Bassett Creek CHLORIDE

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KEY FINDINGS

Chloride concentrations, after adjustment for variation due to flow conditions, may have stabilized in Bassett Creek from 2013-2019. If so, this stabilization is possibly due to action taken in the watershed, including implementation of chloride best management practices

Most chloride is exported from Bassett Creek between April and June. Further investigation is needed to understand seasonal chloride dynamics in the watershed, including an examination of chloride cycling in lakes and transport of chloride in shallow groundwater.

INTRODUCTION

The Metropolitan Council Environmental Services (MCES) is committed to stewardship of Twin Cities streams and tributary rivers and works with its partners to maintain and improve waterbody health and function. These efforts are supported by the collection and analysis of high-quality, long-term data.

In 2014, *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* described statistical water quality trends for streams and tributary rivers in the Twin Cities. At that time, data were insufficient to analyze chloride trends. By 2019, our monitoring work provided sufficient data for statistical trend analysis. Meanwhile, concern about chloride pollution has increased for watershed managers and the general public. This memo includes information about chloride sources and timing of chloride runoff and addresses the following questions:

- How has in-stream chloride changed over time?
- How have upland watershed activities impacted in-stream chloride over time?
- What can monitoring data tell us about chloride sources and pathways in the watershed?

During the analysis period, Bassett Creek Watershed Management Commission (BCWMC), cities within the Bassett Creek watershed (portions of the cities of Plymouth, Minnetonka, St. Louis Park, New Hope, Crystal, Robbinsdale, and Minneapolis, the majority of Golden Valley, and all of Medicine Lake), Hennepin County and Minnesota Department of Transportation have been actively addressing chloride pollution through winter de-icing equipment upgrades, salt application changes, pilot projects and outreach and education.

This memo provides data and analyses from Bassett Creek with state and regional context about chloride pollution. This information has prompted questions from MCES staff and will likely prompt questions from readers. We hope to initiate a dialog about regional chloride dynamics and inspire action to alleviate chloride pollution. Please contact us to discuss potential future partnerships if you are interested in continuing this work.

CHLORIDE POLLUTION IN TWIN CITIES WATERS

Chloride concentrations have been rapidly rising in many Twin Cities waterbodies over the past two decades. In the Twin Cities, 40 lakes and streams are impaired for aquatic life due to chloride contamination and an additional 41 waterbodies are high risk for chloride impairment[1]. A recent study by MCES indicated an increasing trend for chloride concentrations in the Mississippi, Minnesota, and St. Croix Rivers during the recent 30 years[2]. Thirty percent of Twin Cities shallow aquifer monitoring wells have chloride concentrations that exceed the Minnesota state water quality standard.[3]

Chloride is a permanent water pollutant, there is no easy way to remove it with existing technology. It is toxic to fish, aquatic bugs, and amphibians. Chronic toxicity is indicated by samples above 230 mg/L, acute toxicity by samples above 860 mg/L.[4]

Chloride pollution in Minnesota has multiple sources[5]. The three largest are household water softening, synthetic fertilizer and de-icing salt (Figure 1).

<u>Household water softening</u>: More than 70% of the drinking water used in the Twin Cities comes from groundwater[6] and many groundwater users soften their water with chloride salts. This chloride enters surface and groundwater through wastewater treatment plants or residential septic systems.[7]

<u>Synthetic fertilizer</u>: Chloride is associated with macronutrients like potassium. The most common potassium source in Minnesota is potash fertilizer, potassium chloride.[8] Plants consume the potassium and release the chloride into surface and groundwater.

<u>De-icing salt</u>: Approximately 402,000 tons of de-icing salt is annually applied in the Twin Cities.[9] De-icing salt is carried by melting ice and snow into surface and groundwater.

