Minnesota Statewide Chloride Management Plan

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Acknowledgements

The development of this plan was accomplished through a partnership approach with many agencies and organizations across the state. Their contribution to this plan and commitment to the issue has allowed us to develop this comprehensive and strategic approach to reducing salt use while maintaining public needs.

Significant Contributors:

The MPCA contracted with Fortin Consulting, Inc. to provide the necessary research, civic engagement efforts, and development of statewide winter maintenance best management practices (BMPs) for inclusion in the Statewide Chloride Management Plan and Smart Salting Assessment Tool (SSAt). Fortin Consulting also assisted in the development of many sections of this plan and provided critical review throughout its development. This work was funded through State Clean Water Funds.

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Partnerships:

American Public Works Association - Minnesota Chapter
Bassett Creek Watershed Management Commission
Becker County
Big Stone County
Board of Soil and Water Resources
Capitol Region Watershed District
Carver County
Casper Construction
Chippewa County
City of Burnsville
City of Cohasset
City of Detroit Lakes
City of Duluth
City of Fargo
City of Grand Rapids
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Lake County
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LimnoTech
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Marshall Municipal Utilities
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Minnehaha Creek Watershed District
Minnesota Cities Stormwater Coalition
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Minnesota Department of Natural Resources
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Minnesota Pollution Control Agency
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Murray County
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Nine Mile Creek Watershed District
Olmsted County
Ottertail County
Prescription Landscape
Ramsey County
Ramsey-Washington Metro Watershed District
Redwood County
Renville County
Rice Creek Watershed District
Riley Purgatory Bluff Creek Watershed District
Scott County
Scott County Watershed Management Organization
Smith Lawn
SNOW REMOVAL 24/7
Southwest Minnesota State University
SSC Services
Stevens County
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Thomas Tree and Landscape
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Acronyms

AUID	Assessment unit identification
BMP	Best management practice
BWSR	Board of Water and Soil Resources
CaCl ($CaCl_2$)	Calcium Chloride
CFR	Code of Federal Regulations
CMP	Chloride Management Plan
DNR	Minnesota Department of Natural Resources
EOC	Education Outreach Committee
EPA	Environmental Protection Agency
EQuIS	Environmental Quality Information System
gpg	grains per gallon
IPP	Industrial Pretreatment Program
KCl	Potassium chloride
LA	Load allocation
lb	pounds
MCES	Metropolitan Council Environmental Services
MgCl ($MgCl_2$)	Magnesium chloride
mg/L	milligrams per liter
MCWD	Minnehaha Creek Watershed District
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MPRB	Minneapolis Park and Recreation Board
MS4	Municipal Separate Storm Sewer System
MSG	Monitoring Support Group
MWMO	Mississippi Watershed Management Organization
NaCl	Sodium chloride
NMCWD	Nine Mile Creek Watershed District
NPDES	National Pollutant Discharge Elimination System
RO	Reverse osmosis
RWMWD	Ramsey-Washington Metro Watershed District
SSAt	Smart Salting Assessment tool
SWCD	Soil and Water Conservation District
TCMA	Twin Cities Metropolitan Area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, Washington)
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WD	Watershed District
WLA	Wasteload allocation
WMO	Watershed Management Organization
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Executive Summary: What is the Statewide Chloride Management Plan?

Reducing chloride at the source is needed throughout the state of Minnesota, not only to restore already impacted waters but also to protect all water resources. Chloride is persistent in the environment, and once it there, is difficult to remove. This also means that chloride will continue to accumulate in the environment over time. There are multiple sources to consider, a variety of options to reduce chloride, and a large geographical area to address. A main purpose of this plan is to provide guidance, resources, and information to individuals and organizations in assisting with making the important decisions of the what, how and when for managing chloride.

The Minnesota Pollution Control Agency (MPCA) has partnered with local partners, other state agencies, and experts across the state to create a plan for effectively managing salt use to protect our water resources in a responsible and strategic approach. Solutions were developed collaboratively to find a balance between clean water and salt use. The Statewide Chloride Management Plan (CMP) incorporates water quality conditions, sources of chloride, salt reduction strategies, protection strategies, water quality monitoring recommendations, and measurement and tracking of results.

Figure 1: Timeline of Statewide Chloride Management Plan Implementation

The goal of this plan is to provide information and strategies to assist local partners in reducing salt at the source while providing safe and desirable conditions for the public. There are several sources of chloride impacting the state's water resources including: salt applied to roads, parking lots, and sidewalks for winter maintenance; water softener brine discharges to municipal wastewater treatment plants (WWTPs) and septic systems; industrial discharges; agricultural fertilizers; land application of manure and WWTP sludge; and dust suppressants. The MPCA collaborated with multiple state agencies, local partners, and experts across the state to develop a plan to reduce chloride and protect Minnesota's waters. This Statewide CMP incorporates **water quality evaluation, source identification**, **implementation strategies**, **monitoring recommendations,** and **measurement and tracking of results** into a performance-based approach for the state of Minnesota. The Minnesota Statewide CMP is intended to characterize water resources across Minnesota and the overall impacts of chloride. This plan is an adaptation of the Twin Cities Metropolitan Area (TCMA) CMP, which was published in 2016 (TCMA CMP 2016). The TCMA CMP was developed to address the major chloride concerns within the Twin Cities and surrounding counties, and paid particular attention to the role of winter maintenance activities. The implementation strategies of the TCMA CMP were designed for the stakeholders' specific to the area, including municipalities, watershed districts (WDs), MPCA, and winter maintenance professionals. Much of what went into the development of the TCMA CMP has been memorialized, updated, and expanded upon in the publication of this plan. Because of this, this plan is intended to replace the TCMA CMP as the comprehensive statewide plan, addressing issues in the TCMA as well as elsewhere. This CMP is designed to be inclusive of all statewide chloride sources, stakeholder groups, and management techniques, while providing a broader picture of the chloride issues beyond winter maintenance.

As part of the preceding TCMA CMP project, chloride conditions in Minnesota's waters were assessed, and waters not meeting state chloride standards were listed as impaired and Total Maximum Daily Loads (TMDLs) were developed. However, water quality is not the only factor driving the need to reduce chloride entering the state's water resources. Improved practices not only reduce chloride impacts on water quality, but they can also lead to long-term cost-savings as a result of purchasing less salt and reduced impacts on vegetation and corrosion of infrastructure and vehicles. This Statewide CMP provides an emphasis on the broad economic losses for which chloride is responsible.

A key challenge in reducing salt usage is balancing the need for public safety with the growing expectation for clear, dry roads, parking lots, trails, and sidewalks throughout the mix, severity, and duration of winter conditions. Notable efforts have already been made by the Minnesota Department of Transportation (MnDOT) and many cities, counties, and others to improve winter maintenance while reducing salt usage.

Another key challenge is educating the public on proper water softening practices. There is no requirement to soften your water; it is a personal decision that can affect your home and the environment. Certain commercial or residential appliances require or operate more effectively with softened water; however, the specific degree of softening can often be calibrated to individual preferences. Additionally, some municipalities offer centralized hardness reduction at the drinking water facility prior to distribution; supporting higher efficient residential and commercial softening processes and reduces salt use. Older residential softening units may be less efficient than newer models. These various factors often lead to more chloride usage than is necessary to meet specific needs and tastes.

Similar cost-benefit challenges exist for all sources, including the balance between agricultural and turf fertilizer applications and downstream chloride transport, and the balance between industrial process efficiency and chloride discharge.

The Statewide CMP will guide and assist agencies, local governments, permittees, and other stakeholders in determining how best to protect and improve water resources impacted by elevated chloride levels, while balancing the need for public safety, level of service considerations, agricultural production, and water softening needs. This CMP is not intended to resolve all issues. Rather, it provides understanding and guidance for management activities over the next 10 years. The water quality goals, implementation strategies, best management practices (BMPs), and monitoring and tracking recommendations are intended to serve all of Minnesota.

The over-arching implementation strategy identified in this report is a performance-based approach to reduce chloride. This approach allows stakeholders and regulators flexibility in the type of BMPs and the timing of implementation, and allows individuals an opportunity to develop specific chloride management strategies that are practical for their individual situation. The performance-based approach doesn't focus on specific numbers to meet, but rather on making progress through the use of BMPs. Progress is measured by degree of implementation and trends in ambient monitoring. The purpose, scope and audience for the CMP are presented in Figure 2.

Prioritization and Critical Areas: Where Do I Start?

Organizations interested in reducing the amount of chloride entering our water resources should begin with an effort to fully understand the problem and determine what role the organization plays in contributing, preventing, or slowing the growing trend of increased chloride in surface and groundwater. Road salt and water softening are two large statewide sources of chloride in the environment and many of the current reduction strategies focus on these two sources. This plan also identifies critical watersheds and locations around the state based on road density and potential demand for water softening, where chloride loadings are to be expected high and therefore implementation efforts to reduce chloride should be focused. For the protection of surface and ground waters implementation is encouraged statewide.

Know what the primary sources of chloride are in your community. Consider your organization's relationship with the primary sources of chloride in your community. Understand local water resources and conditions, both surface water and groundwater. Addressing these considerations can help determine priorities and critical areas.

Implementation Strategies

The statewide CMP provides the overall framework for the implementation strategies that are necessary to protect and restore our water resources. Section 5 of this plan provides the implementation activities for specific audience and all sources of chloride. The over-arching implementation strategy is a performance-based approach. This approach allows stakeholders and regulators flexibility in the type of BMPs and the timing of implementation, and allows individuals an opportunity to develop specific chloride management strategies that are practical for their individual situation. Success under the performance-based approach is measured in terms of the progress made and BMPs implemented. Local priorities should be set with a plan in place within 1 to 2 years after this Statewide CMP is published. Local priorities will vary by various stakeholder groups and audiences. By years 3 to 5, an implementation plan should be set and successes and progress should begin to be monitored. Years 6 to 10 should be spent sharing successes and revising any necessary components of the localized plan.

Find Your Section of the Plan

This plan was developed to be used by many different audiences and organizations. Every organization will have different priorities based on their local watershed conditions, the role of their organization in the watershed or state, and their organization's specific needs or goals. Section 5 of the Statewide CMP lay out implementation strategies for how each person or organization can reduce chloride based on the types of activities with which they are involved. Example strategies and timelines are also provided as templates. Because the Statewide CMP is meant to be used as a reference document to assist you or your organization in chloride reduction, Section 5 may be the most useful section for you to revisit as you develop and implement chloride reduction strategies.

Minnesota Statewide Chloride Management Plan

Purpose - Scope - Audience

Purpose

- Highlight the impacts of chloride on statewide water resources
- Develop an understanding of the competing demands of level of service and reduced salt usage
- Set performance-based goals for the protection and improvement of water quality
- Inform and guide implementation of best practices and policies
- Provide education, guidance, and resources to reduce chloride
- Point out need for more research and development of additional Best Management Practices (BMPs)

Scope

- Status and trends of chloride levels in Minnesota lakes, wetlands, streams, and groundwater
- Identify statewide sources of chloride
- Chloride reduction and protection goals
- Implementation strategies to reduce chloride impacts
- Educational and training resources
- Continued monitoring, tracking, and adaptive management

Audience

- Local government and working groups (Watershed Districts, Municipalities, SWCDs, WMOs, Townships, etc)
- Winter maintenance groups (MnDOT, local governments, private applicators, commercial property owner, residents, etc)
- Elected officials and policy makers
- Permit holders
- State agencies (MPCA, MnDOT, DNR, BWSR, etc.)
- Any industrial users of chloride (Water Softening Industry Uses, Fertilizer Users)
- Dust control applicators
- Anyone using chloride containing products in MN

Figure 2: Minnesota Statewide Chloride Management Plan - Purpose, Scope, and Audience

1. Sources of Chloride

Chloride enters lakes, streams, wetlands, and groundwater from a variety of sources. The relative significance of each source of chloride is dependent on the watershed characteristics, land use, climate conditions and water resources.

Chemistry of Chloride

At the molecular level, salt dissolves in water due to electrical charges and due to the fact that both water and salt compounds are polar, with positive and negative charges on opposite sides in the molecule. When salt is mixed with water, the salt dissolves because the covalent bonds of water are stronger than the ionic bonds in the salt molecules. After the salt compounds are pulled apart, the sodium, calcium, or magnesium, and potassium or chloride atoms are surrounded by water molecules. The chloride ion will remain with the water molecule. It takes only one teaspoon of salt to permanently pollute five gallons of water. Once in the water, there is no easy or cost effective way to remove the chloride. This is why chloride reduction is such an important topic.

For highly developed urban areas, winter maintenance activities are typically the primary source of chloride to local water resources. Winter maintenance of these surfaces currently relies heavily on the use of salt, primarily sodium chloride (NaCl), but magnesium chloride (MgCl) or calcium chloride are also utilized, to prevent ice build-up and remove ice where it has formed. The chemical properties of NaCl make it effective at melting ice, but these properties also result in chloride accumulating and persisting in the environment. The chloride moves with the melted snow and ice, largely during warm-up events, and ends up in local water resources.

In areas where point source discharges exist, the municipal wastewater treatment facilities may be the primary point source of chloride, which in most cases is due largely to treatment of water coming from in-home water softening activities occurring in the communities they serve, but can also receive chloride from industrial discharges to the facility. The chloride from ion exchange water softener systems makes its way to the environment either through discharge to a septic system or by delivery to a municipal WWTP. Chloride is not removed from wastewater using conventional treatment methods. While technically chloride can be removed from wastewater by using reverse osmosis (RO) technology, treatment technology is considered cost-prohibitive for an issue of this scale and not feasible. Commercial, industrial, and residential water softener use is also a significant source of chloride. In areas with hard water, in-home and on-site ion exchange softeners, which use salt are common even if municipalities provide hardness reduction treatment to the potable water prior to distribution. In industrial settings, on-site softening is often necessitated by the processing use, while taste and scaling preferences typically drive residential and commercial softening.

In more rural and agricultural areas, fertilizer, water softening systems, dust suppressants, and animal manure can also be a significant source of chloride. In addition to anthropogenic sources, chloride is also a naturally occurring anion of the of the element chlorine, and it exists in all waterbodies at a background level (Overbo et al. 2019; Kelly et al. 2008; Mullaneny et al. 2009; Jin and Whitehead 2011). A more detailed assessment of each source is discussed in this section.

A conceptual model diagram of the primary anthropogenic sources is shown in Figure 3. A chloride budget for the TCMA estimated that only 22% to 30% of the chloride applied in the TCMA was exported out of the TCMA via streamflow in the Mississippi, Minnesota, and St. Croix Rivers (Stefan et al. 2008). Therefore, 70% to 78% of the applied chloride remains in TCMA lakes, wetlands, and groundwater, and it may also be stored in soil pore-water where infiltration is slow. Chloride stored in this latter location may be slowly released in base flow throughout the year (Corsi et al. 2015). Since chloride is an element and does not breakdown over time, the high percentage retained suggests that chloride will continue to accumulate, some of which can eventually be transported to shallow and deeper aquifers. This also implies that, on average, chloride concentrations in waterbodies are increasing with time if there is an external loading source. It should be noted that although chloride is considered to be largely inert in soil, which contributes to its ability to readily mobilize, chloride can be immobilized in the soil through chlorination reaction with organic matter (Osswald et al. 2016).

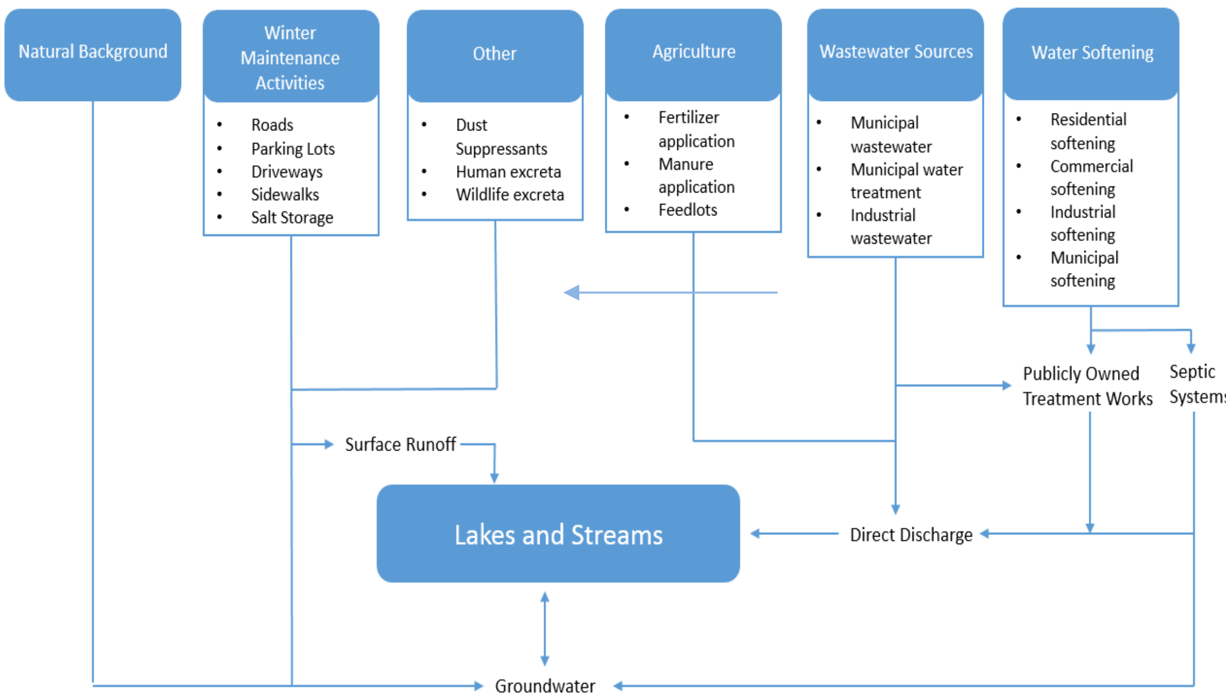


Figure 3: Conceptual model of anthropogenic sources of chloride and pathways

If the chloride loading remains steady, the concentrations will level out when equilibrium develops between loadings and transport out of a particular waterbody. By the same token, if loadings are reduced sufficiently and persistently, the chloride concentrations in the waterbodies will begin to decrease and will continue to decrease until a new equilibrium is reached. Each of these sources is briefly described below.

A 2019 report by University of Minnesota (UNM) researchers, estimated chloride contributions from statewide sources. From a statewide perspective, de-icing salt use, fertilizers, and WWTP (residential, commercial, industrial softening and other sources of chloride in the influent) make up the predominant sources of chloride, shown in Figure 4 (Overbo et al. 2019). Although the data available for statewide purchases and uses of chloride products estimate that the statewide mass balance contribution of WWTPs and fertilizer application are roughly equivalent, we are seeing more chloride impaired water bodies in urban areas, and that in past completed TMDLs the predominant sources to water bodies impaired by chloride are from de-icing salt and municipal WWTPs in others.

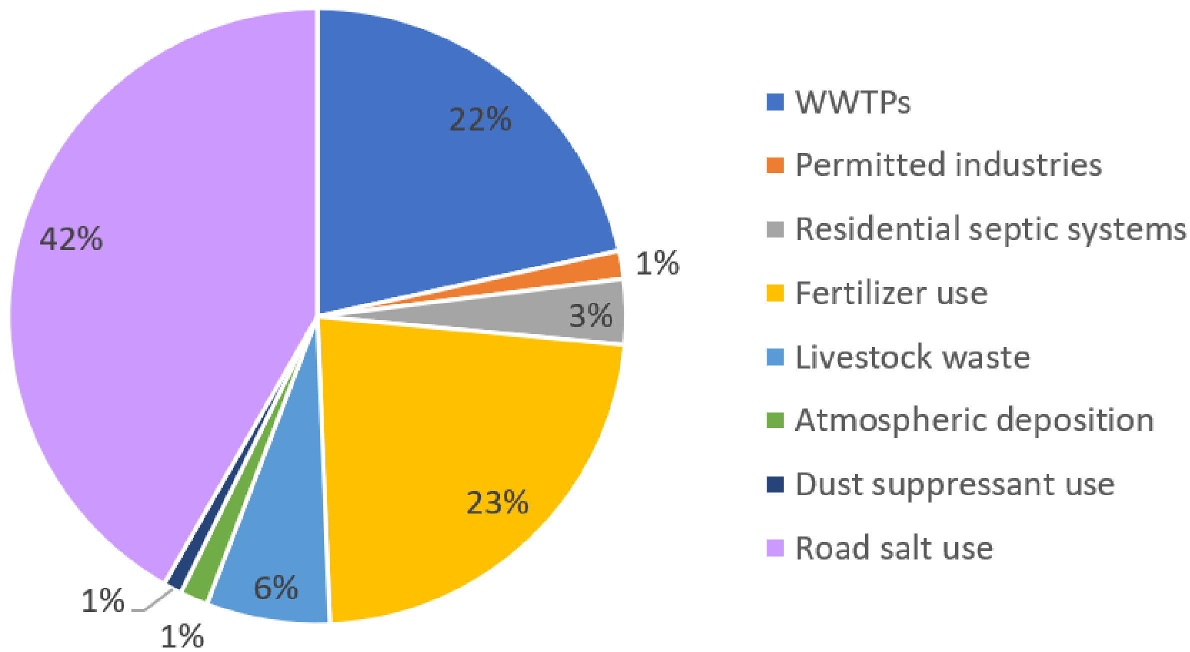


Figure 4: Fraction of annual chloride contributions from major point and nonpoint sources for State of Minnesota (Overbo et al. 2019)
Please note that Road salt use is actually all de-icing salt applied to roads, parking lots, sidewalks, and trails.

