Riley Creek CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

Chloride concentration in Riley Creek increased over the assessment period, 2001 – 2019. The increase is likely due to watershed development and increased use of winter de-icing salt.

Chloride varied seasonally with higher values occurring in the spring and early summer, indicating salt use for winter de-icing is likely the major source for chloride in the stream. Other sources, such as synthetic fertilizer, are not well understood and should be investigated.

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.

The 2014 *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* report 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 2001-2019, the city of Chanhassen and the Riley Purgatory-Bluff Creek Watershed District developed several chloride management programs to control chloride pollution. The city and Watershed District prepared rules, polices, and recommendations for chloride uses aimed at reducing chloride pollution and minimizing the movement of chloride compounds into water resources.

This memo provides data and analyses from Riley 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]

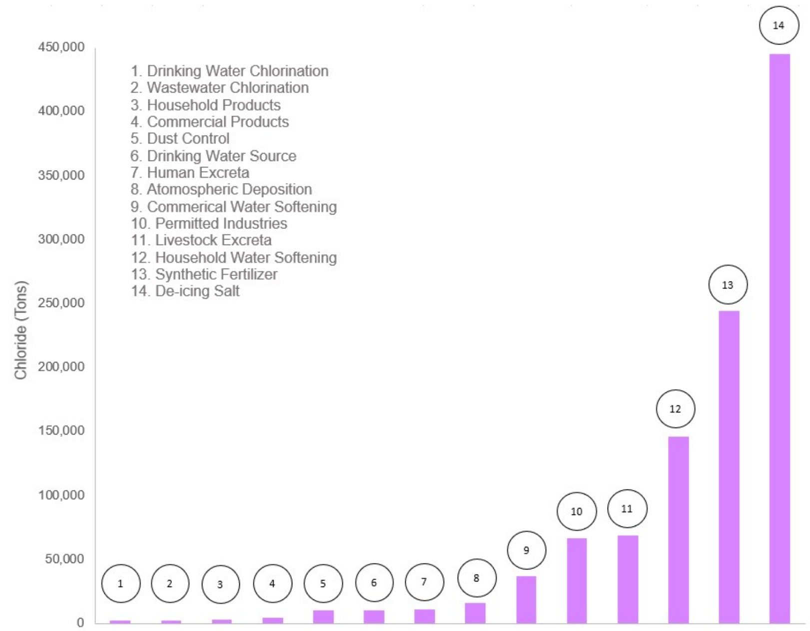

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

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 four largest are livestock excreta, household water softening, synthetic fertilizer and de-icing salt (Figure 1).

Livestock Excreta: Research found elevated chloride in seepage from earthen-lined manure storage and high chloride levels in groundwater downgradient of manure storage,[6] but there is little research investigating effects of livestock feedlots or manure application practices on chloride levels in water.

Household water softening: More than 70% of the drinking water used in the Twin Cities comes from groundwater[7] 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.[8]

Synthetic fertilizer: Chloride is associated with macronutrients like potassium. The most common potassium source in Minnesota is potash fertilizer, potassium chloride.[9] 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.[10] 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

Riley Creek is 9.6 miles long and drains approximately 13 square miles of mixed urban land, open space, and wetlands, located entirely within the cities of Chanhassen and Eden Prairie, in Carver and Hennepin counties. The creek begins at Lakes Lucy and Ann in Chanhassen and flows through three downstream lakes and the Minnesota Valley National Wildlife Refuge before entering the Minnesota River (Figure 2).

The Riley Creek watershed is about 8,387 acres, with 6,642 acres (79%) of the watershed upstream of the monitoring station. Currently 36% of the land use in the watershed is classified as urban (29% residential and 7% commercial), 40% open space and 3% agriculture.[11]

Approximately 19% of the Riley Creek watershed is roadways, based on an analysis completed by the Minnesota Pollution Control Agency (MPCA).[12] The MPCA found that watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[13]

