

2023 WATER MONITORING ANNUAL REPORT



Prepared Apri<u>l 2023</u>



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TERMS

Best management practices (BMPs): Practices that protect water quality.

Chloride: Small amounts of chlorides are required for normal cell functions in plants and animals, but chloride from de-icing and water-softener salt that gets into lakes and streams can be toxic to some aquatic life. The standard for chloride in Minnesota lakes and streams is 230 mg/l for chronic levels. That is the standard level used in this report.

Chlorophyll a: Chlorophyll *a* measures the amount of algae in a lake. Large amounts of algae, which cause green scum and odors, are a symptom of degraded water quality.

Eutrophication: Eutrophication describes a situation where a lake or other body of water has excessive nutrients and minerals, frequently due to polluted runoff. Nutrient excess can lead to dense plant growth and cause stress to animal life due to lack of oxygen.

Orthophosphate: The form of phosphorus that is readily available for use by algae and other aquatic plants for growth.

PFAS (perfluoroalkyl substances): Polluting substances used in a variety of industrial, agricultural, military, and commercial product applications.

Phosphorus: Phosphorus is a nutrient that is essential for plant life, but excessive phosphorus degrades water quality. Common sources of phosphorus in lakes are fertilizers and organic wastes from runoff and soil erosion.

Secchi disc: The clarity or transparency of water is measured by lowering a "Secchi disc" (usually black and white) into the water until it is no longer visible from the surface. The greater the "Secchi depth," the more transparent the water.

Tiered aquatic life uses (TALU): The Minnesota Pollution Control Agency's TALU framework is a significant revision to the aquatic life use classification in the state's water quality standards and is built on existing water quality standards to improve how water quality in streams and rivers are monitored and managed.

Total suspended solids: Particulate matter, including soils, metals, organic materials, and debris suspended in a moving body of water.

STATE STANDARDS

The following information on how Minnesota standards for water quality are determined is taken from the Minnesota Pollution Control Agency's *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List.*

- Total phosphorus and chlorophyll a in lakes: Data used for phosphorus and chlorophyll a calculations are limited to those collected from the upper most 3 meters of the water column (surface). If more than one sample is collected in a lake per day, these values are averaged to yield a daily average value. Following this step, all June to September data for the 10-year assessment window are averaged to determine mean summer values for total phosphorus, corrected chlorophyll a, and Secchi depth. These values are then compared to the standards and the assessment is made.
- **Conventional pollutants (total suspended solids [TSS]):** A stream is considered to exceed the standard for TSS if (1) the standard is exceeded more than 10% of the days of the assessment season (April through September) as determined from a data set that gives an unbiased representation of conditions over the assessment season, and (2) there are at least three such measurements exceeding the standard.
- Aquatic life toxicity-based standards (chlorides): Aquatic life toxicity-based chronic water quality standards are written as 4-day average concentrations. In some cases, pollutant concentrations can be quite variable over such periods, depending on factors such as the type and size of the water body, weather and flow conditions, and the source and nature of the pollutant. For example, chloride concentrations in lakes, streams, and wetlands are relatively stable during low-flow conditions over a 4-day period, while pesticide concentrations during storm events in small streams can vary greatly in that same amount of time. The chloride values presented in this report represent average water column concentrations.

Measuring water clarity with a Secchi disc

This report presents annual historical monitoring data, providing an overall water quality assessment of lakes and streams within the Ramsey-Washington Metro Watershed District (RWMWD or the District). It includes an assessment of 16 lakes and ponds and five streams or conveyances, with a primary focus on total phosphorus, orthophosphate, chlorophyll *a*, Secchi disk depth (lakes only), total suspended solids, and chloride. Data also includes nitrogen in streams. Nitrogen loads contributed by streams may influence the ecological status of aquatic-plant-dominated shallow lakes, and there are many shallow lakes in the District. Chloride is also a pollutant of increasing concern as deicing salt used on impervious areas has the potential to lead to high chloride concentrations in ponds, lakes, and streams, particularly during winter and spring months.

This report includes a section on best-management practices (BMPs) constructed at various locations in the watershed. BMPs are also discussed with lake and stream assessments. Unlike ponds, which settle phosphorus attached to particulate sediment, these BMPs are designed to remove both particulate and dissolved phosphorus. While ponds are still a dominant feature in the District and remove high fractions of particulate pollutants, their phosphorus-removal performance is limited. For this reason, one of the primary BMPs installed to meet total maximum daily load (TMDL) requirements is filtration-type BMPs. Many of the filtration-type BMPs with media designed to bind dissolved phosphorus are still considered somewhat experimental; hence, an assessment of the lifespan, performance, and effectiveness of these systems is warranted. The BMP section will also cover other unique BMPs within the District, such as an alum treatment plant and a pond that received an iron filing application. The District also constructs infiltration BMPs, but due to a lack of monitoring data, they are not discussed in this report.

The report is organized by resource type or subject.

- Chapter 3 includes the most recent and historical lake data, water quality trends, a
 discussion of in-lake management actions and actions in the tributary watershed, and
 an overall assessment.
- Chapter 4 includes recent and historical monitoring data for streams and conveyances, an overall assessment, a discussion of water quality trends, and a description of relevant management actions.
- Chapter 5 provides the results of various monitored BMPs throughout the District.
- Chapter 6 discusses contaminants of emerging concern in the District, including PFAS (perfluoroalkyl), chloride, and mercury.
- Chapters 7 and 8 describe fisheries and aquatic vegetation management strategies the District has used to help improve water quality.

Overall, there is a long-term trend of improving water quality for eutrophication parameters for District lakes. A qualitative review of the figures in Chapter 3 suggests that in 2023, water quality improved in Carver Lake and Lake Owasso, while water quality was worse for Kohlman Lake. For monitored streams (Battle Creek, Fish Creek, Kohlman Creek, Beltline Interceptor, and Gervais Creek), there is also a long-term trend of improving water quality; however, those improvements appear to have plateaued, and trends are potentially starting to worsen again over the last 10 years. Although the period of record for many of these water bodies is short, it appears that chloride concentrations in District lakes and streams are either worsening or stable rather than improving.

Long-term water quality improvements in District lakes and streams suggest that the implementation of numerous BMPs has been successful; however, changes in precipitation may have also contributed to improvements in the water quality of District water bodies. The next generation of BMPs has been implemented over the past two decades to begin removing dissolved phosphorus in addition to particulate phosphorus. A summary of these BMPs is below:

- The Beam Avenue filter, an iron-enhanced sand filter, was first monitored in 2009, with total phosphorus removal ranging from around 70 to 93% and orthophosphate removal ranging from 10 to 80% from 2009 to 2018. Total phosphorus and orthophosphate performance have been variable from 2021 to 2023. This could be due to three drought years and media replaced closest to the inlet in 2022.
- The Woodlyn Avenue iron-enhanced sand-type vegetative filter was monitored from 2012 to 2018. During that period, total phosphorus removal ranged from 22 to 75%, with the most recent removal in 2018 being 75%. Orthophosphate removal during the monitoring period was as high as 90%, but in 2018, the percent removal was 0. In 2022, the BMP was monitored again and had over 90% removal for total phosphorus, orthophosphate, and total suspended solids. One potential explanation is that 2022 was a drought year with small rain events, so the potential for phosphorus release was low. In 2023, the performance once again declined, indicating that 2022 was not an accurate demonstration of the BMP and that media replacement may be required.
- **Three spent-lime media filtration type BMPs** have been constructed in the District. It is instructive to compare the performance of these systems to the iron-enhanced sand filters and critically evaluate them both as it is still not clear which type of media performs best; each has positive and negative attributes. The Wakefield Experimental Filter (Wakefield cell) was monitored from 2012 to 2016 and had annual average total phosphorus removal ranging from 41 to 80%, orthophosphate removal ranging from 67 to 86%, and total suspended solids removal from 0 to 77%. Influent total phosphorus, orthophosphate, and total suspended solids removal at the Frost Kennard Filter decreased from 2018 to 2019. In 2022 and 2023, the filter had mixed removal performance, which could be due to drought or media lifespan. The other spent-lime BMP, Willow Pond, is new and is just beginning to be monitored. Monitoring of the Frost Kennard filter will continue in 2024, and additional "start-up" monitoring will be conducted for Willow Pond in 2024.
- In 2022, the Wakefield cell's spent-lime media was replaced with iron and granite sand media. The performance of the filter for phosphorus and orthophosphate was mixed with an average removal of 9% and 19%, respectively. Total suspended solids performance improved over the year, but the filter still had minimal removals, with two events releasing suspended solids. In 2023, performance increased to over 70% total phosphorus, orthophosphate, and total suspended solids removal. One potential reason for the increased performance is that the new media was not washed properly and contained additional solids at the time of installation.

- The Tanners Lake alum treatment facility deserves some mention as it has performed very reliably and is likely the primary reason that Tanners Lake has been taken off the impaired waters list and also why Battle Creek Lake water quality has improved notably. Since the beginning of operation in 1998, the average annual total phosphorus removal has ranged from 48 to 91%, with the removals from 2015 to 2019 ranging from 78–89%. Total phosphorus removal declined in the past 3 years from 2021 to 2023. One potential reason could be the low-flow conditions from the drought that caused the plant to be shut down for part of 2023.
- The Shoreview Commons Pond has a history of internal loading. In February 2021, iron filings were applied to the frozen lake. The application of iron on ice allows the filings to be equally distributed as the ice melts. The pond was monitored from 2019 to 2023 to evaluate the impacts of the iron-filing application. Orthophosphate and total suspended solids removal were similar pre- and post-filing. Overall, there are unclear trends in the pre- and post-filing application due to external circumstances, including wet/dry years and the installation of a fountain or aerator in the pond.

The following are monitoring recommendations for future annual reports.

1. Chloride

- a. Continue to incorporate chloride monitoring into all routine water quality monitoring.
- b. Continue annual monitoring of water bodies, including ponds, ditches, and creeks, on a rotating basis to better understand where the chloride hotspots are within the RWMWD. In 2023, ice-out chloride monitoring was continued (see Chapter 6), and monitoring in water bodies is planned to continue in 2024.
- c. Measure specific conductance when measuring chloride to develop a relationship between chloride and specific conductance. In the future, specific conductance may be used as a surrogate for chloride by developing a regression between the two parameters.

2. Streams

 a. Continue monitoring the water quality of streams (at minimum, total phosphorus, total dissolved phosphorus, orthophosphate, total Kjeldahl nitrogen, nitrate plus nitrite, total suspended solids, chloride, and chlorophyll *a*). Water quality monitoring will have value even if the flow cannot be monitored.

3. BMPs

- a. A rotating monitoring schedule for the filtration-type BMPs constructed in the District has been developed to document their performance. A rotating schedule will allow for a more widespread monitoring effort when new BMPs come online. It is important to reevaluate the BMP monitoring schedule annually.
- b. The media of the following BMPs needs further evaluation in 2024 or later (another year of monitoring may be appropriate to confirm whether these filters are performing as designed):
 - i. Woodlyn Avenue iron-enhanced sand filter
 - ii. Wakefield Lake experiemental iron and granite sand filter
 - iii. Willow Pond spent-lime filter

3. LAKE WATER QUALITY

BATTLE CREEK LAKE

Minnesota Pollution Control Agency (MPCA) designations	Shallow lake; "non-support" of aqutic life (chloride)
Tributary area	2,638 acres
Surface area	103 acres
Average/maximum depth	4 feet/15 feet
RWMWD nutrient classification ¹	At risk
Accountable municipalities	Landfall, Oakdale, Woodbury, Washington County
Downstream water body	Battle Creek

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Battle Creek Lake is a shallow lake in Washington County that receives flows from Tanners Lake and outlets to Battle Creek. The lake is used for a variety of recreational purposes, including motor boating, canoeing, fishing, picnicking, and aesthetic viewing. A public boat access is located at the lake's southeast corner in Shawnee Park.