It has been difficult to quantify the contribution of chloride loading from agriculture specifically as many times the groundwater and non-permitted sources (outside MS4 permitted areas) will contain both natural background chloride, chloride applied as winter and gravel road maintenance, as well as agricultural sources chloride. A source assessment of chloride sources that goes beyond MS4 and WWTP contributions can be difficult. At the time of the development of this document, the MPCA is developing a new chloride source assessment model that will allow Minnesota communities to evaluate their specific sources and magnitude of chloride, and provide guidance to develop a community specific chloride reduction plan. More information on this project can be found in Section 5.3 below.

1.1. Winter Maintenance Activities

Winter maintenance activities include snow and ice management. Application of de-icing and anti-icing chemicals, primarily salt, is common. Salt is applied to a variety of surfaces including roads, parking lots, driveways, and sidewalks. Runoff from salt storage facilities is another potential source of salt. As an example, an estimated 17% of salt is lost by storing salt/sand piles uncovered over the winter. By implementing the recommended BMP of storing salt/sand piles indoors, there is an estimated 17% reduction potential for a pile. The St. Anthony Falls Laboratory at the UMN developed an inventory of salt uses in the TCMA for a MnDOT Local Roads Research Board study (Sander et al. 2007). The inventory estimated the total amount of salt used for winter maintenance activities in the TCMA, based on purchasing records, to be 349,000 tons per year. Estimates of use by various entities are shown Figure 4. More recent research through the Water Resources Center at UMN estimates that 403,600 tons of de-icing salt are used each season in Minnesota, and that 249,100 tons of de-icing salt are used in the TCMA (Overbo et al. 2019). Figure 5 is an adaptation from an article by Sander et al. in 2007 that provides a summarized distribution of road salt use in the TCMA per season between certain public in private entities. MnDOT has stated in their road salt reports that their declining road salt use is attributable to more recent milder winters (MnDOT 2017).

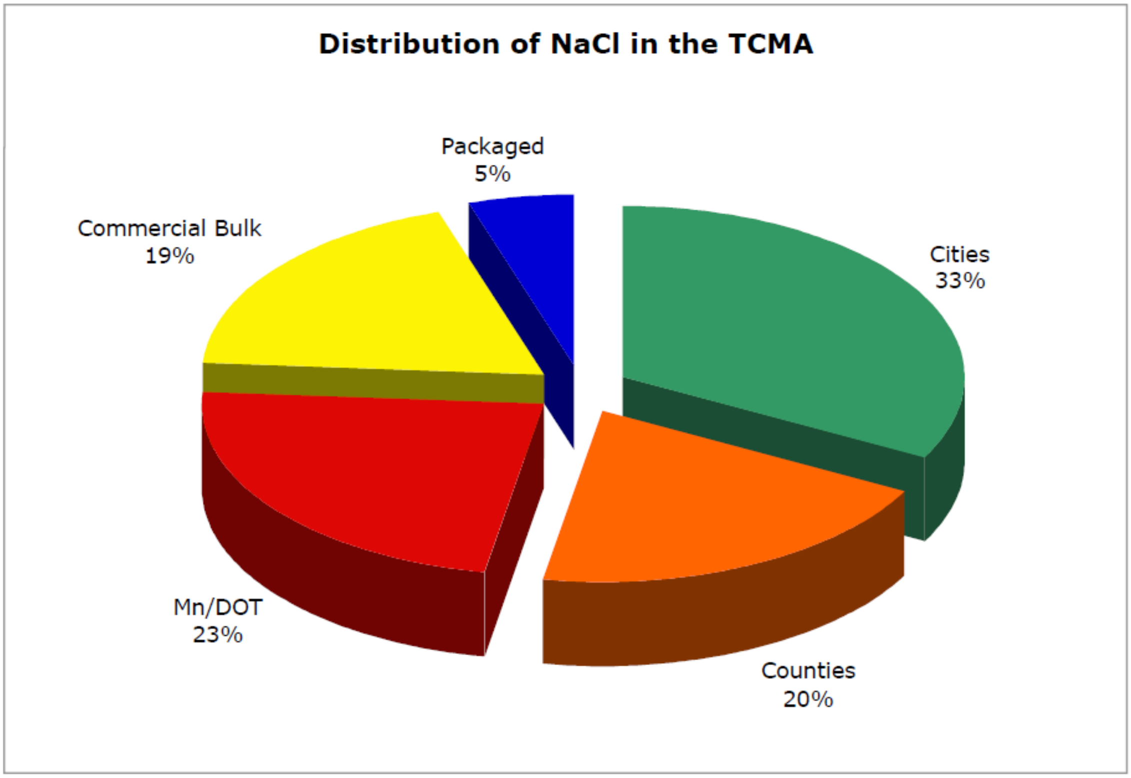


Figure 5: Distribution of NaCl in the TCMA (Figure adapted from Sander et al., 2007)

Salt sales data in the United States shows a dramatic increase in the amount of salt being purchased. The Salt Institute illustrates this increasing trend (Figure 6). Of the average total of 57,000,000 metric tons of salt consumed in the United States per year, highway deicing salt make up 43% (~24,510,000 metric tons) (USGS 2019). Along with the increased use of salt, increasing levels of chloride in lakes, wetlands, and streams should be expected.

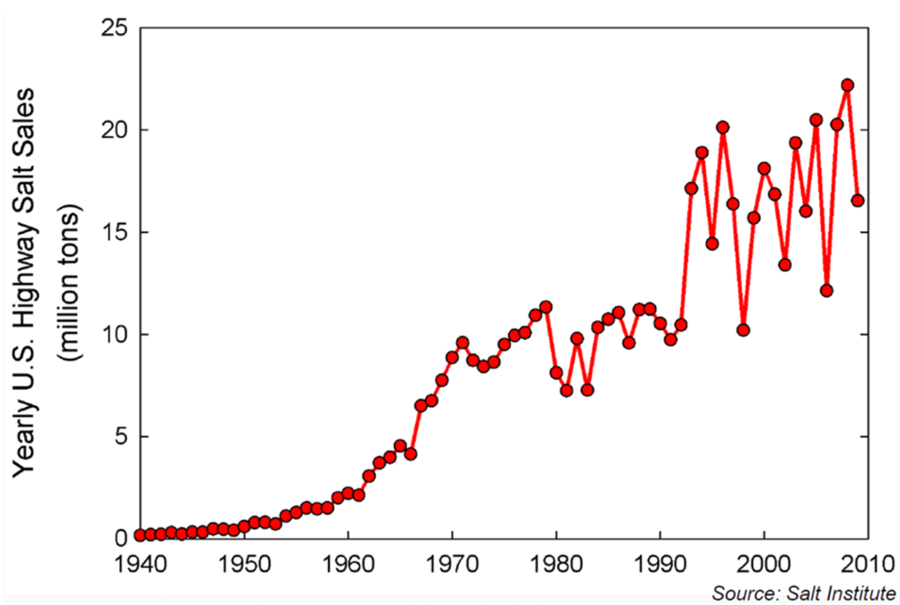


Figure 6: Road Salt Sales Trend in the United States

Roads

The state of Minnesota is estimated to have over 285,000 lane miles of roadways (MnDOT 2018). Application rates range from 3 to 35 tons of road salt, per lane mile, per year, based on the salt purchasing records and the number or lane miles of MnDOT, counties, and cities in the TCMA (Wenck 2009). The preferred level of service and possible seasonal closure of certain roads may affect this estimate in rural counties.

A survey of municipal winter maintenance professionals in the TCMA, done by LimnoTech in 2013, found that typical application rates range from 100 to 600 pounds of salt applied per lane mile per event, which is consistent with previous evaluations of road salt application rates. However, rates can be much higher on hills, near intersections, and other ice problem areas. Higher speed roadways and those that experience high average daily traffic volumes will typically have greater applications rates. Some events may require multiple passes of salt application.

Commercial Parking Lots, Driveways, and Sidewalks

Commercial sources of deicing salt can vary greatly between different watersheds and includes salt applied to parking lots, driveways, and sidewalks on commercial property. The land owner or tenant may conduct winter maintenance activities, or winter maintenance may be contracted with private winter maintenance providers. Because of this, the MPCA has developed Smart Salting training and certification program specific to property managers. Commercial sources are likely responsible for 10% and 20% of the total salt applied to paved surfaces in the TCMA and other urban environments (Wenck 2009). The MPCA and Fortin Consulting conducted research to validate and refine assumptions regarding commercial and private salt application rates specific to Minnesota (Fortin 2012a). There is a range of reported application rates, which is to be expected, because rates should vary based on temperature, type of snow event, surface to where material is applied, number of passes over an area during an event, and type of material used. Application rates of salt on parking lots are estimated to range from 0.1 to 1 ton per acre per event, and typically 6.4 tons per acre per year. For sidewalks, the application rate is estimated to range from 8 to 25 pounds per 1,000 square feet per event (0.2 to 0.5 tons per acre per event).

Review of available information and additional research included application rates from across the United States' and Canada's Snowbelt, with an emphasis on Minnesota specific data. It was determined that an average rate of 6.4 tons per acre per event is the appropriate application rate to expect on parking lots. As a percent of the total deicing salt usage, it is estimated that anywhere between 5% and 45% is used for commercial applications (parking lots, sidewalks, residential, private roads). The amount of chloride from commercial sources is variable, and is dependent on the characteristics of the watershed, including the amount of impervious area. Additional estimates of commercial salt use are presented below.

- The Nine Mile Creek Chloride TMDL report used data on salt purchases from Sander et al. (2007) and Novotny et al. (2008), but weighted the data based on land use. It was determined that the relative contribution for commercial and packaged deicer in the Nine Nile Creek Watershed was 38% of the total amount of road salt that is applied (Barr Engineering 2010).

- In the Shingle Creek TMDL, it was estimated that 7.5% of salt application was by commercial/private applicators. This figure was based on the estimates used in Canada. "Cheminfo (1999) estimated that commercial and industrial consumers represented approximately 5% to 10% of the deicing salt market. In quantifying total deicing salt application in Canada, Environment Canada used the midpoint of these data (7.5%) to represent commercial and industrial salt application (Environment Canada 1999)." (Wenck 2006).
- Sander et al. (2007) estimated that the bulk deicing salt applied by commercial snow and ice control companies accounted for 19% of the total salt used in the TCMA, while packaged deicer for home and commercial use was estimated to account for 5% of the total in the TCMA.
- Novotny et al. (2008) used market share amounts from the USGS annual mineral reports and the market share report published annually from the Salt Institute. TCMA amounts were estimated based on national amounts combined with the commercial bulk (19%) and packaged (5%) deicer estimates for a total of 24%.
    - On a national basis, the Salt Institute estimated that 20% of bulk de-icing salt purchases were by non-governmental entities.
    - The USGS estimated 13% of ice control salt is for commercial use.
- A chloride TMDL study in New Hampshire reported a chloride application rate of 5.7 to 6.4 tons per acre per year for parking lots and drives (Sassan and Kahl 2007). Parking lots were 47% of paved surfaces in the watershed and accounted for 36% of the chloride load. The study also estimated that 45% of salt was applied by private applicators.

Residential Parking Lots, Driveways, and Sidewalks

Residential winter maintenance can also be an important chloride source. Residential winter maintenance salt use has been estimated from purchasing records. Packaged deicer for home and commercial use is estimated to account for 5% to 7% of the total in the TCMA (Novotny et al. 2008)

A Sidewalk Salt Survey was conducted to qualitatively assess the use of sidewalk salt by the general public in the TCMA. The survey was disseminated by local partners including RWMWD, MCWD, and MnDOT. The survey was administered through an on-line Survey Monkey link on the MCWD website (www.minnehahacreek.org) from November 2011 through March 2012. The survey was completed by 606 people online and 148 completed a paper survey. Approximately 47% of the respondents lived in St. Paul or Minneapolis, and other respondents lived in surrounding cities including Woodbury, Richfield, Plymouth, and Maplewood. Although the survey sampled 754 residents, the results represent a small percentage of the TCMA population and are non-random/voluntary; therefore, the survey is not representative of all residents in the state of Minnesota. However, the data provide valuable information on the use of sidewalk salt by a subset of Minnesota residents.

The majority of residents that responded to the survey used sidewalk salt (57%), particularly on sidewalks and steps. Most people selected products based on performance in colder temperatures and environmental safety. The majority of respondents did not know how much sidewalk salt to use (59%). The majority of respondents that applied salt used instruction on the packaging as guidance for application rates. For complete results of the survey see Appendix B.

The chloride that is applied to roads, parking lots, sidewalks, and driveways, is eventually transported to surface water (lakes, streams, wetlands) and groundwater (surficial flow, shallow wells, deep wells).This is contrasted with chloride that enter surface waters through wastewater treatment systems, as described below.

1.2. Water Softening

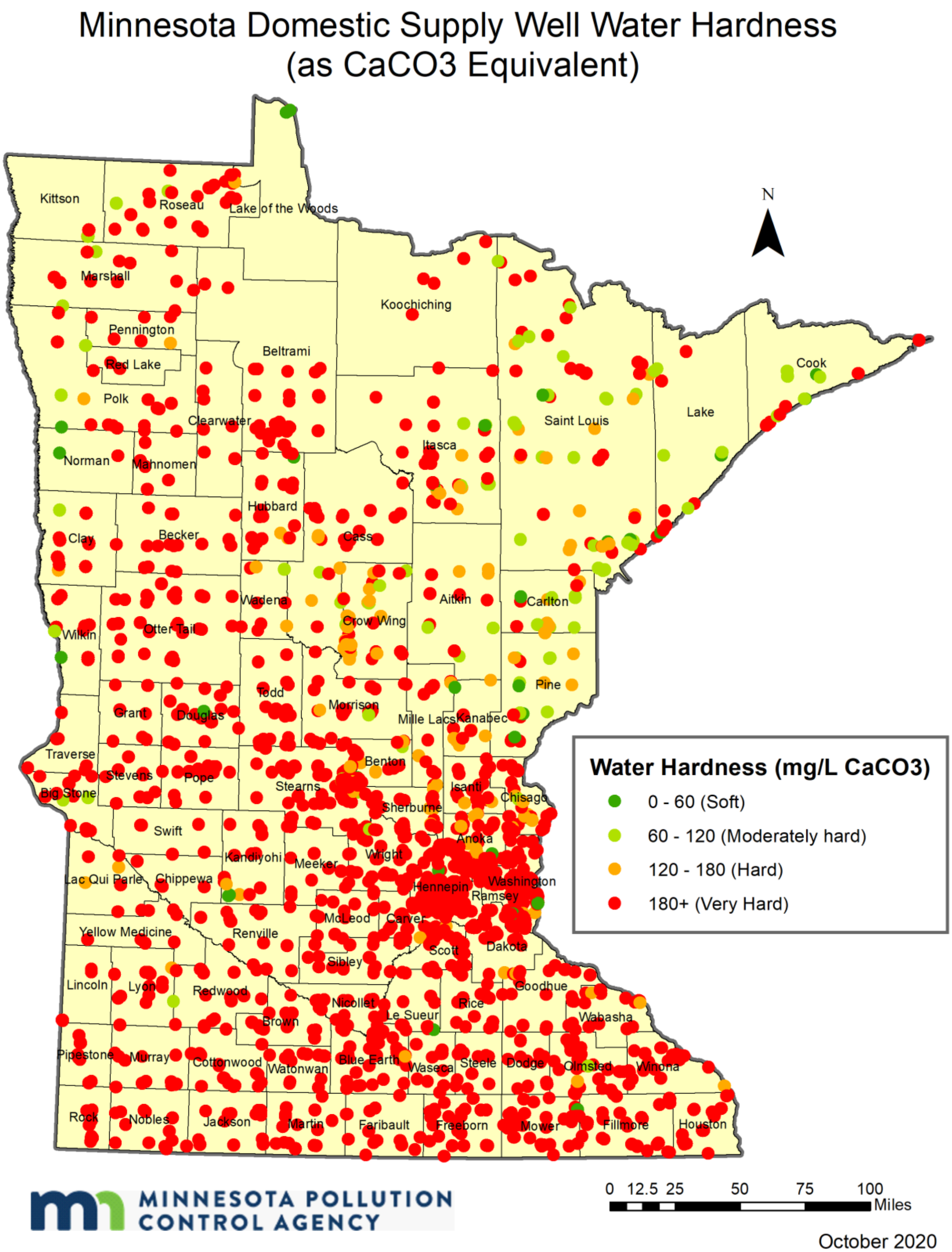
Residential and Commercial Softening

Chloride loading from any individual home water softener is dependent on many variables and is specific to the individual homeowner's water chemistry, water use, hardness preferences, and softener efficiency. Commercial water softeners are most often dependent on the same variables. Chloride, which is a waste product from the softening process, is discharged into a septic system or municipal waste stream, which cannot be removed by typical treatment processes at a municipal WWTP.

The amount of salt that is needed to reach a necessary or desired softness is largely dependent upon the background hardness of the water source, which varies geographically. The USGS provides general guidelines for classification of waters, which are: 0 to 60 mg/L (milligrams per liter) as calcium carbonate is classified as soft; 61 to 120 mg/L as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard (DeSimone et al. 2009). Figure 7 shows values of water hardness around the state of Minnesota per the USGS categories. Please note that these guidelines are not designed to be used to make local decisions or decisions on the scale of individual homeowner property, and is not intended to provide information that is directly relevant to water hardness and other chemical properties at a home or facility. Hardness levels should be measured at specific locations by working with Minnesota Department of Health (MDH), local water utility, or by the vendor of a local water-softening system. Where source hardness is particularly high, residential and commercial softeners can be the primary source of chloride. This was observed in Olmstead County, where there is centralized municipal hardness reduction contributed one-third of the chloride mass to the municipal WWTP (Wilson 2008). Another example is the Sand Creek Watershed, located in Scott County. There, the chloride concentrations in WWTP effluent for three WWTPs located in the watershed average from 521 mg/L to 618 mg/L.

Where necessary, municipalities can reduce the use of chloride in residential and commercial softening salt use by reducing the hardness of potable tap water before it is distributed with higher efficiency processes. The hardness values of drinking water supply wells for the entire state of Minnesota can vary locally and regionally, but are generally considered very high and high when compared to other states, and often receives some sort of hardness reduction process. Consequently, most Minnesota residents have in-home softening equipment or receive water from a utility that uses centralized municipal hardness reduction methods to reduce the hardness of their water. In Morris, Minnesota, approximately 90% of households have softeners. In a 2019 report, UMN researchers estimated that roughly 65% of all chloride passing through WWTPs, or 136,000 tons of chloride annually, originate from residential or commercial water softening processes (Overbo et al. 2019).

Figure 7: Hardness values of drinking water supply wells in Minnesota.



Industrial Softening

While residents and commercial softeners are commonly used to protect appliances from mineral deposits and for taste preferences, industrial softening is implemented to produce higher quality water for processing and to prevent scaling in processing equipment. Depending upon the process and effluent characteristics, industrial waste may be treated on site, sent to a municipal WWTP, or discharged directly into a surface waterbody. In most cases, measures to remove chloride end-of-pipe will be cost prohibitive.

1.3. Wastewater Sources

Municipal and industrial wastewater effluent may contain considerably high concentrations of chloride as a result of user activities. The primary source of chloride in a municipal waste stream typically comes from water softeners (Kyser 2017). Currently, most cities in Minnesota do not reduce the hardness of drinking water before it is distributed to residents, and many residents subsequently soften the water in their home with personal water softeners. The most common water softening systems use NaCl or potassium chloride (KCl) (MPCA 2018). Despite the advanced treatment technologies employed at modern WWTPs, removal of chloride is cost prohibitive, and thus chloride is discharged directly into surface waterbodies.

Industrial Wastewater and Municipal Treatment Facilities

Industrial facilities may discharge directly to surface waters following treatment, or may discharge to a sanitary sewer system, which transports the wastewater to a WWTP for further treatment prior to discharge to surface water. Some industries have chloride in their discharge due to the products they produce or chemicals they use (MPCA 2018). A range of industrial facilities discharge directly to waters that are already impaired by chloride or have elevated levels of chloride, these include but are not limited to food processing facilities, rendering plants, breweries, metal finishing or metal painting, ethanol, biofuel facilities, drink bottlers and water treatment systems that send their reject water to the WWTP. Discharges of chloride from municipal and industrial wastewater sources are covered by individual or general permits. Chloride monitoring is being required for many facilities as permits are re-issued to help better evaluate high chloride discharges.

