Young Environmental Consulting Group, LLC

Technical Findings Memorandum

To: Chris LaBounty, Deputy Public Works Director and City Engineer, City of Plymouth
Laura Jester, Administrator, Bassett Creek Watershed Management Commission

From: Della Schall Young, CPESC, PMP
Grant Goedjen, EIT

Date: July 5, 2022

Re: Parkers Lake Chloride Facilitation and Data Evaluation Project—Technical Findings Memo

---

Parkers Lake is an approximately 100-acre recreation lake located within the city of Plymouth, Minnesota (Plymouth) and Hennepin County (County). The lake is positioned on the west side of the Bassett Creek Watershed Management Commission (BCWMC) watershed boundary, as shown in Figure 1. The Minnesota Pollution Control Agency (MPCA) has placed the lake on the impaired waters list for chloride as the lake has commonly exceeded the chronic chloride state standard. The chronic chloride state standard, or a constant concentration over a four-day period which may result in an impact aquatic life and the health of the lake, set by the MPCA is 230 milligrams per liter (mg/L). The acute chloride standard, or point where irreversible damage to the ecosystem may be possible, is set by the MPCA is 860 mg/L.

As a result of Parkers Lake regularly exceeding the chronic chloride state standard and being listed as impaired for chlorides Plymouth and BCWMC initiated a capital improvement project aimed at mitigating chloride transport to and accumulation in the lake. To determine which projects and strategies should be prioritized for evaluation, Plymouth partnered with the Hennepin County Chloride Initiative (HCCI) to convene a cohort of the local chloride experts to better understand the expected transport of chloride by land use within the lake watershed and possible best management practices (BMPs) to consider.

HCCI is a collaborative of all eleven watershed organizations in Hennepin County, the County, the MPCA, and many cities from across the county. HCCI's goal is to reduce the amount of chloride entering our waterways from the overuse of winter deicing materials. While each of the HCCI members work in their own jurisdictions on this issue, the HCCI project uses Clean Water Funds through a state grant to collectively address this issue by pooling ideas and resources and promoting common messages and strategies, with an emphasis on private property owners and managers, from large retail centers to small properties or residences.

The cohort that was convened included individuals with an understanding of how chloride is used by various applicators, how it is generally transported through developed and natural systems, historic data trends within waterbodies in the County, and mitigation strategies being explored. This group, listed below, provided a holistic review of available data, identified applicable trends, and recommend structural and nonstructural best management practices (BMPs) to be studied for piloting in the city.

- Ben Scharenbroich, City of Plymouth
- Connie Fortin, Fortin Consulting (Bolton & Menk)
- Diane Spector, Shingle Creek Watershed Management Commission (SCWMC) and Stantec
- Emily Resseger, Deborah Manning and Walter Atkins, Metropolitan Council (Met Council)
- Greg Wilson, Nine Mile Creek Watershed District (NMCWD) and Barr Engineering (Barr)
- Jake Newhall, City of Minnetonka (Minnetonka) and WSB
- Jessica Wilson, City of Edina (Edina)
- John Gulliver, University of Minnesota
- Karen Chandler, BCWMC and Barr
- Laura Jester, BCWMC
- Leslie Yetka and Chris Long, City of Minnetonka

Plymouth retained Young Environmental Consulting Group, LLC (Young Environmental) to assist with the design, facilitation, and documentation of the project. The Project Team (Plymouth and Young Environmental) consisted of Chris LaBounty, Plymouth and Della Schall Young and Katy Thompson, Young Environmental.

This memo documents the process and its outcomes.

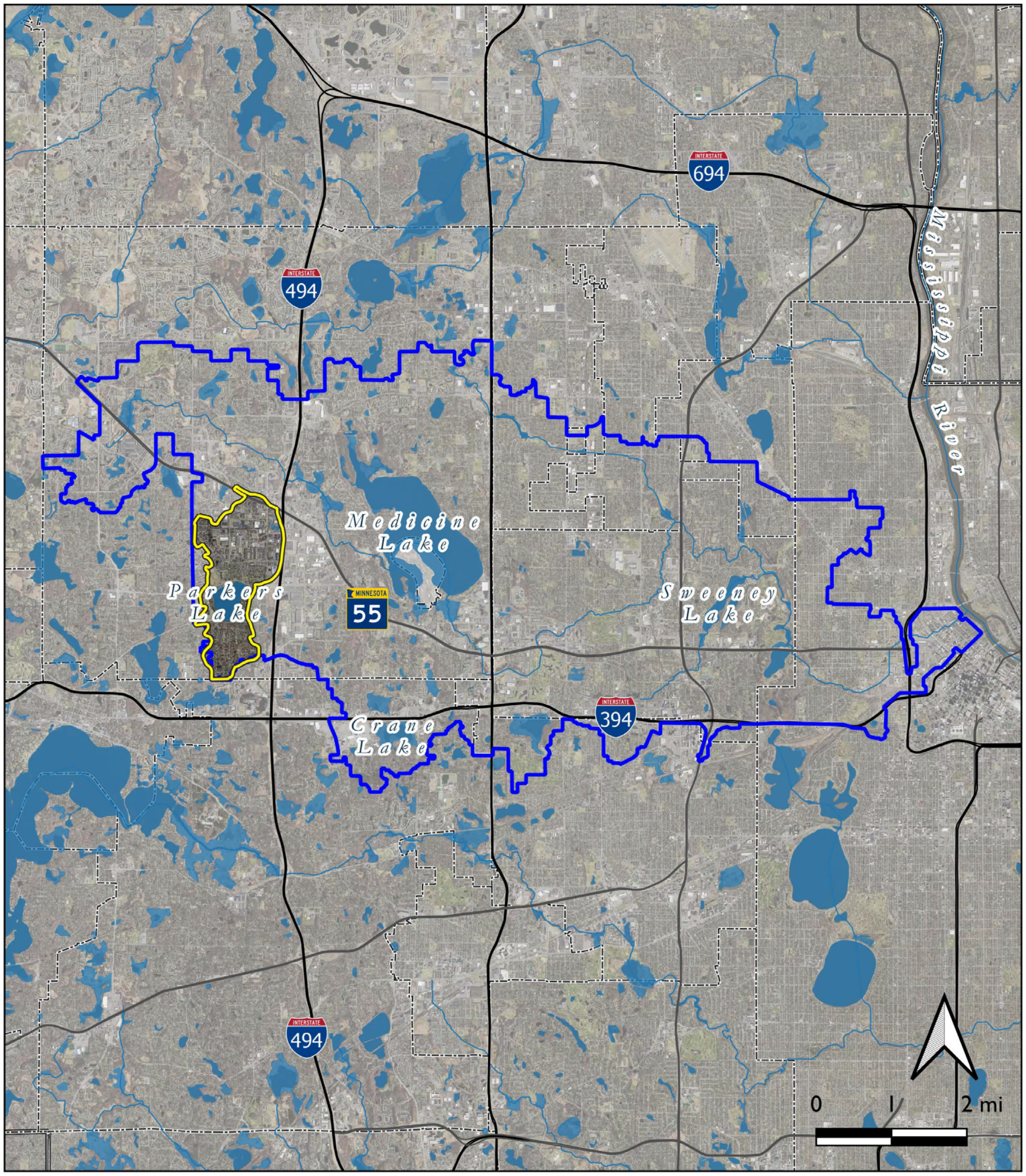
Scope and Purpose

The scope of this project is to examine the chloride issues in and contributing to Parkers Lake. Below is scope of the project as, as detailed in this memo:

1. Compile available land use data and chloride concentrations
2. Develop consensus on the chloride sources to Parkers Lake and potential projects to address these sources
3. Develop a recommendation for a future pilot project to reduce chloride concentrations in Parkers Lake, which could be replicated in other areas of Hennepin County similar to Parkers Lake
4. Help target education and training needs by land use.

The purpose of this memo is to document the data compiled and assessed, as well as summarize the engagement process used to achieve the scope and purpose of the project.

Figure 1: Location Map of Parkers Lake Subwatershed (Plymouth)



LEGEND

- Bassett Creek WMC
- Parkers Lake Watershed
- Public Waters
- Public Watercourses
- City Boundaries
- Interstate and Highways

City of Plymouth

Young Environmental Consulting Group, LLC

Methodology

To achieve the scope of work, Project Team agreed to the approach described in the following section, which includes soliciting and compiling data; designing and facilitating focused cohort engagement; and collecting and documenting applicable chloride mitigation BMPs.

Engagement

Plymouth identified and vetted members of the cohort and extended invitations. Following confirmation of the cohort members, the Project Team designed and facilitated a participatory engagement plan consisting of four virtual workgroup sessions (WGS) and a survey, as described in the following. The information generated through the engagement activities is incorporated into this memo.

WGS 1 was the first and introductory session held on July 26, 2021. Background information about the genesis of the Parkers Lake Chloride Project, its goals and objective, and the project schedule were shared. The session also included a full introduction of the cohort members and the project.

WGS 2 was split and held on October 27, 2021, and November 15, 2021. At those sessions, data from the cities of Plymouth, Edina, and Minnetonka, Metropolitan Council, BCWMC, SCWMC, and NMCWD were reviewed, and themes and trends were discussed as they relate to the conditions within the Parkers Lake sub-watershed.

WGS 3 was held on December 17, 2021. The session focused on reviewing the applicability of implementing 23 BMPs within the Parkers Lake sub-watershed. Following a robust discussion, the cohort gravitated towards six BMPs with the greatest promise for implementation.

Between WGSs 3 and 4, the Project Team designed and solicited input using a survey. The survey requested input on the effectiveness of and gauged interest in the ability of the shortlisted BMPs to improve Parkers Lake chloride impairment.

WGS 4 was the fourth and final session and was held on January 13, 2022. The session focused on reviewing the findings of previous sessions and the BMPs survey results, discussing the advantages and disadvantages of the six BMPs considered, and polling for input from the cohort on the general conclusions of the land use correlations.

The implementation of the outlined engagement plan allowed the Project Team to assess available data on Parkers Lake and comparative data from cohort members, build consensus around upstream land use and its effect on downstream chloride concentrations, and identify viable BMPs for improving the chloride impairments of Parkers Lake.

Data Compilation and Correlation

Parkers Lake is generally considered landlocked, discharging only under elevated water conditions. It flows southeast to wetlands, a lift station, and ultimately flowing into Medicine Lake. The lake's watershed is approximately 1,150 acres made up of commercial and industrial; multi- and single-family residential; and public institutions and roadways (city, county, and highway) land uses.