Battle Creek Lake is on the MPCA's impairment list for mercury (aquatic consumption) and chloride (aquatic life). A statewide mercury TMDL was completed in 2007, and the Twin Cities Metro Area Chloride TMDL was completed in 2016. In 2014, the lake was removed from the MPCA's impaired waters list for excess nutrients.

Battle Creek Lake has been monitored annually for phosphorus, chlorophyll a, and Secchi disc depth from 1997 to 2023; it has been monitored annually for chloride since 2015. In 2023, the lake met Minnesota state standards for summer averages of all parameters but chloride (see table and graphs at right). The 10-year data shows no statistically significant trend for any of the studied parameters.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 68% of the phosphorus in Battle Creek Lake comes from stormwater. Strategies to address stormwater management include implementing waterquality projects that reduce external loading to the lake and BMP cost-share programs. Plans to address chloride include improving road salt management by promoting and adopting strategies outlined in the Twin Cities Metro Area Chloride Management Plan.

Since first establishing water quality goals for Battle Creek Lake, RWMWD has completed several projects that have contributed to improvements in water quality. Recent projects include:

- Woodbury Elementary and Middle School rain gardens (2017): This was one of six school rain garden projects funded, in part, by a \$150,000 Clean Water Fund grant. Two gardens were planted at the site, providing needed pollinator habitat and reducing the volume of polluted runoff that drains to Battle Creek Lake.
- Trinity Presbyterian Church (2017): Two rain gardens were installed at this site to manage runoff from the church's parking lot. This reduces the volume of polluted rainwater draining to Battle Creek Lake.

Parameter	State Standard	2023 Battle Creek Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 60 µg/l	49.6 µg/l	42 µg/l	None
Chlorophyll a	≤ 20 µg/l	10.3 µg/l	7.4 µg∕l	None
Secchi disc transparency	> 1 meter	2.5 meters	2.5 meters	None
Chloride	≤ 230 mg/l²	298 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Secchi transparency (m)

BEAVER LAKE

MPCA designation	Shallow
Tributary area	1,935 acres
Surface area	87 acres
Average/maximum depth	4/11 feet
RWMWD nutrient classification ¹	At risk
Accountable municipalities	Maplewood, St. Paul, Ramsey County, Washington County
Downstream water body	Beltline Storm Sewer and Mississippi River

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Beaver Lake is a small, shallow lake in Maplewood that drains to the Beltline storm sewer and on to the Mississippi River. A Ramsey County park occupies most of the north and west shoreline. The lake has some wildlife habitat and is primarily used for canoeing, fishing, picnicking, and aesthetic viewing. It is impaired for mercury (aquatic consumption), at risk for chlorides, and listed by the Minnesota DNR as infested with Eurasian watermilfoil. In 2012, the lake was removed from the MPCA's impaired waters list for excess nutrients.

Beaver Lake has been monitored annually for phosphorus, chlorophyll *a*, and Secchi disc depth since 1984; chloride monitoring started in 2015. In 2023, the lake met summeraverage state standards for all parameters but total phosphorus (see table and graphs at right). The 10-year data shows no statistically significant change for any parameter.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 51% of the phosphorus in Beaver Lake comes from stormwater, and 47% comes from internal loading. Strategies to address stormwater management include implementing water-quality projects to reduce the total phosphorus load to the lake and BMP costshare programs. Plans to reduce in-lake loading include assessing options for the inactivation of sediment release of phosphorus.

Parameter	State Standard	2023 Beaver Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 60 µg/l	67.0 μg/l	57 µg/l	None
Chlorophyll a	≤ 20 µg/l	12.7 µg/l	14 µg/l	None
Secchi disc transparency	> 1 meter	2.5 meters	2.3 meters	None
Chloride	≤ 230 mg/l²	142 mg/l	N/A	N/A

¹ A minimum of 10 years of data were analyzed. If a year was missing within the most recent 10-year period, the period of record was extended. ² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Chlorophyll **a** (µg/l)

Secchi transparency (m)

BENNETT LAKE

MPCA designation	Shallow
Tributary area	721 acres
Surface area	25 acres
Average/maximum depth	9 feet
RWMWD nutrient classification ¹	Impaired
Accountable municipalities	Roseville, Ramsey County
Downstream water body	Lake Owasso

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Bennett Lake is the start of a chain of lakes that ultimately drains to Grass Lake. The City of Roseville's Central Park surrounds the lake, which has a fishing pier and provides canoeing opportunities. The Minnesota Department of Natural Resources uses Bennett Lake as a fish nursery.

Bennett Lake is considered by the MPCA to be impaired for mercury (aquatic consumption) and excess nutrients. A statewide mercury TMDL was completed in 2007, and a nutrient TMDL was completed in 2017.

Bennett Lake has been monitored annually for chlorophyll *a* from 1984 to 2023 and for phosphorus and Secchi disc depth from 2003 to 2023. Annual chloride monitoring began in 2015. In 2023, the lake met summeraverage state standards for only Secchi disc transparency and chloride (see table and graphs at right). The 10-year data shows no statistically significant trend for any of the monitored parameters.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 56% of the phosphorus in Bennett Lake comes from internal loading, and 43% comes from stormwater. In 2022, a shallow lake aeration study began. The study consisted of monthly monitoring for water quality and sediment coring, as well as continuous dissolved oxygen monitoring. The objective of the study was to determine if shallow aeration could reduce phosphorus loading and improve dissolved oxygen throughout the lake. The benefits of aeration for Bennet Lake were primarily seen close to the aeration system and may have been limited due to the lack of iron. The shallow lake aeration study monitoring was continued in 2023, and a draft report will be provided to RWMWD staff and the board of managers in early 2024.

RWMWD has completed three recent projects that have contributed to the improving water quality of this lake:

- Grace Church retrofit (2015): This project involved the installation of two rain gardens and three native planting areas to intercept and filter runoff from the Grace Church parking lot, reducing the volume of polluted rainwater draining to Bennett Lake.
- Carp management (ongoing since 2017): Carp management in the Lake Owasso system of lakes (Owasso, Wabasso, Bennett, and Grass) is helping control phosphorus loading in these waters. Foraging carp stir up nutrient-rich sediment on the lake bottom, which, in turn, contributes to turbid water and algae blooms. Management efforts include counting carp to understand the extent of the population, tracking them with radio tags to allow efficient harvesting and identification of carp nurseries, and installing barriers.
- Willow Pond spent-lime filter (2018): This project involved the installation of a spent-lime filter that draws water above the pond's outlet elevation off of Willow Pond. The pipe that draws water from Willow Pond can be opened and closed automatically to control the volume of water in the filter and the length of time between filling events.

Parameter	State Standard	2023 Bennett Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 60 µg/l	127.1 µg/l	83 µg/l	None
Chlorophyll a	≤ 20 µg/l	31.7 µg/l	17 µg/l	None
Secchi disc transparency	> 1 meter	1.04 meters	1.6 meters	None
Chloride	≤ 230 mg/l²	198 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Secchi transparency (m)

Chlorophyll a (µg/l)

CARVER LAKE

MPCA designations	Deep lake; "non-support" of aquatic life (chloride)
Tributary area	2,274 acres
Surface area	49 acres
Average/maximum depth	16/36 feet
RWMWD nutrient classification ¹	At risk
Accountable municipalities	Maplewood, Woodbury, Ramsey County, Washington County
Downstream water body	Fish Creek

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Carver Lake, which borders the popular Carver Lake Park, is used primarily for swimming and canoeing. There is a public beach located on the southeast side, along with canoe access.

Carver Lake was removed from the MPCA's impaired list for nutrients in 2012. However, it is still considered to be impaired for mercury (aquatic consumption) and chloride (aquatic life). A statewide mercury TMDL was completed in 2007, and the Twin Cities Metro Area Chloride TMDL was completed in 2016.

Carver Lake has been monitored annually for phosphorus, chlorophyll *a*, and Secchi disc depth from 1997 to 2023. Annual chloride monitoring began in 2016. In 2023, the lake met MPCA summer-average state standards for phosphorus, chlorophyll *a*, and Secchi disc transparency. However, chloride levels were notably over the state standard. The 10-year trend shows a statistically significant improvement in chlorophyll *a* concentrations and Secchi disc transparency (see table and graphs at right).

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 79% of the phosphorus in Carver Lake comes from stormwater, and 19% comes from internal loading. Goals for the lake include improving stormwater management by implementing a BMP cost-share program and water quality projects that decrease the phosphorus load to Carver Lake.

Parameter	State Standard	2023 Carver Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	38.3 µg/l	30 µg/l	None
Chlorophyll a	≤ 14 µg/l	12.8 µg/l	14 µg/l	Improving
Secchi disc transparency	> 1.4 meters	2.76 meters	2.5 meters	Improving
Chloride	≤ 230 mg/l²	506 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Chlorophyll **a** (µg/l)

Secchi transparency (m)

CASEY LAKE

Casey Lake is actually a large wetland. Located in North St. Paul, it is the headwaters of Kohlman Creek.

Casey Lake has been monitored annually for phosphorus, chlorophyll *a*, and Secchi disc depth since 2008; however, as a wetland, state eutrophication standards do not apply. The 10-year data does not show a statistically significant trend in any of the monitored parameters.

In the winter of 2012–2013, a draw-down of Casey Lake was done to kill invasive carp, which used the lake as a nursery. Foraging carp stir up nutrient-rich sediment on the lake bottom, which, in turn, contributes to turbid water and algae blooms. The draw-down dramatically improved the lake's water clarity (from 0.26 meters to 0.88 meters). In the spring of 2013, the DNR stocked bluegills and bass in Casey Lake to keep carp levels low.

Parameter	State Standard	2023 Casey Lake	10-Year Average ¹	10-Year Trend
Phosphorus	N/A	95.9 µg/l	93 µg/l	None
Chlorophyll a	N/A	15.1 µg/l	18 µg/l	None
Secchi disc transparency	N/A	0.91 meter	0.9 meters	None
Chloride	N/A	86.8 mg/l	N/A	N/A

 $^{\rm 2}$ Chloride value is average water-column concentration.

Total phosphorus (µg/l)

Chlorophyll **a** (µg/l)

Secchi transparency (m)

GERVAIS LAKE

MPCA designations	Deep; "non-support of aquatic life (fish and chloride)
Tributary area	893 acres
Surface area	234 acres
Average/maximum depth	22/41 feet
RWMWD nutrient classification ¹	Stable
Accountable municipalities	Little Canada, Maplewood, Ramsey County
Downstream water body	Keller Lake

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Gervais Lake is the second and largest lake in the Phalen Chain of Lakes. It is used primarily for swimming, skiing, and boating. There is a public boat access from Spoon Lake and a Ramsey County swimming beach and park adjacent to the lake. The lake receives flows from Gervais Creek, Kohlman Lake, and runoff from its direct tributary area.

Gervais Lake is on the MPCA's impaired waters list as impaired for mercury (aquatic consumption) and is considered to be impaired for chloride according to the MPCA's 2024 draft impaired waters list. The lake is also listed by the Minnesota DNR as infested with Eurasian watermilfoil. A statewide mercury TMDL was completed in 2007.

Annual monitoring for phosphorus, chlorophyll a, and Secchi disc depth started in 1981. Annual monitoring for chloride began in 1998. In 2023, the lake met summeraverage state standards for all parameters but chloride. The 10-year data shows no statistically significant change for any parameter.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 24% of the phosphorus in Gervais Lake comes from stormwater, and 76% comes from upstream water bodies. Plans to address these conditions include implementing a BMP cost-share program and waterquality projects that decrease the total phosphorus load to the lake.

One project that helps control phosphorus loading in the Phalen Chain of Lakes (Gervais, Lake Phalen, Lake Keller, Kohlman Lake) is carp management (ongoing since 2009). Foraging carp stir up nutrient-rich sediment on the lake bottom, which, in turn, contributes to turbid water and algae blooms. Management efforts include counting carp to understand the extent of the population, tracking them with radio tags to allow efficient harvesting and identification of nurseries, and installing barriers. These efforts have reduced carp in the Phalen Chain by over 60%.

