Crow River CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

Chloride concentrations in the Crow River were generally low throughout the study period and decreased slightly from 2006 – 2019.

Livestock excreta, household water softening, synthetic fertilizer, and de-icing salt are all likely sources of chloride in the Crow River.

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?

This memo provides data and analyses from the Crow River 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]

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).

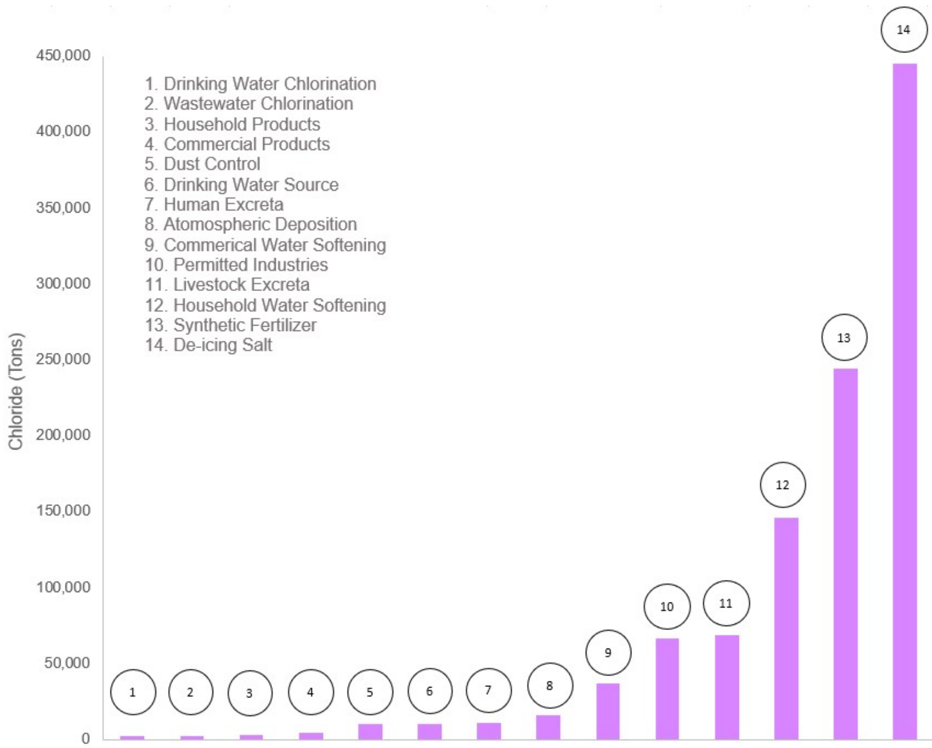

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

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 has the potential to enter 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

The Crow River watershed covers approximately 2,508 square miles of mostly agricultural land in central Minnesota. The Crow River discharges to the Mississippi River near the City of Rogers (Figure 2).

The Crow River watershed is 1,762,955 acres, 58% of the land use is agricultural land use.[11] About 7% of the land is developed urban land use including all or parts of the cities of Albertville, Atwater, Belgrade, Bird Island, Biscay, Brooten, Brownton, Buffalo, Buffalo Lake, Cedar Mills, Cokato, Corcoran, Cosmos, Darwin, Dassel, Dayton, Delano, Elrosa, Glencoe, Greenfield, Grove City, Hanover, Hector, Howard Lake, Hutchinson, Independence, Kandiyohi, Kingston, Lake Lillian, Lester Prairie, Litchfield, Loretto, Maple Lake, Maple Plain, Mayer, Medina, Minnetrista, Monticello, Montrose, New Germany, New Long, Norwood Young America, Otsego, Paynesville, Plato, Regal, Rockford, Rogers, Saint Michael, Sedan, Silver Lake, Spicer, Stewart, Watertown, Waverly, Willmar, and Winsted. The rest of the watershed is forest and grasslands.[12]