Plymouth partners with the Three Rivers Park District (TRPD) to conduct in-lake water quality monitoring, which began in 2000. Watershed sampling at select storm sewer outlets into the lake began in 2013 and sampling along County Road 6 (See Figure 2) began in 2021. The sampling locations shown in Figure 2 and described as follows were analyzed at the Minnesota Pollution Control Agency-certified TRPD lab, using the standard methods established by the Water and Wastewater 22nd edition (2011).

- **PL1:** Monitored for chloride since 2013, this site is located on the south side of Parkers Lake and represents the input from single-family residential land use. Data were collected using an ISCO automatic flow sampler and event-based grab samples.
- **PL2:** Monitored for chloride since 2013, this site is located on the north side of Parkers Lake and represents a mix of open space, transportation rights-of-way, and high-density residential land uses. Also known as HCS1S, this site can be used to approximate the influence of County Road 6 when the inputs from site CS1 are subtracted. Data were collected biweekly using grab samples.
- **PAR:** Monitored for chloride since 2019, this site is in Parkers Lake itself and is collected at the water surface (PAR-0) and at 10 meters in depth (PAR-10). Data were collected biweekly from May through September at the surface and bottom of the lake following U.S. EPA's Field Operations Manual (2007) sampling protocols.
- **CS1S:** A new monitoring location in 2021, established to quantify the chloride loading from various land uses, this site is collected in a drainage swale and represents high-density residential, city park, and commercial land uses. Data were collected using grab samples based on precipitation events.
- **CS1:** A new monitoring location in 2021, established to quantify the chloride loading from various land uses, this site is collected in the Plymouth storm sewer on Niagara Lane. It represents a mix of transportation rights-of-way, high-density residential, and open-space land uses. When CS1S is subtracted from CS1, the results represent only the contributions from Niagara Lane. Data were collected using grab samples based on precipitation events.
- **CS2:** A new monitoring location in 2021, this site is collected in the Plymouth storm sewer on 21st Avenue and represents a mix of commercial and industrial land uses. It does not quantify the chloride loading of all of the northeast Parkers Lake subwatershed but does reflect flow from nearly all of the commercial/industrial areas of it. Data were collected using grab samples based on precipitation events.

Land uses attributed to the Parkers Lake watershed and details on the locations of the northwest and northeast monitoring locations within the Parkers Lake watershed are shown in Figures 3a and 3b and characterized in Table 1. The information provided herein were presented during WGSs 2.1 and 2.2, and correlations were confirmed during the polling exercise at WGS 4.

Portions of the Parkers Lake watershed are not captured by these monitoring locations. This includes single family residential on the east and northeast side of the lake, park land adjacent to the lake, and institutional land use (correctional facility) located on the west side of the lake.

Figure 2: Parkers Lake monitoring locations map (Plymouth)

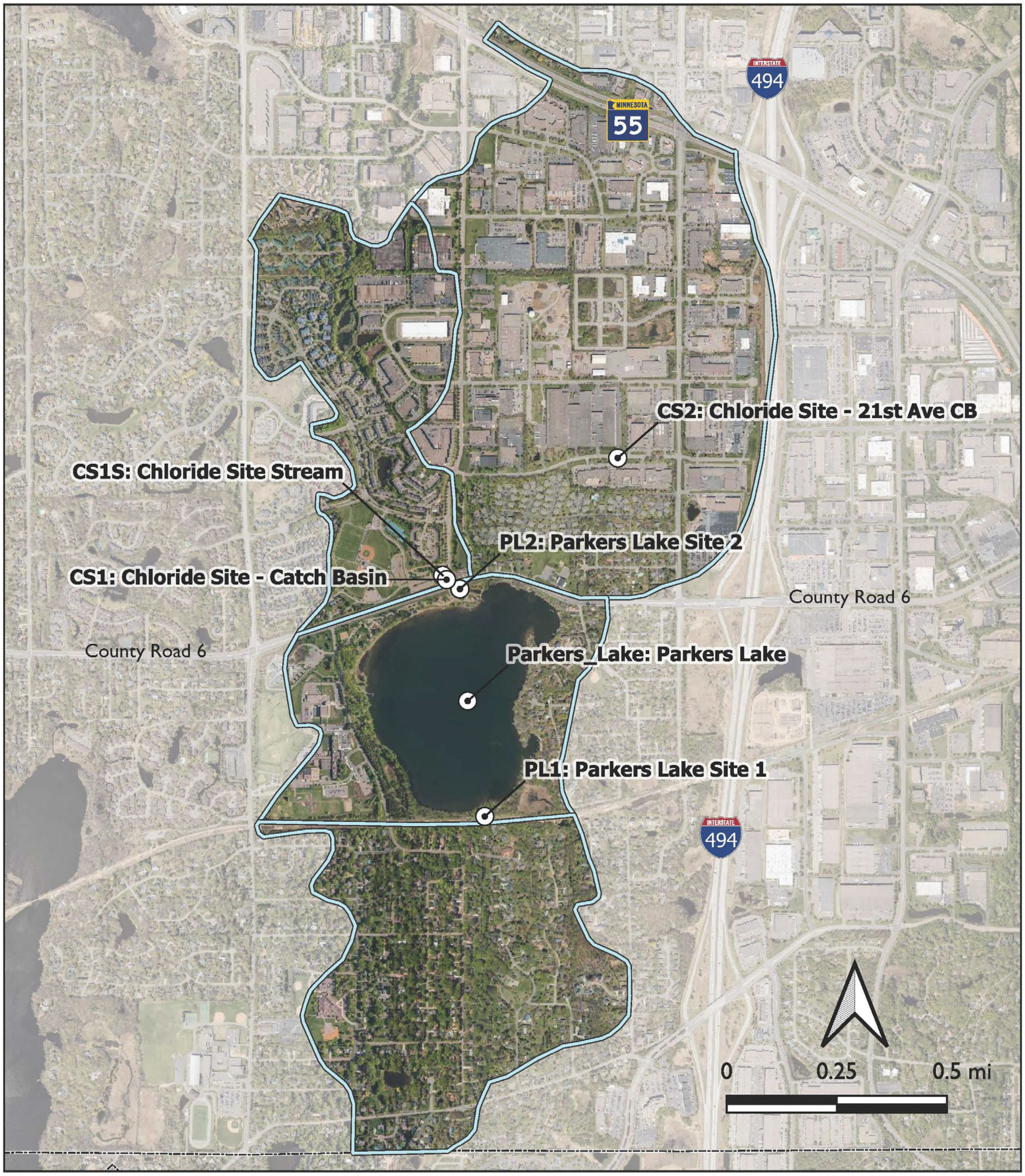


Figure 3a: Parkers Lake NE & NW sampling location details (Plymouth)

Figure 4b: Parkers Lake watershed land uses (Plymouth)

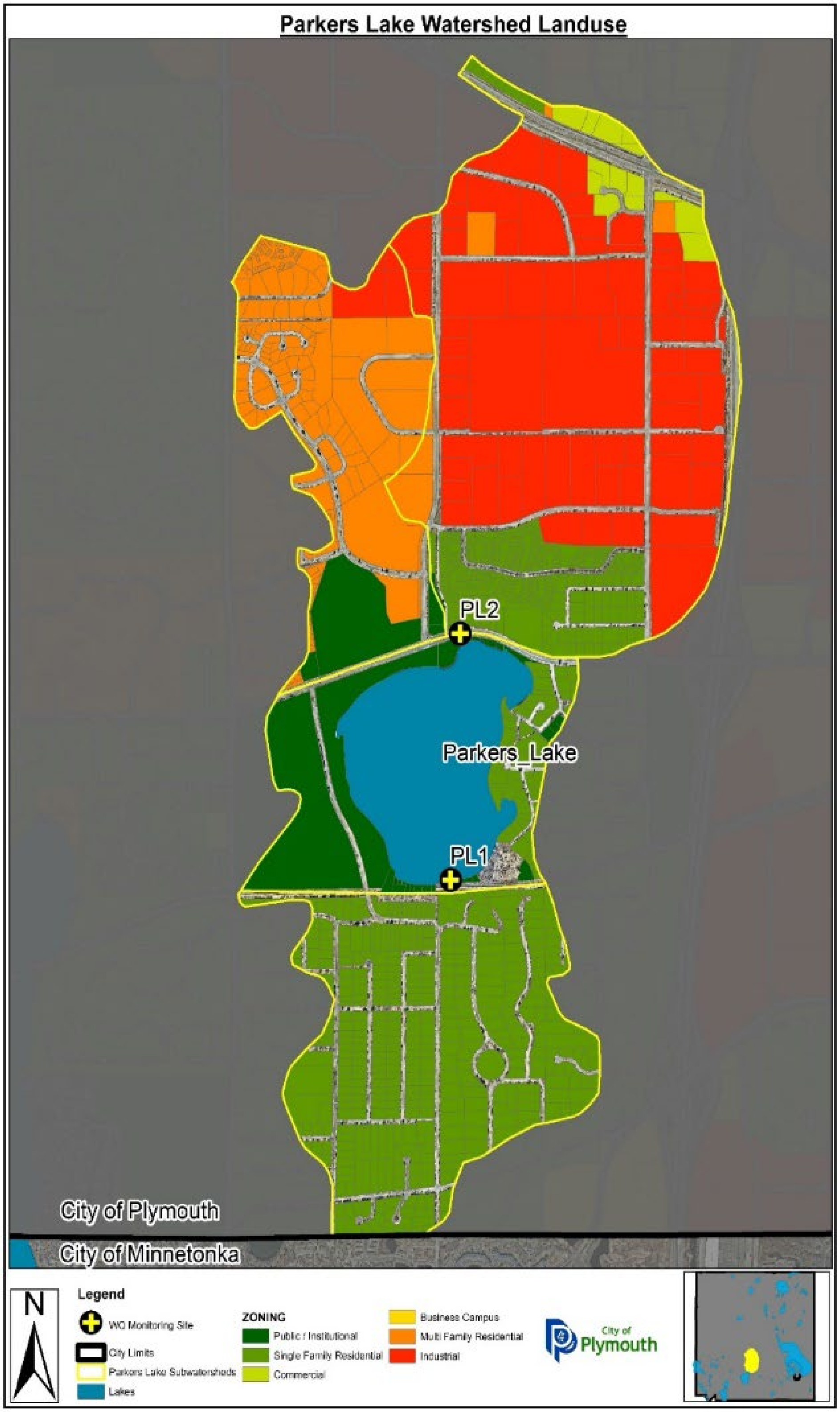


Table 1: Parkers Lake chloride monitoring locations, year monitoring began, and upstream land uses and drainage areas (Plymouth, 2021)

Monitoring Site		**Lane Miles**		**Land Use, Acres[1]**				**Drainage Area, Acres[1]**
Name	Year Start	Local	State/Co	Commercial or Industrial	Multifamily Residential	Single-Family Residential	Public or Institution	
PL1	2013	11.4	0	0	0	237	2	239
PL2	2013	5.8	0.8	82	77	1	30	190
CS1	2021	0.6	0	0	4	0	2	6
CS1S	2021	5.2	0	0	77	1	28	106
CS2	2021	16.2	4.2	378	0	14	0	392

[1] Data were rounded to the nearest whole number.