Parameter	State Standard	2023 Gervais Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	20.9 µg/l	30 µg/l	None
Chlorophyll a	≤ 14 µg/l	8.3 µg/l	12 µg/l	None
Secchi disc transparency	> 1.4 meter	2.5 meters	2.4 meters	None
Chloride	≤ 230 mg/l²	264 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Chlorophyll a (µg/l)

Secchi transparency (m)

0 10 в 20 Chlorophyll a (ug/l) 0 05 07 07 09 С D 70 80 F 90 100 1980 2025 1975 1985 1990 1995 2000 2005 2010 2015 2020 Year

KELLER LAKE

MPCA designation	Shallow
Tributary area	1,577 acres
Surface area	72 acres
Average/maximum depth	4/8 feet
RWMWD nutrient classification ¹	Stable
Accountable municipalities	Little Canada, Maplewood, Ramsey County
Downstream water body	Lake Phalen

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Keller Lake is the third lake in the Phalen Chain of Lakes and is used for motor boating, canoeing, fishing, picnicking, and aesthetic viewing. There is a Ramsey County Park on the lake's east shoreline. Flows to the lake are received from Gervais Lake (through Spoon Lake) and runoff from its direct tributary area.

Keller Lake was listed as impaired for excess nutrients in 2002 but was removed from the list in 2012 after meeting state standards (for shallow lakes). The lake is still at risk of impairment for chlorides. In addition, Keller Lake is listed by the Minnesota DNR as infested with Eurasian watermilfoil.

Annual monitoring for phosphorus, chlorophyll *a*, and Secchi disc depth began in 1981; monitoring for chlorides started in 2015. In 2023, Keller Lake did not meet summeraverage state standards for all parameters except for chloride concentration (see table and graphs at right). The 10-year data shows no statistically significant change for any parameter.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 42% of the phosphorus in Keller Lake comes from stormwater, 8% comes from internal loading, and 49% comes from upstream water bodies. Strategies to address stormwater pollution include implementing a BMP cost-share program and water-quality projects that decrease the total phosphorus load to the lake.

Several recent projects have helped Keller Lake water quality. These include:

- Carp management (ongoing since 2009): Carp management helps control phosphorus loading in the Phalen Chain of Lakes (Keller Lake, Gervais Lake, Lake Phalen, and Kohlman Lake). Foraging carp stir up nutrient-rich sediment on the lake bottom, which, in turn, contributes to turbid water and algae blooms. Management efforts include counting carp to understand the extent of the population, tracking them with radio tags to allow efficient harvesting and identification of nurseries, and installing barriers. Efforts have reduced carp in the Phalen Chain by over 60%.
- Keller Lake shoreline (2012): This ecological restoration project treated over 2,000 feet of shoreline, helping to reduce the volume of polluted stormwater that reaches the lake. The restoration areas now support more than 75 species of native plants.
- Lakeview Lutheran (2013) is one of 12 projects to manage rainwater runoff at churches with large amounts of impervious surface. Three rain gardens were installed, as well as a native planting area that provides pollinator habitat. The gardens and planting area filter runoff from the church parking lot.
- The Highway 36/61 project (2014): This project was

Parameter	State Standard	2023 Keller Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 60 µg/l	47.9 µg/l	51 µg/l	None
Chlorophyll a	≤ 20 µg/l	9.5 µg/l	14 µg/l	None
Secchi disc transparency	> 1 meter	1.50 meters	1.5 meters	None
Chloride	≤ 230 mg/l²	255 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Chlorophyll a (µg/l)

constructed as part of the overall Trunk Highway 36 and English Street interchange effort. It included the installation of a stormwater treatment system to prevent polluted stormwater runoff from entering Keller Lake and downstream Lake Phalen. The project treats stormwater from approximately 70 acres of commercial, residential, and highway areas by channeling it through an enhanced sand filter cell and two wetland treatment basins designed to remove phosphorus-rich sediment and other contaminants.

Secchi transparency (m)

Chloride (mg/l)

• Weaver Elementary School (2016) is one of six school rain garden projects to manage polluted runoff at schools in priority areas of the watershed. This project also provides needed pollinator habitat.

Kohlman Lake

MPCA designations	Shallow; "non-support" of aquatic life (chloride)
Tributary area	1,009 acres
Surface area	84 acres
Average/maximum depth	4/12 feet
RWMWD nutrient classification ¹	At-risk (changed from "impaired" in 2022 MPCA assessment)
Accountable municipalities	Little Canada, Maplewood, Vadnais Heights, Ramsey County
Downstream water body	Gervais Lake

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Kohlman Lake is the first lake in the Phalen Chain of Lakes. It is used for a variety of recreational purposes, including motor boating, canoeing, fishing, picnicking, and aesthetic viewing. While the drainage area that directly reaches the lake is just over 1,000 acres, the total area connected to the lake through Kohlman and Willow Creeks is about 7,500 acres. There is no direct public boat access to Kohlman Lake, but it can be accessed from Gervais Lake.

Kohlman Lake was listed as impaired for excess nutrients in 2002 and is impaired for chloride (aquatic life). In addition, Kohlman is listed by the Minnesota DNR as infested with Eurasian watermilfoil. A nutrient TMDL was completed in 2010, and the Twin Cities Metro Area Chloride TMDL was completed in 2016.

Annual monitoring for phosphorus, chlorophyll *a*, and Secchi disc depth has occurred since 1981. Annual monitoring for chlorides began in 2021. In 2023, Kohlman Lake did not meet the summer-average state standards for any parameter. The 10-year trend shows a statistically significant trend of worsening total phosphorus concentration, chlorophyll *a* concentration, and Secchi disc depth.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 76% of the phosphorus in Kohlman Lake comes from stormwater, and 23% comes from internal loading. Strategies to address stormwater pollution include implementing a BMP cost-share program and water-quality projects that decrease the total phosphorus load to the lake. Internal loading will be addressed by managing carp and curlyleaf pondweed, as needed. An initial alum treatment has been completed on the lake; treatment will be continued if needed, and other options will be assessed.

A few projects have helped improve water quality in Kohlman Lake:

• Beam Avenue iron-enhanced sand filter (2009):

During construction of the new Country View Lane in Maplewood, RWMWD constructed a sand filter to remove dissolved phosphorus from stormwater. Sand filters have been used for years to remove solids and some pollutants from stormwater, but elemental iron (often called zero-valent iron) was added to the sand to remove dissolved phosphorus by forming ironphosphate complexes. RWMWD monitoring indicates this practice is effectively removing about 90% of dissolved phosphorus in the tributary stormwater. This filter is evaluated in Section 7.

 Carp management (ongoing since 2009): Carp management helps control phosphorus loading in the Phalen Chain of Lakes (Kohlman Lake, Lake Phalen, Gervais Lake, Lake Keller). Foraging carp

Parameter	State Standard	2022 Kohlman Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 60 µg/l	124.8 µg/l	71 µg/l	Worsening
Chlorophyll a	≤ 20 µg/l	54.4 µg/l	15 μg/	Worsening
Secchi disc transparency	> 1 meter	0.98 meters	1.6 meters	Worsening
Chloride	≤ 230 mg/l²	168 mg/l	N/A	N/A

² State standard for chronic chloride exposure; chloride value is average water-column concentration.

Total phosphorus (µg/l)

Chlorophyll a (µg/l)

stir up nutrient-rich sediment on the lake bottom, which, in turn, contributes to turbid water and algae blooms. Management efforts include counting carp to understand the extent of the population, tracking them with radio tags to allow efficient harvesting and identification of nurseries, and installing barriers. These efforts have reduced carp in the Phalen Chain by over 60%.

• Maplewood Mall (2012): With 35 acres of asphalt pavement and concrete surfaces surrounding it, Maplewood Mall was a major source of

Secchi transparency (m)

Chloride (mg/l)

phosphorus runoff to Kohlman Lake. But, over 4 years, the RWMWD installed a variety of stormwater management features that capture and filter 67% of rainwater at the mall—up from just 3% before the project. These features include innovative tree trenches, rain gardens, permeable pavers, and a 5,700-gallon cistern that receives runoff from the mall roof. Interpretive signage educates the public about these improvements, and a large watershed map in the entry vestibule shows how water travels from the mall all the way to the Mississippi River.

Lake Emily

MPCA designation	Shallow
Tributary area	244 acres
Surface area	13 acres
Average/maximum depth	7/15 feet
RWMWD nutrient classification ¹	At-risk
Accountable municipalities	Shoreview
Downstream water body	Lake Owasso

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Lake Emily is a small, shallow lake in Shoreview, in Ramsey County. The lake is part of the larger Lake Owasso watershed. Lake Emily is completely surrounded by private land, and there is no public access. Residents use the lake for fishing, canoeing, and aesthetic enjoyment.

The Lake Emily subwatershed is fully developed. Land use is predominantly single-family residential, with some areas of park, recreational, preserve, and institutional land uses.

The RWMWD has assigned a water quality classification of "at risk" to Lake Emily based on water quality data that exceed the MPCA standards and RWMWD goals. RWMWD has not monitored Lake Emily since 2012, but data from the most recent decade of monitoring (2003–2012) is included at right. Based on water quality modeling, approximately 42% of the nutrient load to Lake Emily comes from the lake sediments, approximately 37% from the direct watershed, and approximately 20% from the upstream Lake Judy wetland.

In 2023, the RWMWD constructed a regional underground stormwater filter (Arbogast filter) in the Lake Emily subwatershed. The Arbogast filter diverts stormwater runoff from the storm sewer trunkline along Arbogast Street in Shoreview, filters the stormwater through crushed limestone (CC17) media, and sends the treated water back to the Arbogast storm sewer, which discharges to Lake Emily. The filter is expected to remove approximately 7 pounds of total phosphorus each year. RWMWD staff will monitor the Arbogast filter in upcoming years to evaluate its performance.

Parameter	State Standard	2003–2012 Lake Emily Growing Season Average	Trend (2003–2012)
Phosphorus	≤ 60 µg/l	98 µg/l	Worsening
Chlorophyll a	≤ 20 µg/l	34 µg/l	Worsening
Secchi disc transparency	> 1 meter	1.4 meters	Worsening

² State standard for chronic chloride exposure; chloride value is average water-column concentration.

Total phosphorus (µg/l)

Secchi transparency (m)

Chlorophyll **a** (µg/l)

LAKE OWASSO

MPCA designation	Deep
Tributary area	2,175 acres
Surface area	375 acres
Average/maximum depth	11/37 feet
RWMWD nutrient classification ¹	At risk
Accountable municipalities	Roseville, Shoreview, Ramsey County
Downstream waterbody	Lake Wabasso

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Lake Owasso is the largest lake in the RWMWD and a major regional recreational resource for fishing, boating, waterskiing, and swimming. Roseville's Central Park North (along the south shore of the lake) and Owasso County Park in the city of Shoreview (on the north side) provide two public access points, including a boat launch and a public swimming beach. Lake Owasso receives water from Bennett Lake and Lake Emily.

Lake Owasso is impaired for mercury (aquatic consumption) and is also listed by the Minnesota DNR as infested with Eurasian watermilfoil. A statewide mercury TMDL was completed in 2007.

Phosphorus and Secchi disc depth have been monitored annually at Lake Owasso from 2003 to 2023. Chlorophyll *a* has been monitored annually since 1984, and chlorides have been monitored since 2015. 2023 monitoring shows that the lake meets summer-average state standards for all four parameters. The 10-year data shows a statistically significant improvement in phosphorus and chlorophyll *a* levels.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 31% of the phosphorus in Lake Owasso comes from stormwater, and 63% comes from internal loading. Plans to address stormwater pollution include implementing a BMP cost-share program and water-quality projects that decrease the total phosphorus load to the lake. Internal loading will be addressed by managing carp as needed. Options for the inactivation of sediment release of phosphorus will also be assessed.