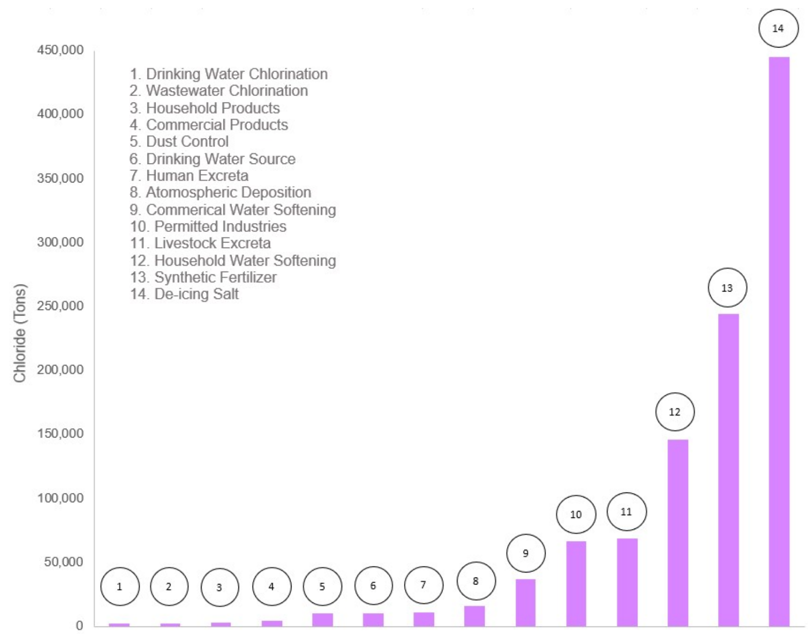

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

Climate change is creating a warmer, wetter climate in Minnesota and the effects are most significant during the coldest months. An altered winter freeze-thaw cycle will have unpredictable effects on chloride use and pollution dynamics.

STREAM AND WATERSHED DESCRIPTION

Bassett Creek is 13.5-miles long and drains approximately 39 square miles of mostly urbanized land in Hennepin County. The mainstem begins at Medicine Lake and it discharges to the Mississippi River through a storm tunnel under downtown Minneapolis (Figure 2).

Bassett Creek watershed is 25,155 acres, 62.5% of the land use is developed/impervious surfaces and there is no agricultural land use[10]. About 25% of the watershed drains directly to Bassett Creek, and almost 50% drains to Medicine Lake prior to discharge to the creek.

Approximately 30% of the Bassett Creek watershed is roadways. An MPCA analysis found that waterbodies having watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[11]

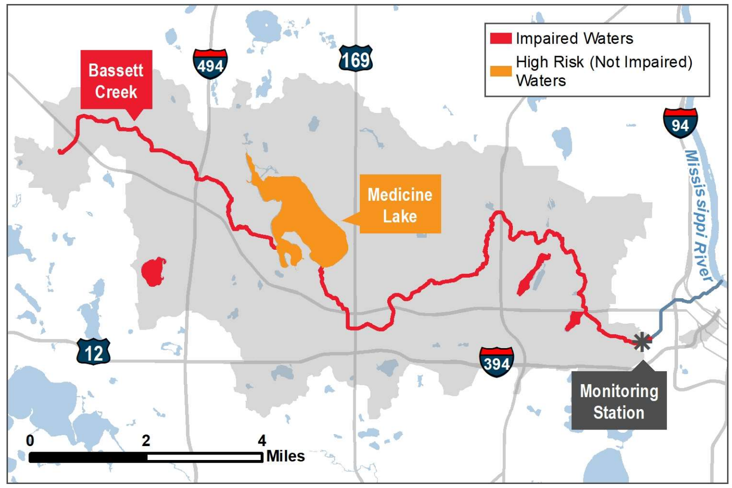

Figure 2: Map of Bassett Creek Watershed

Six waterbodies in the Bassett Creek watershed are known to be impaired or at risk of being impaired for aquatic life use due to excess chloride (Figure 2). Bassett Creek is impaired for chloride from Medicine Lake to the storm tunnel entrance. An unnamed creek discharging to Medicine Lake is impaired for chloride. Sweeney, Parkers, and Wirth Lakes are impaired for chloride and Medicine Lake has high risk of becoming impaired[12].

Household water softening is not likely to be a major chloride source in Bassett Creek watershed. Chloride from household water softening enters surface and groundwater through wastewater treatment plants or residential septic systems. All wastewater in Bassett Creek watershed is treated through the MCES Metropolitan Wastewater Treatment Plant and discharged to the Mississippi River in St. Paul.

Synthetic fertilizer is a possible chloride source in the Bassett Creek watershed. Chloride would come from residential and other urban and suburban turf management application of potash fertilizer.[13] This source of chloride is not well understood in the watershed.

De-icing salt is likely the primary source of chloride pollution in Bassett Creek watershed. De-icing salt is primarily applied between December and March and would likely runoff during melt events from February through April.