Parkers Lake is impaired for chloride and has exceeded the chronic chloride state standard of 230 milligrams per liter (mg/L) in six of the eight years monitored, as shown in Figure 4. Plymouth's watershed monitoring data collected from 2013 to 2015 and from 2017 to 2021 are graphically summarized in Figure 5. For all years except 2014, the chronic standard (230 mg per liter) for chloride was exceeded at the PL2 location. At the PL1 location, the readings collected were well below the chronic standard, except during 2018 when the standard was exceeded. The land use of PL1 is predominantly residential land use, while PL2 consists of a mix made up primarily of commercial, industrial, multifamily residential, and public facilities.

Figure 5: Parkers Lake in-lake chloride readings (Plymouth and TRPD)

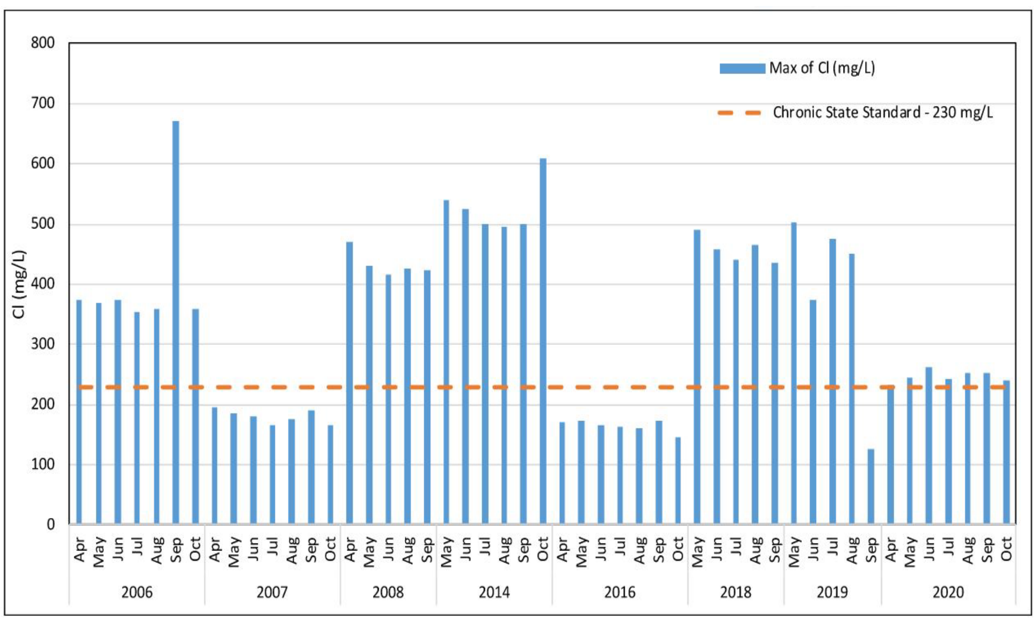
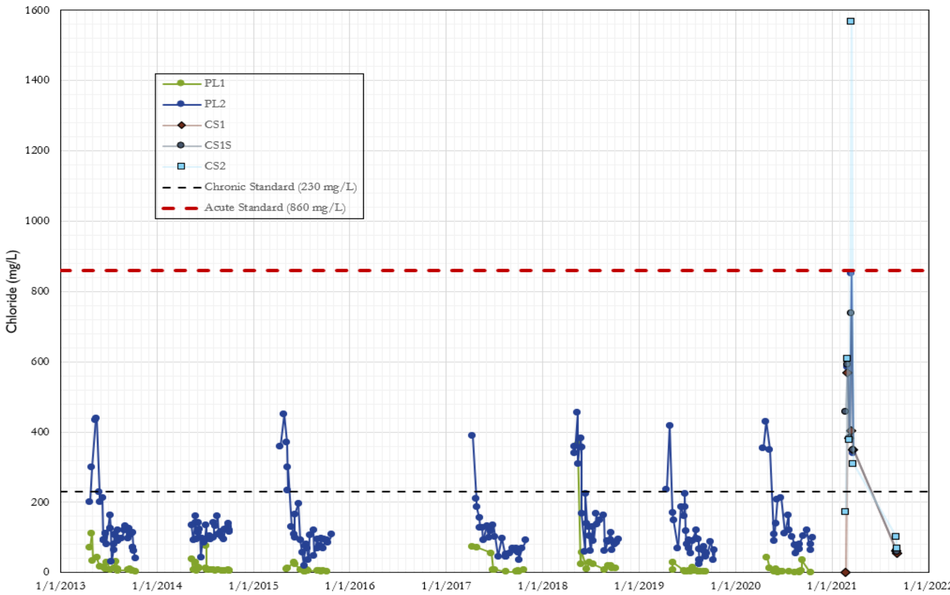
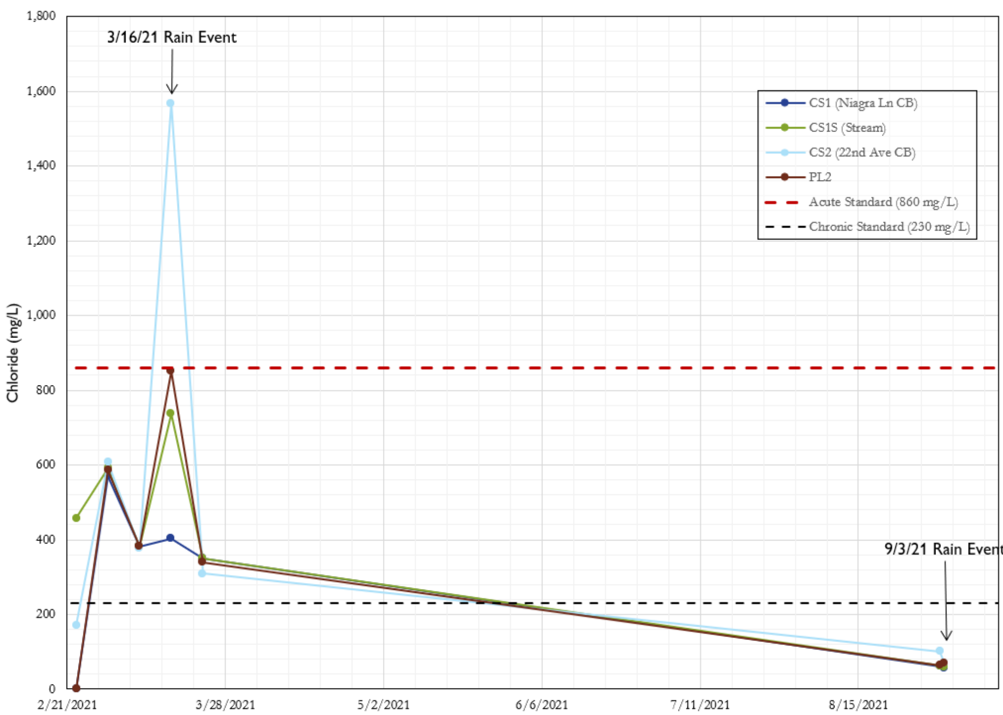


Figure 6: Parkers Lake storm sewer outlet chloride readings (Plymouth and TRPD)



A detailed view of the 2021 monitoring data is provided in Figure 7. For the PL2 and new CS1, CS1S, and CS2 locations, the chronic standard is exceeded. For the CS2 location, the acute standard of 860 mg per liter is exceeded in one sample. Since the additional sampling locations have limited data to determine trends Plymouth is planning to continue sampling in future years.

Figure 7: Parkers Lake 2021 NE & NW storm sewer outlet chloride readings

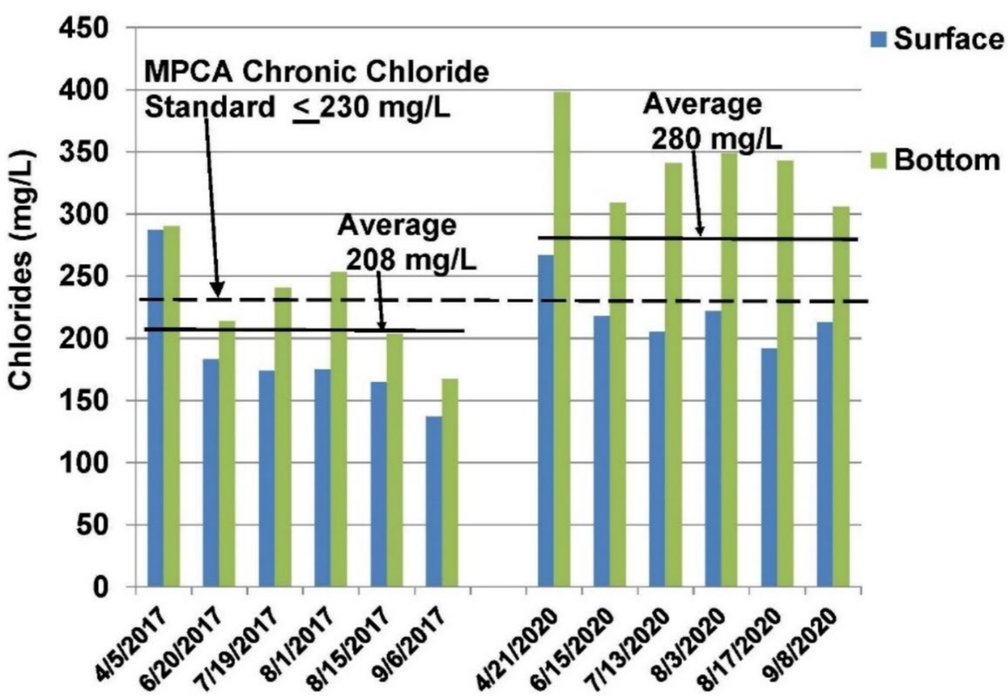


Understanding Plymouth's data on chloride loading to and within Parkers Lake, comparative information from BCWMC, SCMWC, NMCWD, and Minnetonka was considered and presented during WGSs 2.1 and 2.2.