Several projects have been completed to improve water quality in Lake Owasso:

- Prince of Peace Lutheran Church (2015) and North Heights Christian Academy (2017) are two of 12 projects to manage rainwater runoff at churches with large impervious surfaces. The goal of these projects was to install rain gardens to intercept and filter polluted runoff from the church parking lots
- Central Park Elementary (2017) is one of six school rain garden projects providing needed pollinator habitat and reducing the volume of polluted runoff. RWMWD's goal was to manage rainwater runoff at schools in priority areas of the watershed while engaging local communities in a shared learning experience.
- Carp management (ongoing since 2017): With four interconnected lakes (Owasso, Wabasso, Bennett, and Grass) and 12 shallow ponds, the Lake Owasso system offers prime habitat for carp to potentially outcompete native game fish. As carp root for food along the lake bottom, they stir up nutrient-rich sediment, which, in turn, contributes to turbid water and algae blooms. Management efforts include counting carp to understand the extent of the population, tracking them with radio tags to allow efficient harvesting and identification of nurseries, and installing barriers.

Parameter	State Standard	2023 Lake Owasso	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	21.1 µg/l	28 µg/l	Improving
Chlorophyll a	≤ 14 µg/l	8.0 µg/l	12 µg/l	Improving
Secchi disc transparency	> 1.4 meter	2.7 meters	2.0 meters	None
Chloride	≤ 230 mg/l²	81.1 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Secchi transparency (m)

Chlorophyll **a** (µg/l)

LAKE PHALEN

MPCA designation	Deep
Tributary area	1,995 acres
Surface area	200 acres
Average/maximum depth	22/95 feet
RWMWD nutrient classification ¹	Stable
Accountable municipalities	Maplewood, St. Paul, Ramsey County
Downstream water body	Mississippi River via the Beltline Interceptor storm sewer

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Lake Phalen, the downstream-most lake in the Phalen Chain of Lakes, is surrounded by park land that has 2 miles of restored shoreline. The lake is used primarily for swimming, fishing, paddling, picnicking, and aesthetic viewing. It has public boating access and a swimming beach. While the direct tributary area to the lake is close to 2,000 acres, the total land area that ultimately drains through Lake Phalen is closer to 15,000 acres, including the Keller Lake and Wakefield Lake subwatersheds.

Lake Phalen is impaired for mercury (aquatic consumption) and is listed by the Minnesota DNR as infested with Eurasian watermilfoil. A statewide mercury TMDL was completed in 2007.

Phosphorus, chlorophyll *a*, and Secchi disc depth have been monitored annually since 1981. Annual chloride monitoring began in 2015. In 2023, all four parameters met summer-average state standards. The 10-year data shows no statistically significant trends for any tested parameters.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 68% of the phosphorus in Lake Phalen comes from stormwater, and 32% comes from internal loading. Plans to address stormwater pollution include implementing a BMP cost-share program and waterquality projects that decrease the total phosphorus load to the lake.

Projects that have improved water quality in Lake Phalen include:

- Carp management (ongoing since 2009): Carp management helps control phosphorus loading in the Phalen Chain of Lakes (Lake Phalen, Gervais Lake, Lake Keller, Kohlman Lake). Foraging carp stir up nutrient-rich sediment on the lake bottom, which, in turn, contributes to turbid water and algae blooms. Management efforts include counting carp to understand the extent of the population, tracking them with radio tags to allow efficient harvesting and identification of nurseries, and installing barriers. These efforts have reduced carp in the Phalen Chain by over 60%.
- Phalen shoreline restoration (2010): This project has become one of the largest lakeshore restoration efforts in Minnesota. The long-term effort involved restoring deep-rooted native plants to filter stormwater, prevent erosion, and create needed urban wildlife habitat. More than 100 native plant species have become established along the shore.

Parameter	State Standard	2023 Lake Phalen	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	16.8 µg/l	25 µg/l	None
Chlorophyll a	≤ 14 µg/l	4.6 µg∕l	7 µg/l	None
Secchi disc transparency	> 1.4 meters	3.4 meters	3.1 meters	None
Chloride	≤ 230 mg/l²	204 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Chlorophyll a (µg/l)

• Keller Golf Course (2014): Keller is a beautiful public course located just east of Lake Keller. The no-play areas on this course comprise part of the Phalen Chain of Lakes natural areas corridor, providing critical wildlife habitat and improving infiltration. This improvement project restored more than 7 acres of no-play area.

Secchi transparency (m)

Chloride (mg/l)

• Keller Creek buffer (2018): The Keller Creek restoration effort restored native plant communities, removed invasive vegetation, reduced erosion, and brought significant improvements to wildlife habitat and recreation along nearly a mile of the creek.

LAKE WABASSO

MPCA designation	Deep
Tributary area	147 acres
Surface area	52 acres
Average/maximum depth	16/66 feet
RWMWD nutrient classification ¹	Stable
Accountable municipalities	Shoreview, Ramsey County
Downstream waterbody	Grass Lake

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Lake Wabasso is a deep lake in Shoreview that supports a healthy fish population. In addition to fishing, it is used for boating and swimming. Boat access is provided in Lake Owasso County Park on the south side. The lake is at risk of impairment for chloride; however, 2019 data suggest it may not be at risk. It is also listed by the Minnesota DNR as infested with Eurasian watermilfoil.

Chlorophyll a has been monitored annually at Lake Wabasso since 1984. Phosphorus and Secchi disc depths have been monitored annually since 2003. Annual chloride monitoring began in 2015. In 2023, Lake Wabasso met summer-average state standards for all four parameters. The 10-year data shows a statistically significant trend of decreasing Chlorophyll a concentration.

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 13% of the phosphorus in Lake Wabasso comes from stormwater, 62% comes from internal loading, and 22% comes from atmospheric deposition. Plans to address stormwater pollution include implementing a BMP cost-share program and waterquality projects that decrease the total phosphorus load to the lake.

Parameter	State Standard	2023 Lake Wabasso	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	18.4 µg/l	23 µg/	None
Chlorophyll a	≤ 14 µg/l	4.1 µg/L	6 µg/	Improving
Secchi disc transparency	> 1.4 meters	4.1 meters	3.2 meters	None
Chloride	≤ 230 mg/l²	70.0 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)

Chlorophyll **a** (µg/l)

SNAIL LAKE

MPCA designation	Deep
Tributary area	961 acres
Surface area	190 acres
Average/maximum depth	28 feet
RWMWD nutrient classification ¹	Stable
Accountable municipalities	Shoreview, Ramsey County
Downstream waterbody	Landlocked

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Snail Lake is a 190-acre landlocked lake in the city of Shoreview; a 35 acre wetland can be found on the northwest side of the lake. The lake, used for fishing, boating, and swimming, is bordered by Snail Lake Regional Park to the south. The park includes public access and a swimming beach.

Snail Lake is impaired for mercury (aquatic consumption); a statewide mercury TMDL was completed in 2007. The lake is also listed by the Minnesota DNR as infested with Eurasian watermilfoil.

Phosphorus, chlorophyll *a*, and Secchi disc depth have been monitored annually since 2005. Annual monitoring of chloride began in 2015. In 2023, the lake met summer-average state standards for all four waterquality parameters. The 10-year data shows a statistically significant trend of Secchi depth increasing..

According to the 2017 Ramsey Washington Metro Watershed District Watershed Restoration and Protection Strategies Report, 30% of the phosphorus in Snail Lake comes from stormwater, 11% comes from internal loading, and 51% from upstream water bodies. Strategies to address stormwater pollution include implementing a BMP cost-share program and water-quality projects that decrease the total phosphorus load to the lake.

One project that has improved water quality in Snail Lake is:

• Wetland A ecological restoration (2020 and 2021): RWMWD partnered with Ramsey County and other organizations to conduct a 3-year ecological restoration project in the area. Between 2020 and 2021, RWMWD staff and volunteers restored 4.8 acres of shoreline that stretched approximately 4,500 feet. Over 80 species of native plants were installed as natural buffers in place of invasive species like common buckthorn.

Parameter	State Standard	2023 Snail Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	19.1 µg/l	19 µg/l	None
Chlorophyll a	≤ 14 µg/l	5.1 µg/l	4.6 µg/l	None
Secchi disc transparency	> 1.4 meters	3.79 meters	3.5 meters	Improving
Chloride	≤ 230 mg/l²	114.4 mg/l	N/A	N/A

² State standard for chronic chloride exposure.

Chlorophyll **a** (µg/l)

Secchi transparency (m)

TANNERS LAKE

MPCA designations	Deep; "non-support" of aquatic life (chloride)
Tributary area	1,707 acres
Surface area	74 acres
Average/maximum depth	20/46 feet
RWMWD nutrient classification ¹	Stable
Accountable municipalities	Landfall, Maplewood, Oakdale, Woodbury, Ramsey County, Washington County
Downstream water body	Battle Creek Lake

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.

Located almost entirely within the cities of Oakdale and Landfall, Tanners Lake discharges into the headwaters of Battle Creek—a tributary of the Mississippi River. The lake is used primarily for swimming, skiing, motor boating, fishing, canoeing, picnicking, and aesthetic viewing. Tanners Lake Park, which includes a beach for swimming and boat access for fishing, is located on the east shore of the lake. Facilities are also present for softball and volleyball.

Tanners Lake was listed as impaired for excess nutrients in 2002, but after meeting state standards was removed from the impaired waters list in 2004. It is currently impaired for mercury (aquatic consumption) and chloride (aquatic life). A statewide mercury TMDL was completed in 2007, and the Twin Cities Metro Area Chloride TMDL was completed in 2016.

Phosphorus, chlorophyll *a*, and Secchi disc depth have been monitored annually since 1993. Annual chloride monitoring began in 2017. In 2023, the lake only met summer-average state standards for Chlorophyll *a* and Secchi disc depth. The 10-year data shows no statistically significant trends.

RWMWD currently operates an aluminum sulfate (alum) treatment facility on the north end of Tanners Lake that treats a significant portion of watershed runoff before it enters the lake. Alum is injected into the stormwater runoff, which causes phosphorus to precipitate out and settle into a sedimentation pond.

Strategies to address stormwater pollution include implementing the BMP cost-share program and waterquality projects that decrease the total phosphorus load to the lake. Plans to address chloride include improving road salt management by promoting and adopting strategies in the Twin Cities Metro Area Chloride Management Plan.
Parameter	State Standard	2023 Tanners Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	41 µg/l	25 µg/l	None
Chlorophyll a	≤ 14 µg/l	9.7 µg/l	9 µg/l	None
Secchi disc transparency	> 1.4 meters	2.51 meters	2.8 meters	None
Chloride	≤ 230 mg/l²	254.4 mg/l	N/A	N/A

¹ A minimum of 10 years of data were analyzed. If a year was missing within the most recent 10-year period, the period of record was extended.

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)



Secchi transparency (m)



Chlorophyll **a** (µg/l)



Chloride (mg/l)



TWIN LAKE



MPCA designation	Deep
Tributary area	192 acres
Surface area	35.5 acres
Average/maximum depth	33 feet
RWMWD nutrient classification ¹	Stable
Accountable municipalities	Little Canada, Vadnais Heights, Ramsey County
Downstream waterbody	Gervais Creek

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.



Twin Lake lies in Little Canada and Vadnais Heights. It is a small and relatively deep lake, mainly surrounded by homes. Formerly landlocked, an outlet was installed in the lake in 2020 to allow water to discharge to Gervais Creek during high water periods. Twin Lake has some wildlife habitat and is primarily used for canoeing, aesthetic viewing, fishing, and occasional jet skiing; there is no public access. The lake is not impaired.

With the exception of 2007, phosphorus, chlorophyll *a*, and Secchi disc depth have been monitored annually since 1996. Annual monitoring of chloride began in 2015. In 2023, the lake met all four summer-average state standards. The 10-year data shows no statistically significant trend for any parameter.

