Eagle Creek CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

Chloride concentrations have increased in Eagle Creek since 2001 but at a slower rate since 2016.

There is little monthly variation in chloride export from Eagle Creek, likely because it is a groundwater dominated system. More investigation is needed on chloride transport in shallow groundwater to further understand chloride dynamics in the Eagle Creek watershed.

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 those analyses, 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, the Lower Minnesota River Watershed District in partnership with the Scott Soil and Water Conservation District, and the Scott Watershed Management Organization, have been actively working to address chloride pollution through monitoring investigations and outreach and education efforts.

This memo provides data and analyses from Eagle Creek with state and regional context about chloride pollution. This information has prompted questions from MCES staff and will likely prompt questions from readers. This memo is intended 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]

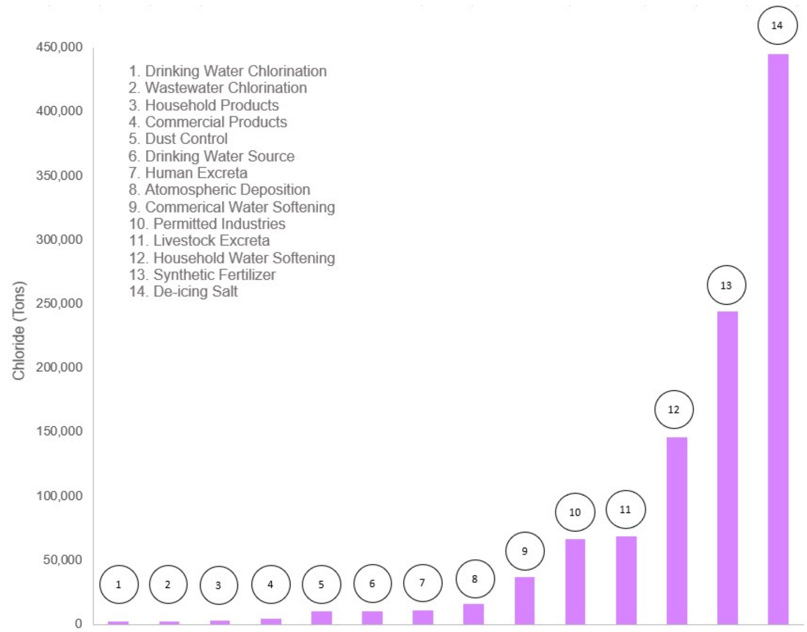

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

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

Household water softening: 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. The chloride waste from the water softening process enters surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems.[7]

Synthetic fertilizer: 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.

De-icing salt: 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.

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

Eagle Creek is 2.1-miles long and drains approximately 2.6 square miles of mixed suburban land, forest, open space, bluff land, and wetlands in Scott County (Figure 2). The stream is dominated by groundwater flows and the ratio of flow to precipitation is greater than 2.0 (most metro streams are between 0.05 – 0.3). Eagle Creek begins at Boiling Springs, a large and constantly flowing spring in Shakopee, and runs through the Minnesota Valley National Wildlife Refuge before joining the Minnesota River. Eagle Creek is a Minnesota Department of Natural Resources designated trout stream.

The Eagle Creek watershed has 810 acres/48.4% (450 acres/41.5% within the monitored area) of developed urban land, including portions of the cities of Prior Lake, Shakopee, and Savage. The watershed also has 297 acres/17.7% (267 acres/24.6% within the monitored area) of forested land, 245 acres/14.6% (142 acres/13.1%) of grasses/herbaceous cover, 218 acres/13.0% (121 acres/11.2% within the monitored area) of wetlands, and 99 acres/5.9% (99 acres/9.1% within the monitored area) of agricultural land in the watershed, the majority of which is at the most upstream point.[10]