Chloride levels and land use for Sweeney Lake and the Sweeney Branch of Bassett Creek were presented to the cohort by BCWMC as a site-specific example for the Parkers Lake comparative analysis. Sweeney Lake is impaired for chloride and nutrients with an approximate watershed of 2,400 acres within the cities of Golden Valley and St. Louis Park. Sweeney Lake's watershed is approximately 40 percent impervious, composed mainly of single-family residential; commercial and industrial; and major highways. The lake has a maximum depth of 25 feet and a weir outlet with a residence time of one to two months.

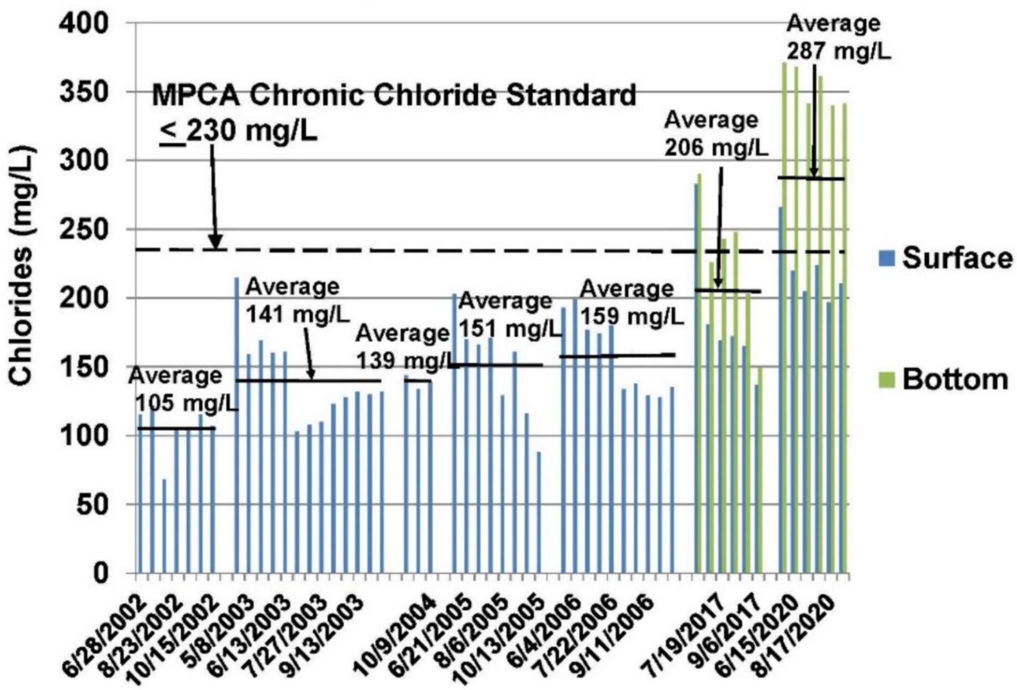
Two monitoring stations are located on Sweeney Lake for the north and south basin. In 2017 and 2020, as shown in Figure 8, the north basin samples exceeded the chronic chloride standard for ten of the twelve samples collected from the lake bottom and two of the twelve taken from the lake's surface.

Figure 8: Sweeney Lake north basin chloride sampling (BCWMC and Barr)



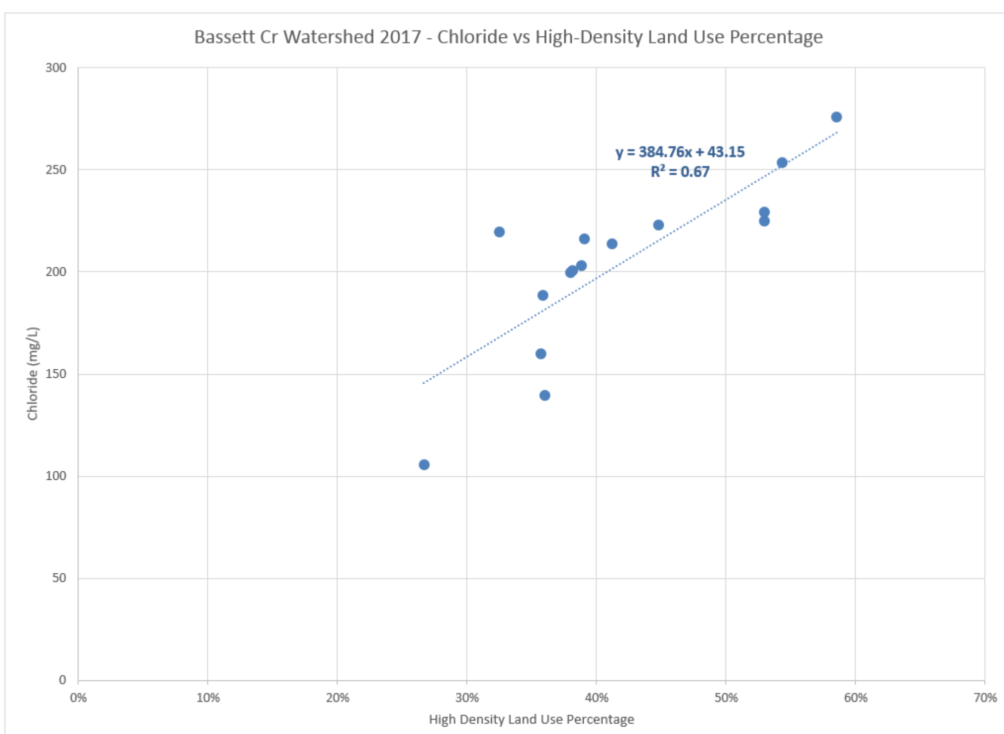
Monitoring data for the south basin was collected over two timeframes including 2002 through 2006 of surface monitoring, and 2017 through 2022 of surface and base monitoring as shown in Figure 9. The south basin surface readings were well below the chronic chloride standard until 2017, when two of the twelve sample readings exceeded the MPCA's chronic chloride standard. The basin's bottom reading exceeded the chronic lake standard in July and August 2017 and for all the samples taken in 2020.

Figure 9: Sweeney Lake south basin chloride sampling (BCWMC and Barr)



BCWMC reviewed the sampling information in 2017 and found a relatively strong relationship between high density land use and chlorides to Sweeney Lake. This is shown in Figure 10.

Figure 10: BCWMC Chlorides and high-density land use relationship data (BCWMC and Barr)



As presented on behalf of the SCWMC, Shingle Creek was one of the first chloride impairments in Minnesota in 1998, followed by Bass Creek chloride impairment in 2002, and the TMDL study completed in 2007. There are four standard stream monitoring locations: SC-0 (Mississippi River); SC-3 (middle of watershed); BCP (high up in watershed, much less impervious than rest of watershed); and SC-1 or USGS location shown in

Figure 11. Table 2 presents contributing watershed areas and land uses to the SCWMC monitoring stations.

Figure 11: Shingle Creek monitoring locations (SCMWC and Stantec)

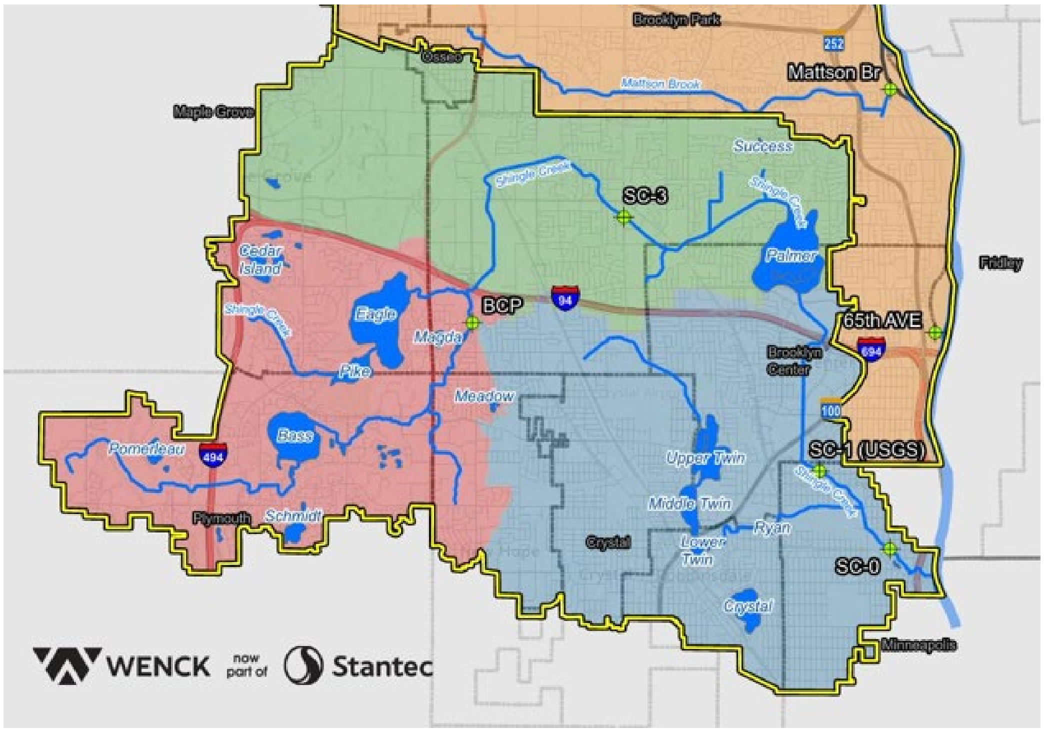
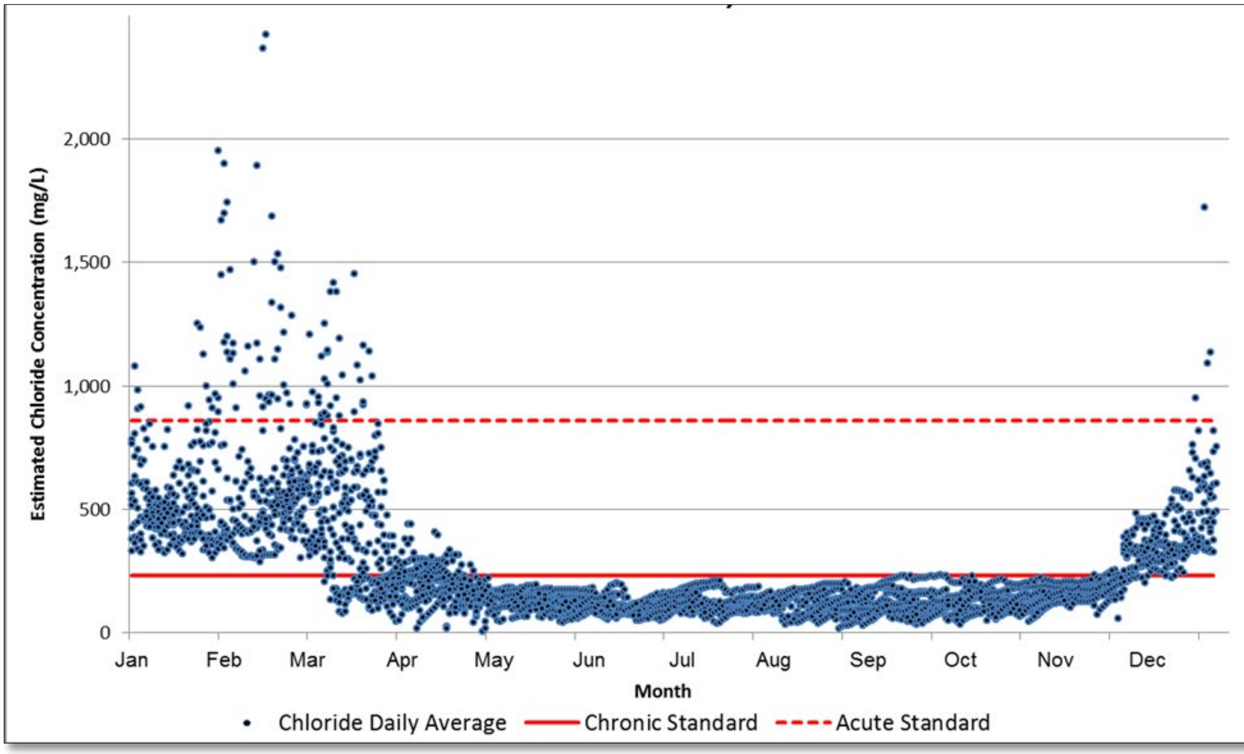