Strategies to address stormwater pollution include implementing a BMP cost-share program and waterquality projects that decrease the total phosphorus load to the lake.

Parameter	State Standard	2023 Twin Lake	10-Year Average ¹	10-Year Trend
Phosphorus	≤ 40 µg/l	20.0 µg/l	26 µg/l	None
Chlorophyll a	≤ 14 µg/l	15.0 µg/l	10.0 µg/l	None
Secchi disc transparency	> 1.4 meters	2.45 meters	2.4 meters	None
Chloride	≤ 230 mg/l²	66.1 mg/l	N/A	N/A

¹ A minimum of 10 years of data were analyzed. If a year was missing within the most recent 10-year period, the period of record was extended.

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)



Secchi transparency (m)



Chlorophyll **a** (µg/l)



Chloride (mg/l)



WAKEFIELD LAKE



MPCA designation	Shallow
Tributary area	948 acres
Surface area	23 acres
Average/maximum depth	4.6/9 feet
RWMWD nutrient classification ¹	Impaired
Accountable municipalities	Maplewood, North St. Paul, St. Paul, Ramsey County
Downstream water body	Lake Phalen

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.



Wakefield Lake is located in Maplewood and is primarily used for shoreline fishing, picnicking, and aesthetic viewing. It is bordered by park land on the north and east sides of the lake. Public access is available in Wakefield Park, although there is no boat launch.

Wakefield Lake was added to the MPCA's impaired waters list for excess nutrients in 2002; a nutrient TMDL was completed in 2017. Wakefield is also at risk for chloride impairment.

In 2022, a shallow lake aeration study began. The study consisted of monthly monitoring for water quality and sediment coring, as well as continuous dissolved oxygen monitoring. The objective of the study was to determine if shallow aeration could reduce phosphorus loading and improve dissolved oxygen throughout the lake. The shallow lake aeration study monitoring was continued in 2023, and a draft report will be provided to RWMWD staff and the board of managers in early 2024.

Phosphorus, chlorophyll a, and Secchi disc depth have been monitored annually since 1984. Chloride has been measured annually since 1992. In 2023, Wakefield Lake met summer-average state standards for all parameters except chloride. The 10-year data shows a statistically significant trend of improved Secchi disc transparency.

Strategies to address stormwater pollution include implementing a BMP cost-share program and waterquality projects that decrease the total phosphorus load to the lake. Plans to reduce in-lake loading by 80% include developing a plan for macrophyte management (including curlyleaf pondweed) and assessing options for the inactivation of sediment release of phosphorus.

Recent projects to improve the water quality of Wakefield Lake are:

- **Presentation Catholic Church (2015)** is one of 12 projects managing rainwater runoff at churches with large amounts of impervious surfaces. The goal was to install six rain gardens and one infiltration trench that intercept and filter runoff from the church parking lot. This reduces the volume of polluted rainwater draining to Wakefield Lake.
- The Wakefield spent-lime filter (2018): This project involves piping stormwater from a large portion of the 944-acre Wakefield Lake subwatershed into a large underground chamber where it interacts with spent lime. The lime material is a repurposed byproduct of municipal drinking water treatment, and it binds to phosphorus in the stormwater. Water leaving the spent-lime chamber was projected to contain about 70% less dissolved phosphorus than when it entered. (This treatment system, during the first year of operation, is evaluated in Chapter 7).

Parameter	State Standard	2023 Wakefield Lake	10-Year Average ¹	10-YearTrend
Phosphorus	≤ 60 µg/l	46.3 µg/l	89 µg/l	None
Chlorophyll a	≤ 20 µg/l	11.0 µg/l	31 µg/l	None
Secchi disc transparency	> 1 meter	1.72 meters	1.4 meters	Improving
Chloride	≤ 230 mg/l²	245.6 mg/l	N/A	N/A

¹ A minimum of 10 years of data were analyzed. If a year was missing within the most recent 10-year period, the period of record was extended.

² State standard for chronic chloride exposure.

Total phosphorus (µg/l)



Chlorophyll a (µg/l)



• Wakefield Park stormwater improvements (2020): The goal of this project was to install two large rain gardens that intercept and filter rainwater runoff from the streets. This reduces the volume of rainwater runoff and increases the quality of runoff that drains into Wakefield Lake. This project was completed in conjunction with a City of Maplewood project to narrow Frost Avenue, which also improves the quality of runoff going into Wakefield Lake.

Secchi transparency (m)



Chloride (mg/l)



- Aldrich Ice Arena (2020): The goal of this project was to remove the asphalt parking lot and install 15 rain gardens. The rain gardens reduce the volume of stormwater runoff and remove pollutants from the runoff before reaching Wakefield Lake.
- Mounds Park Academy (2022): The goal of this project was to remove a section of unused parking lot to build a rain garden to treat runoff before it enters the school's pond. The school is interested in funding an outdoor learning space alongside the rain garden.





4. STREAMS

BATTLE CREEK



Tributary area	2,972 acres
Creek length	3.8 miles
Downstream waterbody	Mississippi River
MPCA designations	Impaired for "non-support" of aquatic life (chloride, fish, macroinvertebrates)
Accountable municipalities	Maplewood, St. Paul, Woodbury, Ramsey County, Washington County
RWMWD nutrient classification ¹	Impaired (TSS)

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.



Battle Creek is a perennial, urban stream that originates at the outlet from Battle Creek Lake in Woodbury. The creek then flows west and ultimately discharges to Pigs Eye Lake and the Mississippi River. A well-maintained regional park with trails for hiking, cross-country skiing, and cycling is situated along the creek in St. Paul.

Historically, Battle Creek has been plagued by frequent and devastating floods that caused loss of life, substantial property damage, and heavy stream erosion. The District completed a significant restoration project in 1982 and continues to conduct maintenance on the creek to sustain that project.

Battle Creek has been monitored annually for phosphorus and total suspended solids since 1996. Annual monitoring for nitrate began in 2000 and for chloride in 2002. The creek is currently impaired for chloride and was also listed in 2014 as impaired for degraded fish and macroinvertebrate biological community health. A stressor identification report was completed in 2015 and found that chloride and total suspended solids (TSS) are the primary stressors to the fish and macroinvertebrates in the creek. The study identified total phosphorus as a probable secondary stressor. For that reason, the District has assigned Battle Creek a RWMWD nutrient water quality classification of "Impaired. "

As seen in the chart at right, the creek failed to meet state standards for phosphorus, total suspended solids, and chloride in 2023. The 10-year data shows a statistically significant trend of worsening nitrate and chloride concentrations.

Recent projects to improve the water quality of Battle Creek include:

- Christ United Methodist Church (2016): Two rain gardens were installed to intercept and filter runoff from the church's parking lot—reducing the volume of polluted runoff that drains to Battle Creek.
- Slumberland Clearance Outlet Store (2016): A native planting area replacing 20,000 square feet of parking lot surface provides pollinator habitat and filters rainwater runoff before it drains to Battle Creek.
- Target—Suburban Avenue (2020): The project included the removal of impervious parking lot to install seven rain gardens and a linear tree trench. The installed best management practices can reduce the volume of polluted runoff that drains to Battle Creek, as well as remove pollutants such as total suspended solids and total phosphorus.
- St. Pascal Baylon Church (2022): The project included retrofitting the existing parking lot to maintain the existing grading and adding a tree trench and small rain garden. The tree trench and rain garden will remove phosphorus and sediment from stormwater that travels to Battle Creek.

Parameter	State Standard	2023 Battle Creek	10-Year Average	10-Year Trend
Phosphorus	≤ 100 µg/l	194 µg/l	136 µg/l	None
Total suspended solids	<15 mg/l	74 mg/l	42 mg/l	None
Nitrate	N/A	0.35 mg/l	0.28 mg/l	Worsening
Chloride	≤ 230 mg/l¹	265 mg/l	201 mg/l	Worsening

¹ State standard for chronic chloride exposure.



Nutrients and solids (mg/l)

Chlorides (mg/l)



BELTLINE INTERCEPTOR







The Beltline Interceptor is a large storm sewer pipe system constructed in 1920 and maintained by the RWMWD. The system is approximately 5 miles long, extending from the outlets of Lake Phalen and Beaver Lake to the Mississippi River. It collects a large percentage of stormwater runoff from St. Paul's east side and also conveys runoff from the entire Phalen Chain of Lakes subwatershed and the Beaver Lake subwatershed to the Mississippi River. The total drainage area to the Beltline Interceptor is 27.8 square miles—over half of the District's water.

The Beltline Interceptor has been monitored annually for phosphorus and total suspended solids since 1995. Annual monitoring for nitrates began in 2000 and for chloride in 2002. As seen in the chart at right, the Beltline Interceptor met state standards for only chlorides in 2023. At 30 mg/L, the decrease in total suspended solids has been dramatic since reaching its peak in 1997 (349 mg/L). The 10-year data shows a statistically significant trend of worsening chloride concentration.

Recent projects to improve the water quality of Beltline Interceptor include:

• Saint Paul Urban Tennis Center (2020): A new infiltration basin was installed to reduce the volume of runoff to the Beltline interceptor and remove pollutants from stormwater runoff.

Parameter	State Standard	2023 Beltline Interceptor	10-Year Average	10-Year Trend
Phosphorus	≤ 100 µg/l	198 µg/l	118 µg/l	None
Total suspended solids	<15 mg/l	30 mg/l	35 mg/l	None
Nitrate	N/A	0.61 mg/l	0.33 mg/l	None
Chloride	≤ 230 mg/l¹	207 mg/l	138 mg/l	Worsening

¹ State standard for chronic chloride exposure; chloride value is average water-column concentration



Nutrients and solids (mg/l)



FISH CREEK



Tributary area	783 acres
Creek length	1.8 miles
Downstream waterbody	Eagle Lake
MPCA designations	"Non-support" of aquatic life (benthic macroinvertebrates); at risk for chloride; "non-support" of aquatic recreation (E. coli; and total suspended solids)
Accountable municipalities	Maplewood, St. Paul, Woodbury, Ramsey County, Washington County
RWMWD nutrient classification ¹	Impaired (TSS)

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.



Fish Creek is a perennial, urban stream that originates at Carver Lake and ultimately discharges to Eagle Lake and the Mississippi River. The majority of the Fish Creek subwatershed is in Ramsey County and the southeastern portion of Washington County.

Fish Creek was placed on the 2014 303(d) impaired waters list due to elevated levels of E. coli bacteria. E. coli is used in water quality monitoring as an indicator of water that is contaminated with human or animal waste and accompanying disease-causing organisms. Bacterial abundance in excess of the water quality standards can pose a risk to human health. The draft 2024 impaired waters list includes TSS and benthic macroinvertebrates bioassessments as impairments for Fish Creek.

Fish Creek has been monitored annually for phosphorus and total suspended solids since 1995. Annual monitoring for nitrates began in 2000 and for chlorides in 2002. In 2023, Fish Creek failed to meet state standards for phosphorus, total suspended solids, and chloride (see chart at right). The 10-year data shows a statistically significant trend of worsening total phosphorus, nitrate, and chloride concentrations.

Parameter	State Standard	2023 Fish Creek	10-Year Average	10-Year Trend
Phosphorus	≤ 100 µg/l	119 µg/l	108 µg/L	Worsening
Total suspended solids	<15 mg/l	30 mg/l	58 mg/l	None
Nitrate	N/A	0.51 mg/l	0.46 mg/l	Worsening
Chloride	≤ 230 mg/l¹	234 mg/l	158 mg/l	Worsening

¹ State standard for chronic chloride exposure; chloride value is average water-column concentration.



Nutrients and solids (mgl/l)





GERVAIS CREEK



Tributary area	1,847 acres
Creek length	2.2 miles
Downstream waterbody	Gervais Lake
MPCA designations	"Non-support" of aquatic life (benthic macroinvertebrates)
Accountable municipalities	Little Canada, Vadnais Heights, Ramsey County
RWMWD nutrient classification ¹	At risk

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.