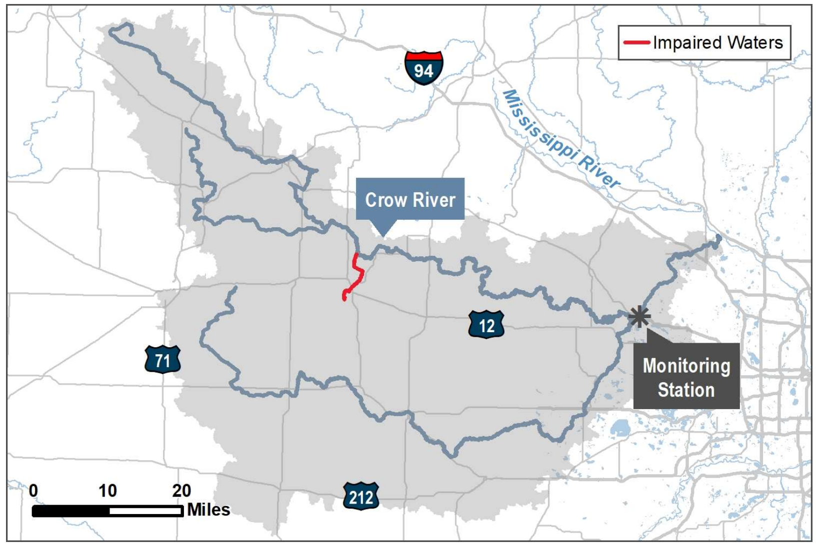

Figure 2: Map of the Crow River Watershed

Approximately 5% of the Crow River watershed is roadways, based on an analysis completed by the Minnesota Pollution Control Agency (MPCA). The MPCA found that watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[13]

Since 2010, Jewitts Creek, which discharges to the Crow River, has been listed by MPCA as impaired for aquatic life use due to excess chloride (Figure 2).[14]

Crow River chloride pollution sources likely include livestock excreta, household water softening, synthetic fertilizer, and de-icing salt.

<u>Livestock Excreta:</u> The Crow River watershed has 1,776 registered feedlots, with a total of 305,339 animal units.

<u>Household Water Softening</u>: There are 16 domestic wastewater treatment plants in the watershed. In addition, there are many residential developments served by subsurface sewage treatment systems. The chloride waste from the water softening process has the potential to enter surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems.[15]

<u>Synthetic Fertilizer:</u> Chloride may come from agricultural and urban application of potash fertilizer.[16] This source of chloride is not well understood in the watershed.

<u>De-icing Salt:</u> 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 Wright County Soil and Water Conservation District collected 432 chloride samples from the Crow River 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 river.

These values are affected by precipitation, flow, and watershed factors, including those caused by human activity.

The ambient chloride concentrations in Figure 3 show a wide range. Concentrations are generally low and far below the chronic water quality standard of 230 mg/l, though there have been a few samples in recent years near that standard. Annual median chloride concentration showed some variation but was fairly stable over the period of record.

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.

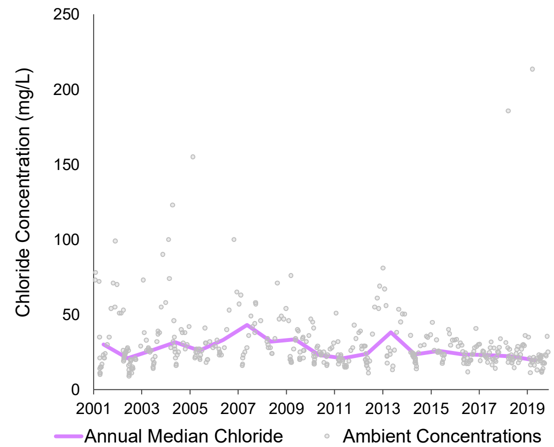

Figure 3: Annual median and ambient chloride concentrations in the Crow River

Precipitation and Streamflow

Ambient concentrations are often closely tied to rainfall and resulting flow conditions in the river. 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[17] with Crow River annual mean flows. Flow is usually higher in years with greater rainfall. Annual mean flow in the Crow River varied dynamically during the assessment period with higher flows in 2011 and 2019.