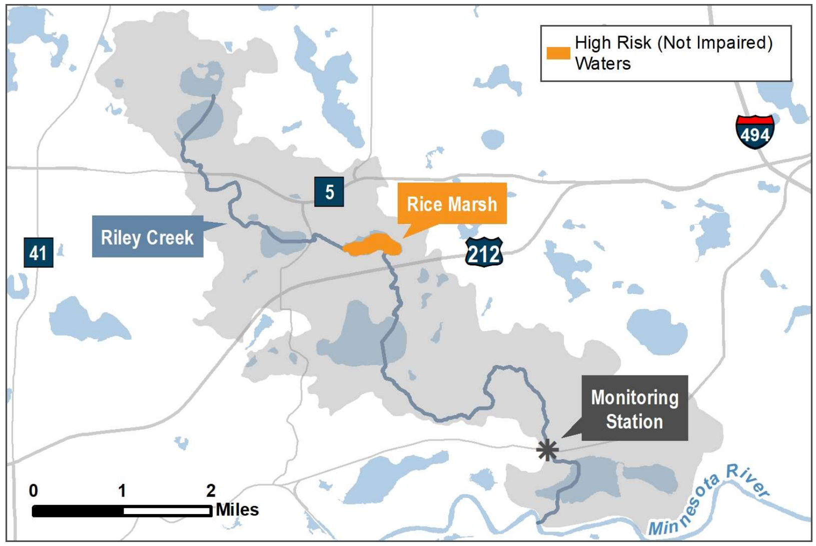

Figure 2: Map of Riley Creek Watershed

Riley Creek flows through Rice Marsh Lake which MPCA has designated high risk for chloride impairment. While Riley Creek itself has not been designated as high risk for chloride impairment, Riley Creek flows through Rice Marsh. High chloride levels in Rice Marsh may be affecting chloride levels in Rice Creek.

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

Synthetic fertilizer is a possible chloride source in the Riley Creek watershed. Chloride may come from residential and other urban and suburban turf management application of potash fertilizer.[14] This source of chloride is not well understood in the watershed.

De-icing salt is likely the primary source of chloride pollution in Riley 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 collected 159 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 over the assessment period with the highest values in 2011 and 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.

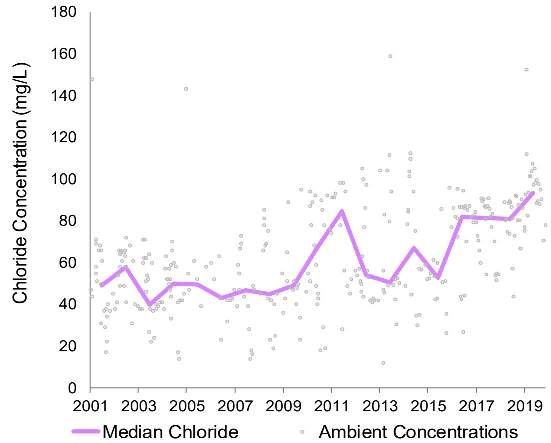

Figure 3: Annual Median and Ambient Chloride Concentrations Riley Creek

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[15] with Riley Creek annual mean flows. Flow is usually higher in years with greater rainfall. Annual median flow (Figure 4) in the stream varied slightly from 2001 to 2015 with a high flow in 2014. Flow generally increased from 2016 to 2019.

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

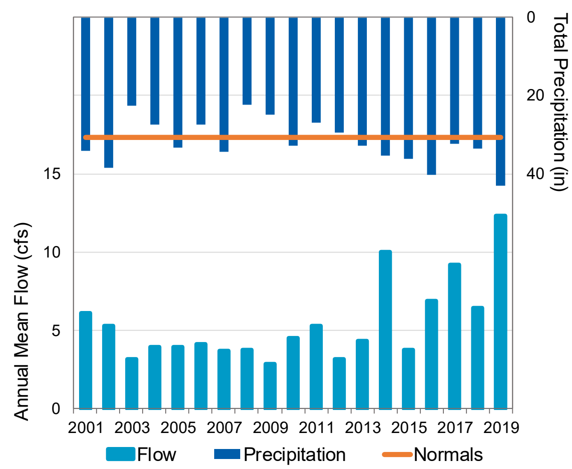

Figure 4: Annual Mean Flow and Precipitation for Riley Creek

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 high, and when flow has been low, concentration has been low. 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.