As part of the TCMA Chloride TMDL, several facilities were identified that are expected to discharge chloride within impaired watersheds. There are likely additional facilities with the reasonable potential to have chloride in their discharge that will be evaluated as permits expire and chloride monitoring is required.

Other Municipal Treatment Facility Sources

Municipal wastewater, backwash from municipal water treatment facilities, and industrial facilities with waste streams may contain extraneous chloride inputs beyond water softening and processing discharges. De-icing salt that contaminates the groundwater can enter the sanitary sewer system through cracks and/or leaks in the manholes, pipes, and pipe joints. These sources are minor in comparison to residential water softeners and industrial processing, but are present nonetheless.

Septic Systems

Salts containing chloride are often used in the water softening process. (Please see the following section for a discussion of water softening and water hardness). Chloride from this salt is delivered to the environment either through discharge to a septic system or by delivery to a WWTP. Septic systems are more prevalent in the rural areas. The chloride that comes from septic systems enters the shallow groundwater or local streams and lakes through subsurface flow.

1.4. Agriculture

Fertilizers

Agricultural crop land may be a considerable source of chloride to lakes and streams. Fertilizers and biosolids from food processing and WWTPs contain chloride. The application of fertilizers and biosolids on crop land can result in chlorides being transported to lakes and streams through surface runoff, as well as infiltration into shallow groundwater and subsequent transport to lakes and streams. Potash (KCl) is the most commonly used fertilizer containing chloride and contains about 47% of Cl by mass. It has been estimated that between 220,000 and 260,000 tons of chloride are applied to croplands per year across Minnesota as a component of certain fertilizers (Montgomery 2018) (Overbo et al. 2019). Application rates may be highest in the Central Sands region where the natural background of Potassium is relatively low. While application of fertilizers will vary by specific location, estimates of applications in the predominately agricultural Olmsted County suggest nearly one-fourth of its salt mass balance is from fertilizer application (Wilson 2008). Chloride is often a component of a common commercial fertilizer called potash. Muriate of Potash, or KCl, is the most commonly applied form of potash to agricultural fields that require potassium amendments. Chloride additions to the soil through potash applications can be estimated using fertilizer sales records. A presentation given at the 2020 Salt symposium estimated 245,362 tons of chloride were applied an annual basis, with a higher proportion of chloride derived from potash being applied in the southern and southeast regions of Minnesota—Figure 8 (Aicam 2020). Although we see an overall pattern of lower concentrations of chloride in surface waters in areas with less development, chloride levels in less developed watersheds can be elevated from natural background levels from agricultural inputs (David et al. 2016).

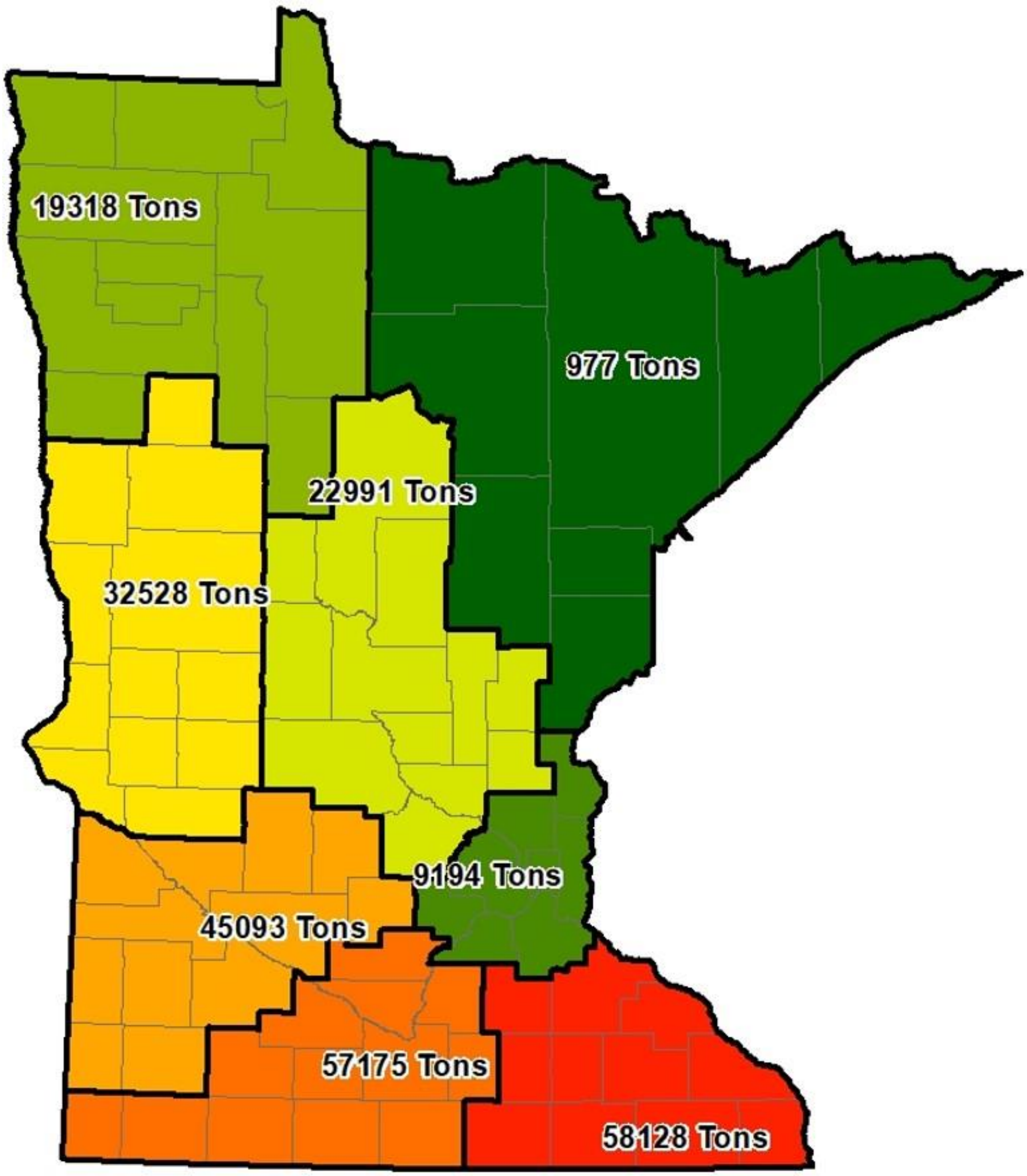


Figure 8: Annual chloride (tons) estimated from potash sales by district (Aicam 2020)

Manure

Manures from concentrated animal feeding operations are usually high in salt content. Most dairy and feedlot manures contain 5% to 10% salt (50,000 to 100,000 ppm) (University of Arizona 2018).

Manure is often land applied on agricultural fields as a fertilizer. Chloride levels in the soil profile and shallow groundwater have been found to increase over time as a result of land application of manure (Olson, 2003). Chloride can also be delivered to surface waters and groundwater through runoff from large feedlots such as concentrated animal feeding operations, though these facilities are designed to be zero-discharge under typical circumstances.

Tile Drainage

Given the wide-spread network of drain tiles used in agricultural fields across the state, this may be an important conveyance of dissolved chloride from the land to surface waters. An on-going evaluation of agricultural drainage water quality done by North Dakota State University – Department of Agriculture and Biosystems Engineering indicates that chloride concentrations from agricultural drainage can range from 8.6 mg/L to 37.4 mg/L. [The results of this study have not been published yet]. Two other studies in agricultural areas in the Midwest found median concentrations of chloride in drain tiles to be between 14.5 mg/L and 25.4 (Kelly et al. 2012). In another study from North Dakota, researchers found that chloride concentrations in tile drains ranged from 41 mg/L to 120 mg/L (Galloway and Nustad 2017). A summary of flow weighted mean chloride concentration data in tile lines from the Minnesota Discovery Farm Network from 2011 to 2019 found that concentrations ranged from non-detect levels to 360 mg/L with the median concentration being 25.9 mg/L. Figure 9 and Figure 10 show the variability in chloride concentrations in Discovery Farm drain tile by site and by date. These data are indicative of chloride concentration and not total loading (mass) in the tile drainage, which would be dependent on flow volumes as well. Figure 10 may also show that elevated levels of chloride may be present for newly tilled fields and may decrease with time, as may be the case from data from Norman County.

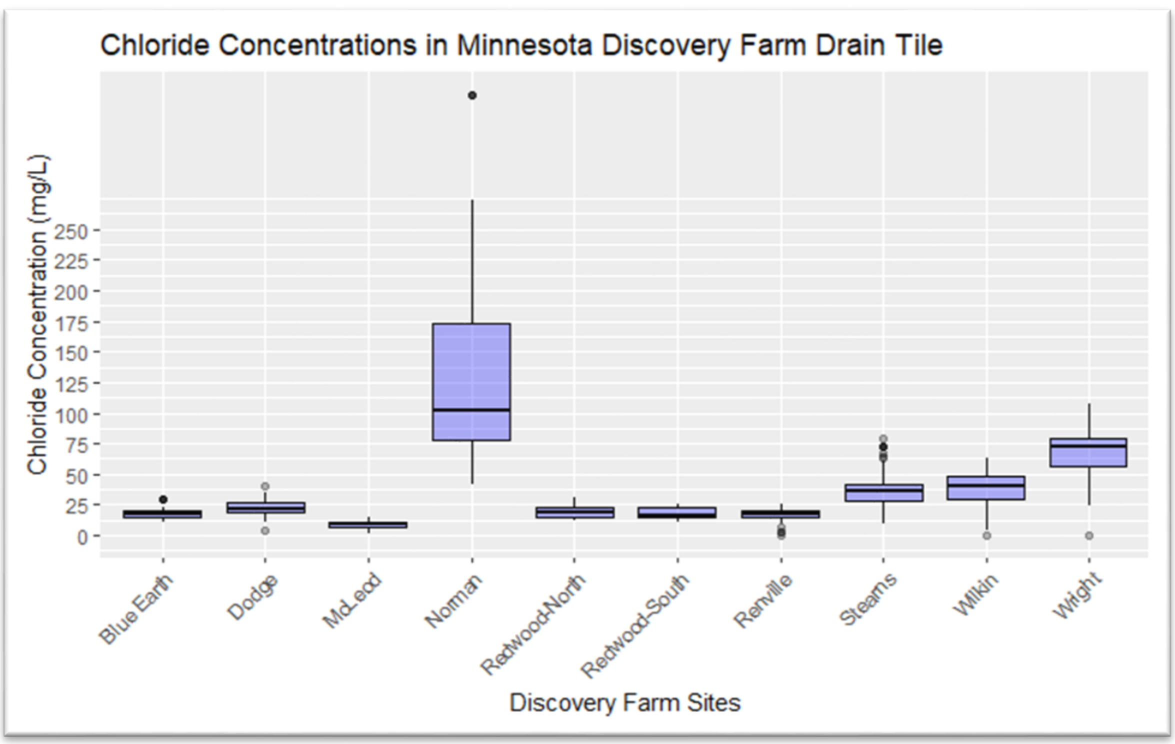


Figure 9: Chloride Concentrations in Minnesota Discovery Farm Drain Tile (2011 to 2019)

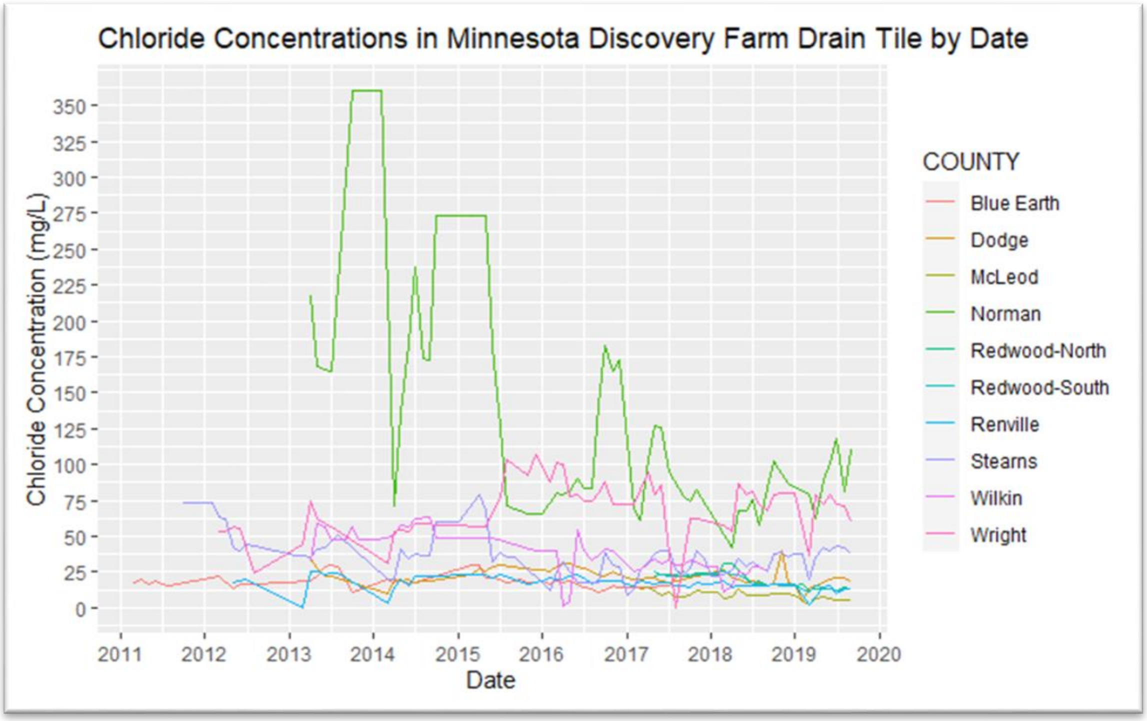


Figure 10: Chloride Concentration in Minnesota Discovery Farm Drain Tile by Date

Natural background concentrations of chloride in soils and surficial groundwater are needed to better understand the impact of agricultural inputs on chloride concentration and loading. There is a natural background consideration that should be taken into account when viewing this data, as chloride is a naturally occurring anion in soils and concentrations would be depended upon specific geography and geology.

1.5. Natural Background

Chloride occurs naturally in soil, rock, and mineral formations. Chloride is naturally present in Minnesota's groundwater due to the natural weathering of these formations. Glacial deposits from eroded igneous rocks and clay minerals with chloride ions attached are potential sources across Minnesota. Natural background levels of chloride in surface runoff and groundwater vary depending on the geology. The natural background concentration in small streams in the TCMA has been estimated to be 18.7 mg/L, but streams statewide are likely to be variable (Stefan et al. 2008). A specific natural background concentration for lakes has not been estimated across Minnesota, but is expected to be low in most areas (18 mg/L or less). Background concentration characterizes runoff that is not impacted by current or historical applications of anthropogenic sources of chloride. Concentrations of chloride in precipitation are estimated to be 0.1 mg/L to 0.2 mg/L (Chapra et al. 2009).

1.6. Other

Dust Suppressants

Dust suppressants that contain chloride, typically $MgCl_2$ or $CaCl_2$, commonly applied to gravel roads one or two times during summer months. The fraction of chloride that is washed off of the roadway surface after application can vary within the range of 20% to 70% (Reference USDA Forest Service 1972). In a particular catchment located near Duluth, Minnesota, chloride concentrations have been shown to increase from 3 mg/L prior to application to over 1,000 mg/L in samples taken 2 and 6 weeks after application (USDA 1972). This suggests that chloride applied as dust suppressants can have a significant impact on the water quality under certain circumstances. A 2009 study of 16 streams in Colorado measured chloride levels upstream and downstream of roads that received MgCl as a dust suppressant treatment. Eight of sixteen streams had significantly higher downstream than upstream concentrations of chloride or magnesium over the entire monitoring period, though a regional water response was not observed with application of MgCl2 (Goodrich 2009).

Human and wildlife excreta

Salt is a natural mineral that is required for biotic processes within humans, pets, and wildlife. Salt is a large part of every diet and chloride is a waste byproduct found in excreta. Chloride from human excreta will be transported to a municipal WWTP or septic system, while chloride derived from uncollected pet and wildlife waste will seep into shallow groundwater or runoff into surface waterbodies.

Other Potential Sources

Sources of chloride to lakes, wetlands, and streams other than those discussed above exist, but are considered to be small. Landfill leachate has been shown to contain elevated levels of chloride (Mullaney et al. 2009). The use of poly-aluminum chloride for treatment of lake sediments or ferric chloride for treatment of stormwater are sources of chloride and should be avoided in waters and watersheds with chloride impairments.

Household cleaning products such as soaps, detergents and toilet cleansers often contain chloride and other potential sources of chloride will ultimately end up at a wastewater treatment facility or in a septic system (Overbo 2019).

2. Minnesota's Land Use, Water Resources, Climate and Climate Change

2.1. Land Use and Water Resources

Figure 11: Panorama of Lake Superior in autumn

The state of Minnesota includes 87 counties, 853 cities, and 1,782 townships, and has a population of approximately 5.6 million people. Minnesota covers approximately 87,000 square miles, most of which is rural. However, several large urbanized areas do exist, such as the TCMA, Rochester, Duluth, St. Cloud, Moorhead, Mankato, and Brainerd. The TCMA includes 186 cities and townships and a population of approximately 3 million people. The TCMA is approximately 3,000 square miles, with over 1,000 square miles of developed land uses. Minnesota has 11,842 lakes (greater than 10 acres), 69,200 miles of rivers and streams and over 10 million acres of wetlands. Over 10% of the state is covered in a lake, river, stream, or wetland. Minnesota also borders Lake Superior, the largest of the great lakes, is home to the headwaters of the Mississippi River and its National River and Recreation Area in the Twin Cities, and borders a National Scenic River, the St. Croix. Shallow and deep groundwater aquifers also cover large portions of the state (DNR 2018). Minnesota's lakes, rivers, streams, wetlands, and groundwater are valuable public resources, providing drinking water, recreational and tourism opportunities, wildlife habitat, water for agriculture and industrial uses, and more. Thus, chloride water pollution is of great importance.

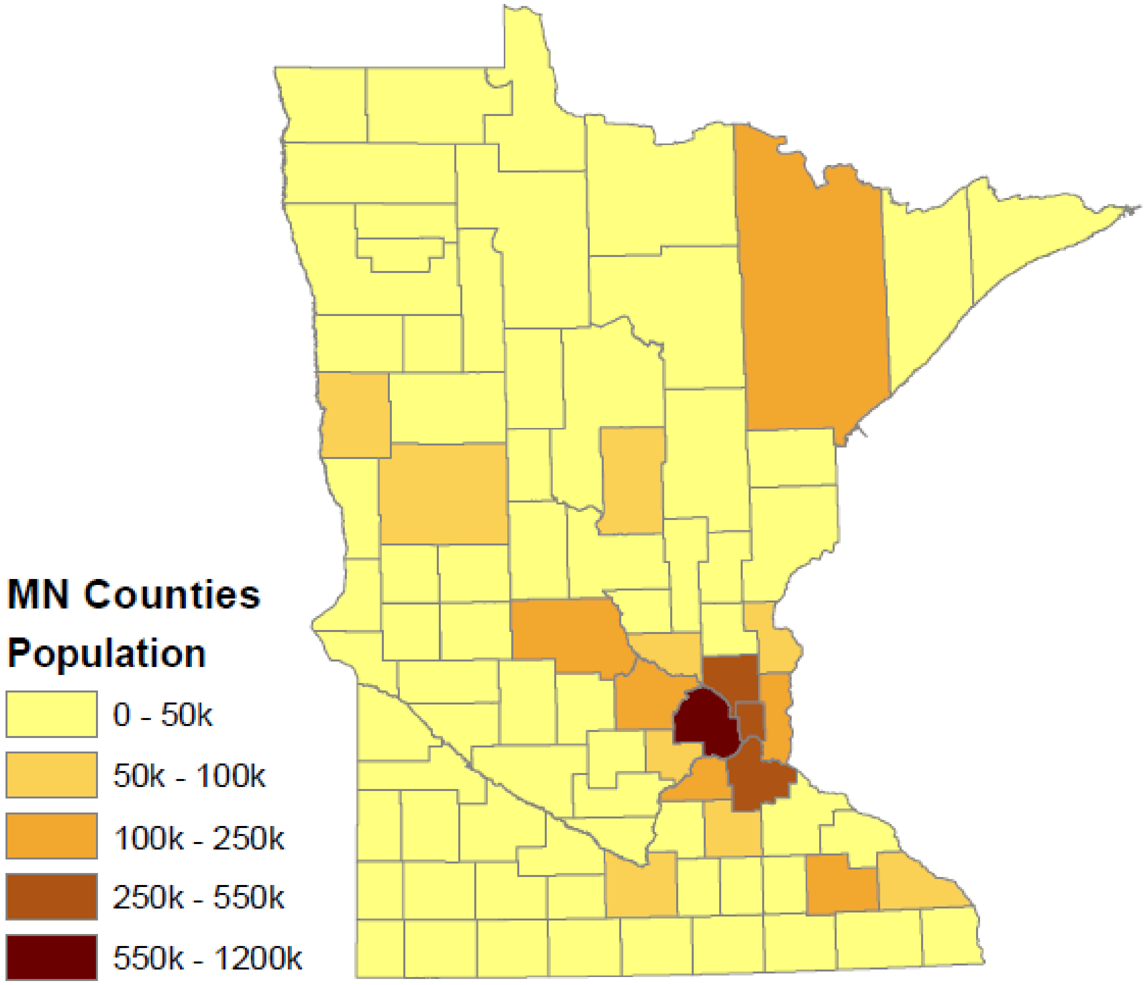


Figure 12: Minnesota County Populations

As shown in Figure 13, land use in Minnesota is largely rural, with several urban areas scattered throughout the state. The most common land use type is agricultural (cultivated and hay/pasture), which covers about 50% of the state, followed by forested areas. Minnesota's population grew 6.1% between 2010 and 2018 and is expected to continue to increase and exceed 6 million by 2032. The fastest growing counties by population between 2010 and 2018 were Carver (16.4%), Scott (12.5%), Washington (9.8%), Wright (9.5%), and Hennepin (9.4%), which are all in or bordering the TCMA, according to the Minnesota State Demographic Office.