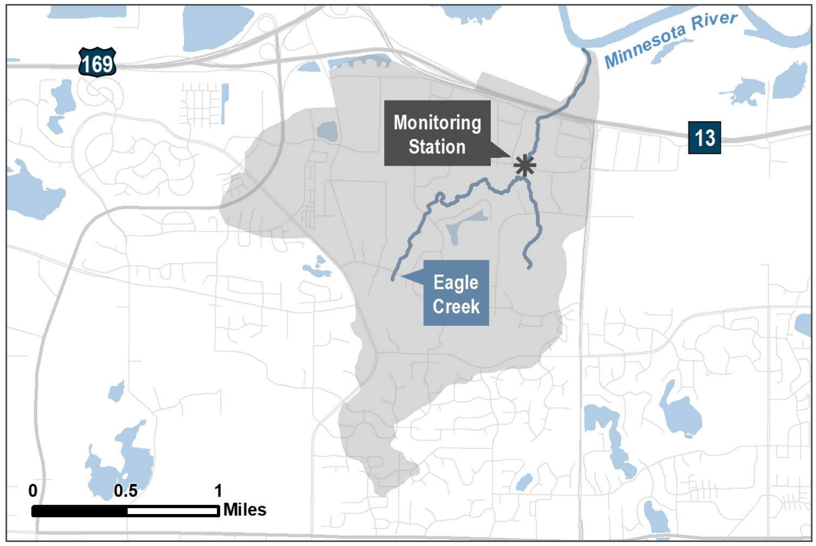

Figure 2: Map of Eagle Creek Watershed

Approximately 19% of the Eagle Creek watershed is roadways, based on an analysis completed by the Minnesota Pollution Control Agency (MPCA). [11] The MPCA found that waterbodies having watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[12]

The groundwater watershed of Eagle Creek is not well understood and may be significantly larger than the Eagle Creek surface water watershed shown in Figure 2.

The WOMP Station location does not capture the total watershed chloride load, as several stormwater ponds flow to the mainstem of the creek just north of Highway 101. Additional sampling conducted by Scott SWCD in winter 2018 - 2019 indicated that median and mean chloride concentrations from these ponds were two to three times those measured at the monitoring station. These ponds likely contributed high amounts of chloride to the creek below the monitoring station during this period.

Household water softening is not likely to be a major chloride source in the Eagle Creek watershed. Chloride from household water softening enters surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems. Most wastewater from the watershed is treated through the MCES Seneca Wastewater Treatment Plant and discharged to the Minnesota River in Eagan.

Synthetic fertilizer is a possible chloride source in the Eagle Creek watershed. Chloride may 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 the Eagle Creek watershed. De-icing salt is primarily applied between December and March and would likely runoff during melt events from February through April. Runoff containing de-icing salt infiltrates the soil and likely contributes to chloride in the groundwater flow that eventually enters Eagle Creek.

FINDINGS

Annual Chloride Dynamics 2001-2019

Chloride Concentration

MCES and the Lower Minnesota River Watershed District partner to monitor Eagle Creek; Scott County Soil and Water Conservation District (Scott SWCD) collects the samples. The partners collected 438 chloride samples between 2001 and 2019. The ambient concentrations are plotted with the annual median concentration (Figure 3). These values are affected by precipitation, flow, and watershed factors, including those caused by human activity.

Annual median chloride concentration generally increased from 2001 to 2019.The increase appears extreme in Figure 3, but the concentrations are still far below water quality standards.

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.

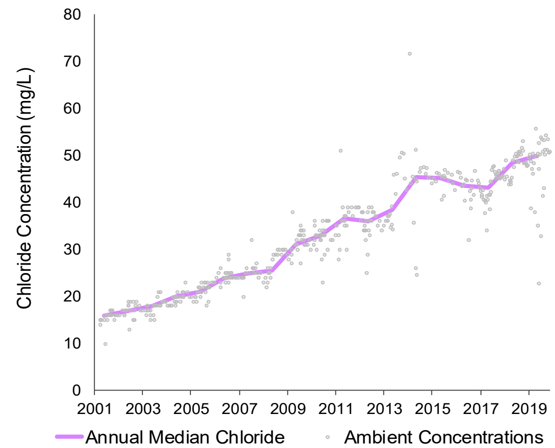

Figure 3: Annual Median and Ambient Chloride Concentrations of Eagle Creek

Precipitation and Streamflow

Ambient concentrations are often closely tied to rainfall and resulting flow conditions in the stream. Figure 4 shows annual total precipitation and the 1981-2010 National Weather Service Climate Normal precipitation at Minneapolis-St. Paul airport[14] with Eagle Creek annual mean flows. Precipitation appears to have a minimal effect on flow in this groundwater-dominated stream.