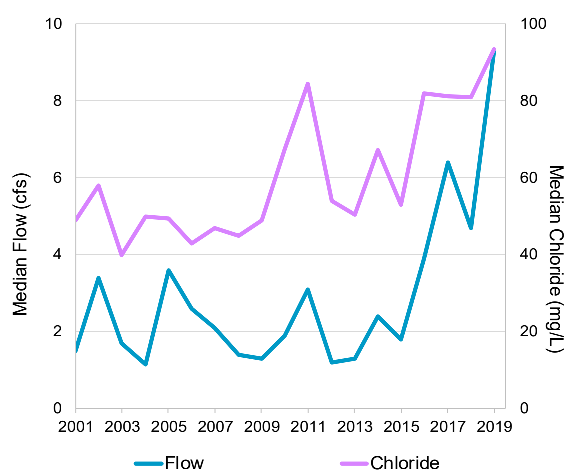

Figure 5: Annual Median Flow and Chloride Concentration in Riley Creek

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 Riley Creek can be best represented by a statistically significant two-trend model ($p = 2.9 \times 10^{-10}$) over the assessment period of 2001 to 2019 (Table 1 and Figure 6). This model has two significant periods: the flow-adjusted chloride concentration steadily increased from 2001 to 2013 and then increased more quickly from 2014 to 2019.

Table 1: Statistical Trend for Chloride Concentration in Riley Creek

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
2001 – 2013	45.9 - 56.8	24%	0.9	0.0025	⬆
2014 – 2019	56.8 - 72.6	28%	2.64	0.0081	⬆

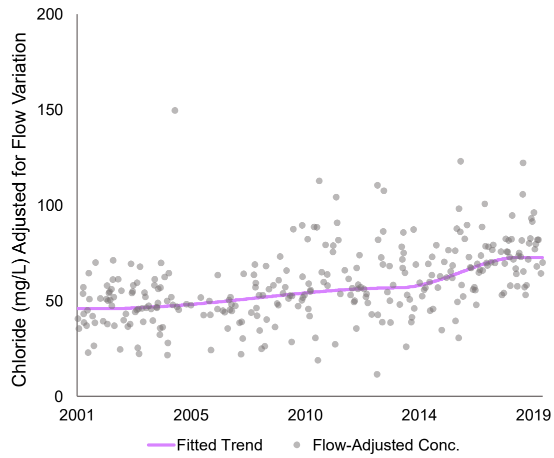

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Riley Creek

The increase in chloride concentrations during the assessment period (2001 – 2019) is likely due to watershed development and increased use of de-icing salt.

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

Figures 7 illustrates annual loads and annual mean flow. The annual loads for chloride exhibited year-to-year variation over the assessment period. Variation in flows was more evident from 2014-2019 indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream.

The increase in chloride 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

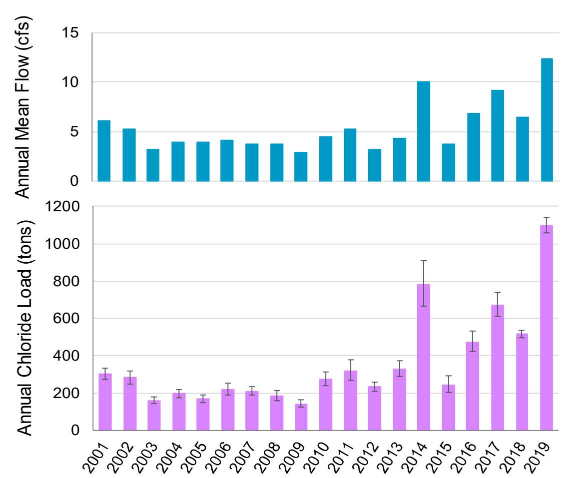

Figure 7: Annual Chloride Loads in Riley Creek (Error bars = 95% Confidence Interval)

load variability in Riley Creek is also likely due to quantity and timing of winter storm events and de-icing response to those storm events.