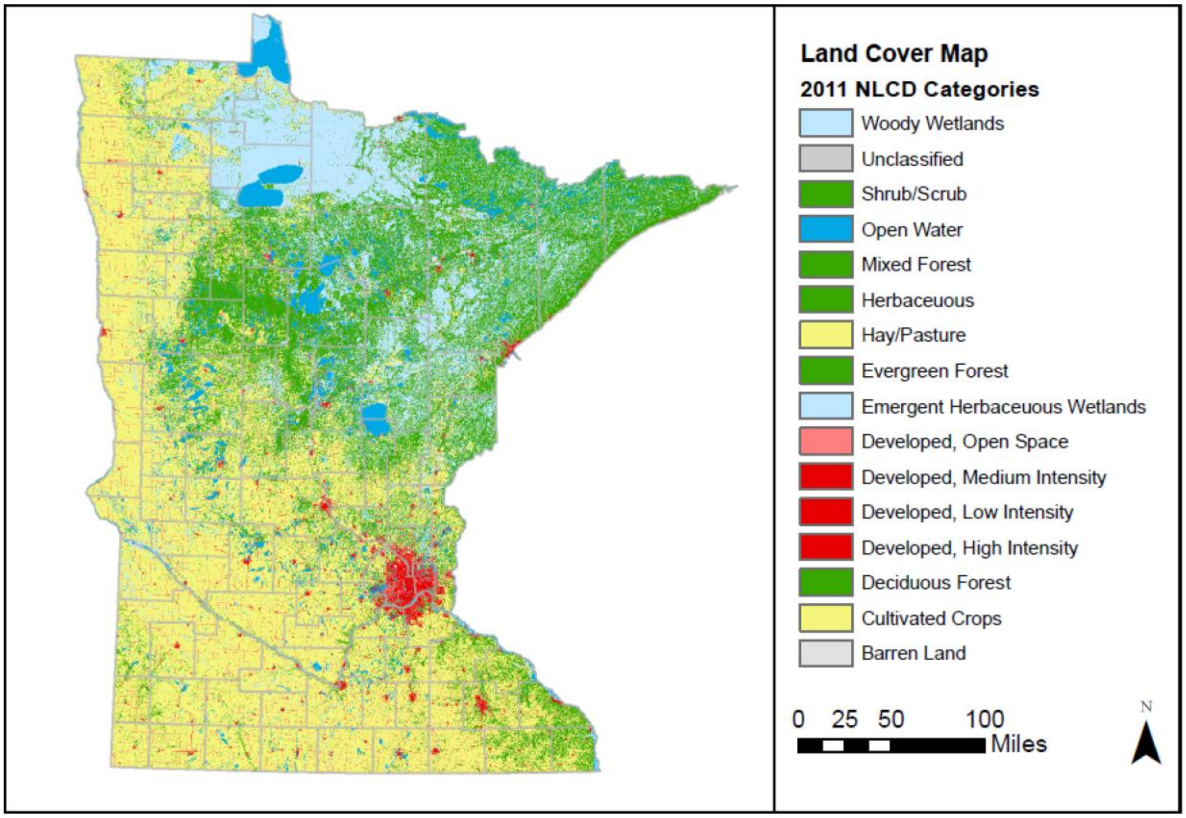


Figure 13: Land Use across Minnesota (based on the National Land Cover Database from 2016)

Nearly 80% of Minnesotan's receive their drinking water from public water systems, with the remainder using private wells. Groundwater is the primary source of drinking water across most of the state, with 923 community water systems utilizing this valuable resource (MDH 2019)

Water contains minerals such as calcium and magnesium, and as the concentration of those minerals increases, the hardness of the water increases. The United States Geological Survey (USGS) classify soft water as having 0 to 60 mg/L as calcium carbonate, moderately hard 61 to 120 mg/L, hard 121 to 180 mg/L, and very hard more than 180 mg/L. Figure 14 shows the natural (untreated) hardness values of groundwater wells across Minnesota (Overbo et al. 2019). The majority of Minnesota's water supply wells have hardness values in the hard to very hard range.

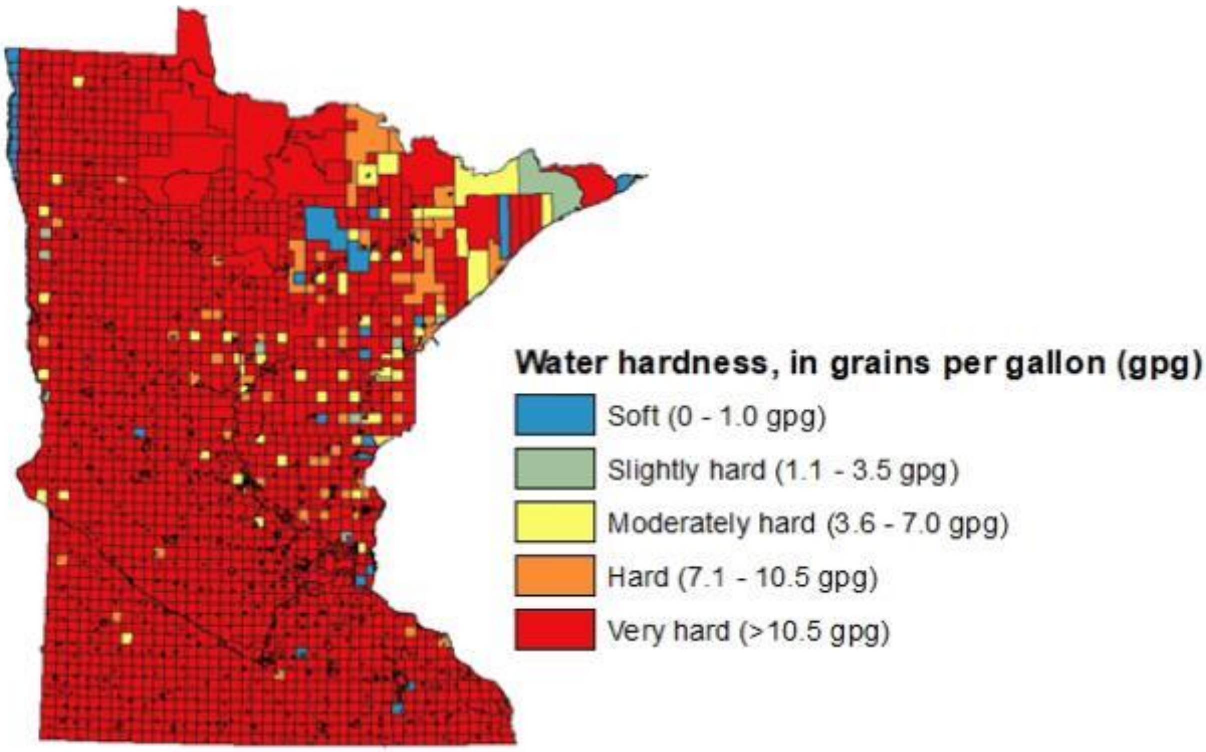
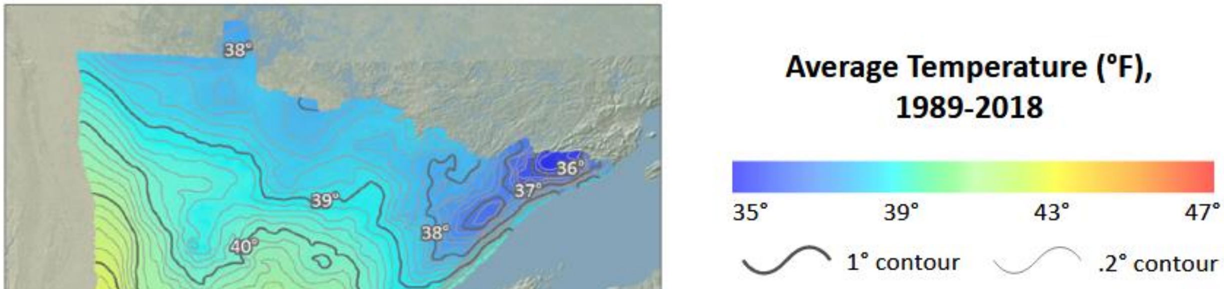


Figure 14: Hardness values of drinking water supply wells in Minnesota (Overbo et al. 2019)

2.2. Climate Conditions

Minnesota's climate also affects and influences chloride in our environment. Minnesota has a continental-type climate and is subject to frequent outbreaks of continental polar air throughout the year, with occasional Arctic outbreaks during the cold season. The average temperatures ranges from 36 degrees Fahrenheit (°F) in the extreme north to 49°F along the Mississippi River in the southeast, as shown in Figure 15. The coldest temperature on record is -60°F in St. Louis County near Tower on February 2, 1996. The average winter (December through March) temperatures ranges from 8°F in the north to 18°F in the south. The largest temperature change in a 24-hour period was 72°F, which occurred on February 2, 1970 in Koochiching County. (DNR 2020)



Time period	Value
Annual	41.6°
Winter (Dec. - Feb.)	13.5°
Spring (March - May)	41.5°
Summer (June - Aug.)	66.8°
Fall (Sept. Nov.)	44.5°

MINNESOTA POLLUTION CONTROL AGENCY

Figure 15: Average Minnesota Temperature
(https://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/climate_summary_statewide.pdf)

Approximately two-thirds of the annual precipitation in Minnesota occurs May through September, which is the time when row crops are grown.

Seasonal snowfall averages near 70 inches along the north shore of Lake Superior in northeast Minnesota, and gradually decreases to 40 inches along the Iowa border and near the North Dakota and South Dakota borders. Snow cover of one inch or more over the state occurs on an average of about 110 days annually, ranging from 85 days in the south to 140 days in the north.

Snowfalls greater than 4 inches are common mid-November through mid-April. Heavy snowfalls with blizzard conditions affect the State on average about two times each winter. Blizzard conditions occur when visibilities are reduced to less than ¼ mile for several hours due to falling and/or blowing snow with wind speeds at least 35 miles per hour. On October 31 through November 3, 1991, during the “Halloween Blizzard” the Twin Cities received 28.4 inches of snow. Freezing rain and glaze storms have not been frequent historically, but do occur several times each season in Minnesota, according to the Minnesota State Climatology office.

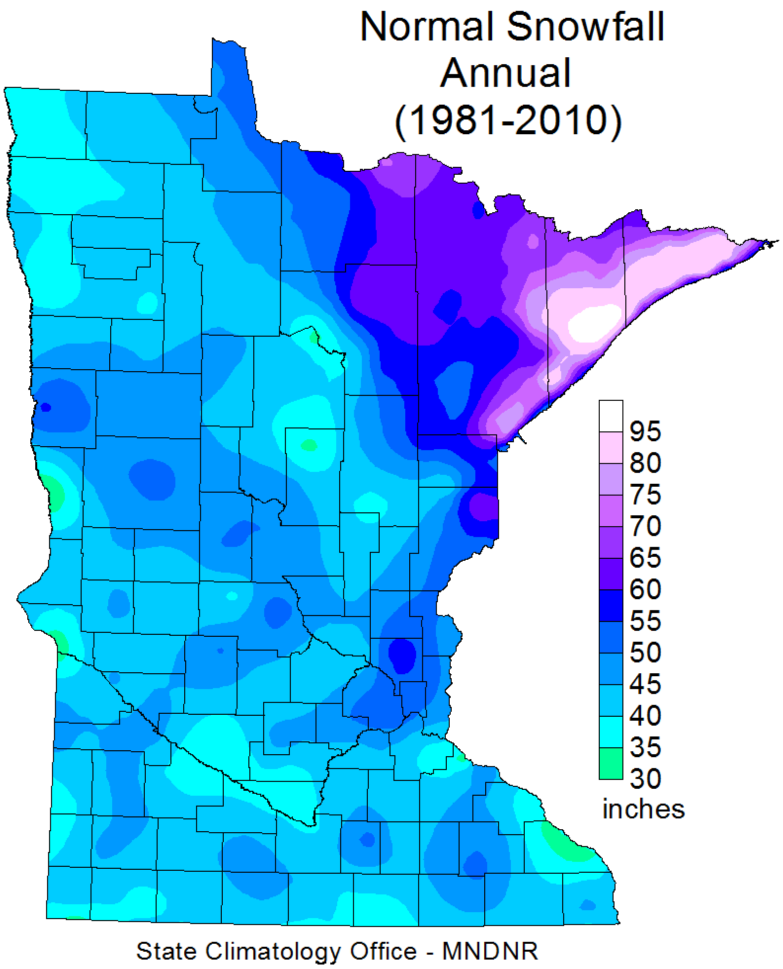


Figure 16: Normal Annual Minnesota Snowfall
https://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/climate_summary_statewide.pdf

2.3. Effects of climate change in Minnesota

Below are excerpts taken from the report "Adapting to Climate Change in Minnesota 2017, Report of the Interagency Climate Adaptation Team" (MPCA 2017). Climate change is already occurring in Minnesota and its impacts are affecting our state's environment, economy, and communities. Minnesota state government is concerned about the impacts of a changing climate on our natural resources, economy, health, and quality of life, and is taking action to address these emerging challenges.

Hazard	Observed Trend	Confidence Change is Occurring
Extreme cold	Rapid decline in severity & frequency	Highest
Extreme rainfall	Becoming larger and more frequent	
Heavy snowfall	Large events more frequent	High
Severe thunderstorms & tornadoes	Overall numbers not changing but tendency toward more "outbreaks"	Moderately Low
Heat waves	No recent increases or worsening	Lowest
Drought		

Confidence Scale

Lowest	Low	Moderately Low	Moderately High	High	Highest

Snapshot of observed trends among common weather hazards in Minnesota, and confidence that those hazards are changing in response to climate change. Graphic based on information from 2014 National Climate Assessment and data analyzed by the Minnesota DNR State Climatology Office.

Figure 17: Observed Trends Among Common Weather Hazards in Minnesota

Minnesota's position near the center of North America, halfway between the Equator and the North Pole, subjects us to an exceptional variety of weather. During the course of a single year, most Minnesotans will experience blinding snow, bitter wind chills, howling winds, pounding thunderstorms, torrential rains, and heat waves, as well as dozens of bright and sunny days. Given the high variability that we expect from Minnesota's climate, it can be difficult to discern where, when, and how climatic conditions have changed in our state.

In 2014, the U.S. Global Change Research Program completed its third National Climate Assessment. Both the science summarized in the National Climate Assessment and high-quality climatic data show that in Minnesota and the Midwest, rising temperatures have been driven by a dramatic warming of winter and also nights, with both the frequency and the severity of extreme cold conditions declining rapidly. Annual precipitation increases have been punctuated by more frequent and more intense heavy rainfall events. The heaviest snowstorms have also become larger, even as winter has warmed.

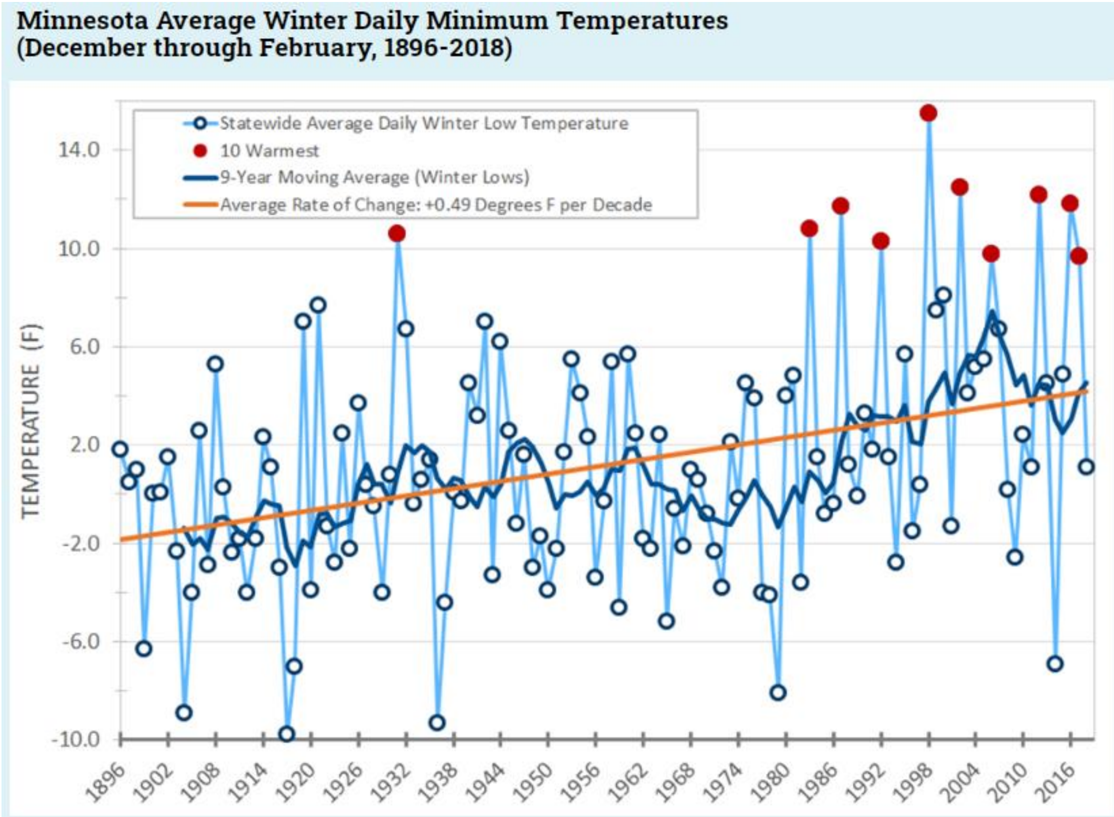
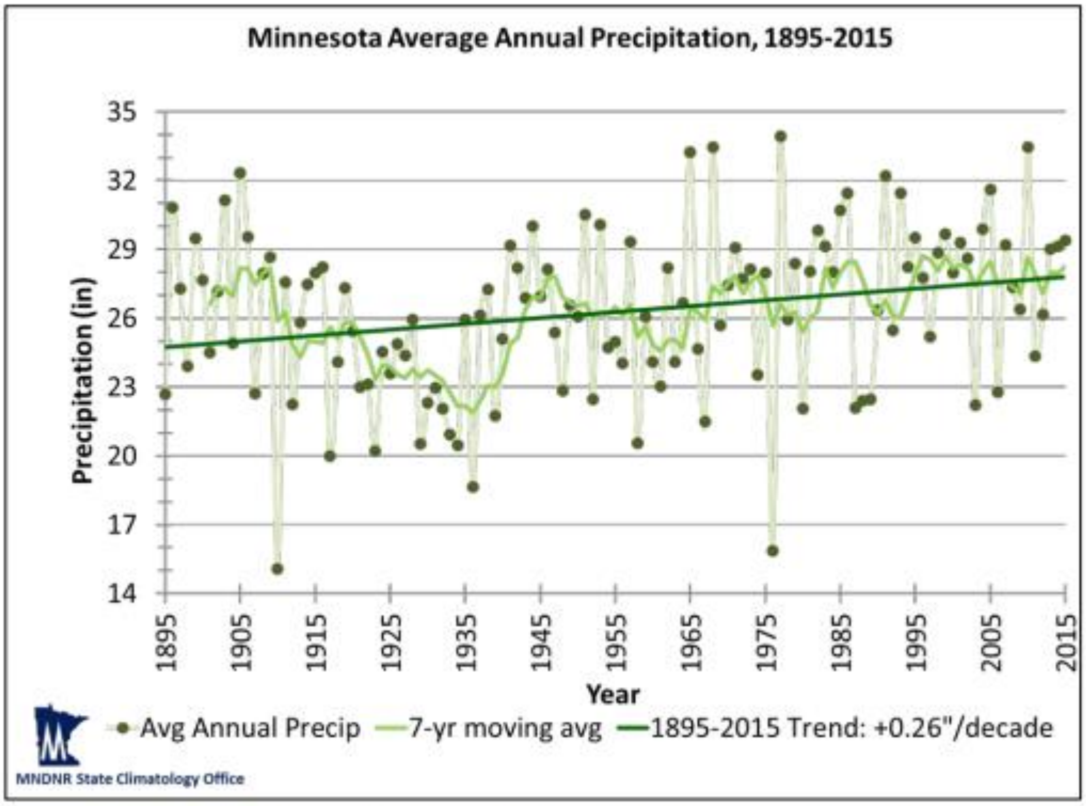


Figure 18: Minnesota Average Winter Daily Minimum Temperatures
https://www.dnr.state.mn.us/climate/climate_change_info/climate-trends.html

Minnesota's warming is well underway, with annual temperatures increasing at an average rate of nearly a quarter degree Fahrenheit (F) per decade since 1895. Much of the total warming; however, has been concentrated in the most recent several decades, with warming rates averaging nearly a half a degree per decade since 1970. Many people are surprised to learn that much of the observed temperature increase in Minnesota has not resulted from more warm weather, but instead from major reductions in cool and cold weather. The majority of Minnesota's warming has taken place where and when it's usually the coldest — namely during winter, at night, and especially in the northern parts of the state. For example, of the 50 winters from 1944 to 1945 through 1993 to 1994, only 6 failed to produce a reading of -40° F at an official weather observing site in Minnesota. By contrast, nine of the last 22 winters have failed to do so, meaning that it is now over 3 times more likely that Minnesota will not see a -40°F reading than it was historically. Although some Minnesotans view any warming during winter as a major improvement, the reality is that we have already begun to see detrimental impacts on our natural resources and availability of popular winter recreational activities such as ice fishing and skiing. Although it's most noticeable in winter, this "cold weather warming" is affecting the lowest temperatures of each of our seasons, and accounts for the majority of our observed annual warming.