Gervais Creek is an intermittent stream that was previously managed as a county ditch (County Ditch 16). It is managed by the RWMWD as a stormwater system.

Gervais Creek has been monitored annually for phosphorus and total suspended solids since 2010. Annual monitoring for chlorides began in 2010 and for nitrates in 2016. In 2023, the creek exceeded the state standard for phosphorus and chloride. The 10-year data shows no statistically significant trend for any parameter.

Parameter	State Standard	2023 Gervais Creek	Average	10-Year Trend
Phosphorus	≤ 100 µg/l	131 µg/l	143 µg/l (10-year average)	None
Total suspended solids	<15 mg/l	14 mg/l	17.6 mg/l (10-year average)	None
Nitrate	N/A	0.17 mg/l	0.15 mg/l (6-year average)	N/A
Chloride	≤ 230 mg/l¹	255 mg/l	165 mg/l (10-year average)	None

¹ State standard for chronic chloride exposure.







Year

Chlorides (mg/l)

KOHLMAN CREEK



Tributary area	3,653 acres
Creek length	2.8 miles
Downstream waterbody	Kohlman Lake
Accountable municipalities	Maplewood, North St. Paul, Oakdale, Ramsey County, Washington County
RWMWD nutrient classification ¹	At risk

¹RWMWD nutrient classifications are based on the relationship between the historical average water quality (based on phosphorus concentration alone) and the MPCA water quality (phosphorus) standards.



Kohlman Creek is an intermittent stream that was previously considered a county ditch (County Ditch 18 South). The stream generally flows from southeast to northwest and eventually discharges to the Kohlman Basin in the Kohlman Lake subwatershed. The creek has been managed by the District as a stormwater conveyance system. Most of the creek remains in its natural state.

Kohlman Creek has been monitored annually for phosphorus, total suspended solids, and chlorides since 2008. Annual monitoring for chlorides began in 2015. In 2023, Kohlman Creek failed to meet the state standard for all monitored parameters. The 10-year data show a statistically significant increase in chloride.

Recent projects to improve the water quality in Kohlman Creek include:

- Maplewood Mall (2012): With 35 acres of asphalt pavement and concrete surfaces surrounding it, Maplewood Mall was a major source of phosphorus runoff to Kohlman Lake and Kohlman Creek. But, over 4 years, the RWMWD installed a variety of stormwater management features that capture and filter 67% of rainwater at the mall—up from just 3% before the project. These features include innovative tree trenches, rain gardens, permeable pavers, and a 5,700-gallon cistern that receives runoff from the mall roof. Interpretive signage educates the public about these improvements, and a large watershed map in the entry vestibule shows how water travels from the mall all the way to the Mississippi River.
- Harmony Learning Center and Maplewood Middle School (2016): These school rain garden projects provide pollinator habitat and reduce the volume of polluted runoff that drains to Kohlman Creek.
- North Presbyterian Church (2017): This rain garden intercepts and filters runoff from the church parking lot, reducing the volume of polluted rainwater draining to Kohlman Creek.
- Target—North Saint Paul (2021): The project included the removal of an impervious parking lot to install four rain gardens and two linear tree trenches. The installed best management practices can reduce the volume of polluted runoff that drains to Kohlman Creek, as well as remove pollutants such as total suspended solids and total phosphorus.

Parameter	State Standard	2023 Kohlman Creek	Average	10-Year Trend
Phosphorus	≤ 100 µg/l	150 µg/l	111 µg/l (10-year average)	None
Total suspended solids	<15 mg/l	17.0 mg/l	18 mg/l (10-year average)	None
Nitrate	N/A	0.21mg/l	0.14 mg/l (6-year average)	N/A
Chloride	≤ 230 mg/l¹	279 mg/l	178 mg/l (10-year average)	Worsening

¹ State standard for chronic chloride exposure.













5. Best Management Practices (BMPs)

SAND FILTERS



City	Maplewood
Subwatershed	Kohlman Creek
Completed	2009
Cost	\$235,000
Funding Sources	District Levy Fund, Stormwater Impact Fund
Partners	City of Maplewood, University of Minnesota– St. Anthony Falls Laboratory

Beam Avenue Iron-Enhanced Sand Filter

RWMWD's iron-enhanced sand filter on Beam Avenue was installed in 2009 to improve the water quality of Kohlman Lake. It was the first filter of its kind in Minnesota.

Sand filters have been used for years to remove solids and pollutants from stormwater. Newer, iron-enhanced sand filters (sand mixed with iron filings) are now being used as an efficient and cost-effective means of removing phosphorus. The filter works through a chemical process in which phosphorus molecules bind to the iron particles in the sand filter as water passes through.

The RWMWD has monitored its iron-enhanced sand filter since 2009. Between 2009–2018, total phosphorus removal ranged from 70–93%. But, in 2019, it declined significantly (56%). For 2021 and 2022, the total phosphorus removal improved to 82% and 79%, respectively. However, in 2023, there was again a performance decrease to 56% removal. Removal of orthophosphate has declined, dropping from 70% removal in 2016 to -47% in 2019 (perhaps an indication that the filter is releasing dissolved phosphorus).

In 2021 and 2022, orthophosphate removal rates increased slightly to approximately 30%. In 2023, the removal of orthophosphate increased to roughly 75%. The increased removals between 2021 and 2023 could be because of drought conditions in the watershed but could also be attributed to the replacement of the media closest to the system's inlet in 2022. Removal of total suspended solids remains relatively steady, with average yearly removal consistently exceeding 85% for almost all monitored years. The average percent removal for the period of monitoring (2009–2023) is 73% for total phosphorus, 40% for orthophosphate, and 89% for total suspended solids













City	Maplewood
Subwatershed	Kohlman Lake
Completed	2009
Cost	\$72,900
Funding Sources	District funds
Partner	Simon Property Group, Minnesota Pollution Control Agency (monitoring)

Woodlyn Rain Garden Iron-Enhanced Sand Filter

The Woodlyn iron-enhanced sand filter is part of the larger Maplewood Mall stormwater retrofit effort. The goal of that project—designed to capture and filter 67% of rainwater at the mall site—was to decrease the phosphorus runoff to nearby Kohlman Lake. Prior to the project, only 3% of the stormwater runoff from the mall was captured and filtered.

The Woodlyn iron-enhanced sand filter is a narrow strip of iron-enhanced sand beneath a rain garden. Runoff is intercepted from a parking lot and directed to the rain garden. There, the stormwater filters through the ironenhanced sand for a period until it is treated. The average annual phosphorus removal with the filter has ranged from 3% during the first year of operation to 75% in 2018. The average annual removal of orthophosphate ranged from 0% in 2018 to 93% in 2015. The average removal for the period of monitoring (2012–2018) was 58% for total phosphorus, 73% for orthophosphate, and 94% for total suspended solids.

In 2022, over 10 years after the construction of the filter, total phosphorus, orthophosphate, and total suspended solids removal were all over 90%—the highest yearly removal rates since monitoring began. The infrequent and small rainfall events in 2022 may account for this increased performance, as the rain washed down impervious surfaces laden with atypically high levels of accumulated sediment. Due to the improved performance in 2022, Barr recommended monitoring of Woodlyn before deciding whether filter media replacement was required. In 2023, the filter was sampled more frequently, and the total phosphorus removal dropped to 61%. Orthophosphate removal dropped to 36%, and total suspended solids removal dropped to 83%. These results indicate that the 2022 monitoring data may not have been an accurate representation of the BMP and that the filter media should be replaced in the near future.

Total phosphorus removal performance



Orthophosphate removal performance





TSS removal performance

City	Maplewood
Subwatershed	Wakefield Lake
Completed	Fall 2011; filter media changed in 2022
Cost	\$40,000
Funding Source	MPCA 319 Grant
Partner	City of Maplewood

Wakefield Lake Experimental Iron and Granite Sand Filter

In 2022, the media in the Wakefield Lake experimental filter was replaced with iron and granite sand. Iron and granite sand were selected due to granite sand's high infiltration rate and iron's ability to remove dissolved phosphorus. The system was monitored in 2022 in three locations: inlet, "midlet," and outlet. The inlet is the inflow location, the "midlet" is where water leaves the filter media system, and the outlet is the outflow of the pond downstream of the filter (before Wakefield Lake).

In 2022, the filter system had mixed total phosphorus removal performance. The filter removed phosphorus during some events but released it during others. From inlet to outlet, almost all events had a reduction in total phosphorus, but the majority of removals came from the downstream pond. The filter had an average total phosphorus removal (between the inlet and the "midlet") of 9%, while the pond's average removal (between the midlet and the outlet) was 38%. A similar trend was apparent for orthophosphate and total suspended solids. The average orthophosphate removal from the filter was 19%, while the average removal from the pond was 61%. The average total suspended solids removal from the filter was negative, while the pond was 91%.

In 2023, the performance of the filter and the pond showed different trends. Phosphorus, orthophosphate, and total suspended solids were consistently removed, but the removal came from the filter and not the pond. In 2023, most removals were from the inlet to the midlet, and loading was from the midlet to the outlet. For example, the yearly average total phosphorus and orthophosphate removal for the filter was over 70%, while the pond was over -100% (i.e., loading). Similarly, the yearly total suspended solids removal was over 75% for the filter and -67% for the pond. The results of 2023 indicate that the filter is functioning as designed and is removing contaminants.

It is also important to note that in 2023, the total suspended solids concentrations in the effluent have remained constant compared to the high effluent concentration in May of 2022. One potential explanation for the high midlet concentration of total suspended solids in May of 2022 is that the granite sand was not washed well enough before being installed in the filter, resulting in a pulse of suspended solids getting washed off of the new media. In 2023, the "midlet" concentration of total suspended solids ranged from 11 to 21 mg/L, which supports that the granite sand has been washed thoroughly by storm flows.

Total phosphorus removal performance











SPENT-LIME FILTERS





City	Maplewood
Subwatershed	Wakefield Lake
Completed	2018
Cost	\$390,000
Funding Sources	Clean Water Fund (\$300,000) and District funds
Partner	City of Maplewood

Frost and Kennard Spent-Lime Filter

This innovative stormwater filter is at the corner of Frost Avenue and Kennard Street in Maplewood, a few blocks upstream from Wakefield Lake. It is designed to capture and filter stormwater runoff from a large portion of the lake's 944-acre subwatershed.

The filter intercepts water from the storm sewer and routes it into a 20- by 36-foot underground chamber. There, the water interacts with spent lime—a chalky claylike material consisting of calcium carbonate, which is a waste product of municipal drinking water treatment. Phosphorus in the water binds to calcium in the spentlime material, decreasing the amount of phosphorus in the water leaving the chamber.

Spent lime is particularly effective in removing a form of phosphorus called orthophosphate, often found in stormwater runoff. While orthophosphate is a vital nutrient for bacteria and plants in surface waters, too much orthophosphate can promote algae growth and decrease water clarity.

Sampling equipment monitors phosphorus levels and total suspended solids as water enters and leaves the filter on its way to Wakefield Lake, which is impaired for phosphorus. The goal is to help the lake meet the state standard for phosphorus (60 micrograms per liter).

The removal performance of total phosphorus, orthophosphate, and total suspended solids all show a similar pattern. From 2018 to 2021, there was a slight decrease in removals for all parameters. For example, total phosphorus performance was 68% in 2018, 61% in 2019, and 55% in 2021. This decreasing trend would indicate that the media may need to be replaced. However, in 2022, the filter had its best removal performance, with removals of 78% for total phosphorus, 65% for orthophosphate, and 93% for total suspended solids.

One potential reason for the increased performance in 2022 could be that 2022 was a drought year with typically small rainfall events. Monitoring from 2023 indicates total phosphorus and orthophosphate removals have declined, while total suspended solids removal remained high. Similar to 2022, 2023 was a drought year, so it is interesting to see removals decrease even when the climactic conditions were consistent. It is important to continue to monitor the Frost Kennard filter to see if performance is improving or if the media is reaching its lifespan, as the 2018–2021 and 2023 data suggests.