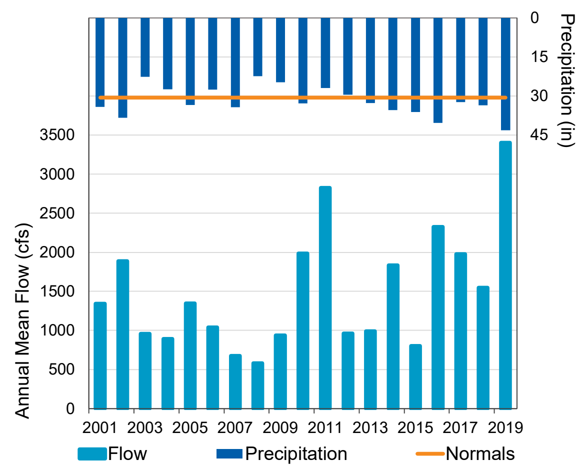

Figure 4: Flow and Precipitation for the Crow River

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

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 generally 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 river.

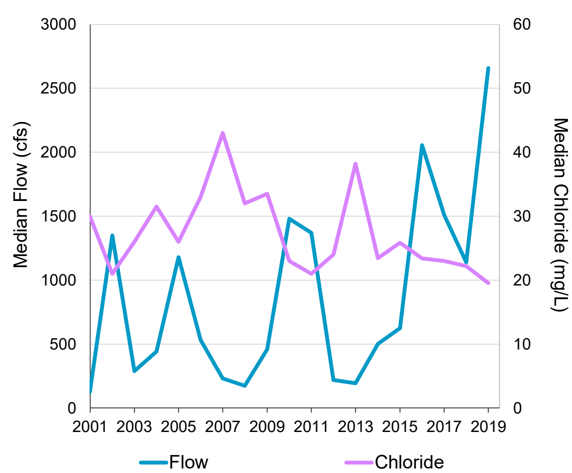

Figure 5: Annual Median Flow and Chloride Concentration in the Crow River

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

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 the flow-adjusted chloride concentration in the Crow River can be best represented by a statistically significant two-trend model, $p = 7.8 \times 10^{-4}$. The results (Table 1 and Figure 6) show that the flow-adjusted chloride concentration in the river increased from 2001 to 2005 and then decreased slightly from 2006 to 2019.

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

Table 1: Statistical Trend for Chloride Concentration in the Crow River

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
2001 – 2005	27.2 - 33.4	23%	1.24	0.0015	↑
2006 – 2019	33.4 - 30.8	-8%	-0.19	0.0570	↓

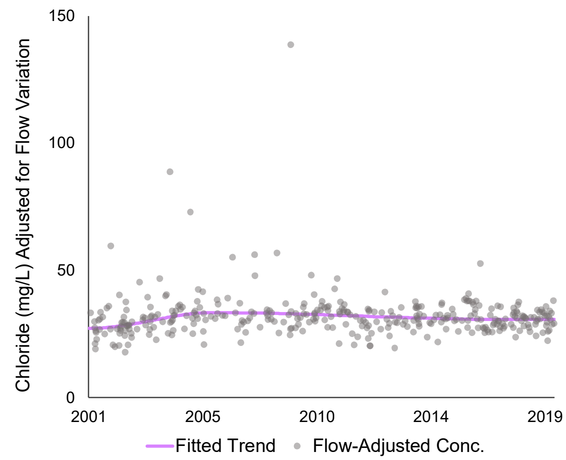

Figure 6: Flow-Adjusted Trends for Chloride Concentration in the Crow River

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 Loads

Figures 7 illustrates annual loads and annual mean flow. The annual loads for chloride exhibited significant year-to-year variation, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the river.