Statewide average annual precipitation, 1895-2015. The 1895-2015 trend (solid dark green line) is based on linear statistical techniques and does not imply an exact decade-by-decade precipitation increase. Source: National Oceanic and Atmospheric Administration (NOAA) Climate at a Glance (http://www.ncdc.noaa.gov/cag/)

Figure 19: Minnesota Average Annual Precipitation, 1895-2015

Higher temperatures globally have evaporated more surface and ocean water into the atmosphere, which in turn has provided more potential moisture for precipitating weather systems. In Minnesota, the result has been increased precipitation, with annual totals increasing at an average rate of just over a quarter inch per decade statewide since 1895. This precipitation increase is found in all seasons, but spring and summer are becoming wetter at faster rates than fall and winter. Whereas temperature increases have been greatest in the northern parts of the state, precipitation increases have been well distributed geographically, and have somewhat favored southern Minnesota, which has better access to moisture from the Gulf of Mexico, and is more frequently near the “low-level jet” airflow (a relatively fast-moving zone of winds in the lower atmosphere) that influences precipitation production.

Heavy rainfall events in Minnesota are already becoming larger and more common, and have been contributing to an increasing share of annual precipitation in Minnesota. Research specific to the Upper Midwest indicates that the physical mechanisms supporting heavy rainfall events in Minnesota are likely to have begun intensifying in response to climate change. This research also shows that these major events may be taking place earlier during the growing season than the historical average. Thus, in addition to increases in the frequency and intensity of heavy rainfall, its seasonal timing may be expanding across the calendar.

The observed measurements and future projections described by the National Climate Assessment and the Minnesota State Climatology Office provide insight into climate trends that are impacting Minnesota now as well as those anticipated in the future. Complicating the varied impacts of climate change is that these changes also interact with and reinforce each other. In addition, climate change will amplify the effects of existing public health and environmental challenges, such as impaired air quality, loss of wildlife habitat, invasive species, and limitations to clean water supplies.

Climate change also is altering Minnesota's natural lands and waters and the uses they sustain. For example lakes, rivers, and streams will likely experience climate-induced impacts that include earlier ice-out dates; less seasonal ice cover; increases in warmwater fish species and decreases in coldwater fish species, such as ciscoes; increased growth of algae and diatom blooms; warmer surface water temperatures in lakes; and increased variability in the seasonal and annual flow volume in Minnesota watersheds. Climate change also reduces the effectiveness of fish and macroinvertebrate indicators currently used as biomonitors to evaluate the ecological health of water bodies. (MPCA 2017)

According to Minnesota Sea Grant, Lake Superior is responding to global climate shifts as clearly as anywhere on Earth (Minnesota Sea Grant 2020) Lake Superiors' observed changes include:

- Surface water temperature in summer has warmed twice as much as the air above it since 1980.
- The area covered by ice each winter is decreasing by about 0.5% per year. Ice cover in Lake Superior has decreased from 23% to 12% over the last century.
- Since 1985, wind speeds have increased by nearly 5% per decade, exceeding trends over land. Scientists believe the faster winds could accelerate the speed of Lake Superior's water currents, which in turn could affect the aquatic food web.
- Spring turnover has become earlier by about 1/2 day per year, leading to earlier summer stratification. The sun-warmed upper layer extends farther into the water column, making fall mixing later. The length of the positively stratified season has increased from 145 to 170 days over the last century.

2.4. How does this affect chloride levels?

Land use, the source of drinking water, and Minnesota's climate conditions significantly influence the amount of chloride entering our water resources (see Section 2: Minnesota's Land Use, Water Resources, Climate and Climate Change for more information). The thousands of miles of streets and highways in Minnesota, along with parking lots and sidewalks, often utilize chloride salt to manage snow and ice. Reducing hardness in drinking water is often achieved with the use of ion-exchange softening systems that utilize salt containing chloride. Agriculture contributes chloride to our water resources with the use of KCl as a fertilizer. Therefore understanding the land uses, drinking water systems and their connectedness to our water resources is important to effectively addressing the impact of chloride on Minnesota's waters.

As climate change is measured and observed in Minnesota in a variety of ways, there are many unknowns about future changes and impacts associated with this change. How these changes and impacts affect the use of chloride products is uncertain and more research is needed. However, based on what we know today about the climate change impacts Minnesota is already experiencing, it is likely that changes in winter conditions will present new challenges for winter maintenance activities. One of the key strategies to effectively manage snow and ice is to take a proactive approach. As winter weather events and conditions increase in variability and potentially become less predictable, we are likely to see more reactive approaches to managing snow and ice, which most often rely heavily on de-icing chemicals, primary chloride-based products.

The increase in frequency of heavy snowfalls combined with the warming trend of winter, will likely create changes in snowmelt conditions, and as rainfall continues to expand across the seasons, drainage problems and increases in refreeze situations will create new challenges for winter maintenance professionals. These changes include difference in the character of snow accumulation and melt, more variable local winter weather, and possible increases in the number of thaw and freeze days over the winter season. Based on the existing data, it seems quite likely that

- snow will fall in changed patterns and which falls will accumulate less;
- snowfall terminus lines will shift northward;
- the mix of ice storms and rain-on-snow may increase as temperatures change and the rainfall season lengthens;
- the timing and rate of snowmelt will vary from current conditions; and
- the likelihood of flooding events associated with rainfall during spring melt will increase.

This is a future that could result in more deicing chemical used to provide winter safety, less chance for effective management of snowmelt, and increases in flooding. As Minnesota begins to experience additional impacts of climate change, it will become even more important to properly train and educate winter maintenance professionals from all sectors to effectively adapt to the new and unknown impacts on winter weather conditions. Detailed and accurate, real-time weather prediction tools will become an essential tool as Minnesota's continues to experience unpredictable winter conditions.

Tracking these changes and the impact they have on the use of KCl fertilizer will be important to evaluate as communities work to adapt to climate change. Agriculture is highly dependent on specific climate conditions and, consequently, is sensitive to the effects of climate change. As the climate continues to change, agricultural producers will need to adapt their livestock and crop management, which includes; pest, nutrient, and water management, conservation practices, crop rotations, and areas of crop production (MPCA 2017).

In addition to impacts associated with the use of chloride-based products, the additional changes and stresses on our water resources will likely negatively affect the ability of aquatic life and vegetation to adapt with chloride toxicity. Continued monitoring of climate change impacts in Minnesota and chloride concentrations in water resources, tracking salt use, and the ability to adapt to changing conditions is critical to protecting Minnesota waters from the impacts of chloride with a changing climate. Supporting research efforts to better understand the specific implications that climate change will have on chloride use, as well as continued research on new technologies and strategies to reduce the use and need for chloride-based products, will be even more important as climate change continues More about research needs can be found in Section 8: Research Needs.

3. Environmental and Infrastructure Damage

Low levels of chloride can be found naturally in lakes and streams and chloride is essential for aquatic life to carry out a range of biological functions. However, high concentrations of chloride in the surrounding water harm aquatic life as a result of a disruption in the cellular process called osmosis which moves molecules, such as water, through cell membranes. Too much chloride in the surrounding water can cause water to leave the cell, and also prohibit the transport of needed molecules into the cell. If elevated concentrations of chloride persist in the water, aquatic life such as fish, invertebrates, and some plant species become stressed and/or die. The MPCA has adopted the United States Environmental Protection Agency's (EPA) recommended water quality criteria for chloride, which is designed to protect aquatic life from the harmful effects of excessive chloride. The current allowable chloride concentration to protect for acute (short-term) exposure is 860 mg/L. And the current allowable chloride concentration to protect for chronic (long-term) exposure is 230 mg/L. These values were developed based on toxicity test results for a range of freshwater aquatic organisms. Short-term exposure (one hour or more) to concentrations greater than 860 mg/L or continued exposure (four days or more) to chloride concentrations greater than 230 mg/L can be expected to have detrimental effects on community structure, diversity, and productivity of aquatic life. There are also indications that some species of aquatic animals are sensitive to dissolved chloride concentrations at level less than 230 mg/L. The DuPage River Salt Creek Workgroup in Northeast Illinois has begun developing a statistical approach using water quality data from their region's watersheds to better understand the relationships between chloride concentrations in streams, presence of chloride sensitive species, and biologic integrity scores. Their results have found that streams with less than good biological scores are often associated with chloride concentrations lower than the 230 mg/L chronic standard. Increased chloride concentrations can also have indirect effects on biota. Additives and contaminants such as phosphorus, cyanide containing compounds, copper, and zinc may cause additional stress or accumulate to a potentially toxic level (Wenck 2009).

A STREAM, LAKE OR WETLAND IS IMPAIRED BY CHLORIDE IF:

Two or more samples exceed 230 mg/L within a three-year period;
Or,

One sample exceeds 860 mg/L.

Impacts on water quality in lakes, wetlands and streams are not the only concern related to high levels of chloride in the environment. Chloride can affect groundwater and drinking water supplies, infrastructure, vehicles, plants, soil, pets, and wildlife. The Phase 1 Feasibility Study documented the results of a literature review on the impacts of chloride from salt. Research identifies the negative impacts that chloride has on the environment, whether from deicers or water softeners, but there are still many unknowns (Wenck 2009). Continued research will help us understand how chloride interacts with the environment and therefore, how to protect our water resources. Additional concerns associated with chloride in the environment, including an analysis of the estimated cost of those impacts, are discussed below.

Monitoring Chloride: Specific Conductance, Conductivity, and Chloride

Specific conductance or simply "conductivity" is a measure of water's ability to conduct electricity, which increases with elevated dissolved ion concentrations. Measuring conductivity is also a measurement of the ionic strength of water, which is affected by the presence of dissolved solids such as salts of chloride, which includes NaCl, MgCl, KCl, and calcium chloride. Conductivity of surface and groundwater can be influenced by both natural background sources of chloride and from pollution. Chloride concentrations can also be measured in surface waters directly using an EPA approved reference method, such as the EPA reference method 325.2. Often, a conductivity measurement is taken along with a direct chloride measurement. The MPCA offers guidance for monitoring for chloride in lakes and streams. (https://www.pca.state.mn.us/sites/default/files/wq-iw11-06w.pdf and https://www.pca.state.mn.us/sites/default/files/wq-iw11-06v.pdf).

Chloride is Persistent in the Environment

Once chloride is in water, the only known technology for its removal is RO through massive filtration plants or through evaporation, which currently are not economically feasible. This means that chloride will continue to accumulate in the environment over time. A study by the UMN found that about 78% of salt applied in the TCMA for winter maintenance is either transported to groundwater or remains in the local lakes, streams, wetlands, groundwater, and soil (Stefan et al. 2008).

3.1. Infrastructure

Chloride corrodes road surfaces and bridges and damages reinforcing rods, increasing maintenance and repair costs. The costs associated with infrastructure are based on damage to infrastructure and maintenance and replacement costs associated with this damage. A study by economist Vitaliano, included an estimate of expenditures of an additional $332 per ton of salt per season for bridge maintenance (1992). One ton of road salt results in $1,460 in corrosion damage to bridges, and indirect costs may be much higher (Sohanghpurwala 2008). The total annual cost of bridge decks damages due to road salt was estimated at greater than $500 million nationwide (Murray and Ernst 1976). Costs would be substantially higher now.

In addition to damage to bridges, chloride deicers also damage concrete pavement, requiring higher maintenance costs. Vitaliano (1992) estimates an overall increase in roadway maintenance costs of over $600 per ton. This figure is believed to include the extra cost due to damage to bridges. Salt applied to pavement is also damaging to parking garages and underground utilities (Michigan DOT 1993).

More recently, the City of Madison, Wisconsin has estimated that the cost of repairing infrastructure is at $7 billion per year for the entire United States (City of Madison 2006). This value excludes any costs associated with active protection against corrosion on highways and bridges, which were estimated at $8.3 billion per year, and any epoxy coatings, which could cost as much as $109 billion per year.

Vehicle Corrosion

Deicing salt also accelerates rusting, causing damage to vehicle parts such as brake linings, frames, bumpers. Vitaliano (1992) estimated that vehicle depreciation due to corrosion from road salt results in a cost of $113 per ton of salt. Automobile manufacturers have improved corrosion resistance in cars since the 1992 study; however, measures to protect vehicles against corrosion cost auto manufacturers an estimated $4 billion each year, which is passed on to consumers (Adirondack Council 2009). Similarly, AAA estimated that $3 billion per year was spent on rust repairs in recent years (AAA 2017).

Water Distribution Safety

Chloride causes corrosion and consequently affects water distribution infrastructure and drinking water quality (Stets, et al. 2017). Specifically, copper and lead are the focus of corrosion control in water distribution systems, and this control is made more difficult when source waters have high chloride concentrations. Stets, et al., found a strong link between increasing chloride concentrations in urban surface waters and increased potential for corrosivity in water distribution systems. This link was found in urban settings, where the majority of chloride was assumed to be from de-icing salts. Since most water treatment facilities do not have RO systems in place due to cost, dissolved chloride from the source water is generally distributed to consumers. This is of particular concern for municipalities that use surface water as a source.

Wastewater Reuse

Chloride is a major challenge for planning and developing wastewater reuse infrastructure. *Advancing Safe and Sustainable Water Reuse in Minnesota*, the 2018 report of the Interagency Work Group on Water Reuse (MN Department of Health), documented where wastewater reuse is practiced in Minnesota and the growing interest in this practice (MDH 2018). The report notes that high chloride concentrations in wastewater are a challenge for wastewater reuse. The cost and technological challenges of reducing chloride at WWTPs often makes wastewater reuse cost-prohibitive. Chloride reduction upstream of a WWTP can make wastewater reuse more feasible.

Cumulative Costs

Table 1: Overall Cost Considerations: Sources: MnDOT (2012), Stefan (2009), Vitaliano (1977) and Murray et. al (1992).

	Low Overall Estimate	High Overall Estimate
Cost component	**Cost per ton of salt**	**Cost per ton of salt**
Material	$73	$73
Labor and equipment	$150	$150
Overall damages	$803	$3,341
Combined Cost	**$1,026**	**$3,564**

Estimates of damage to infrastructure, automobiles, vegetation, human health and the environment due to de-icing salt were found in the literature from several sources. They ranged from $803 to $3,341 per ton of road salt used. Table 1 shows the overall range of the cost estimate with a low and high range. The money saved from reducing damage to infrastructure, vehicles, plants, water supplies, and human health is much higher than that from the material and labor savings. A 70% salt use reduction in the TCMA would amount to $251 to $870 million cost savings each year (Fortin 2014). Using the estimated 403,600 tons of de-icing salt used each season statewide in Minnesota, a 70% salt use reduction would amount to a $290 million to $1 billion in savings (Overbo 2019) (Fortin 2014).

3.2. Environmental Impacts

Surface Water

Chloride concentrations in lakes, wetlands and streams in Minnesota, as well as in many cold climate states have been increasing (Novotny et al. 2007; Novotny et al. 2008; Dugan et al. 2017). Fifty lakes, wetlands, and stream reaches are known to be impaired for aquatic life due to high concentrations of chloride statewide according to the MPCA's 2018 303(d) List of Impaired Waters (MPCA 2018). Impacts on lakes include toxicity to aquatic life as well as the potential interruption of the vertical mixing (turnover) process.

It is difficult to put a financial value on the impacts of chloride impairments. However, the Adirondack Watershed Institute (Kelting and Laxson 2010) conducted a simulation using published scientific literature and an ecosystem services model of road salt impacts on surface waters and forests and showed a $2,320 per lane mile per year reduction in environmental value in the Adirondack Park. If this value is applied to the 285,000 lane miles of roadways in Minnesota (MnDOT 2018), the resulting estimate of economic impacts on surface waters and forests in Minnesota is roughly $660 million per year. These are not actual out-of-pocket costs, but indicate the cost of the loss of environmental value.

Streams and Rivers

There has been observed and recorded increasing trends in chloride concentrations and specific conductance in streams across North America, specifically in urban streams within watersheds with high percentages of impervious surface and in northern parts of the country where de-icing salt use is abundant. This can have adverse effects on riverine aquatic ecosystems as chloride can be both directly toxic at certain concentrations, but also be considered a stressor to sensitive species at sub-lethal concentrations. There are strong observed negative correlations between increasing chloride trends in streams and declines in abundance and diversity of freshwater communities, with deicing salts being a primary driver in northern states (Moore 2020). Chronic or persistent salinization of streams has also been shown to affect the aquatic communities in general, with declines in community wide metrics such as richness and diversity observed (Timpano 2018). Research has shown that elevated chloride levels has an effect on aquatic communities at all trophic levels and has an influence on the food web and energy flows (Hintz and Relyea 2019). In general, elevated chloride concentrations can have adverse impacts at the ecosystem, community, and species level.

There are many factors that play a role in the concentration of chloride in streams, such as watershed landuse and impervious surface, precipitation, baseflow throughout the year, groundwater influence, long term salt use influencing groundwater, and seasonality all having an influence on chloride concentrations. Smaller urban streams may also experience greater variability in chloride concentrations with substantial fluctuations in chloride concentrations on a smaller timescale due to their lower flow volumes and influence from storm events. With the increasing pace of urbanization, it is expected that exceedances of water quality standards with respect to chloride will also increase (Corsi et al. 2015) (Victoria et al. 2019)

Lakes

Upward trends in chloride concentration has been observed in the North America's lakes region since 1985. The most important predictors of such increases have been found to be impervious land cover and road density surrounding the lake (Dugan et al. 2017). With as little as >1% impervious surface surrounding a lake, there is an increased likelihood of salination.

Dissolved chloride also increases the density of water and thus will tend to collect at the bottom of a lake. This can establish a salinity gradient and as these differences become greater, the normal mixing patterns of the lake can be inhibited and potentially stop all together. This can negatively affect the seasonal mixing of lake waters creating potential biogeochemical problems for lake ecosystems (Novotny et al. 2008). The natural mixing of lakes increases oxygen levels required by aquatic life for survival. Prevention of turnover can result in anoxia in the bottom of lakes and potential death of aquatic biota (Michigan DOT 1993). Changes in mixing can also affect phosphorus nutrient cycling processes, phytoplankton community composition and productivity, zooplankton community composition and phenology, and fish through trophic cascades. Recent research has also suggested that persistent anoxic sediment zones in lakes with higher chloride concentrations compared to ones with lower chloride concentrations alter the biogeochemistry of the lake with potential for greater increases of methane gas emission, a potent greenhouse gas (Dupuis et al. 2019). No specific loss of value has been attributed to chloride toxicity or the impact of altered mixing regimes in lakes due to increased chloride. More research is needed to better understand this potential impact.

Stormwater Pond Function

It has been shown that excess chloride concentrations can stratify lakes by density gradients, with denser chloride impacted water residing below less dense fresher water toward the surface. The implications of such persistent stratification in lakes has been suggested that oxygen may become depleted in the salt-dense layer near the sediments. This could result in increased phosphorus release into the water column from these anoxic sediments (Novotney and Stefan 2012). This same stratification has been observed in stormwater ponds, where persistent layers of high chloride were found (Herb et al. 2017). There is continued ongoing research to determine the possible potential impacts of chloride loading and phosphorus release from stormwater ponds specifically.