Table 2: Shingle Creek Watershed land use information (SCWMC and Stantec)

Land Use	SC-0		SC-3		BCP	
	Area (acres)	Percent (%)	Area (acres)	Percent (%)	Area (acres)	Percent (%)
Highly Impervious (51 –100%)	14,282	50	6,582	37	2,376	28
Low-Moderate Impervious (5–50%)	5,645	20	4,810	27	2,165	26
Wetlands	2,452	9	2,143	12	1,250	15
Grassland and Shrubland	3,951	14	2,526	14	1,104	13
Open Water	1.045	4	675	4	665	8
Forest	1,049	4	853	5	617	7
Agriculture	189	1	173	1	154	2
Total	27,569		17,762		8,331	

The watershed areas draining to BCP, SC-3, and eventually to SC-0 are made up of between 50 to 70 percent imperviousness associated with highly impervious (51–100 percent) and lot-moderate impervious (5–50 percent) surfaces. Data presented from 2002 to 2014 showed that small runoff events in the late part of winter have the highest exceedances of chronic and acute chloride standards in the stream, as shown in Figure 12.

Figure 12: SCWMC average daily chloride concentrations, 2002–2014 (SCWMC and Stantec)



Nine Mile Creek, impaired for chloride, was first listed on the MPCA and EPA 303 (d) list in 2004 because the levels sampled exceeded the chronic standard of 230 mg/l. The MPCA, NMCWD, and Barr completed the TMDL Chloride Study in 2010. From this, the information presented by NMCWD on the main stem and the north and south fork of Nine Mile Creek was extracted for comparison to Parkers Lake. The fully developed contributing watershed area is approximately 44.5 square miles, consisting of high-density (various colors representing 40 percent or higher imperviousness) and low-density (gray representing 39 percent or lower imperviousness) areas, as shown in Figure 1.

Within the watershed district, there are four MCES watershed outlet monitoring program (WOMP) stations (see Figure 2), which have been operational since 2004: one on the north fork or branch WOMP station at Green Valley Drive, Edina, Minnesota; one on the south branch WOMP station at West 78th Street in Bloomington, Minnesota; and two WOMP stations on the main stem, with one at West 98th Street and the other downstream at 106th Street, both located in Bloomington, Minnesota.

Within the watershed, there are 1,415 miles of road within the permitted MS4s that include the cities of Bloomington, Eden Prairie, Edina, Hopkins, Minnetonka, and Richfield; Hennepin County; and the Minnesota Department of Transportation. The MS4s, commercial and private applicators, and background chloride loading data from the TMDL show that the single largest contributor, representing 37 percent of the total chloride load of Nine Mile Creek, was the commercial and private applicators (see Table 1). In addition, using the Saint Anthony Falls Laboratory 2007 study on salt applications for the Twin City Metro Area (TCMA) proportional land uses, combined with road salt applied by MS4 public works within NMCWD, the overall percentage of higher-density land uses in NMCWD is five times higher than the percentage in TCMA. This may be contributing to the continued upward trend of chloride levels despite the efforts of the MS4s to comply with the allocations from the TMDL.

Table 3: Estimated Existing Chloride Load within the Nine Mile Creek Watershed District (NMCWD and Barr)

Sources		MS4 Road Miles	Estimated Existing Chloride Load	
			Tons/year	Percentage
MS4s	Bloomington	**377**	692	11
	Eden Prairie	**245**	128	2
	Edina	**206**	1,085	17
	Hopkins	**48**	421	7
	Minnetonka	**257**	278	4
	Richfield	**127**	42	1
	Hennepin County	**60**	761	12
	MnDOT	**95**	413	6
Commercial/ Private Applications		**-**	2,339	37
Background		**-**	198	3
Total		**1,415**	6,357	100

Figure 13: Nine Mile Creek Land Use and Density Map (NMCWD and Barr)