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

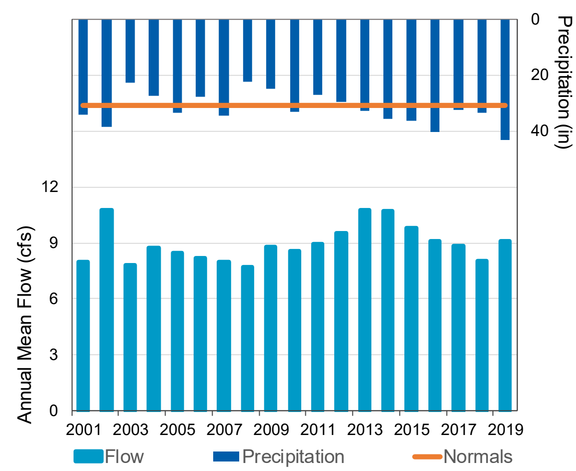

Figure 4: Annual Mean Flow and Precipitation for Eagle Creek

Streamflow and Chloride Concentration

Figure 5 shows little relationship between flow and concentration: concentration has generally increased regardless of increasing or decreasing flow. Factors other than flow impact chloride conditions in the stream. It is likely that high chloride concentrations in groundwater are the primary factor affecting the median concentrations at the monitoring station.

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

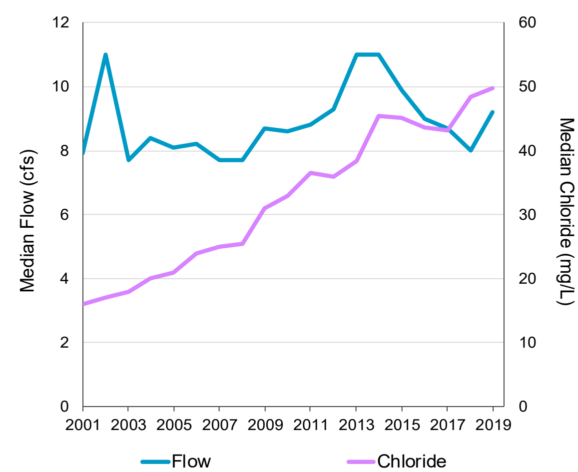

Figure 5: Annual Median Flow and Chloride Concentration in Eagle Creek

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 Eagle Creek can be best represented by a statistically significant two-trend model ($p = 7.8 \times 10^{-16}$) over the assessment period from 2001 to 2019 (Table 1 and Figure 6). The model shows that the flow adjusted chloride concentration increased significantly from 2001 to 2015 and then continued increasing but at a slower pace from 2016 to 2019.

Table 1: Statistical Trend for Chloride Concentration in Eagle Creek

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
2001 – 2015	17.1 - 44.4	160%	1.95	0.00	⬆
2016 – 2019	44.4 - 47.1	6%	0.67	0.05	⬆

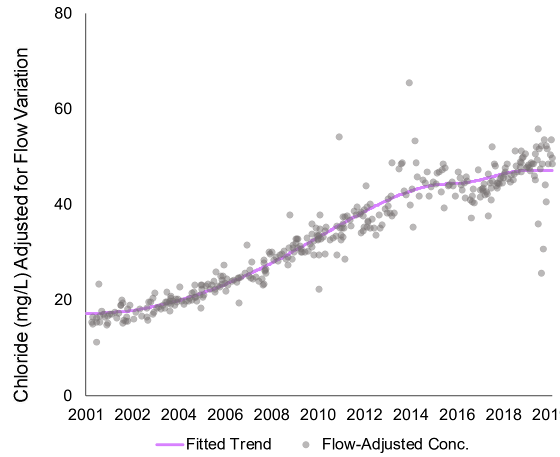

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Eagle Creek

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

Chloride Load

Figure 7 illustrates annual loads expressed as mass and annual mean flow also shown in Figure 3. The annual mass loads for chloride calculated with Flux32 increased from 2001 – 2014 even though annual mean flow did not vary much, meaning chloride concentrations were the primary driver of loads. The increase in load during this period may have been due to increased road salt application in the watershed.

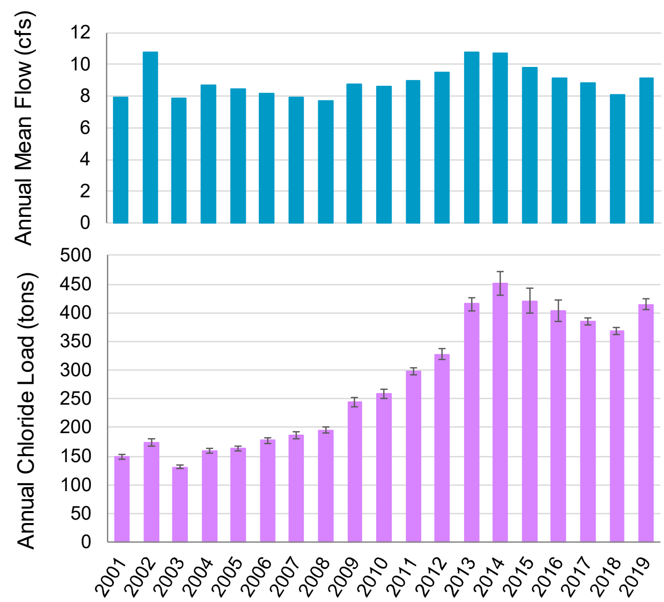

Figure 7: Mean Annual Flows and Annual Chloride Loads in Eagle Creek (Error bars = 95% Confidence Interval)

From 2014 – 2019, flow and chloride load were more closely correlated, indicating flow had more of an influence on load than concentration. This reflects the previously observed slowing increasing trend in chloride concentration.