Groundwater and Drinking Water

Groundwater is another important resource in Minnesota; about 75% of Minnesotans rely on it for their drinking water supply (MPCA 2019). Groundwater also contributes flow to lakes, wetlands, and streams, and can release elevated concentrations of a number of pollutants into surface waterbodies. Deicing salt application, in particular, is resulting in high chloride concentrations in groundwater. Ambient groundwater monitoring data collected by the MPCA from 2013 through 2017 found that 16% of monitoring wells tested in shallow sand and gravel aquifers in the TCMA exceeded the state chronic standard for surface waters of 230 mg/L for chloride, and this percentage was even higher than this when monitoring wells near gas stations were sampled (Kroening, 2018 personal communication). In the neighboring State of Wisconsin, they are beginning to see the effects of chloride in shallow groundwater releasing chloride into surface waters in the Yahara Watershed due to applications in Madison, Wisconsin (Wenta 2018). In the State of New York, it has recently been estimated that 24% of private wells are impacted by de-icing salt application (Pieper et al. 2018). Further, the amount of sodium (a common component of salt) in drinking water is a human health concern, particularly for individuals on sodium restricted diets, though sodium tends to increase at a slower rate than chloride (EPA 2003; EPA 2014; Wenta 2018).

The cost of mitigating groundwater contamination is substantial. The EPA has set a Secondary Maximum Contaminant Level (SMCL) of 250 mg/L for chloride in drinking water, which is a guideline for protection based on taste (EPA 2014). According to a 1991 report, $10 million is spent nationally each year on mitigating impacts to groundwater from salt (Transportation Research Board 1991). The United States uses approximately 20 million tons of deicing salt per year (Anning and Flynn 2014). This equates to a cost of about $0.50/ton for mitigating groundwater impacts. A 1976 estimate (Murray and Ernst 1976) was much higher, with a figure of $150 million per year for damages due to contamination of water supplies by deicing salt. This estimate includes more direct and indirect costs such as treating water, replacing wells, supplying bottled water, adding practices to prevent additional contamination, human health concerns, and property value damage. Using an estimate of 9 million tons of salt used in 1976, this equates to $16.67 per ton for damages to water supplies.

Drinking water infrastructure is also susceptible to increased concentrations of chloride. Lead and copper pipes become more corroded as chloride levels reach a certain threshold, which can cause human health concerns and reduce the lifetime of infrastructure. A thorough review of temporal trends of chloride and potential corrosivity in water systems suggests that adaptive corrosive management and monitoring should be employed to better track the possible leaching of lead and copper (Stets et al. 2018). The Town of Orleans, located in New York State, is just one example of a municipality constructing infrastructure in response to chloride and de-icing salt issues. The region has recently completed plans to construct a new water line to supply 500 homes. This 3-mile long system will cost over $13 million, and the majority of the cost will be covered by citizens through increases to water bills (Pieper et al. 2018).

Ecotoxicology

Chloride is toxic to aquatic organisms and its presence in high concentrations can alter the function of aquatic communities. In turn, individual populations and communities may become too small or impaired to perform an essential ecosystem function, such as producing oxygen or acting as a source of food for higher organisms. Chloride is also toxic to higher organisms, such as fish, at high concentrations (Evans and Frick 2001). Consequently, the trophic interactions may become unstable and the biological functions regulating water quality may be lost or altered (Hintz et al. 2016).

Plants

Deicing salt can kill plants and trees along roadsides, sidewalks, and parking lots. Plants can also be harmed by taking up salty water directly through their roots. Depending upon species-specific chloride tolerance, soil chloride concentrations as low as 68 mg/L can have detrimental effects on growth and reproduction (Wegner and Yaggi 2001), however, some species are tolerant up to 200 mg/L (TRB 1991). Although the effects of chloride are negligible beyond about 12 meters from roadsides (Marosz 2011), there are certain cases where this zone can cause economic losses in recreational areas.

Using patterns of campground site selections, Vitaliano estimated that the aesthetic damage to trees in the Adirondacks due to road salt was $75 per ton (1992). Research in the Adirondacks has shown that the application of deicers and abrasives on roads has severely changed the chemical and physical structure of soil along roads (Langen et al. 2006). The New York State Department of Transportation spent $10,000 per mile to replant and reestablish natural vegetation along a 2-mile stretch of highway in the Adirondacks (NYSDOT Press Release 2008).

Pets and Wildlife

Pets may consume deicing materials by eating them directly, licking their paws, or by drinking snow melt and runoff, which can be harmful to pets. Exposure to deicing salt can cause pets to experience painful irritation, inflammation, and cracking of their feet pads. Some birds, like finches and house sparrows, have an increased risk of death if they ingest deicing salt. Deer and other large mammals consume the salt on roadsides and roadside ponds to fulfill their sodium needs, resulting in increased traffic incidents (Environment Canada 2001; Amundsen 2010). Deicing salt may also cause a decline among populations of salt sensitive species, reducing natural diversity.

Amphibians

A body of literature has identified that de-icing salt exposure may put amphibians at risk at many points throughout their life-cycle, resulting in abnormalities, reduced growth, behavior changes, lower survival rates, and changes in community structure (Environment Canada 2001; Denoël et al. 2010; Karraker 2008; Collins and Russel 2009). Amphibians have been shown to be more sensitive to salt-induced mortality and deformities (Tiwari and Rachlin 2018). In particular, the permeable nature of amphibian eggs make them especially sensitive to salt exposure. Within adult amphibians, exposure to salt in the environment results in the loss of osmoregulatory control, effectively causing desiccation or death (Jones 2015). The population dynamics and male to female ratios can also be altered by de-icing salts, as observed with wood frog populations (Lambert 2016). Higher chronic values of road-salt derived chloride have also been found to affect larval resistance to infection by parasites at early stages of development (Milotic et al. 2017; Buss and Hua 2018). Wood frog tadpoles have been shown to have a significant decrease in survivorship at important developmental stages at low chronic exposure concentrations (Tiwari and Rachlin 2018). Field experiments have shown that high and relatively lower concentrations of de-icing salt, as measured by specific conductivity, are correlated with declines in frog embryo survival (Karraker et al. 2008).

Aquatic Invertebrates and Fish

Freshwater aquatic invertebrate species have been found to sensitive to elevated ion concentration in freshwater ecosystems. Aquatic insect species found in Minnesota, such as mayflies (*Ephemeroptera*) spend part of their life developing in sediment and freshwater, whereas other species may spend the entirety of their lives in freshwaters habitats, such as freshwater mussels. Mayflies are a commonly studied species with respect to toxicology. They been found to be specifically susceptible to chemical stressors such as chloride at both acute and chronic exposure concentrations in both laboratory settings and in field studies (Soucek et al. 2018). Invertebrate species also include freshwater mussel species. Different developmental stages of common freshwater mussels (glochidia, juvenile, adult) have been shown to be sensitive to environmentally relevant chloride concentrations in winter road runoff (Prosser et al. 2017).

Adverse effects of elevated chloride levels can have an adverse impact on the invertebrates beyond direct toxicity and can impact the freshwater ecosystem as a whole, which in turn can increase certain biotic stressors imposed on a species. These impacts can include relevant biological endpoints such as developmental delays, changes in physiology, resistance to disease, altered food webs, and changes in predation pressures (Jones et al. 2017). Mangahas et al. found that high levels of de-icing salts exposure can compromise the immune response of dragonfly larvae (Mangahas et al. 2019).

Fish species and communities are also affected by increased salinization at sub-lethal exposure concentrations, with significant changes to fish species assemblages associated with chloride concentrations below 230 mg/L (Morgan et al. 2012). Chloride can influence fish at various life stages, such as reducing egg survival rates, stressing embryo development, and influencing development of fish from juvenile fry to adults. Although research may suggest that fish may be relatively tolerate to osmotic stress compared to other freshwater organisms, the developmental life stage is an important consideration (Hintz and Relyea 2018)

Soil

Soil along roadsides can be impacted by de-icing salt (primarily the sodium) in a number of ways, including change in soil structure, effects on the nutrient balance, accelerated colloidal transport, mobilization of heavy metals, reduced hydraulic conductivity and permeability (Amundsen 2010; Michigan DOT 1993). These changes can lead to reduced plant growth. Soil structure changes also may result in increased erosion and sediment transport to surface waters (Kelting and Laxson 2010).

Soil also has an impact on the transport and fate of chloride in the environment. Although de-icing salt readily dissolves into sodium/potassium and chloride ions, previous research has shown that chloride does not always move freely in water, and that soil and chloride interact in complex ways depending on a multitude of factors. A 2019 study by the UMN investigated the effects of various chloride dosing regimen in different soil types. They found that chloride is both stored (adsorbed and in capillary spaces) and released from soil as environmental conditions and concentrations change (Erickson et al.2019). The researchers also collected field core samples at sites with similar soil types and found that chloride is found in soil alongside roads that have historically been treated with de-icing salt.

De-icing salt can lead to soil salinization and has an impact on diversity and composition of microbial ecology found within the soil column, which can also influence the amount of soil organic matter (Ke et al. 2013).

4. Chloride Water Quality Conditions and Trends

4.1. Chloride Water Quality Conditions and Trends

Chloride data across the state of Minnesota was compiled and assessed to support the development of the Statewide CMP. Data was acquired from the EPA Storage and Retrieval (STORET) database (now named the Water Quality Portal https://www.epa.gov/waterdata/water-quality-data-wqx), Metropolitan Council-Environmental Information Management Systems (EIMS) and the USGS National Water Information System (NWIS) database. The data in EPA's Water Quality Data Exchange includes data from many sources and entities, including Watershed Management Organizations (WMOs), citizens, cities, and counties. The EPA data is also available through the State of Minnesota's Environmental Quality Information System database (EQuIS).

Additionally, the MPCA worked with local partners to develop and implement a chloride monitoring program as part of the TCMA Chloride Project. The objective of the monitoring program was to better inform an understanding of chloride conditions across the TCMA, including seasonality, trends over time, and the potential for high chloride concentrations in the deepest part of lakes. Seventy-four lakes, 27 streams, and 8 storm sewers were monitored as part of this effort from 2010 through 2013. The

Chloride Monitoring Guidance for Lakes and Chloride Monitoring Guidance for Streams and Stormsewers were developed by the MPCA and local experts from the TCMA Chloride Monitoring SubGroup and can be found on the MPCA's TCMA Chloride Project website. The monitoring guidance provides recommendations on sample collection, times of the year to sample, as well as guidance for monitoring high risk waters.

This section of the plan provides an overview of the assessments conducted based on the available data, including determinations of impairment, time and spatial trends in chloride concentrations, the TMDLs developed for impaired waters, and waters showing a high risk for future impairment.

4.2. Condition Status

This section describes the current status of water resources with respect to applicable chloride criteria. Subsections are provided for statewide conditions, and an in-depth look is also provided for conditions in the TCMA. The status of surface waters including lakes, wetlands and streams is presented first. The status of groundwater resources is presented second.

The MPCA's approach to determining whether or not a stream, lake, or wetland is impaired by chloride relies on an assessment of available data. The MPCA conducted an assessment for chloride in the TCMA waterbodies in 2013, and has updated this assessment with the collection of routine data. Two or more exceedances of the chronic criterion of 230 mg/L within a 3-year period are considered an impairment. One exceedance of the acute criterion of 860 mg/L is considered an impairment. It should be noted that only a fraction of Minnesota's surface waters are currently assessed for chloride. The MPCA, Metropolitan Council and our partners around the state have begun to monitor for chloride on a greater number of waterbodies and at more ecologically and hydrologically relevant times (for deicing salts), namely during winter and spring snowmelts, as well as in the fall when chloride levels should hypothetically be at their lowest concentrations.

Statewide there are currently 50 waters impaired with chloride being identified as the primary pollutant or stressor on the 2018 impaired waters list, 41 of which have completed Chloride TMDLs. TMDLs for TCMA Chloride TMDLs, Shingle Creek, Nine Mile Creek, and Cannon River have been completed and provide loading capacities for chloride. There are an additional 75 surface waters across the state that have been classified as high risk. High risk is defined as a waterbody having one sample in the last 10 years that was within 10% of the chronic criteria (207 mg/L). An interactive webmap showing assessed, impaired, not impaired, and high risk waters can be found on the MPCA Minnesota Chloride Project website (Minnesota Chloride Management Plan Web Map).

TCMA Surface Water Conditions

In the TCMA there were 40 chloride impairments (17 streams, 19 lakes, and 4 wetlands) on the 2018 impaired waters list. Approximately 11% of the 340 waterbodies assessed were determined to be impaired. An additional 38 (11%) were classified as high risk and 11% did not have enough data. The assessed lakes, wetlands, and streams are shown in Figure 20. The highest density of impairments is in the heavily urbanized area in Hennepin and Ramsey Counties, though several streams in the outlying suburban areas of the TCMA and Greater Minnesota are also impaired by chloride. The primary source of chloride causing the listed impairments in urbanized areas is deicing salt, while in the more rural parts of the TCMA and the state the listed impairments are primarily from WWTP effluent. Little is known yet about the transport of chloride from fertilizers.

It is important to keep in mind that of the over 1,000 lakes, wetlands and streams in the TCMA, less than one-third had sufficient chloride data to make an assessment of impairment/attainment of water quality criteria. Also, of those waters with adequate data to make an assessment, only 30% were part of the TCMA Chloride Project monitoring program, which was developed to collect samples at critical times of the year and collected in critical locations. As a result, data used to evaluate water quality conditions in waters not part of the TCMA Chloride Project monitoring program, may not have been representative of critical conditions. Critical times of the year for collecting chloride samples in developed areas are typically during the winter snowmelt runoff (February through March) and during low flow periods. Methods for collecting chloride samples in lakes may also include collecting samples at different depths in the water column to determine if there may be stratification of chloride concentrations.

The impaired lakes, wetlands, and streams were compared by the concentrations of chloride ranked from highest to lowest based on the number of days with samples exceeding the state water quality standard of 230mg/L. These rankings are presented in Figure 21 and Figure 22. These figures are not a direct reflection of the 303(d) listing assessment; they are intended to make a relative comparison of the extent of impairment across impaired waters. The values presented in these figures were calculated by identifying the maximum chloride concentration measured in a waterbody on individual sampling days, then averaging all individual sampling day maximums that exceeded the standard of 230 mg/L from 2008 through 2017. These figures indicate the variability in one waterbody or watershed to the next by the severity of the impairment. Figure 23 and Figure 24 present the concentrations of high-risk waterbodies (lakes, wetlands, and streams) with at least one chloride measurement within 10% of 230 mg/L (i.e. 207 mg/L) within the last 10 years, ranked in order of number of days with samples exceeding 207 mg/L. These rankings can be used by chloride users to prioritize management activities by area. Since only a portion of the TCMA waters have chloride monitoring data, the rankings can also be used to determine specific areas that are close to impaired and high-risk watersheds for further monitoring and higher levels of management. Some of these water bodies listed in these figures may have reported samples that exceed the state chloride standard of 230 mg/L and may be assessed as impaired by chloride, or may be assessed for impairment by chloride in the future.

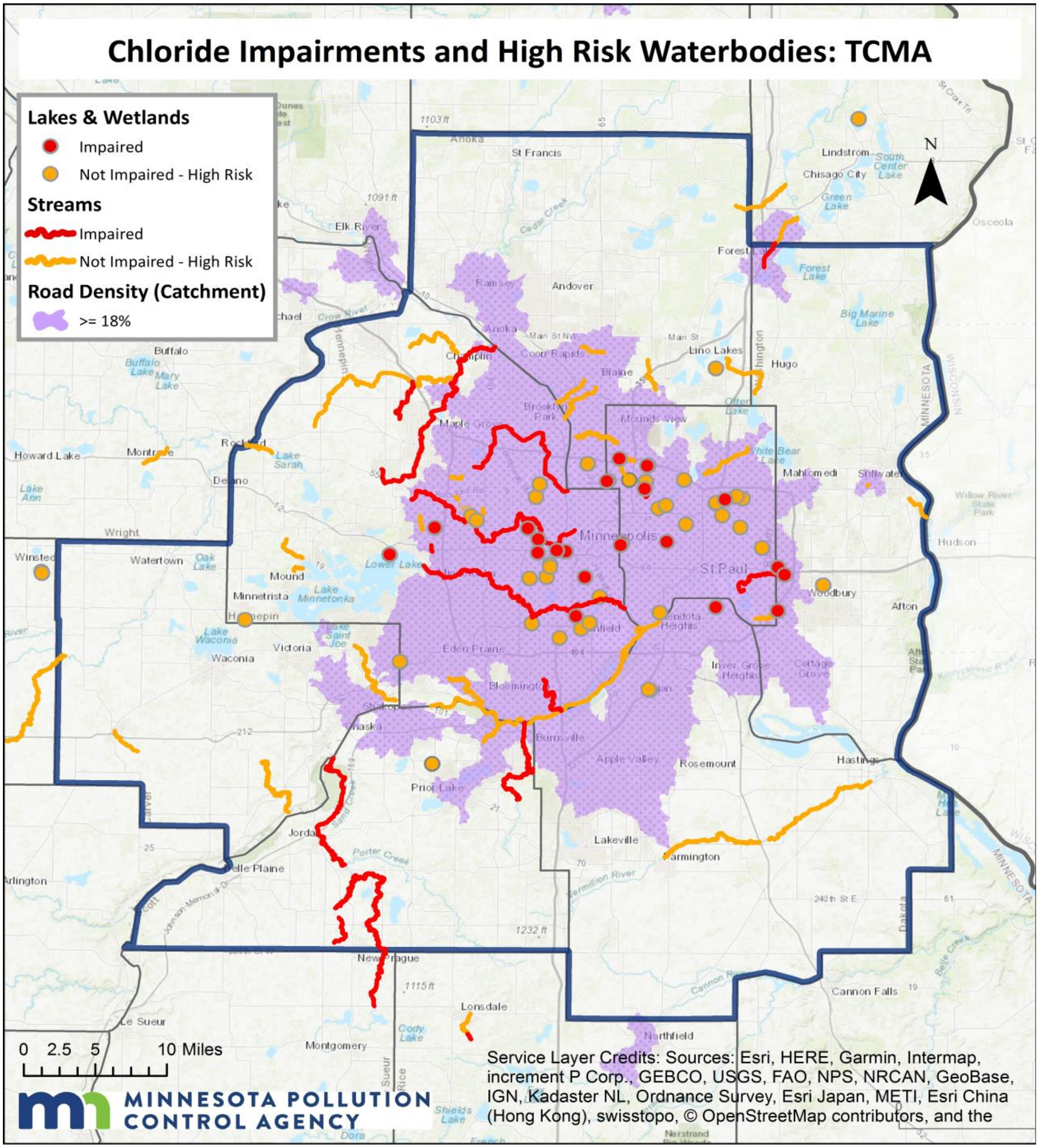


Figure 20: Chloride Condition in TCMA Surface Waters

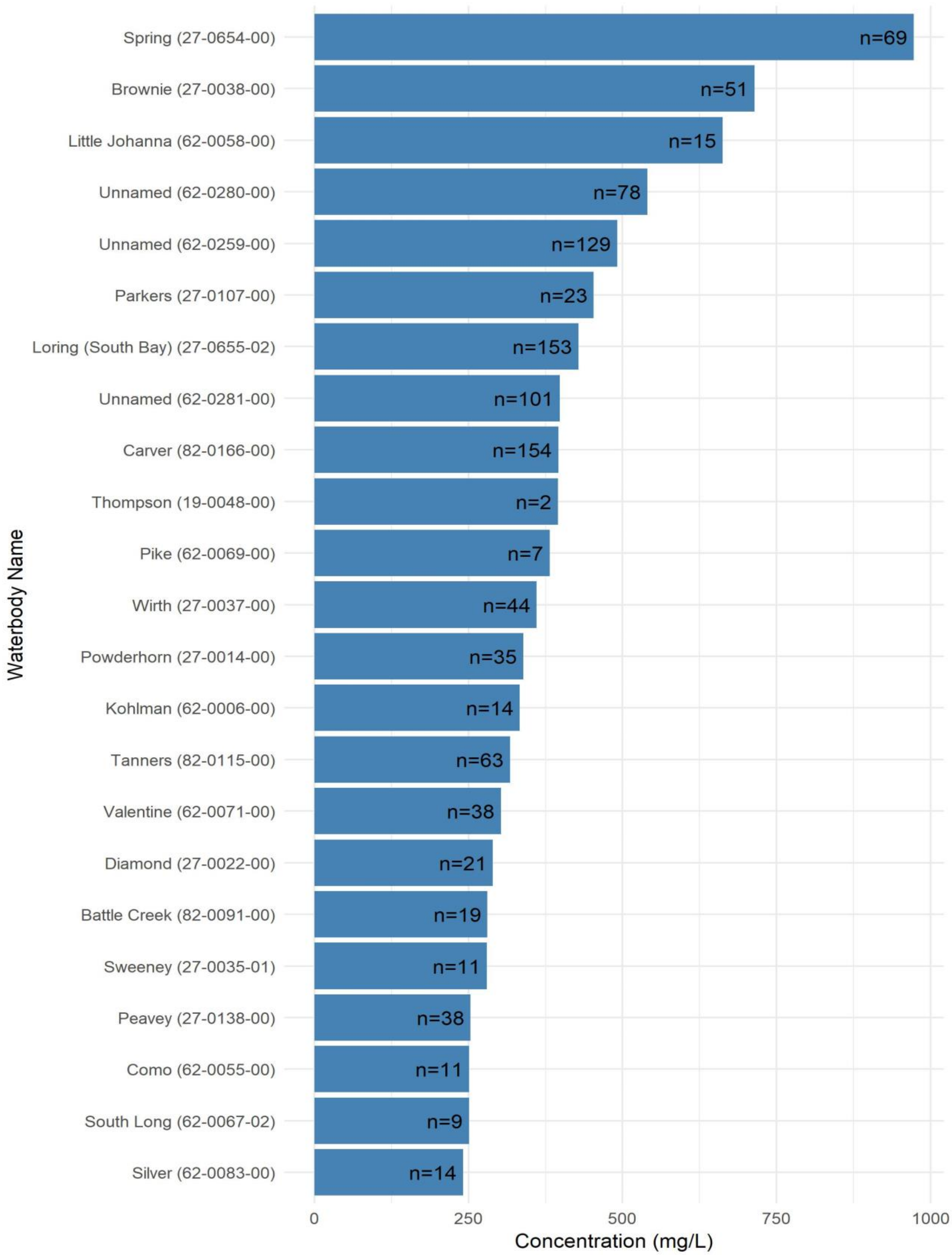


Figure 21: Comparison of lakes and wetlands in the TCMA

Comparison of lakes and wetlands in the TCMA that are listed on the MPCA's 2018 Impaired Waterbodies list. Data from 2008-2017. Average chloride concentration of samples exceeding 230 mg/L; n is the number of days with samples exceeding 230 mg/L.