FINDINGS

Annual Chloride Dynamics 2001-2019

Chloride Concentration

MCES and BCWMC collected 513 chloride samples between 2001 and 2019. The ambient concentrations are plotted with the annual median concentration (Figure 3). Ambient concentration describes the conditions experienced by aquatic organisms in the stream. These values show great variability and they are affected by precipitation, flow, and watershed factors, including those caused by human activity.

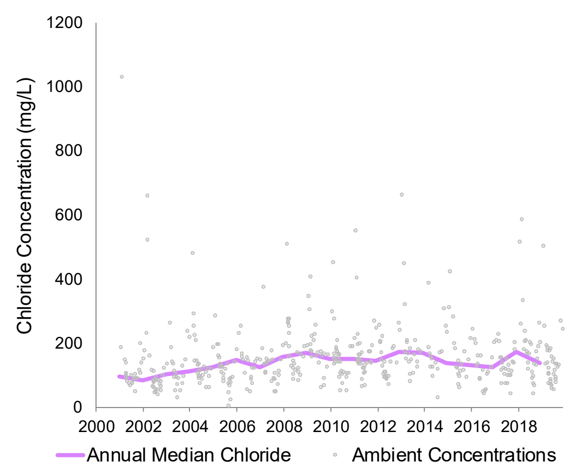

Figure 3: Annual Median and Ambient Chloride Concentrations of Bassett Creek

Annual median chloride concentration generally increased from 2002 to 2009, afterwards there is annual variability with no clear upward or downward shape through 2019.

Ambient Concentration: The mass of chloride divided by the total volume of water in a stream at a specific time. This value represents the instantaneous amount of chloride in the stream water.

Annual Median Concentration: This is the 'typical' concentration observed in the stream during the year. It is the center of our observed data and is not affected by extreme high or low concentrations.

Precipitation and Streamflow

Ambient concentrations are often closely tied to rainfall and resulting flow conditions in the stream. Higher streamflow can lower pollutant levels through dilution, and lower streamflow can increase pollutant levels through concentration.

Figure 4 shows annual total precipitation and the 1981-2010 National Weather Service Climate Normal precipitation at Minneapolis-St. Paul airport[14] with Bassett Creek annual mean flow, a representation of the total volume of flow in the stream for the year. Flow is usually higher in years with greater rainfall. Flow in Bassett Creek varied dynamically during the assessment period. Flows generally increased from 2013 to 2019, corresponding with higher than normal annual precipitation amounts during that period.

Annual Mean Flow: The average of all daily flows for the year.

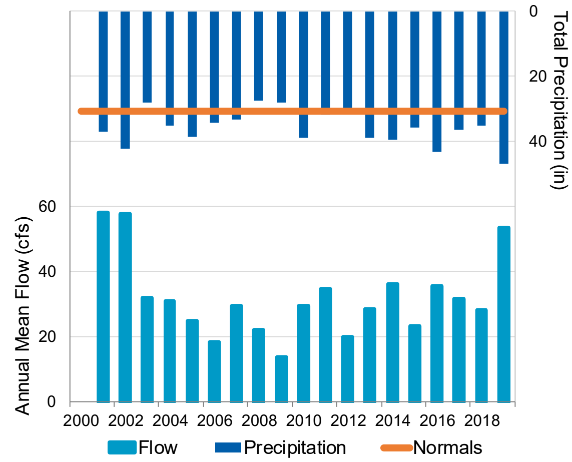

Figure 4: Flow and Precipitation for Bassett Creek

Streamflow and Chloride Concentration

Figure 5 shows annual median chloride concentration and annual median flow values, representing typical conditions for each year. There is a general relationship between flow and concentration: when flow has been high, concentration has generally been low due to dilution, and when flow has been low, concentration has increased. However, there is variability in concentration that does not vary perfectly with flow. This means that factors other than flow impact chloride conditions in the stream.

In order to see how non-flow factors such as watershed practices may have affected chloride concentrations, we used the R-QWTREND model.

