588
Josephine	401.69	66	0.0746	0.4226
Karth	115.03	71	0.0727	0.4122
Langton	215.84	66	0.0953	0.5402
Little Johanna	551.80	61	0.0860	0.4875
Little Josephine	267.24	70	0.0703	0.3982
Long South	1535.45	64	0.0772	0.4373
Moore East	608.77	61	0.0670	0.3795
Oasis	581.71	70	0.1001	0.5674
Pike	899.03	66	0.0633	0.3587
Poplar	38.09	77	0.1068	0.6054
Richmond Pond	108.87	68	0.0675	0.3826
Round	341.63	77	0.0816	0.4626
Valentine	1611.55	68	0.0673	0.3812
Zimmerman	531.64	70	0.0915	0.5185

Assumptions:

- Impervious runoff coefficient = 0.9
- Indirectly connected impervious = 15% of total
- Direct connected impervious = 85% of total

Table 56. P8 Model Pond Configuration Assumptions and Output

	Permanent Pool			Flood Pool		Bottom	P8 Output
Device	Surface Area (ac)	Mean Depth (ft)	Volume (ac-ft)	Surface Area (ac)	Volume (ac-ft)	Area (ac)	TP Removal (%)
Oasis	6.94	2	13.88	7.63	3.82	3.5	20.2%
Richmond Pond	11.59	2	23.18	12.75	6.37	5.8	33.1%
Hansen Park Pond	5.37	2	10.74	5.91	2.95	2.7	16.0%
Cleveland C2 Pond	3.18	2	6.36	3.50	1.75	1.6	17.4%
Jones	37.49	0.8	29.992	41.24	20.62	18.7	24.5%
Langton	23.54	1.64	38.606	25.89	12.95	11.8	30.9%
Poplar	12.65	1.64	20.746	13.92	6.96	6.3	34.3%
Zimmerman	13.24	3.28	43.427	14.56	7.28	6.6	27.3%

Assumptions:

- Outlet modeled as 48" orifice
- Where unknown, maximum depth = 4 feet and mean depth = 2 feet