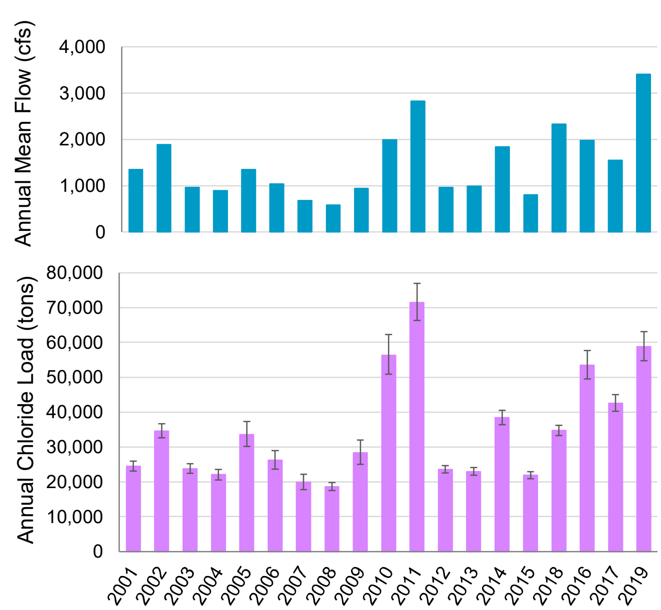

Figure 7: Annual Chloride Loads in the Crow River (Error bars = 95% Confidence Interval)

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.

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. Higher flows occurred during the spring while higher chloride concentrations occurred in the winter.

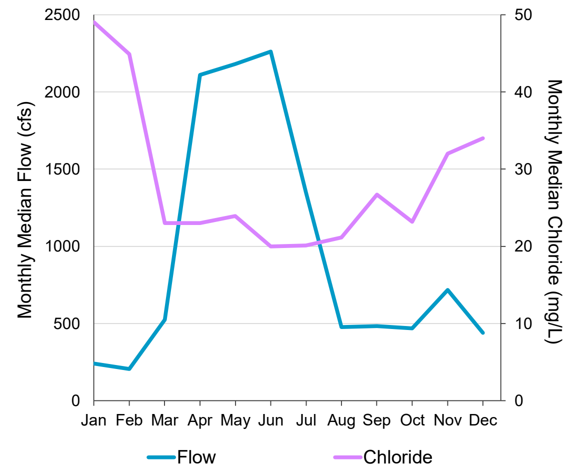

Figure 7: Monthly Median Flow and Chloride Concentrations in the Crow River

Chloride Load

Chloride load is seasonally dynamic. The highest chloride load occurs from April through July. 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, higher monthly loads occur in the spring and early summer, possibly due to de-icing salt and synthetic fertilizer runoff coupled with the higher flows occurring during that period.

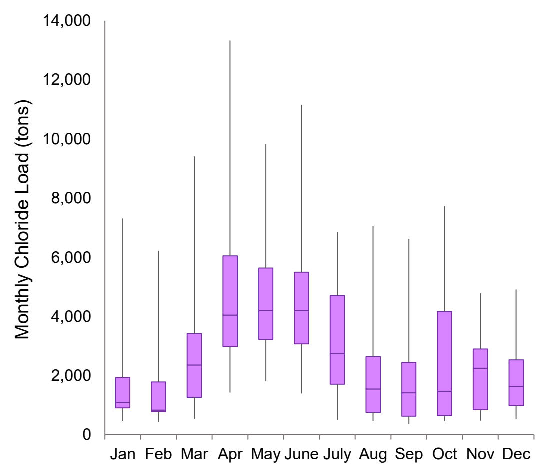

Figure 9: Monthly Chloride Loads in the Crow River

LIMITATIONS

The analyses described in this memo identify changes in chloride concentrations in the river, 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 river.

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. The Flux load calculation method changed in 2016.

RECOMMENDATIONS & NEXT STEPS

Chloride pollution reduction projects and initiatives are most effective when guided by data collection and analysis. In order to support Wright County Soil and Water Conservation District, Carver County Watershed

Management Organization, Pioneer Sarah Creek Watershed Management Commission and partners to prioritize 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, fertilizer use, livestock waste management, household water softening, wastewater treatment plant discharge, and de-icing salt application.
- 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.
- Evaluate upstream water quality and flow data to better identify chloride sources to the Crow River.
- Pursue a home water softener upgrade incentive program or centralized water softening.
- Promote chloride mitigation and management BMPs including trainings to minimize de-icing salt use and synthetic fertilizer runoff.

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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