Total phosphorus removal performance



Orthophosphate removal performance





TSS removal performance



City	Maplewood
Subwatershed	Wakefield Lake
Completed	Fall 2011
Cost	\$40,000
Funding Source	MPCA 319 Grant
Partner	City of Maplewood

Wakefield Lake Experimental Spent-Lime Filter

This stormwater filter is adjacent to Larpenteur Avenue and Prosperity Road. It is designed to capture and filter stormwater runoff from a large portion of the lake's 944acre subwatershed.

The filter intercepts water from the storm sewer and routes it into an underground chamber. From 2011 to 2021, the filter media was spent lime. Spent lime is a chalky clay-like material consisting of calcium carbonate, which is a waste product of municipal drinking water treatment. Phosphorus in the water binds to calcium in the spent-lime material, decreasing the amount of phosphorus in the water leaving the chamber.

Spent lime is particularly effective in removing a form of phosphorus called orthophosphate, often found in stormwater runoff. While orthophosphate is a vital nutrient for bacteria and plants in surface waters, too much orthophosphate can promote algae growth and decrease water clarity. The goal of this filter is to decrease the amount of phosphorus and total suspended solids entering Wakefield Lake, which is impaired for phosphorus.

The graphs at right show the effectiveness of the spentlime filter in reducing total phosphorus, orthophosphate, and total suspended solids in 2012, 2013, 2015, and 2016. Peak performance for total phosphorus and orthophosphate removal occurred in 2015 (73 and 77%). In 2016, performance dipped to 42 and 38%. Removal of total suspended solids improved substantially from 2012 (-19%) to 2016 (61%). Over the four years of monitoring, the average removal for the three parameters was 51% for total phosphorus, 55% for orthophosphate, and 37% for total suspended solids. These averages include periods where performance was altered due to structural changes in the media after placement. For example, total suspended solids removal of around 50% is probably more typical as the media broke down and filled in pore space, improving the filtration effectiveness.

Total phosphorus removal performance









TSS removal performance

PONDS

City	Shoreview
Subwatershed	Snail Lake
Completed	2021
Cost	\$20,000
Funding Source	District funds
Partner	University of Minnesota

Shoreview Commons Pond

The Shoreview Commons Pond is north of Highway 96 in the Shoreview Commons Park. The pond has a drainage area that is approximately 144 acres (35% impervious), primarily comprising residential and institutional land. The outflow of the pond travels to Snail Lake. Shoreview Commons Park Pond has a historical trend of odor problems, low water clarity, and significant duckweed growth.

The pond was initially studied in 2018 using sediment cores, laboratory mesocosms, and in-situ water quality sampling. The 2018 study determined the baseline water quality for the pond, which was used to develop an iron filings treatment plan and dose. St. Anthony Falls Laboratory researchers chose to add iron filings to the pond to reduce internal loading and improve the pond's water quality. In February 2021, 12,000 pounds of iron filings were applied to the surface of the frozen Shoreview Commons Pond. The application of iron on ice allows the filings to be equally distributed into the pond as the ice melts.

From 2018 to 2019 (pre-iron-filing application), the annual average total phosphorus removal in the pond was 32% and 56%, respectively. In 2021 and 2023, post-application, the average annual total phosphorus removal was 84% and 72%, respectively. During 2021 and 2023, there were only three monitoring events (out of 19) that resulted in negative or no total phosphorus removal. These results indicate that the filings have the potential to reduce internal phosphorus loading. Unlike total phosphorus, there is no clear trend for orthophosphate removal. In 2018 and 2019, pre-application, the orthophosphate removal was 38% and 61%, respectively. Meanwhile, in 2021 and 2023, post-application, the orthophosphate removal was 68% and 29%, respectively. Therefore, it appears the iron-filing application may not impact orthophosphate removal. There is no clear trend for total suspended solids removal; the removals pre- and post-filings have been consistent with the yearly averages, exceeding 80%.

It is difficult to draw conclusions on the Shoreview Commons Pond performance due to two important facts. First, the 2021 and 2023 data periods were drought years, while 2018 and 2019 were wet/average years for precipitation. Therefore, the years may not be very comparable because the precipitation conditions impact loading and removals for the pond. Second, the pond had a fountain (aerator) installed between October 2020 and August 2021, which may have interfered with the pond's water quality. Based on Google Earth imagery, it appears the fountain was on in 2023.



Phosphorus removal performance (mg/l)







Total suspended solids removal performance (mg/l)

ALUM TREATMENT SYSTEM





City	Oakdale
Subwatershed	Tanners Lake
Completed	1998
Cost	\$1.9 million1
Funding Sources	District funds, Minnesota Pollution Control Agency State Revolving Fund Loan

¹ This cost reflects the alum facility as well as other related water quality improvements: Tanners Lake 5th Street Basin, Tanners Lake Berm, Tanners Lake Tartan High School Pond

Tanners Lake Alum Treatment Facility

The Tanners Lake alum treatment facility was constructed in 1998 to reduce the amount of phosphorus reaching Tanners Lake. The facility receives stormwater runoff from a 1,246-acre watershed and injects it with aluminum sulfate (known as alum). The alum then binds with the phosphorus in the water and forms a floc that settles to the bottom of a pond upstream of Tanners Lake. The water that ultimately drains out of the pond to Tanners Lake has significantly lower phosphorus content.

The graphs below show the effectiveness of the alum treatment system in reducing total phosphorus over the last 20-plus years of monitoring. Peak performance for phosphorus removal occurred in 2003 (91%) after improvements to the system in 2002. From 2004 to 2019, total phosphorus removal would consistently range from 72% to 89%. From 2021 to 2023, there has been a downward trend in total phosphorus removal.

In 2023, there were multiple events with phosphorus outflow concentrations that were over 0.1 mg/L from the end of May to the end of July. One potential explanation for these high concentrations is that in 2023, the alum treatment plant was shut down from May 9 to May 26 due to low-flow conditions. After the alum treatment plant was shut off, the inlet was flushed, resulting in untreated water entering the alum pond and, potentially, higher phosphorus concentrations. It will be important to continue monitoring total phosphorus removal to determine if the downward trend persists or is a byproduct of the low-flow conditions for 2021 to 2023







Total aluminum

69



Perfluoroalkyl substances (PFAS)

Perfluoroalkyl substances (PFAS) are also referred to as Perfluorochemicals (PFCs). PFAS are a family of manmade chemicals that have been widely used for decades. PFAS are extremely stable and do not breakdown in the environment. Common uses of PFAS include the following:

- Nonstick cookware, stain-resistant carpets and fabrics
- Coatings on some food packaging (especially microwave popcorn bags and fast food wrappers)
- Components of fire-fighting foam
- Many industrial applications

PFAS have been found in the groundwater in certain parts of Minnesota and are considered to be "emerging contaminants." Emerging contaminants are contaminants about which the MPCA has a new awareness or understanding of how they move in the environment or affect public health. PFAS, like other emerging contaminants, are the focus of active research and study, which means that new information is released occasionally.

Generally, surface water foam on natural water bodies is naturally occurring and does not contain PFAS. However, if PFAS-containing foam is found on surface water, MDH states that it does not pose a risk to human health if skin contact with the foam is minor and infrequent. Overall, with respect to contact with water bodies containing PFAS, MPCA recommends "when in doubt, stay out."

In 2019 and 2020, the Minnesota Department of Health (MDH) collected samples for PFAS analysis from Battle Creek (surface water and foam) and Battle Creek Lake (surface water) after discussions with the Minnesota Department of Transportation related to transit route planning in the area. All samples were analyzed for seven different PFAS compounds by the MDH Public Health Laboratory.

Various forms of PFAS (PFOS, PFOA, PFBA, PFPeA, PFPxA, PFBS, and PFHxS) were detected in surface water from both Battle Creek and Battle Creek Lake. Concentrations were low, especially in Battle Creek Lake. High concentrations of PFAS (PFOS, PFOA, PFBA, PFPeA, PFPxA, PFBS, and PFHxS) were detected in samples from the surface foam on Battle Creek.

This work is being conducted under MPCA's Superfund Site Assessment program. The objective of the program is to confirm earlier monitoring results and to develop lines of evidence for determining the potentially responsive party that can be brought into the Superfund program.

The Minnesota Department of Health (MDH) has guidelines for the recommended consumption of fish based on species type. The MDH has also tested fish for contaminants throughout the state to determine if guidelines should be more stringent based on contaminant concentration results and potential impacts to humans. For example, should the frequency of eating bass be reduced from once a week to once a month because bass in a given lake have a higher concentration of PFAS or mercury? The MDH has determined that the following lakes in the District should have more strict guidelines for fish consumption based on PFAS/PFOS results: Battle Creek Lake, Bennett Lake, Gervais Lake, Keller Lake, Lake Phalen, Tanners Lake, and Lake Owasso (low PFAS concentrations).



MPCA's 2019 PFAS sampling locations



MPCA's 2020 PFAS sampling locations


Chloride is a component of total dissolved solids (or total dissolved salts); chloride alone or in combination with other dissolved salts can be toxic to aquatic life. The MPCA's chronic chloride criteria is 230 mg/L.

Most aquatic life criteria are based on testing with sensitive species; hence, the cumulative ecological impact of shortterm or persistently high chloride is challenging to identify. Clearly, maintaining chloride below the 230 mg/L criteria will have ecological benefits by reducing overall stress on aquatic life. However, the potential ecological effect can be expected to be a function of the degree to which a given water sample exceeds criteria (e.g., how much greater than 230 mg/L), the frequency of the exceedance, and the persistence. The first step is to examine which water bodies have high chloride concentrations and consider if there are areas within the District with high concentrations ("hot spots").

Chloride monitoring work prior to 2021 was focused on the routine annual sampling that occurs in lakes and streams, as presented in earlier sections of this report. Starting in 2021, the District began sampling chlorides after ice out, typically taking place from late March to early April. The goal of ice-out chloride sampling was to understand the worst-case chloride concentrations that are a result of road salt application. The 2021 and 2022 sampling efforts focused on sampling the District areas that do not drain to Pig's Eye Lake, a public water that is in the floodplain of the Mississippi and has been impacted by industrial activities. Between 2021 and 2022, 63 samples were collected, representing approximately 80% of the District's stormwater runoff that does not enter Pig's Eye Lake (see Figures 6-1

through 6-3 on the following pages).

In 2023, the ice-out chloride sampling protocol was shifted. Thirty sampling locations were identified; half were selected because they were in the top 50th percentile of chloride concentrations between 2021 and 2022. The primary goal of collecting samples at these locations was to understand potential annual fluctuation in chloride concentrations. The remainder of the sample locations were chosen because they are in the Tanner Lake, Battle Creek Lake, Carver Lake, or Kohlman Lake subwatershed all of which are listed by the MPCA as impaired for chlorides. Another goal of collecting samples at these locations was to understand local hot spots in impaired water body subwatersheds. An additional 16 samples were taken by RWMWD and Ramsey County; these were focused on larger lakes in the District and county.

Results of the 2023 sampling are presented in Figure 6-4. These results were used to understand the following: impacts of winter weather on chloride, potential statistical relationships between chloride and land use, and chloride concentrations in impaired subwatersheds.

Eighteen locations were sampled consecutively between 2021 and 2023. For 15 of the locations, the concentration of chlorides in 2023 was less than in 2021 and 2022. In addition, the 2021 samples were, on average, 25% higher than the 2023 samples. Barr reviewed the climate and precipitation data for the winter period of interest (presented in Table 1) to better understand these annual fluctuations in chloride concentration.