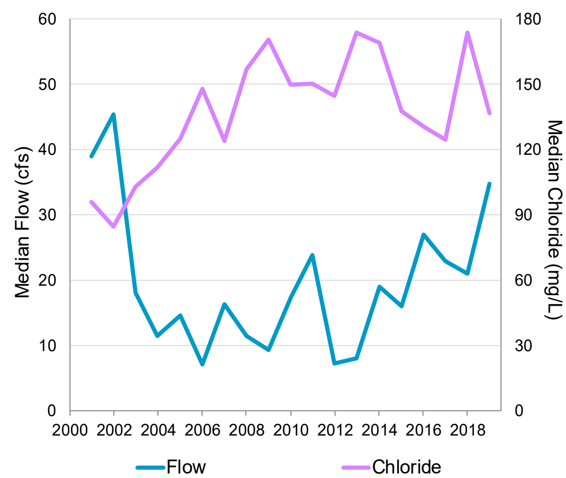

Figure 5: Annual Median Flow and Chloride Concentration in Bassett Creek

Chloride Trends

R-QWTREND is a statistical model specifically designed to investigate pollutant trends, which tests potential trends (increase or decrease in concentration) against a no-trend model (no increase or decrease in concentrations). This model removes the variability of annual flow and seasonality from the statistical analysis. If the model does not show a statistically significant trend for a given time period, there is not sufficient evidence to claim that concentrations are increasing or decreasing. If increasing or decreasing concentrations cannot be described, then concentrations are assumed to be stable.

R-QWTREND analysis shows that changes in chloride concentration in Bassett Creek can be best represented by a statistically significant three-trend model, $p = 2.9\times10^{-10}$. This model has only one significant period, from 2006-2012, which shows an increase in flow-adjusted concentration. From 2001-2005 and 2013-2019 there is not strong enough evidence that a trend exists. These two periods are reported as statistically non-significant (NS) and the modeled trend concentrations, changes in percentages, and rates are not provided (Table 1).

Table 1: Statistical Trend for Chloride Concentration in Bassett Creek

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
2001 – 2005	-	-	-	0.4	NS
2006 – 2012	124.7 – 176.2	41.3%	7.36	0.00002	⬆
2013 – 2019	-	-	-	0.99	NS

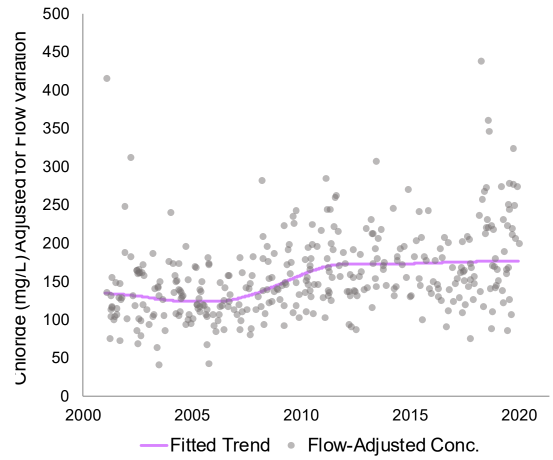

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Bassett Creek

From 2005 – 2012, chloride concentrations increased, likely due to behaviors in the watershed, including potentially an increase use of de-icing salt. Since 2013, concentrations have not changed significantly. At this time, it appears that the increasing trend from 2005 to 2012 may have been slowed or halted in 2013 by actions occurring in the watershed, including implementation of chloride best management practices, which interrupted the increasing chloride trend.

Additional data from 2020 and into the future has the potential to impact the significance and the direction of the most recent trend period.

Pollutant Trend: An analysis that shows the direction of change (improving vs. declining water quality) in a pollutant over time. This study examined changes in flow-adjusted chloride concentration from 2001 – 2019, allowing us to look at human-caused influences in chloride concentrations.

Flow-Adjusted Concentration: An adjustment to ambient concentration that removes variability of annual flow and seasonality mathematically, for use in statistical analysis.

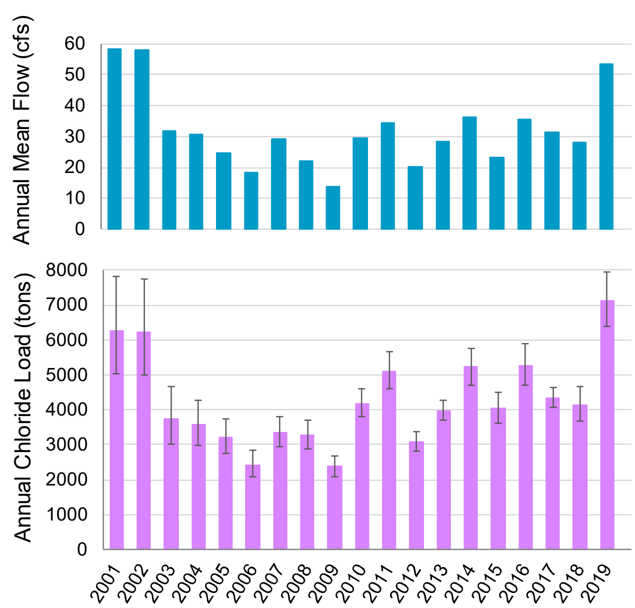

Figure 7: Mean Annual Flows and Annual Chloride Loads in Bassett Creek (Error bars = 95% Confidence Interval)