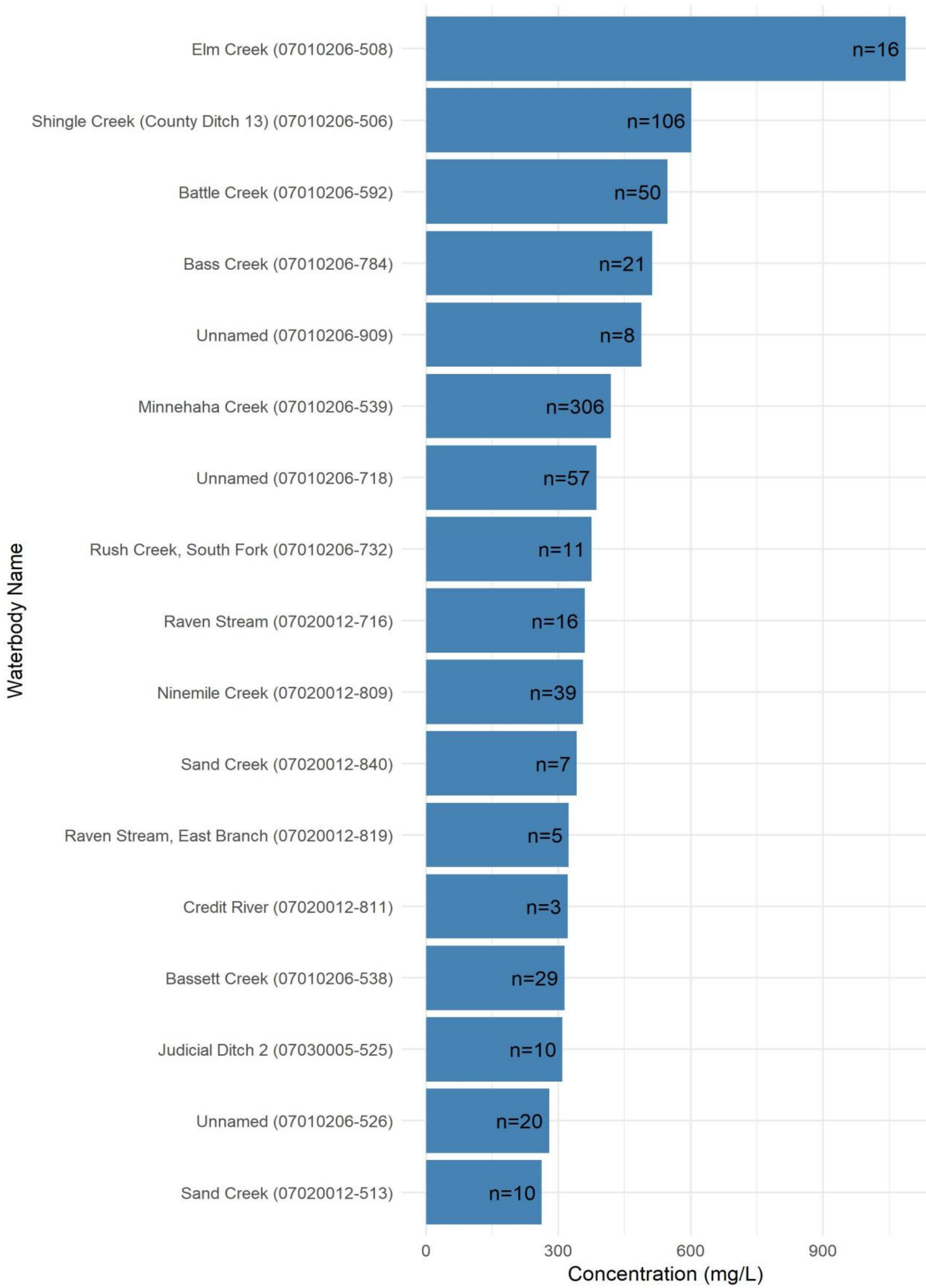


Figure 22: Comparison of streams in the TCMA that are listed on the MPCA's 2018 Impaired Waterbodies list.
Data from 2008-2017. Average chloride concentration of samples exceeding 230 mg/L; n is the number of days with samples exceeding230 mg/L. Multiple unique stream reaches were assessed.

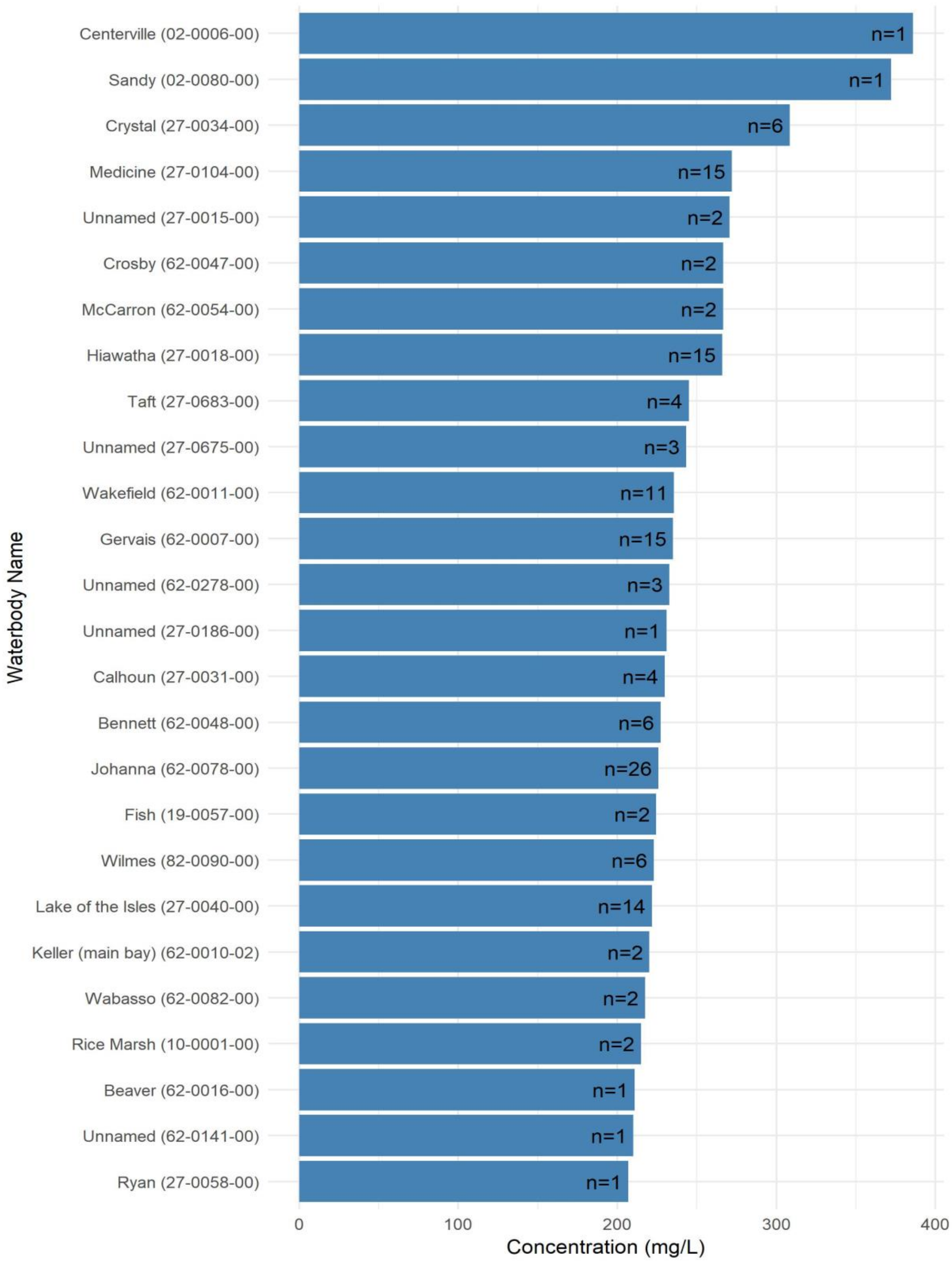


Figure 23: Comparison of high risk lakes in the TCMA that are not listed on the 2018 Impaired Waterbodies list.
High risk waterbodies are defined as those with at least one measured chloride concentration within 10% of the 230 mg/L standard (at least one sample >207 mg/L). Data from 2008-2017. Average chloride concentration of samples exceeding 207 mg/L; n is the number of days with samples exceeding 207 mg/L.

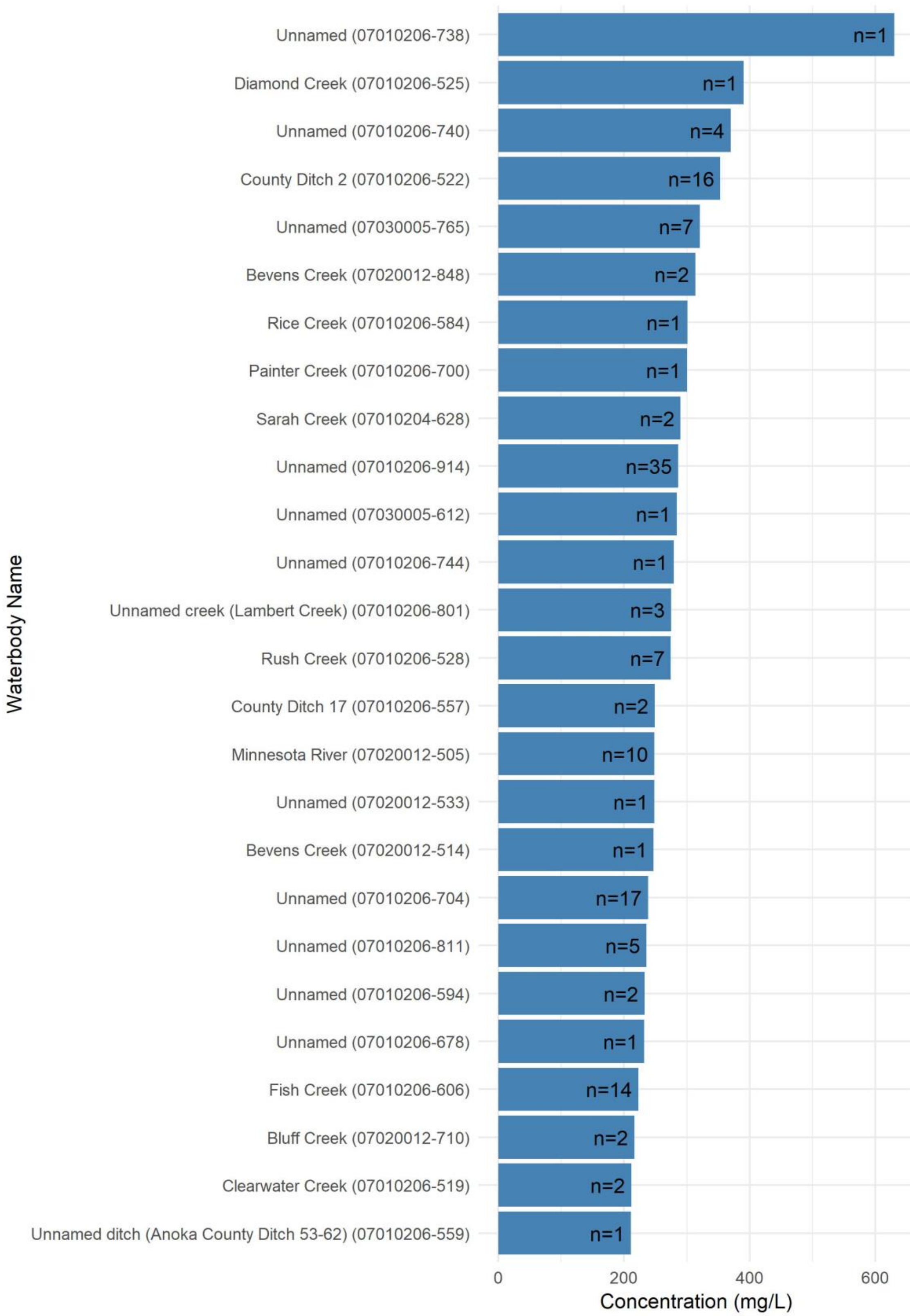


Figure 24: Comparison of high-risk streams in the TCMA that are not listed on the 2018 Impaired Waterbodies list.
High risk waterbodies are defined as those with at least one measured chloride concentration within 10% of the 230 mg/L standard (at least one sample >207 mg/L). Data from 2008-2017. Average chloride concentration of samples exceeding 207 mg/L; n is the number of days with samples exceeding 207 mg/L. Multiple occurrences of a waterbody indicate multiple unique stream reaches were assessed.

Statewide Surface Water Conditions

The 2018 Minnesota impaired waters list currently includes 10 chloride impaired waterbodies located outside of the TCMA. The data gathered from the MPCA EQuIS, USGS NWIS, and MCES EIMS databases included 3,485 statewide sampling locations (excluding the TCMA) and measurements taken as far back as 1945, allowing for an extensive assessment of current and historical impairment conditions. The samples taken from these 3,485 locations demonstrate that 6 lakes and 56 stream reaches have at least one monitored exceedance of 230 mg/L in the last 10 years.

The concentrations of all high risk waterbodies (the lakes, wetlands, and streams with at least one chloride measurement within 10% of 230 mg/L within the last 10 years) are presented alongside those waterbodies with an exceedance of 230 mg/L in Figure 25, Figure 26, and Figure 27, and Table 2 and Table 3. These figures are not a direct reflection of the 303(d) listing assessment; they are intended to make a relative comparison of the extent of impairment across impaired waters, and only reflect those water bodies for which there are available data. The values presented in these figures were calculated by identifying the maximum chloride concentration measured in a waterbody on individual sampling days, then averaging all individual sampling day maximums that were within 10% of the 230 mg/L standard from 2007 through 2017. These figures indicate the variability in one waterbody or watershed to the next by the severity of the impairment. These rankings can be used by chloride users to prioritize management activities specific to areas that are close to impaired and high risk watersheds for further monitoring and higher levels of management.

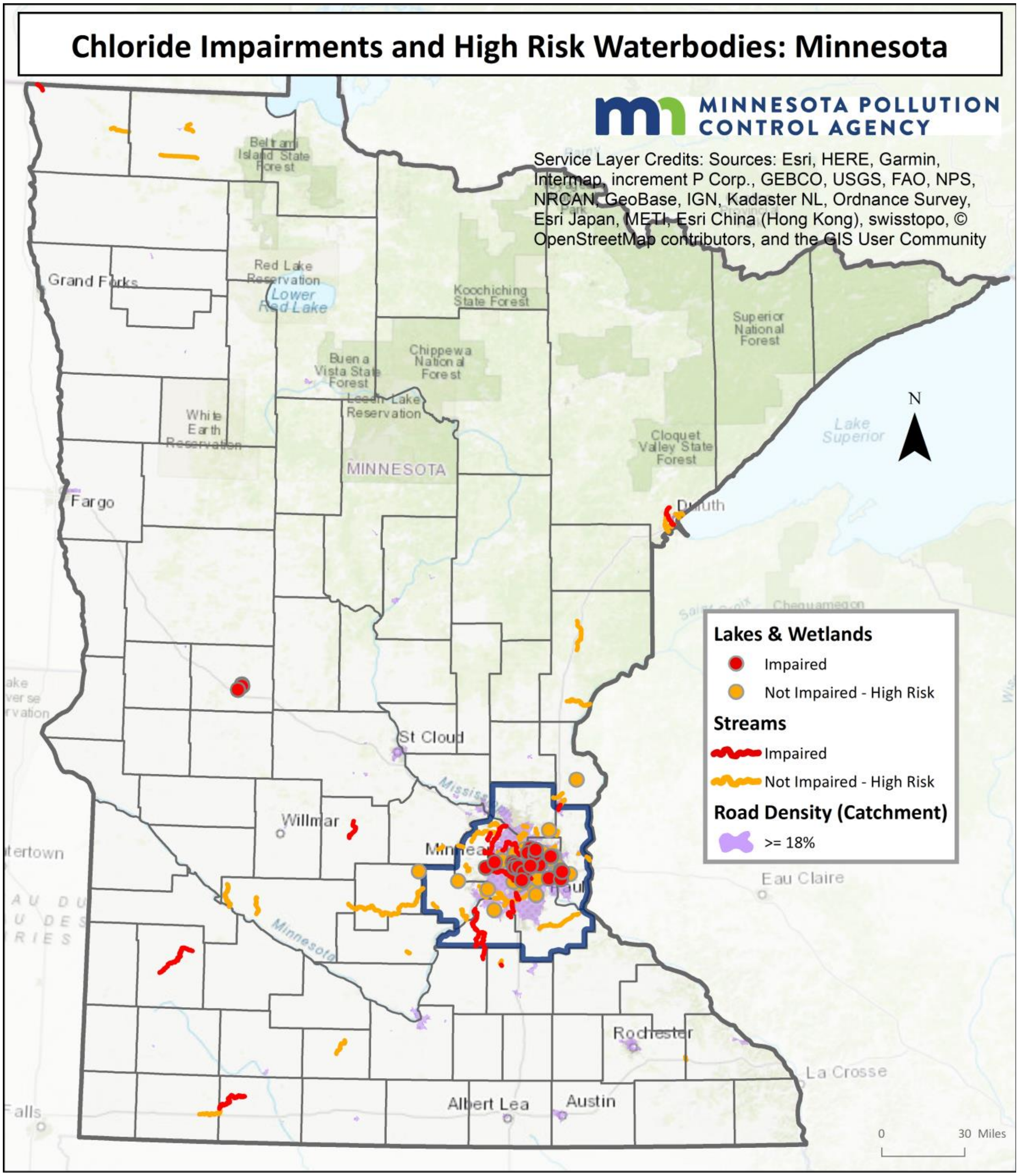


Figure 25: Chloride Conditions in Statewide Minnesota Surface Waters. The concentrations of all high risk waterbodies (the lakes, wetlands, and streams with at least one chloride measurement within 10% of 230 mg/L within the last 10 years) and those waterbodies with an exceedance of 230 mg/L

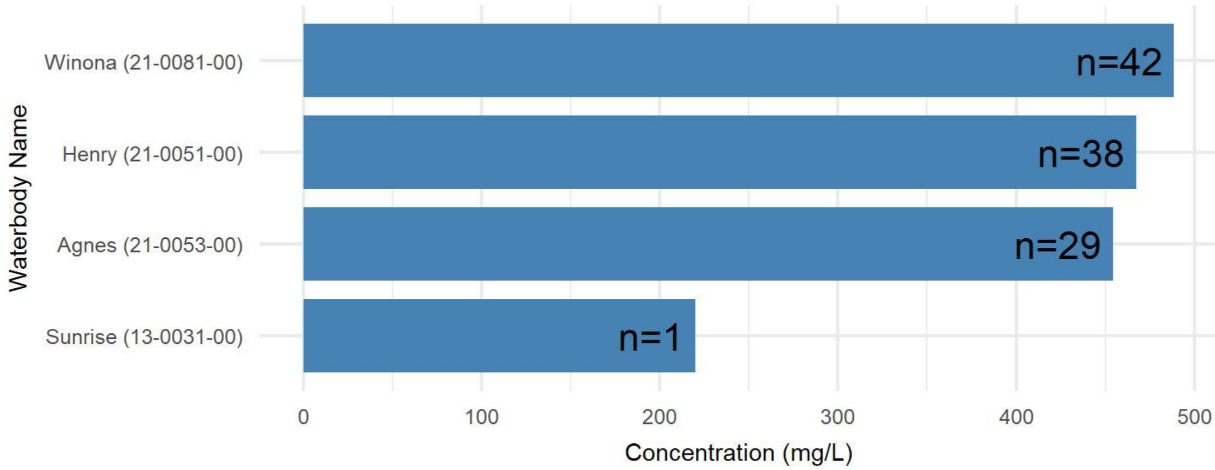


Figure 26: Comparison of statewide lakes outside of the TCMA that are listed on the 2018 Impaired Waterbodies list or are of high risk.