Table 1: Winter Weather Statistics (November 1–March 30)						
Year	Average Max Daily Temperature	Average Min. Daily Temperature	Total Season Precipitation (inches)	Total Season Snowfall (inches)	Total Days of Precipitation	Total Days of Snowfall
2021	35.6	20.1	6.26	38.90	39	27
2022	32.4	15.2	7.2	48.6	47.0	33.0
2023	31.8	17.5	11.57	86.10	56	46

One potential cause for a decrease in chloride concentration (i.e., salt use) in 2023 is that it was a colder winter, which had more snow in terms of days and snowfall. During colder events, road salt effectiveness is decreased, and use is not recommended to improve driving conditions. During snowstorms, there will primarily be a focus on plowing instead of road salt application. During warmer events with mixed precipitation, rock salt or chemical anti-icing methods are commonly applied to prevent slick roads. These results indicate that during colder years with more snowfall, the chloride concentrations in local waterbodies may be lower.

Barr used the 2023 results to understand if there are any trends between chloride concentration or chloride exceeding the state standards based on properties of the drainage area (i.e., total drainage area, imperviousness, percent type of land use, acres of land type, and primary land use). Land use for this study was defined as highway, parks/recreational/preserve, industrial, commercial, residential, and undeveloped. Results showed there was no statistical correlation with chloride concentration for total drainage area, percent of land use type, acres of land type, or the primary land type. Similarly, there was no statistical correlation for a pond being above or below the state chloride standard based on the percent of land use type, acres of land type, or primary land type. However, statistical tests show a positive correlation between the imperviousness of the drainage area and chloride concentration in the receiving waterbody.

Another area of interest for the 2023 data was to identify local hot spots in impaired chloride lake subwatersheds and corresponding potential salt applicators, with the goal of performing targeted outreach. In the Tanners Lake subwatershed, three ponds were sampled (Figure 6-5), and two areas had higher chloride concentrations. One pond, with a concentration of 213 mg/L, has primarily a large commercial drainage area. Another (a concentration of 229 mg/L) has a drainage area that comprises only an apartment building and residential housing. These two ponds are close to the standard but are still relatively low compared to some of the other samples taken in 2023. It is interesting to note that during the ice-out period, Tanners Lake (205 mg/L) was at a concentration lower than the state standard.

The Battle Creek Lake subwatershed had six samples taken, with one sample collected in the lake (Figure 6-6). Four ponds and the lake (255 mg/L) were above the state standard for chloride. Overall, these drainage areas primarily comprise industrial plots and commercial plazas. It is important to note that the drainage areas of ponds measured at 371 mg/L and 335 mg/L also included a large residential component. One potential outreach opportunity for the Battle Creek Lake subwatershed is to communicate with commercial and residential property owners about their salt use and potential ways to decrease it.

Similar to Battle Creek Lake, Carver Lake's chloride concentration (314 mg/L) was above state standards. Out of the nine ponds monitored in the subwatershed, only one was over the state standard, as shown in Figure 6-7. The hot spot in the watershed (435 mg/L) receives direct runoff from a townhome community and highway. It is important to note that four ponds were within 45 mg/L of the state standard criteria, and their drainage areas are primarily residential. A potential action in this subwatershed is to better understand whether the hot spot monitored in 2023 is primarily impacted by direct runoff or runoff further upstream. Understanding the source could help reduce the concentration in this pond and, theoretically, in Carver Lake.

The final lake of interest was Kohlman Lake, measured at 741 mg/L, a concentration 40% higher than the next highest impaired lake (Carver Lake). Three ponds were sampled in the Kohlman Lake subwatershed as part of the ice-out monitoring (Figure 6-8). The lowest measured sample was 256 mg/L, which is over the state standard. This pond has a drainage area that consists of a manufactured housing development, a church, and a commercial plaza. The other two ponds had chloride concentrations of 486 mg/L and 538 mg/L. These ponds are interesting because some of the primary land users include car dealerships and car collision repair shops.

It is also important to note that samples were taken in Kohlman Creek as part of the annual monitoring effort. The Kohlman Creek monitoring location receives runoff from a drainage area that is not included in the ice-out monitoring. Data from Kohlman Creek was analyzed from mid-March 2023 to the end of April 2023 to understand ice-out conditions. The average creek baseflow chloride concentration was 346 mg/L, and the storm chloride concentration was 183 mg/L. Based on these sampling results, it appears that the creek and its drainage area also contribute to the high chloride concentration in Kohlman Lake. A potential outreach opportunity in the Kohlman Lake subwatershed is to work with the car dealerships and car repair shops that are potentially responsible for the chloride in the ponds adjacent to Kohlman Lake.



Very High, Above 500 mg/L High, 230 mg/L to 499 mg/L Medium, 116 mg/L to 229 mg/L Low, below 115 mg/L *Numbers represent chloride concentration in mg/L 0 2 Miles

SAMPLING RESULTS

FIGURE 6-1





2021 Subwatershed Concentrations In 2021 Very High, Above 500 mg/L In 2021 High, 230 mg/L to 499 mg/L In 2021 Medium, 116 mg/L to 229 mg/L

🖊 In 2022 High, 230 mg/L to 499 mg/L 116 mg/L to 229 mg/L to 229 mg/L Z In 2022 Low, below 115 mg/L



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CHLORIDE ICE OUT SAMPLING RESULTS

FIGURE 6-3











Mercury

n Minnesota, numerous lakes have aquatic consumption impairments due to mercury in fish tissue. These lakes are considered impaired by mercury. Mercury contamination in Minnesota is primarily due to air deposition and not from point sources. Therefore, the MPCA developed a statewide TMDL to address mercury impairment in its lakes.

Mercury in fish tissue is problematic and dangerous for two primary reasons. First, there is no method for cooking or cleaning fish to reduce the concentration of mercury in the fish before consumption. Second, mercury is a compound that is prone to bioaccumulation and biomagnification in fish tissue. Bioaccumulation is the process of chemical concentrations increasing in a single fish over its life span because it consumes a chemical, and the chemical will not degrade via ingestion or other biological processes. Biomagnification is the process of chemical concentrations increasing from lower to higher on the food pyramid by animals high on the food pyramid consuming animals lower on the food pyramid.

The combination of bioaccumulation and biomagnification of mercury results in larger fish being more likely to have a high concentration of mercury in their fish tissue. Given the issues with bioaccumulation and biomagnification, the Minnesota Department of Health (MDH) has guidance on which fish can be eaten and at what frequency (i.e., if a sunfish from a given lake can be eaten as one meal a week or one meal a month, depending on the contamination levels). In addition, guidance from the MDH can be more stringent if the lake is impaired by mercury.

RWMWD has nine lakes that are designated as impaired by the MPCA for aquatic consumption due to mercury in fish tissue:

- Battle Creek Lake, listed in 2012
- Beaver Lake, listed in 2002
- Bennett Lake, listed in 2012
- Carver Lake, listed in 1998
- Eagle Lake, listed in 2008
- Gervais Lake, listed in 1998
- Lake Owasso, listed in 1998
- Lake Phalen, listed in 2012
- Snail Lake, listed in 2002
- Tanners Lake, listed in 2002

Currently, the District does not monitor for mercury in surface water or fish tissue. However, the Minnesota DNR has tested fish in all nine lakes listed above. More information on fish contamination testing and results can be found for each specific lake on the Minnesota DNR LakeFinder Database.





This section describes the work the District has done managing fisheries in its water bodies to improve the water quality of its lakes. To date, efforts have been focused on carp management due to their ability to decrease water quality. Below is a summary of the carp management projects that the District has implemented.

Carp are notorious for deteriorating the water quality of lakes because they stir up sediment and sediment-bound phosphorus while searching for food at the lake bottom. Carp also tend to uproot and disturb submerged aquatic vegetation. They reproduce quickly, have long life cycles, and lack natural predators—increasing the longevity of their impact on water quality. Studies have indicated that carp biomass over 90 pounds per acre can lead to reduced lake water quality (Bajer et al., 2009). Over the past several years, RWMWD has completed significant work to quantify, track, remove, and limit the movement of carp in various waterbodies in the District. Since 2009, the District has worked to reduce carp in the Phalen Chain of Lakes with the use of fish surveys, capture events, the draw down of Casey Lake (a major carp nursery), and the installation of carp barriers. Due to the success of this program, a similar effort was initiated on the Owasso chain of lakes and is detailed below:

- In 2017, electrofishing surveys for carp were completed on Lake Owasso, Bennett Lake, Lake Wabasso, Lake Emily, Grass Lake, and West Vadnais. Due to high catch rates, a recapture study was completed on Lake Owasso. The Lake Owasso recapture study was completed by marking over 200 carp and releasing them back to the lake, then recapturing them again later in the summer. Results of the recapture study predicted that the population of carp was roughly 15,500 adult carp with a biomass of 195 pounds per acre (double the water quality management threshold).
- From August 2017 to February 2018, 20 carp in Lake Owasso were monitored with radios to record their movements. Tracking the movement of carp can be a beneficial tool for understanding where carp spawn and potential locations to try to capture and remove them. Tracking showed that during the winter, carp move to and typically stay in the northwest bay of Lake Owasso. In February 2018, a commercial carp fishing company was hired to assist with catching the carp in the northwest bay. Unfortunately, the event was unsuccessful due to the nets breaking on submerged objects.
- In May 2018, carp barriers were installed in five locations on the Owasso chain. The barriers prevent carp from migrating in shallow channels to smaller ponds and wetlands where they prefer to spawn. If carp spawn in larger lakes, the spawn rate is lower due to eggs and young being eaten by native fish. To date, the carp barriers have been successful—the carp are seen at the barriers during checks and unable to access the small channels. Any carp found during carp barrier checks are removed. Success can also be seen by fewer young carp in the main lakes and decreasing carp biomass.

Given the success on the Phalen Chain and Owasso Chain, an electric carp barrier was installed at the West Vadnais Lake Outlet in 2021. The barrier also has passive integrated transponder (PIT) technology. Over the years, hundreds of carp have been tagged with PIT. If a carp with a PIT sensor hits the barrier, the PIT technology will track the hit and record it. This information can be used to determine if the barrier is preventing tagged fish from traveling elsewhere.



Over the years, the District has pursued aquatic vegetation projects to help improve lake health and water quality. Below is a summary of the aquatic vegetation management projects the District has conducted over the last decade.

A healthy lake should have aquatic vegetation, which provides food and shelter to many aquatic animals. However, too much aquatic vegetation can be detrimental to water quality. Excess aquatic vegetation can store phosphorus and then release it to the water column when it dies and decays. In addition, invasive species such as Eurasian watermilfoil or curly leaf pondweed can grow densely, limiting the growth of native plants and the ability of the lake water to mix oxygen throughout the water column. In such cases, aquatic vegetation management (i.e., harvesting) may be required.

The District has, on occasion, selectively employed aquatic vegetation harvesting in District lakes. From June to August 2015, the District hired a contractor to conduct aquatic plant harvesting on Kohlman Lake. The aquatic plant harvesting occurred multiple times throughout the summer, going to a depth of 1 meter; this protected against over-harvesting. The harvesting was conducted primarily in the middle of the lake to provide open-water space for recreation. Results from the harvesting predict that 33 kg of total phosphorus in plant matter was removed.

The District has also conducted a macrophyte study in Kohlman Lake that looked at the impacts of macrophyte management. This study is in draft form but will be published on the District's website and presented to the board of managers in 2024.

Harvesting has been regularly conducted on Casey Lake since a carp removal event in 2012. The harvesting depth in Casey Lake is set to 0.3 meters to minimize substrate disturbance. The 2013 harvesting was analyzed, determining that the phosphorus removed from harvesting was the equivalent of 53% of the total phosphorus inflow to Casey Lake.

Evaluation of monitoring data for Casey Lake and Kohlman Lake indicates that limited harvesting (e.g., selectively cutting one foot deep) has potential benefits such as reduced phosphorus loading to lake bottom sediment and potential water quality improvement for downstream lakes by removing phosphorus from the overall system.





2665 Noel Drive Little Canada, MN 55117 P: 651-792-7950 E: office@rwmwd.org