Chloride Load

Figure 7 illustrates annual loads expressed as tons and annual mean flow. The annual loads for chloride calculated with Flux32 exhibited significant year-to-year variation indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream.

The increase in Cl loads in years of higher flow could be due to the increased flushing of salt that had built up in watershed lakes and groundwater during drier years, when pollutants are less likely to be mobilized. Annual chloride load variability in Bassett Creek is also likely due to quantity and timing of winter storm events and de-icing response to those storm events.

Pollutant Load: The total mass of a pollutant exported from a stream over a period of time. MCES uses Flux32 software to estimate pollutant loads.

Seasonal Chloride Dynamics 2001 – 2019

Chloride Concentration and Streamflow

Figure 8 shows monthly median chloride concentration and monthly median flow values, representing typical conditions in each month. Seasonal changes can influence monthly median flow and monthly median chloride concentration. De-icing salt is likely the primary source of chloride in the watershed. De-icing salt is primarily applied between December and March and would likely runoff during melt events from February through April. Peak flow was observed during the spring, while peak chloride concentration occurred in winter.

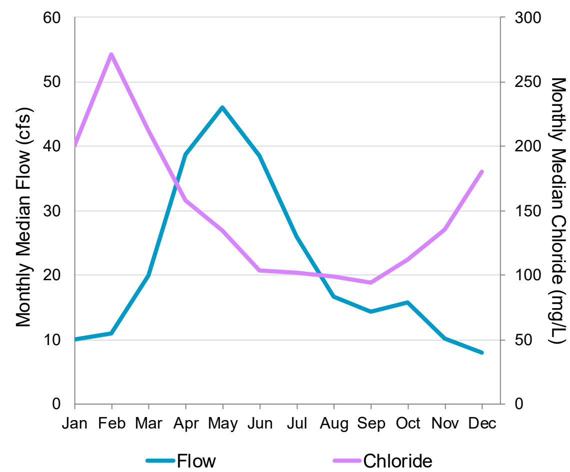

Figure 8: 2001 – 2019 Monthly Median Flow and Median Ambient Chloride Concentrations in Bassett Creek

Chloride Load

Chloride load is seasonally dynamic. The highest chloride load occurs from April through June. Chloride loads calculated with Flux32 were compiled as monthly averages for 2001-2019, Figure 9 uses a line to indicate maximum and minimum values for each month. The bottom of each box represents the first quartile, the top represents the third quartile, and the line in the middle of the box represents the median monthly chloride load.

From 2001-2019, highest monthly loads occur in the spring and early summer, likely due to snow melt and spring precipitation. Chloride dynamics are likely affected by chloride cycling in Medicine Lake and other upstream lakes with high chloride, shallow groundwater storage and additional, unknown factors.

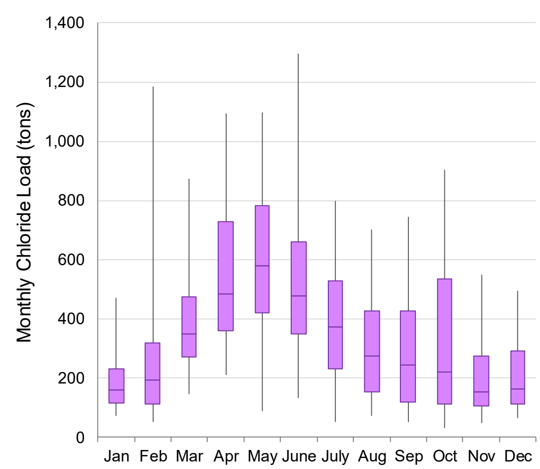

Figure 9: 2001 – 2019 Monthly Chloride Loads in Bassett Creek

LIMITATIONS

The analyses described in this memo identify changes in chloride concentrations in the stream, but they do not identify the cause of those changes. MCES has suggested hypotheses about causes of changing chloride dynamics but additional information or research is needed to identify specific changes in watershed management, climactic changes, or any other factors which may have affected concentration in the stream.