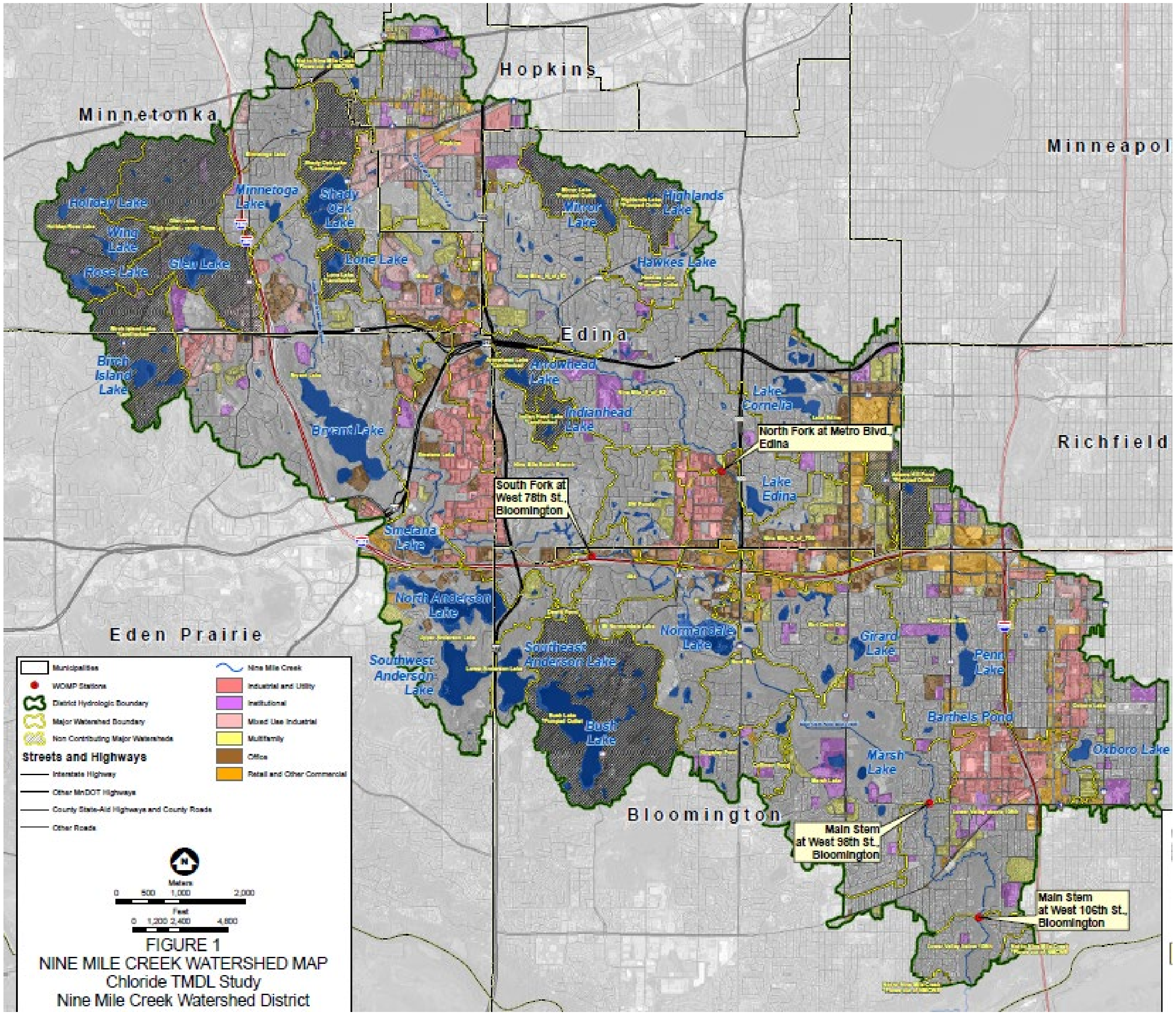
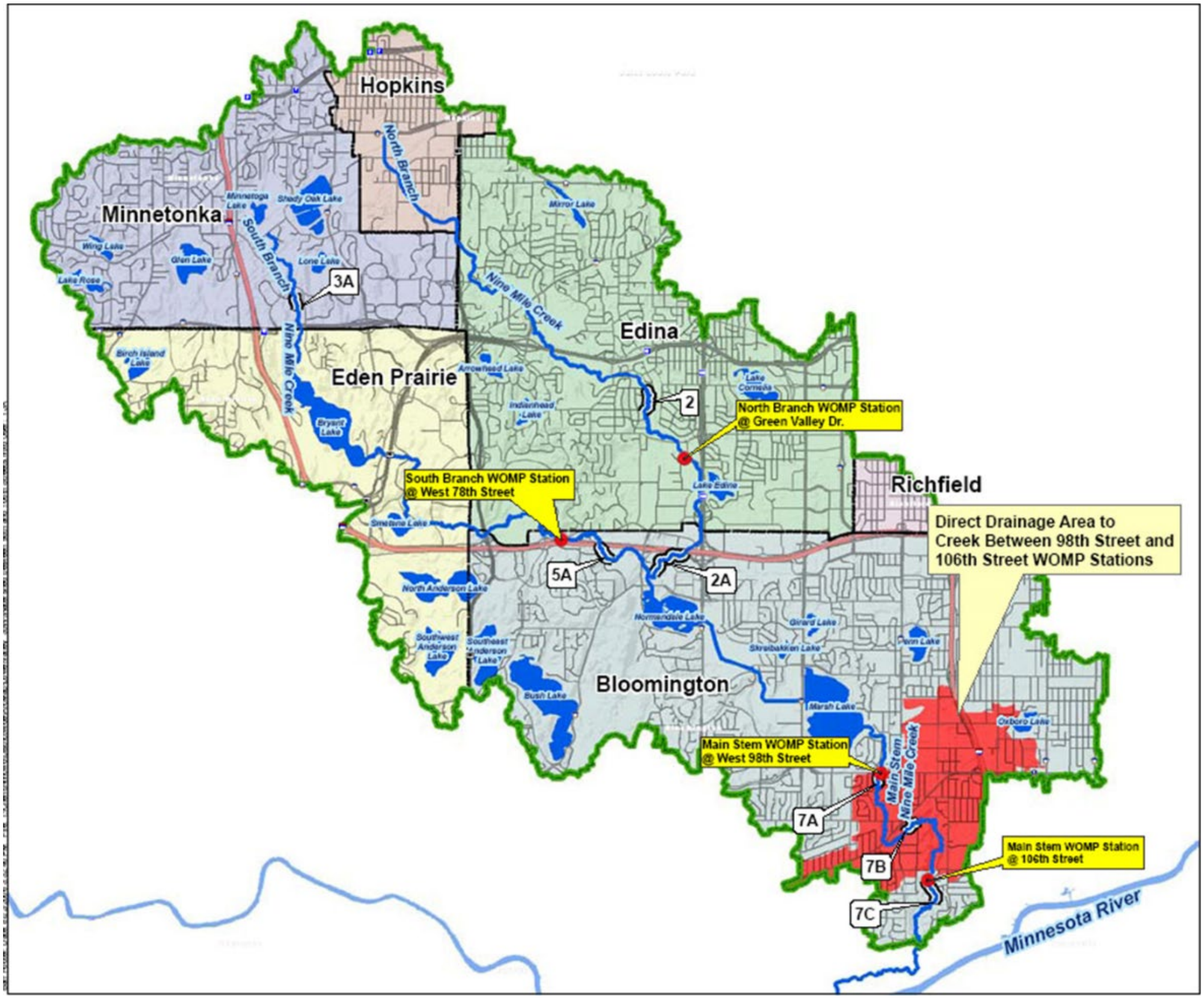
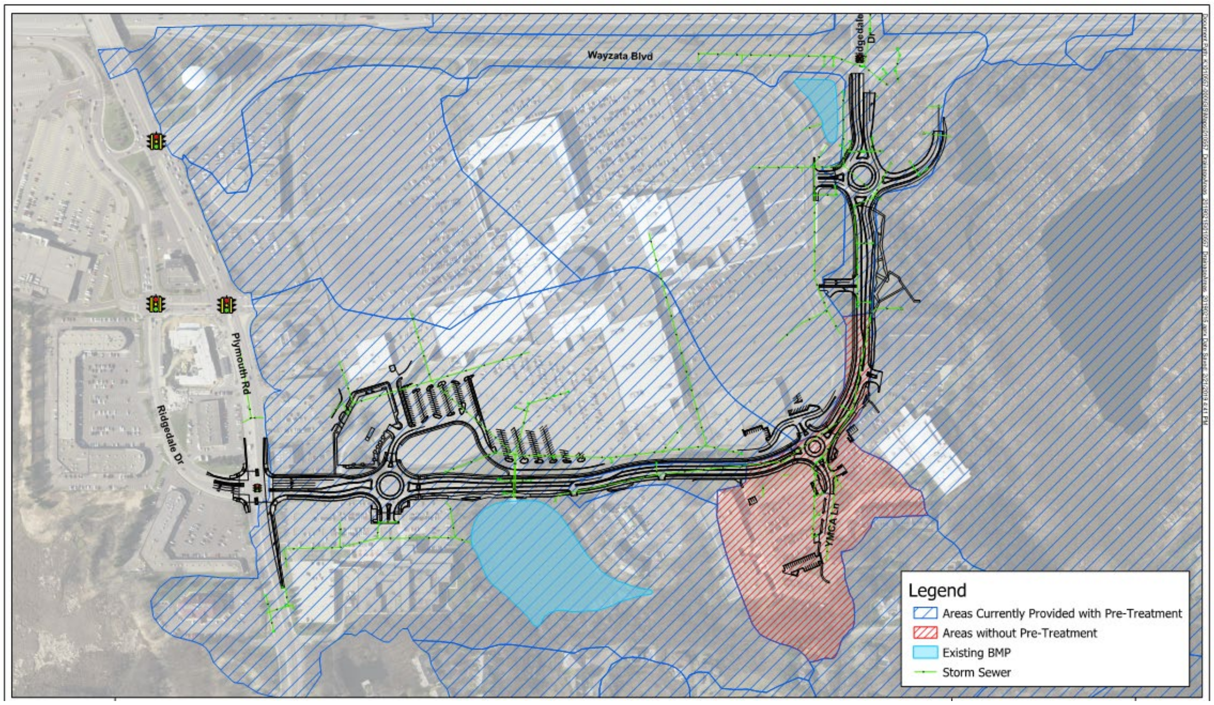


Figure 14: Nine Mile Creek Monitoring Locations (NMCWD and Barr)



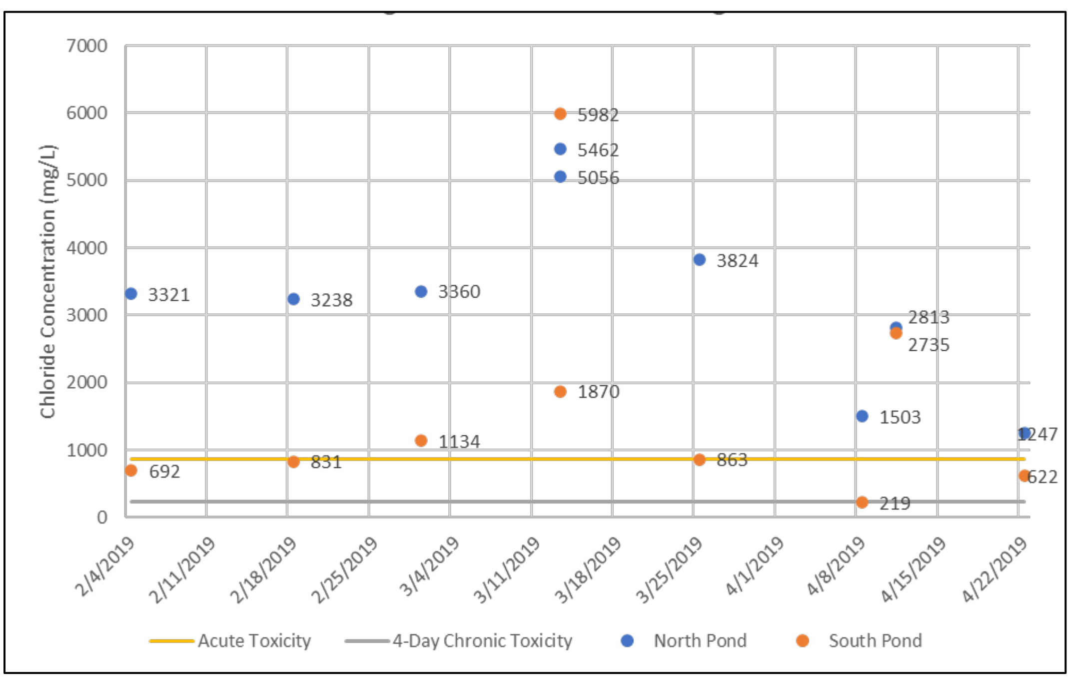
In 2019, Minnetonka and BCWMC completed a feasibility study in conjunction with the Ridgedale Drive improvements to investigate stormwater BMPs for chlorides, total phosphorus, and total suspended solids. To assess chloride conditions, two monitoring locations were started, one at the North Pond (Ridgedale Mall and Interstate 394) and one at the South Pond (Ridgedale Mall and single-family residential areas), as shown in Figure 13. The drainage area to the North Pond (90 percent commercial and 10 percent highway) and the South Pond (55 percent commercial and 45 percent single-family residential) is 59 acres and 182 acres, respectively.

Figure 15: Ridgedale Mall Subwatershed Drainage System (Minnetonka and WSB)



Sampling readings from 2019, as shown in Figure 14, show the chronic chloride standard exceeded for all but one reading. Additionally, the readings from the North Pond with greater imperviousness have higher chloride concentrations.

Figure 16: 2019 North Pond and South Pond chloride monitoring (Minnetonka and WSB)



Minnetonka expanded the sampling for another year. Figure 15 and Figure 16 show the 2020 chloride monitoring results illustrating the higher chloride concentrations from the North Pond compared to the South Pond.