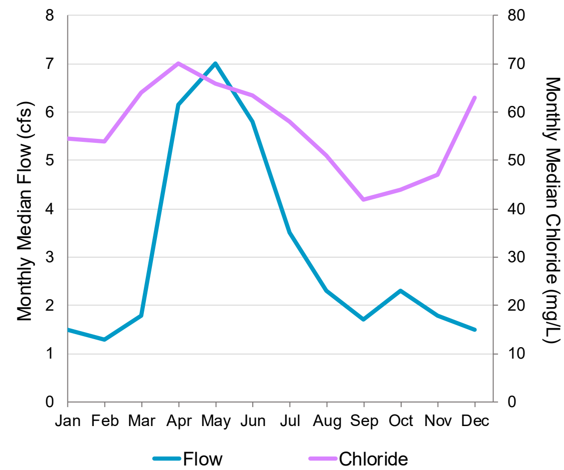

Figure 8: Monthly Median Flow and Median Ambient Chloride Concentrations in Riley Creek

Seasonal Chloride Dynamics 2001 – 2019

Chloride Concentration and Streamflow

Seasonal changes can influence monthly median flow and monthly median chloride concentration. Monthly median flow had an apparent seasonal variation (Figure 8). Higher flows were observed during the spring and early summer while lower flows were observed in the fall and winter.

Monthly median chloride concentration also had a seasonal change but at a much smaller scale. The higher concentrations were observed in the spring through early summer while the lower concentrations occurred in the fall and winter.

Chloride Load

Chloride load is seasonally dynamic. The higher 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.

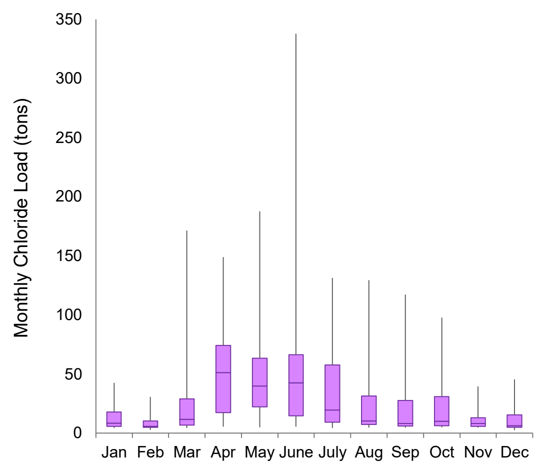

Figure 9: Monthly Chloride Loads in Riley Creek

From 2001-2019, higher 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 upstream lakes with high chloride, shallow groundwater storage and additional, unknown factors.

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 prioritizing resources to understand chloride dynamics and mitigate chloride pollution, MCES provides the following recommendations:

- Calculate or compile the watershed water and chloride budgets including but not limited to synthetic fertilizer use and de-icing salt application.
- Investigate chloride concentrations and cycling in lakes to understand how lakes affect in-stream chloride.
- Investigate the potential for stormwater runoff to enter shallow groundwater and how that affects chloride pollution timing and concentration.
- 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.
- Compile a timeline of land use changes, chloride best management practices and stormwater management installations in the watershed.
- Determine whether milder winters exacerbate seasonal chloride pollution by investigating winter chloride trends during thaw events. A thaw is two or more days with air temperature lows above 32F.
- Continue to monitor water quality and flow upstream of the WOMP station and investigate data to better identify chloride sources to Riley Creek.
- Continue to identify and implement chloride mitigation and management BMPs including trainings to minimize de-icing salt use.

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] Minnesota Pollution Control Agency. 2001. Effects of Liquid Manure Storage Systems on Groundwater Quality. <https://www.pca.state.mn.us/sites/default/files/rpt-liquidmanurestorage.pdf>
[7] Metropolitan Council, 2013. Municipal Water Use in the Seven-County Twin Cities Metro Area. <https://metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx>
[8] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[9] Rehm, G. and M. Schmitt. 1997. Potassium for crop production. Minnesota Extension Service. Minneapolis: University of Minnesota.
[10] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[11] Riley Purgatory Bluff Creek Watershed District. 2021. Riley Creek Watershed Characteristics. <http://www.rpbcwd.org/waterbody/riley-creek>
[12] Minnesota Pollution Control Agency. 2020. Draft Statewide Chloride Management Plan <https://www.pca.state.mn.us/water/draft-statewide-chloride-management-plan>
[13] 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>
[14] 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.
[15] Minnesota Department of Natural Resources. 2020. *Minneapolis/St. Paul Climate Data Normals and Averages.* *https://www.dnr.state.mn.us/climate/twin_cities/normals.htmll mean*