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

Seasonal changes can influence monthly median flow and monthly median chloride concentration.

During the analysis period, median chloride concentrations in Eagle Creek were highest in December through February and decreased slightly from March through November. However, both monthly median flows and median chloride concentrations show only small seasonal variation (Figure 8). This is most likely due to groundwater contributions to the stream that maintain a more consistent flow throughout the year.

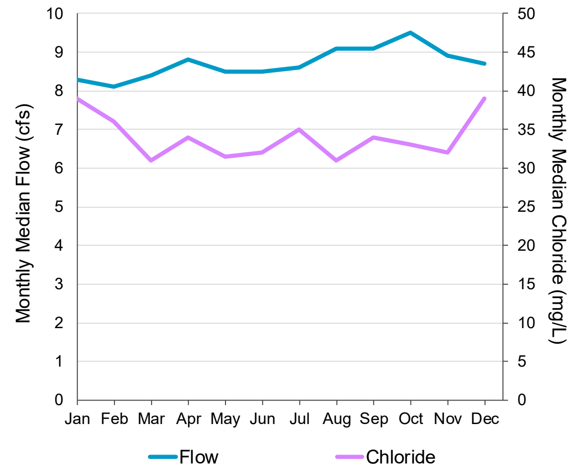

Figure 8: Monthly Median Flow and Median Ambient Chloride Concentrations in Eagle Creek

Chloride Load

Chloride loads calculated with Flux32 were compiled as monthly averages for 2001-2019. Figure 9 uses a bar 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.

Monthly chloride loads in Eagle Creek show little variation or seasonal pattern, which follows from the fairly consistent flows and concentrations shown in Figure 8.

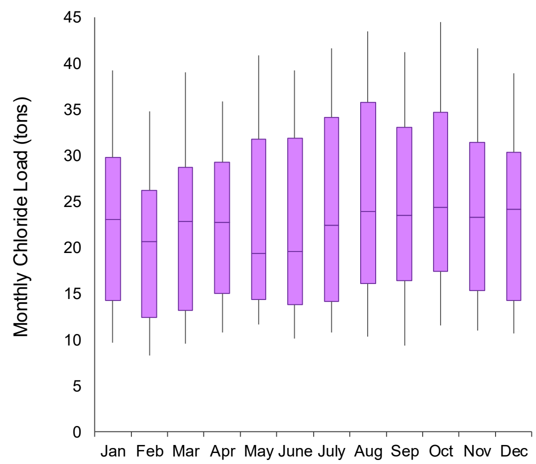

Figure 9: Monthly Chloride Loads in Eagle Creek

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 from 2001 – 2019, hazardous 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 Lower Minnesota Watershed District and partners to prioritize resources to understand chloride dynamics and mitigate chloride pollution, MCES provides the following recommendations:

- Delineate the contributing groundwater watershed and groundwater sources to Eagle Creek.
- Measure ambient groundwater chloride concentrations for the contributing groundwater watershed.
- Calculate or compile the watershed water and chloride budgets including but not limited to fertilizer use and de-icing salt application.
- Investigate baseflow separation and chloride concentration dynamics.
- Continue investigating chloride concentrations in the creek downstream of the WOMP monitoring station, to understand chloride contributions from the entire Eagle Creek watershed.
- Compile a timeline of land use changes, chloride best management practices and stormwater management installations in the watershed.
- Continue to implement chloride mitigation and management BMPs including trainings to minimize salt use on roads, parking lots, sidewalks and other impervious surfaces.

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] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>

[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] Minnesota Pollution Control Agency. <https://www.pca.state.mn.us/water/chloride-101>

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

[9] Minnesota Pollution Control Agency. <https://www.pca.state.mn.us/water/chloride-101>

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

[11] Minnesota Pollution Control Agency. 2020. Draft Statewide Chloride Management Plan <https://www.pca.state.mn.us/water/draft-statewide-chloride-management-plan>

[12] 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>

[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>*