Figure 17: 2020 North Pond chloride and conductivity readings (Minnetonka and WSB)

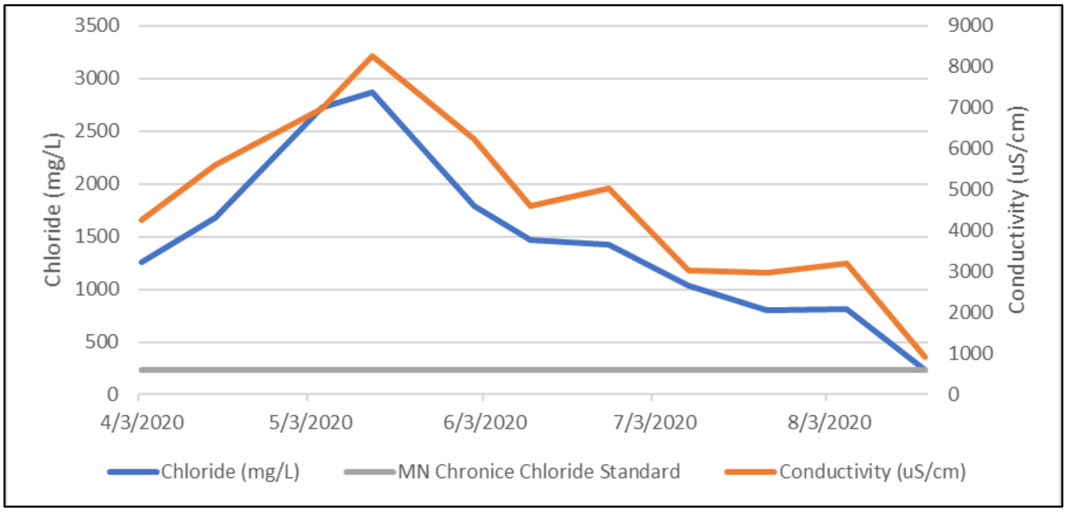
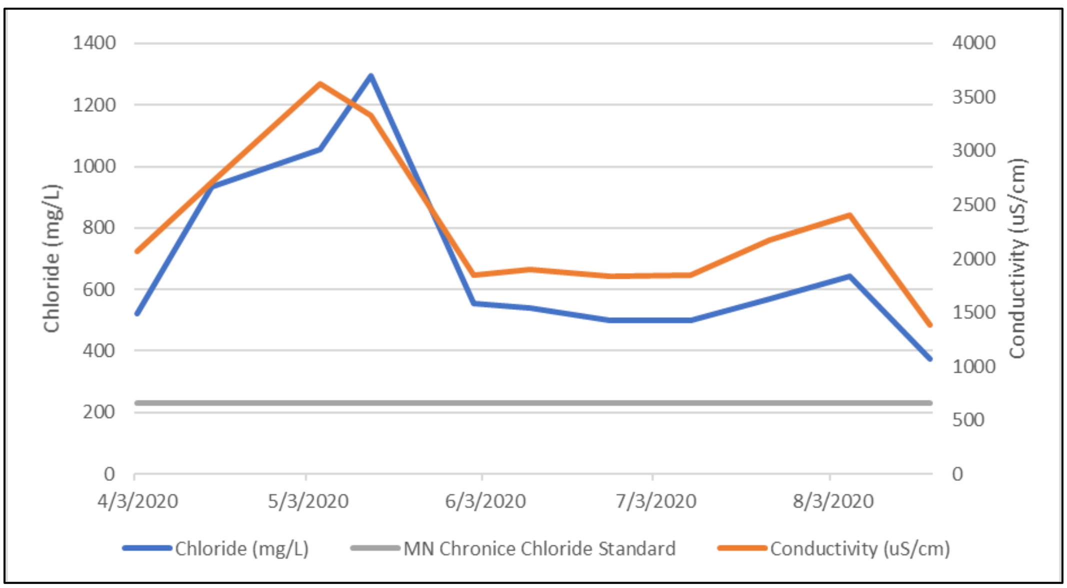


Figure 18: 2020 South Pond chloride and conductivity readings (Minnetonka and WSB)



The following factors became apparent during WGS 2.1 and 2.2 by the City of Plymouth, BCWMC, SCWMC, and Minnetonka with commentary by Edina, the Metropolitan Council, and NMCWD:

- Because it acts like a landlocked lake, Parkers Lake will require both a reduction of chloride from upstream sources and chloride treatment within the lake to reduce its chloride concentrations.

- A direct relationship exists between high-density land use or highly impervious areas and chloride. Examples of this relationship can be found in multifamily residential areas, retail and other commercial areas, office buildings, mixed-use industrial buildings, industrial and utility buildings, institutions, and transportation rights-of-way (e.g., city lane miles, county roads, state highways).

- Chloride concentrations generally peak between March and May, following large snowmelt events, unseasonably warm temperatures, rain, or all.

- Parkers Lake generally does not compare to any of the lakes previously discussed (i.e., Crane, Sweeney, or Edina) because of its limnology and that it is larger, deeper, and landlocked. Because of the nature of chloride contamination and differences in limnology between Parkers Lake and the other lakes, attempts to apply water quality improvements that were successful in those lakes qualitatively may not be effective.

The Project Team considered whether the Parkers Lake background information and monitoring program could be used to effectively identify discernable trends and correlations between land uses and chloride concentrations downstream and applied to similar areas within Hennepin County. Based on those considerations and the corresponding data, the Project Team, with validation from the cohort through a poll at WGS 4, was able to make the following generalizations (See Figure 2 for the monitoring locations).

1) The monitoring location and contributing watershed area to PL1, which is made up of 99 percent single-family residential (SFR) land use and 1 percent public/institutional land use, can represent an SFR suburban area within Hennepin County. PL1 also has more than twenty years' worth of monitoring data segmented in years prior to installation of curb and gutter and ponding in 2005 as well as post.

2) The monitoring location at PL2 contains multiple land uses and does not provide a discernable correlation between land uses and chloride concentrations, even with the inclusion of CS1 to segment the contribution of chloride from County Road 6. This watershed and the monitoring network should be reconfigured to segment contributing land uses more effectively.

3) The monitoring location and contributing watershed area to CS2, which is made up of 90 percent commercial/industrial (C/I) land use and 10 percent SFR, multifamily, and highway land uses, could represent a typical C/I suburban area in Hennepin County. Generally, most C/I areas within suburbs are close to a highway system and minimal residential areas. However, only one year's worth of data is available for this area, and continued monitoring is recommended for at least four more years so that the information can be compared to the information being collected from the Ridgedale Mall North Pond location.

Best Management Practices (BMPs) Research and Selection

BMPs Research and Considerations

Following a review of the data, the cohort provided and discussed possible BMPs that could be implemented to improve water quality. Anecdotal information shared by the cohort and knowledge learned in research completed by Young Environmental for each BMP area are presented in Table 3 on the ability to mitigate chloride problems.

Table 4: BMPs research and considerations by the Parkers Lake cohort

BMPs	Description	General Comments
Nonstructural BMPs[1]		
Fertilizers	Many commercial fertilizers contain potassium chloride as an efficient means of applying potassium on lawns. It was suggested Plymouth consider alternative fertilizers in the playfield north of the lake.	Plymouth is investigating different fertilizers (which could include those with potassium nitrate or potassium sulfate) to improve water quality.
Winter Sweeping Public Right-of-Way	Collection of salt and chloride residual from roadway in the winter would reduce chloride transport to the lake.	Sweeping excess salt discharges during the winter is incorporated into Plymouth normal operations using a regenerative air enhanced sweeper.
Application Rates in Public Winter Deicing Operations	Analyzing usage, training staff, and evaluating the rate of application of granular salt, brine, and pretreatment liquid per event can minimize chloride being applied to public roadways and parking lots.	Plymouth staff are utilizing this BMP. A recent evaluation showed that rates are lower than comparable cities reported in a NMCWD study (2007). Plymouth adjusted protocols in an area near the maintenance facility (within sub-watershed) to further reduce salt applications.
Hydrant Flushing	During annual hydrant maintenance and flushing, the discharge water could be used to dilute chloride concentrations in Parkers Lake.	Annual dilution could be beneficial if timed correctly for maximum benefit. Due to lake outlet conditions this may be difficult to time and there was discussion about potable water's potential to add chloride and phosphorus to the lake.
Education and Limited Liability	Continue to develop and distribute education materials regarding the use and consequences of over-applying salt considering the ever-looming liability claims.	This nonstructural approach was mentioned during almost every WGS as being one that should always be on the table.

[1] Plymouth does not plan to pursue incorporating these nonstructural BMPs as part of the city's funding request to BCWMC. However, this would be pursued through other channels and partnerships.

BMPs	Description	General Comments
Prevention Structural BMPs Aimed at Reducing the Amount of Salt Used in the Watershed		
Public Brine Tank	City could construct and operate a brine tank for private applicator and public use.	Capital costs are high as a heated facility would be necessary. Would increase operational costs. May also introduce a source of liability to the city and be a possible pollution point source.
Deicing Equipment Loan Program	The City of Plymouth would purchase equipment for private applicators or the public to rent/check-out for private use. This could reduce erroneous salt application on private property.	Similar methods have been used for nitrate/nitrite reduction in agricultural areas. There may be liability concerns for the City of Plymouth. HCCI survey indicated access to equipment is not a significant barrier for private applicators.
Chloride Effluent Reuse	Chloride-contaminated effluent in sub-watershed could be recycled and used as pre-treatment/brine liquids thus reducing future chloride demand.	Reuse may require pretreatment but could significantly reduce salt demand during winter operations. Effluent salt concentrations are too low to be used without supplementing salt.
Solar Pavements	Solar pavements reduce the need for salt applications by heating the pavement.	High capital cost and unknown benefit. Unknown if it be regularly useful at facility like Plymouth DVS.
Construct Reuse and Recycling Drop-Off Sites	Construction of a salt drop-off site that would allow local community members and organizations to drop off excess salt for recycling at the end of the snowy season. This could reduce salt waste and prevent outdoor storage of salt being washed into lake through the summer.	City of Minneapolis' has a program to supply free salt-sand mixtures for residential use. Hopkins has a salt recycling drop-off where salt is recycled into City operations. Recycling would be low-cost and may be worth pursuing with even marginal reductions in Parkers Lake chloride concentrations.
Evaporation Structure	Use of a solar evaporation system to remove water from chloride-contaminated effluent and generate rock salt as a byproduct.	High capital and operational cost for a solar evaporation system. Rock salt could be resold to offset costs.
Pond Cleaning	Removal of the sediment layer in ponds that retain chlorides and re-release that chloride back into the pond during low-concentrations periods. Removing the source material may reduce chloride reaching Parkers Lake.	The amount of chloride contained in stormwater pond sediment is unknown. Plymouth will be studying sediment samples to know if cleaning would remove chloride from sub-watershed.
Private Salt Application and Cleaning	Private property owners would work as a district/group to purchase and apply deicing	Would require business buy in and coordination.