During some winter months in from 2001 – 2019, hazardous ice conditions precluded sample collection. This data gap possibly biases our understanding of seasonal and annual chloride dynamics.

RECOMMENDATIONS & NEXT STEPS

Chloride pollution reduction projects and initiatives are most effective when guided by data collection and analysis. In order to support Bassett Creek WMC and partners to prioritize resources to understand chloride dynamics and mitigate chloride pollution, MCES provides the following recommendations:

- Calculate or compile a watershed chloride budget including but not limited to de-icing salt application and turf grass management.
- Develop a watershed water budget including groundwater contribution.
- Investigate chloride concentrations and cycling in lakes to understand how lakes affect chloride in the creek.
- Investigate the potential for stormwater runoff to enter shallow groundwater and how that affects chloride pollution timing and concentration.
- Compile a timeline of land use changes, chloride best management practices and stormwater management installations in the watershed to better understand the flow-adjusted concentration trend.
- Update flow and load duration curves from 2014 *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* This analysis calculates the likelihood of a chloride standard exceedance for a particular flow.
- Investigate whether milder winters exacerbate seasonal chloride pollution by investigating winter chloride trends during thaw events, two or more days with air temperature lows above 32°F.
- Investigate monthly or seasonal chloride trends.
- Investigate relationship between continuous conductivity and chloride to understand chloride dynamics at a higher resolution.
- Investigate chloride dynamics grouped by decadal intervals or in response to known watershed changes. MCES has some preliminary decadal assessment available to share.
- Monitor water quality and flow upstream of the WOMP station to better identify chloride sources to Bassett Creek.

We are aware that not all watershed organizations have the time, capacity, or resources to take these or other future next steps. MCES may have the ability to assist with future data collection, data analysis or other technical advice. Please contact us to discuss the potential of future partnerships if you are interested in continuing this work. Please contact us for additional technical information or information on field, laboratory and data analysis methods. Method documentation is also available as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* report, *Introduction and Methodologies* section, available on the Council website at https://metrocouncil.org/streams.

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[1] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[2] Metropolitan Council Environmental Services, 2018. Regional Assessment of River Quality in the Twin Cities Metropolitan Area. <https://metrocouncil.org/Wastewater-Water/Services/Water-Quality-Management/River-Monitoring-Analysis/Regional-Assessment-of-River-Quality-(2).aspx>
[3]Ibid. Footnote 1, page 2

[4] Minnesota Administrative Rules. *Minnesota Water Quality Standards for Protection of Waters of the State*. Minn. Rules 7050.0218 and Minn. Rules7050.0222. < https://www.revisor.mn.gov/rules/7050/>

[5] Overbo and Heger, n.d. *Estimating annual chloride use in Minnesota.* Water Resources Center. <wrc.umn.edu/chloride>

[6] Metropolitan Council, 2013. Municipal Water Use in the Seven-County Twin Cities Metro Area. <https://metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx>

[7] Ibid. Footnote 1, page 2

[8] Rehm, G. and M. Schmitt. 1997. Potassium for crop production. Minnesota Extension Service. Minneapolis: University of Minnesota.

[9] Ibid. Footnote 1, page 2

[10] Metropolitan Council Environmental Services. 2014. *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams*. St. Paul: MCES.

[11] Minnesota Pollution Control Agency. 2016. Twin Cities Metropolitan Area Chloride Management Plan. <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

[12] Minnesota Pollution Control Agency. 2019. 2018 Minnesota's Impaired Waters List. <https://www.pca.state.mn.us/water/2018-impaired-waters-list>

[13] Granato, G.E., DeSimone, L.A., Barbaro, J.R., and Jeznach, L.C., 2015, Methods for evaluating potential sources of chloride in surface waters and groundwaters of the conterminous United States: U.S. Geological Survey Open-File Report 2015–1080, 89 p., http://dx.doi.org/10.3133/ofr20151080.

[14] Minnesota Department of Natural Resources. 2020. *Minneapolis/St. Paul Climate Data Normals and Averages.* *<https://www.dnr.state.mn.us/climate/twin_cities/normals.html>*