BMPs	Description	General Comments
Partnership for Private Property	materials through the winter months and cleaning surfaces in the spring. Consistent application by a trained professional may result in chloride reductions and savings to businesses. A City or business could act as managing agency.	
Removal Structural BMPs Aimed at Removing and Relocating Salt		
Proprietary Wetland BMP	Diversion of stormwater into a wetland where plants would uptake chloride and other contaminants before discharge to Parkers Lake. Wetlands could be created in collaboration with private industry in parking lots, streets, or detention basins.	Plants have a limited capacity for chloride uptake and may not survive high-saline substrates. Plants would need to be maintained and regularly removed to prevent rerelease of any chloride taken up by the plant after death. Plants capable of large salt uptake and surviving MN climate may be invasive species.
Portable RO System	Use of a portable reverse osmosis system to extract salts from Parkers Lake water.	RO systems have high capital and operations costs and would require a disposal strategy for the highly concentrated reject water that may be contaminated with nontarget pollutants.
Sacrificial Shallow Pond	Shallow constructed wetlands having large quantities of biomass would uptake chloride before being harvested and removed.	Similar comments to propriety wetland BMP. Requires more land but lower capital cost.
Salt Capture Underground Chloride Chambers	Construction of an on-site underground storage tank to capture runoff formed by the Plymouth/MnDOT salt storage facilities before it can escape the premises.	Underground chambers would need to be sized and set-up to only store highly concentrated effluent and would require a disposal strategy for the highly concentrated reject that may be contaminated with nontarget pollutants.
Parkers Lake Dilution Pump	Physical dilution of Parkers Lake using an on-site dilution pumping system to extract the highest-concentration water from the hypolimnion and pump to downstream bodies that are more resilient to chloride.	The Mississippi River is the best candidate for discharge, with no existing chloride problems and a high capacity for dilution. A better understanding of the concentrations, magnitudes, and trends expected at the pumping site may be needed.
Chloride Effluent for Irrigation	Reuse of extracted chloride contaminate effluent/reject water for graywater irrigation of local agricultural operations.	High salt concentrations in the graywater may exceed the sorptive capacity of the soil/plants with chloride. Could be source for shallow

BMPs	Description	General Comments
		groundwater chloride contamination. Any plants irrigated would need to be salt tolerant. Would require transportation of effluent.
Relocate Plymouth's Salt Storage Facility	Moving the Plymouth's salt storage facility would remove a potential point source of chloride from the lake watershed.	Moving the facility just moves the problem to another watershed. High cost. Facility not believed to be significant contributor to problem.
Redesign Plymouth Salt Storage Facility	Redesigning the facility to mitigate any losses of chloride to the environment may significantly reduce chloride loadings to Parkers Lake.	Public works already use several BMPs to prevent salt from leaving the facility. Cutting a single point source may not reduce salt loading on a watershed-level scale.
Reuse Chloride Effluent in Centralized Water Softening	Centralized potable water softening systems require salt or salt biproducts. Could byproduct of RO system be used in water softening at water treatment plant.	The City of Plymouth does not have the capacity for centralized softening at its current facilities. Would require transportation and treatment.
Hydrogen Desalination	Distillation of captured or extracted chloride-contaminated water via hydrogen to separate ions from the water.	Process requires substantial amounts of heat/energy and would require a partnership with local utility or energy producing business to be practical.

Selected Shortlist of Potential BMPs

Cohort polling of the BMPs following WGS 3 showed participants strongly favored chloride source reduction above active removal of chloride from Parkers Lake. Legislative and ordinance-based source reduction was ranked highest (with a score of 8.09) among participants when polled on which solutions they believed would be most effective for chloride reduction in Parkers Lake. Public operations and education and training ranked slightly lower with scores of 6.4 and 6.3, respectively, followed by nonoperational structural source reduction BMPs with a score of 5.50. Vegetation uptake scored the lowest of the proposed BMPs with a score of 2.4, followed by chloride reuse with a score of 4.18.

Following WGS 4, six (6) BMPs which would be eligible for BCWMC capital project funding were selected by the group as having the highest likelihood of reducing the concentration of chloride in Parkers Lake. The selected BMPs (some were developed as a blend of two or more BMPs in the table above) are a combination of source reduction practices and in-lake chloride reduction. The BMPs that were selected for further review and analysis include:

1. Development of low-chloride site design or private sweeper equipment grant program
2. Construction of publicly available salt recycling or reuse center
3. Construction of publicly available brine tank
4. Development of watershed business agreement for joint winter maintenance
5. Development of on-site storage tank for chloride-contaminated effluent
6. Lake dilution

Construction of on-site storage tanks, collection of saltwater effluent (run-off) and reuse in deicing operations, and Lake dilution were selected for further research through a comprehensive literature review.

Below is a detailed description of the six BMPs along with the identified opportunities and challenges with each. A summary of findings of the literary review are also included below for those BMPs where one was completed.

Development of low-chloride site design or private applicator equipment grant program

The aim of a low-chloride site design and/or private applicator equipment grant program is to incentivize businesses, developers, and institutions in the community to take chloride usage into consideration in future designs by using low-chloride construction and maintenance techniques. Promoting low-chloride site design for new developments could reduce non-point source chloride used in the developments and reduce the chloride entering Parkers Lake. Low-chloride designs include preventative measures or alteration in site design to limit the amount of salt required for safe operation during winter periods (e.g., heated pavement, driveways, or parking lots). Low-chloride site design may also include structures or BMPs which prevent excess salt from leaving the site (e.g., runoff gardens with salt-tolerant plants). Such measures could be put in place as part of the initial design or by retrofitting existing sites. The grant program would incentivize ownership and operation of private salt sweepers or liquid deicing equipment in the community for the removal of salt on privately maintained infrastructure (e.g., sidewalks, driveways, parking lots, and roads), thereby limiting the amount of salt available to enter Parkers Lake during snow melt season. Proposed incentives for the use of low-chloride design included:

- Public grants for purchase and maintenance of private salt sweepers
- Reduction in stormwater fees
- Increased stormwater fees for developments not utilizing low-chloride design

It is unknown how effective such a program would be in reducing chloride loading into Parkers Lake, and if it would need political and private business support.

Construction of publicly available salt recycling or reuse center

Construction of a publicly accessible salt recycling or reuse center would allow residents, businesses, and private applicators to dispose of unused salt at the end of the snowy season at little-to-no cost to the residents. Those entities who may have purchased too much salt during the winter season would then be free to return salt for recycling without fear of wasting or storing unused salt through the summer, many of whom lack the capacity to do so. The program would reduce the inclination among residents and private applicators to "use up" their remaining salt in the early springtime and prevent overapplication during the rainy season, when salt is most susceptible to runoff into Parkers Lake. Such a strategy would have limited return in the reduction of chloride in Parkers Lake, but would be a low-risk, low-cost system that would increase awareness of the issue.

If stored throughout the next winter, a salt storage facility could reuse the salt by mixing with their current supply similar to how the City of Hopkins system operates. Further reuse salt by directly offering it back to residents or creating a program like the City of Minneapolis salt and sand distribution program, which offers a mixture of salt and sand free to the public for private use.

The existing salt storage facility in the City of Plymouth is located behind secure fencing and discourage public access. Construction of a new facility for public use may not be fiscally feasible in the immediate future for the city given the limited return on chloride reduction in Parkers Lake.

Construction of publicly available brine tank

Construction of a publicly accessible brine tank would provide access to brine for public and commercial use. The use of brine over rock salt could reduce the application rate of chloride to infrastructure that requires salt application, thereby reducing the salt available to enter Parkers Lake. Construction of such a facility would introduce liability if unrestricted access by the public is permitted. A public brine tank would be relatively expensive in cost in that it would require a new heated structure be constructed to house the operating equipment and public water supply required for creating the brine. It could be scaled to other communities wishing to participate. The tanks could be implemented on the local or city level and provide increased access to brine to the community.

There are concerns that providing free or low-cost brine may increase the use of brine generally and may result in an increase in chloride transport because the low cost of brine to the consumers would encourage increased consumption and application where there may have been limited consumption previously. Such an effect would mitigate any reduction in chloride generated by using brine as an alternative to rock salt resulting in minimal improvements to Parkers Lake.

A second alternative for use of public brine tanks could include the use of small site-size brine tanks that would be available to be loaned out for public use. Such a program would still increase access to brine for use in deicing to the public while eliminating many of the maintenance and liability hazards associated with a larger, centralized structure.

Development of watershed business agreement for joint winter maintenance

A watershed business agreement would provide regular winter maintenance to areas within the Parkers Lake watershed through a joint venture with the watershed or city. Business in the area would pool resources to fund a third party or local business within the agreement to take over snow removal and winter maintenance for the included parties. The joint business arrangement would additionally aid the maintaining business or third party in designing winter maintenance activities that align with smart salting practices to reduce the amount of chloride entering Parkers Lake. A similar joint business arrangement has already proven effective in the City of Edina, which has already implemented a similar arrangement in the 50th and France Business District and has been largely successful. Such a business arrangement would require strong political will to gather support among local business and may require additional incentives for a limited return on the reduction of chloride.

Development of on-site storage tank for chloride-contaminated effluent

A runoff capture and storage system for municipal salt storage facilities would reduce chloride-contaminated runoff from escaping salt facilities into the surrounding regions. Runoff from salt storage facilities are a known potential point source for chloride pollution, but to what extent they are impacting Parkers Lake is unknown. If runoff from salt storage facilities contributes meaningfully to Parkers Lake chloride, then implementing a chloride-contaminated effluent capture and storage system could reduce a significant source of chloride in the lake. Such a system would have to be large enough to store runoff and winter snow melt from the upstream drainage area.

One alternative to a large storage holding tank is a conductivity-based diversionary structure that would only capture and divert high-conductivity stormwater into a smaller tank or the sanitary sewer system before it could escape into the surrounding region. Such a system would require advisement and permitting with Metropolitan Council Environmental Services (MCES), which currently does not accept chloride effluent stormwater into the sanitary sewer system for treatment. Such a system would also not be capable of recovering the lost chloride compared to a storage tank.

An underground tank system could also add a reuse system for the captured chloride-contaminated effluent for use in later brine generation, recapturing previously lost material and reducing the overall demand for salt in the winter months and reducing the cost of brine generation. More information is required regarding the impact the salt storage facilities have on Parkers Lake water quality.

Storage collection systems have proven effective at improving water quality of high nutrient or contaminated lakes in the literature when first-flush is captured and/or diverted from entering surface water bodies. However, in the case of a salt storage facility, there is such a large source of contaminated material that first flush principles may not apply, and recapture of only the first fraction of runoff water may not show significant improvements with respect to Parkers Lake chloride levels.

Parkers Lake dilution

Dilution of Parkers Lake would reduce the concentration of chloride in Parkers Lake by actively removing high-chloride water from the hypolimnion of the lake, where the chloride is most concentrated, or flushing the lake with low-chloride water to further dilute the concentration of chloride and flushing contaminated water further downstream to less impacted or more resilient water bodies. Two main methods of dilution were proposed for Parkers Lake: (1) withdrawal of high-chloride water from the bottom portion of the lake to a location further downstream of the lake, which has the capacity to accept such water, and (2) introduction of large volumes of low-chloride water, such as water from annual hydrant flushing, to dilute and flush out the existing water in the lake to effectively reduce the concentration of water. Seasonal or one-time flushing of Parkers Lake could effectively dilute the lake and wash chlorides downstream to more resilient bodies at low cost to the city.

Dilution water could potentially be discharged into the sanitary sewer system, as opposed to natural waters downstream, but would require consideration and permitting with MCES which currently does not accept chloride effluent stormwater into the sanitary sewer system for treatment.