High risk waterbodies are defined as those with at least one measured chloride concentration within 10% of the 230 mg/L standard (at least one sample >207 mg/L). Data from 2008-2017. Average chloride concentration of samples exceeding 230 mg/L; n is the number of days with samples exceeding 230 mg/L.

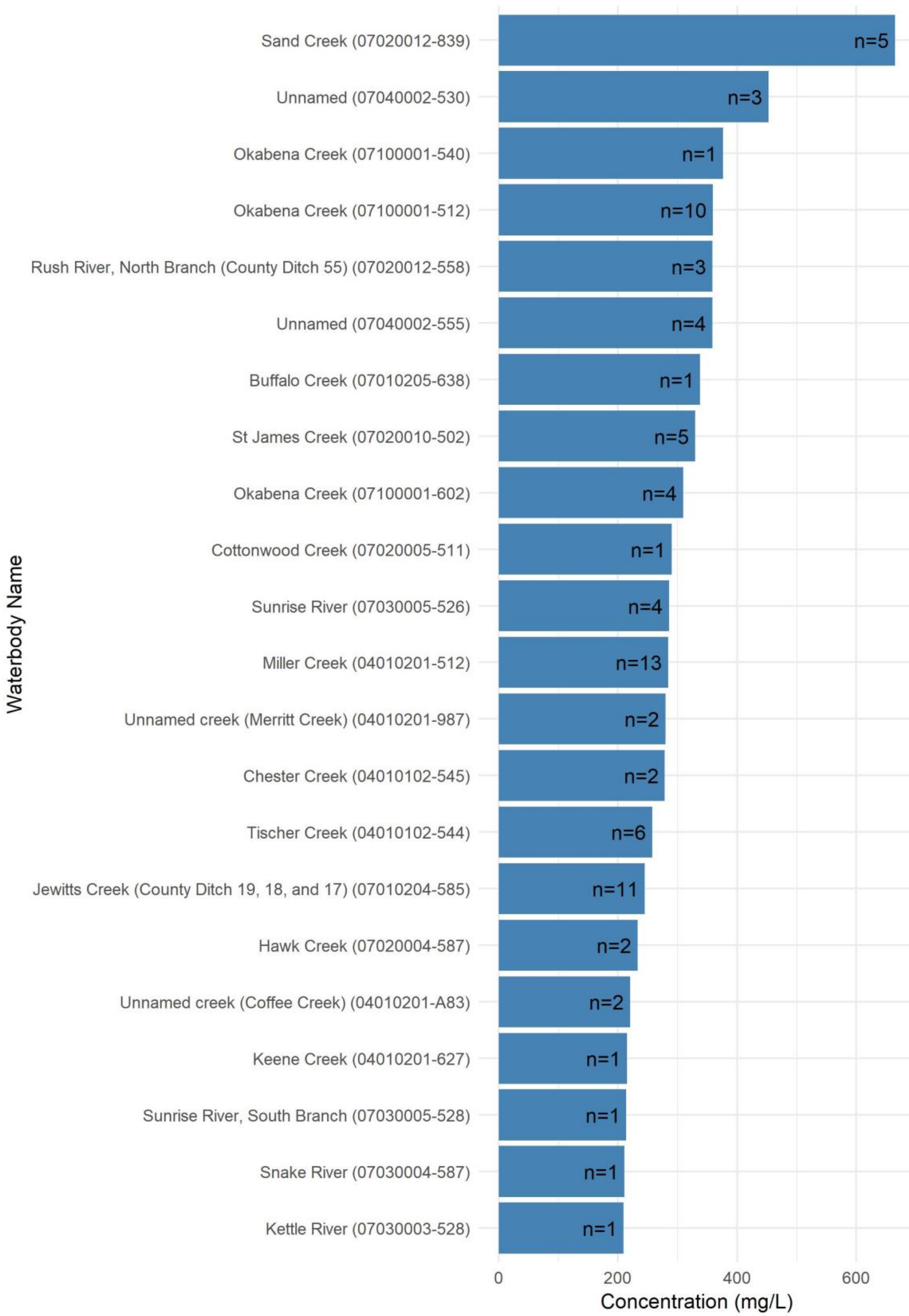


Figure 27: Comparison of statewide streams outside of the TCMA that are listed on the 2018 Impaired Waterbodies list or are of high risk.

High risk waterbodies are defined as those with at least one measured chloride concentration within 10% of the 230 mg/L standard (at least one sample >207 mg/L). Data from 2008-2017. Average chloride concentration of samples exceeding 207 mg/L; n is the number of days with samples exceeding 207 mg/L. Multiple occurrences of a waterbody indicate multiple unique stream reaches were assessed.

Table 2: Impaired and High Risk Lakes and Wetlands in Minnesota

Waterbody Name	Counties	AUID	Status	Highest Observed Chloride Concentration (mg/L)
Agnes	Douglas	21-0053-00	impaired	515
Bass	Hennepin	27-0015-00	high risk	321
Battle Creek	Washington	82-0091-00	impaired	555
Beam Pond	Ramsey	62-0141-00	high risk	210
Beaver	Ramsey	62-0016-00	high risk	211
Bennett	Ramsey	62-0048-00	high risk	234.5
Brownie	Hennepin	27-0038-00	impaired	1250
Calhoun	Hennepin	27-0031-00	high risk	268
Carver	Washington	82-0166-00	impaired	850
Centerville	Anoka	02-0006-00	high risk	386
Como	Ramsey	62-0055-00	impaired	260.5
Crosby	Ramsey	62-0047-00	high risk	322
Crystal	Hennepin	27-0034-00	high risk	526
Fish	Dakota	19-0057-00	high risk	230
Gervais	Ramsey	62-0007-00	high risk	290
Henry	Douglas	21-0051-00	impaired	536
Hiawatha	Hennepin	27-0018-00	high risk	558
Johanna	Ramsey	62-0078-00	high risk	289
Kasota Pond North	Ramsey	62-0280-00	impaired	1823
Kasota Pond West	Ramsey	62-0281-00	impaired	624
Keller (main bay)	Ramsey	62-0010-02	high risk	223
Kohlman	Ramsey	62-0006-00	impaired	1100
Lake of the Isles	Hennepin	27-0040-00	high risk	250
Little Johanna	Arden Hills	62-0058-00	impaired	1060
Loring (South Bay)	Hennepin	27-0655-02	impaired	1273
Mallard Marsh	Ramsey	62-0259-00	impaired	819
McCarron	Ramsey	62-0054-00	high risk	296
Medicine	Hennepin	27-0104-00	high risk	374.88
Mud	Hennepin	27-0186-00	high risk	231
Pamela Pond	Hennepin	27-0675-00	high risk	292
Parkers	Hennepin	27-0107-00	impaired	716
Peavey	Hennepin	27-0138-00	impaired	278
Pike	Ramsey	62-0069-00	impaired	710
Powderhorn	Hennepin	27-0014-00	impaired	660
Rice Marsh	Carver	10-0001-00	high risk	220
Ryan	Hennepin	27-0058-00	high risk	207
Sandy	Anoka	02-0080-00	high risk	372
Silver	Ramsey	62-0083-00	impaired	276
South	McLeod	43-0014-00	high risk	310
South Long	Ramsey	62-0067-02	impaired	298

Waterbody Name	Counties	AUID	Status	Highest Observed Chloride Concentration (mg/L)
Spring	Hennepin	27-0654-00	impaired	1881
Sunrise	Chisago	13-0031-00	high risk	220
Sweeney	Hennepin	27-0035-01	impaired	341
Taft	Hennepin	27-0683-00	high risk	259
Tanners	Washington	82-0115-00	impaired	530
Thompson	Dakota	19-0048-00	impaired	460
Unnamed	Ramsey	62-0278-00	high risk	248
Valentine	Ramsey	62-0071-00	impaired	399.5
Wabasso	Ramsey	62-0082-00	high risk	225
Wakefield	Ramsey	62-0011-00	high risk	350
Wilmes	Washington	82-0090-00	high risk	235
Winona	Douglas	21-0081-00	impaired	593
Wirth	Hennepin	27-0037-00	impaired	815

Table 3: Impaired and High Risk Streams in Minnesota

Waterbody Name	Counties	AUID	Status	Highest Observed Chloride Concentration (mg/L)
Bass Creek	Hennepin	07010206-784	impaired	1930
Bassett Creek	Hennepin	07010206-538	impaired	551
Bassett Creek - Medicine Lk to underground diversion at Van White Memorial Blvd	Hennepin	07010206-811	high risk	250
Battle Creek	Ramsey, Washington	07010206-592	impaired	2248
Bevens Creek	Carver	07020012-514	high risk	247
Bevens Creek	Carver	07020012-848	high risk	374
Bluff Creek	Carver	07020012-710	high risk	717
Buffalo Creek	Carver, McLeod, Renville, Sibley	07010205-638	high risk	338
Chester Creek	St. Louis	04010102-545	high risk	330
Clearwater Creek	Anoka, Washington	07010206-519	high risk	213
Cottonwood Creek	Chippewa, Swift	07020005-511	high risk	290
County Ditch 17	Anoka	07010206-557	high risk	253
County Ditch 2	Ramsey	07010206-522	high risk	755
Credit River	Scott	07020012-811	impaired	388.9
Diamond Creek	Hennepin	07010206-525	high risk	390
Dutch Lake Outlet	Hennepin	07010206-678	high risk	232
Eagle Creek	Scott	07020012-519	high risk	437
Elm Creek	Hennepin	07010206-508	impaired	1600
Fish Creek	Ramsey, Washington	07010206-606	high risk	244

Waterbody Name	Counties	AUID	Status	Highest Observed Chloride Concentration (mg/L)
Hawk Creek	Renville	07020004-587	high risk	250
Jewitts Creek (County Ditch 19, 18, and 17)	Meeker	07010204-585	impaired	310
Joe River	Kittson	09020311-513	impaired	
Judicial Ditch 2	Washington	07030005-525	impaired	499
Keene Creek	St. Louis	04010201-627	high risk	215
Kettle River	Pine	07030003-528	high risk	209
Miller Creek	St. Louis	04010201-512	impaired	440
Minnehaha Creek	Hennepin	07010206-539	impaired	3457
Minnesota River	Dakota, Hennepin, Ramsey, Scott	07020012-505	high risk	366
Ninemile Creek	Hennepin	07020012-809	impaired	796
Okabena Creek	Jackson, Nobles	07100001-512	high risk	413
Okabena Creek	Nobles	07100001-540	high risk	376
Okabena Creek	Jackson	07100001-602	impaired	344
Painter Creek	Hennepin	07010206-700	high risk	300
Purgatory Creek	Hennepin	07020012-828	high risk	221
Raven Stream	Scott	07020012-716	impaired	781
Raven Stream, East Branch	Scott	07020012-819	impaired	391
Redwood River	Lyon	07020006-502	impaired	530
Rice Creek	Anoka, Ramsey	07010206-584	high risk	301
Rush Creek	Hennepin	07010206-528	high risk	405
Rush Creek, South Fork	Hennepin	07010206-732	impaired	750
Rush River, North Branch	Sibley	07020012-558	high risk	428
Sand Creek	Le Sueur	07020012-839	impaired	367
Sand Creek	Le Sueur, Scott	07020012-840	impaired	987
Sand Creek	Scott	07020012-513	impaired	475
Sarah Creek	Hennepin, Wright	07010204-628	high risk	290
Shingle Creek (County Ditch 13)	Hennepin	07010206-506	impaired	3600
Snake River	Pine	07030004-587	high risk	211
St James Creek	Watonwan	07020010-502	high risk	533
Sunrise River	Chisago, Washington	07030005-526	high risk	468
Sunrise River, South Branch	Anoka, Chisago	07030005-528	high risk	214
Tischer Creek	St. Louis	04010102-544	high risk	436
Unnamed	Washington	07030005-612	high risk	284
Unnamed	Ramsey	07010206-801	high risk	310
Unnamed	Anoka	07010206-594	high risk	246

Waterbody Name	Counties	AUID	Status	Highest Observed Chloride Concentration (mg/L)
Unnamed	Anoka	07010206-559	high risk	211
Unnamed	Hennepin	07010206-738	high risk	630
Unnamed	Hennepin	07010206-740	high risk	415
Unnamed	Washington	07030005-765	high risk	588
Unnamed	St. Louis	04010201-987	high risk	295
Unnamed	Anoka	07010206-744	high risk	279
Unnamed	Carver	07020012-533	high risk	248
Unnamed	Cannon River	07040002-530	high risk	538
Unnamed	St. Louis	04010201-A83	high risk	230
Unnamed Creek	Hennepin	07010206-704	high risk	382
Unnamed creek	Hennepin	07010206-526	impaired	404.9
Unnamed creek	Hennepin	07010206-718	impaired	688
Unnamed creek	Ramsey	07010206-909	impaired	1140
Unnamed creek - to Long Lk	Ramsey	07010206-914	high risk	600
Unnamed creek - Woodland WMA wetland (86-0085-00) to N Fk Crow R	Wright	07010204-667	high risk	260
Unnamed ditch	Rice	07040002-555	impaired	417

Statewide Groundwater Conditions

Chloride concentrations in shallow groundwater are high in urban areas, likely as a result of the application of deicing salt. This correlation is observed in several studies conducted by the MPCA and USGS (Fong 2000; Trojan et al.2003; Kroening and Ferrey 2013), which found that chloride concentrations were higher in wells sampled in urban areas, where salt is commonly applied in winter months, compared to wells sampled in areas that were undeveloped. Recent enhancements to the MPCA's ambient groundwater quality monitoring network, combined with data collected from the Minnesota Department of Agriculture's ambient network, in 2014 provide the best picture on how concentrations in the state's shallow groundwater vary with land use (Kroening and Vaughan 2019). These monitoring network enhancements included the installation of about 150 new shallow monitoring wells in land use settings that were underrepresented by the current network, such as commercial/industrial areas and residential areas that use subsurface sewage treatment systems for wastewater treatment and disposal. The monitoring of this enhanced network found the highest chloride concentrations generally occurred in commercial/industrial and residential areas that are served by centralized sewage treatment systems (Table 4) (likely because of the high density of impervious surfaces, more pavement to salt, and high level of service expectations for clear winter pavement in these sewered areas).

Table 4: Median chloride concentrations in groundwater based on land use, 2013-2017 (Kroening and Vaughan 2019)

Land Use	Median Chloride (mg/L)
Sewered Residential	45 mg/L
Unsewered Residential	16 mg/L
Commercial/Industrial	82 mg/L
Agricultural	14 mg/L
Undeveloped	1 mg/L

Minnesota is one of the few states in the U.S. that collects sufficient groundwater quality data to determine if trends in chloride concentration are present. This work has found that chloride concentrations are increasing in both the shallow groundwater and aquifers used for water supply. The wells with chloride data that extend the furthest back in time are located in the vicinity of Bemidji, Brooklyn Center, and St. Cloud. The data in some of the wells in Bemidji extend back to 1987, and the data from the other wells extend back to the mid-1990s. The MPCA analyzed the data from these wells for chloride trends using all of the information collected up to 2011, and found that concentrations significantly increased in 30% of the tested wells. The MPCA recently updated this analysis using information collected from 2005 through 2017 (Kroening and Vaughan 2019). This updated analysis included additional wells located in several other cities such as Austin, Rochester, and Wabasha and many of these wells were installed in the deep bedrock aquifers. The MPCAs updated trend analysis found that chloride concentrations had a statistically significant upward trend in 40% of the tested wells, and most of these were installed in the state's bedrock aquifers (Figure 28 and Figure 29). In a well located near the City of Austin, the chloride concentration increased from 13 mg/L in 2005 to almost 52 mg/L in 2017.

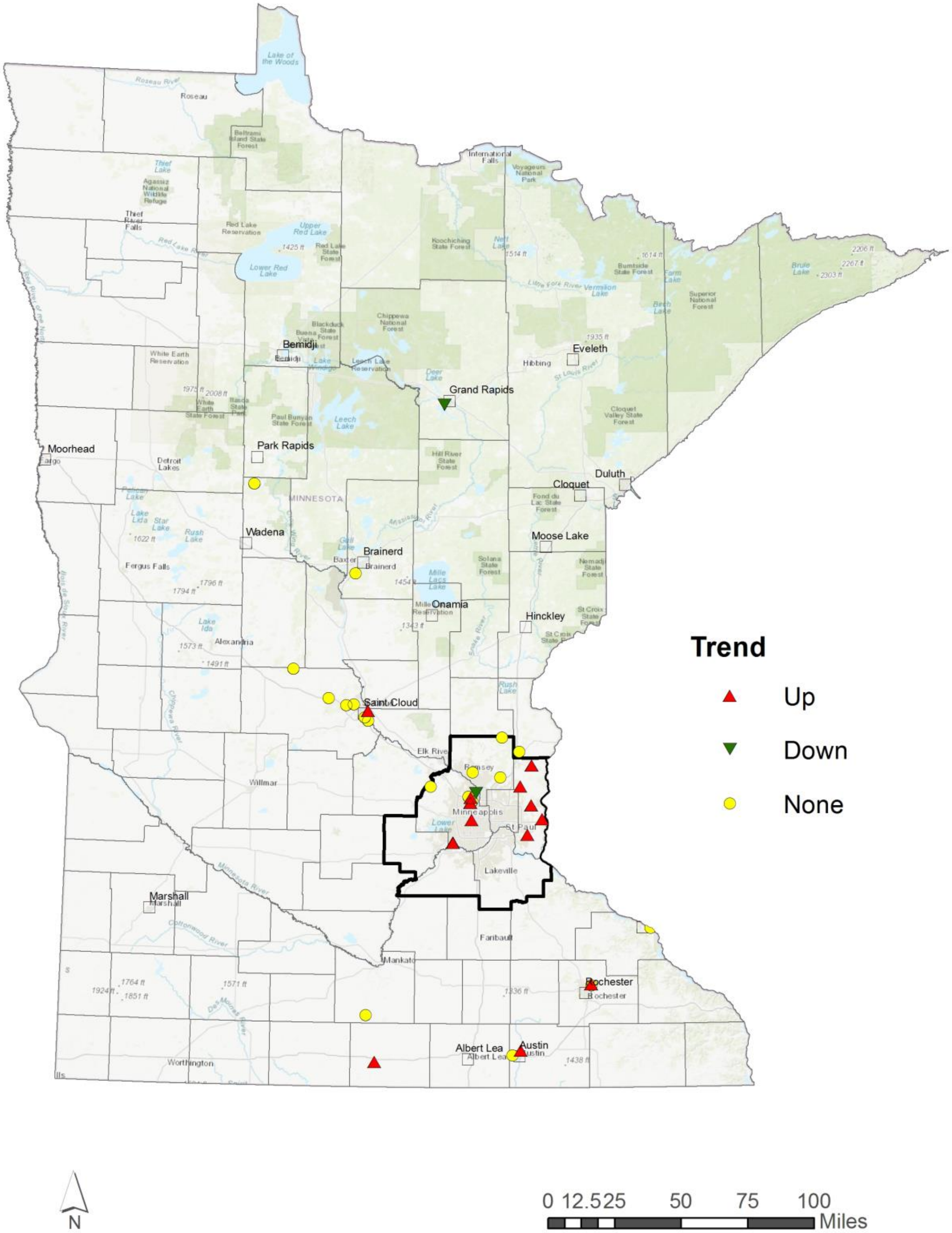


Figure 28: Map showing temporal trends in chloride concentrations in Minnesota's groundwater, 2005-2017.

The highest chloride concentrations typically were measured in the shallow groundwater in the TCMA. The most recent assessment of chloride concentrations in the state's groundwater used information from 2013 through 2017. Twenty-four of the monitoring wells contained water in which the chloride concentration exceeded the SMCL of 250 mg/L set by the EPA for drinking water. Most of these were shallow monitoring wells, with a median depth of 26 feet. Two-thirds of the wells with chloride concentrations exceeding the SMCL were located in the TCMA, and the remaining wells were located in other urban areas such as Cloquet or Moose Lake.

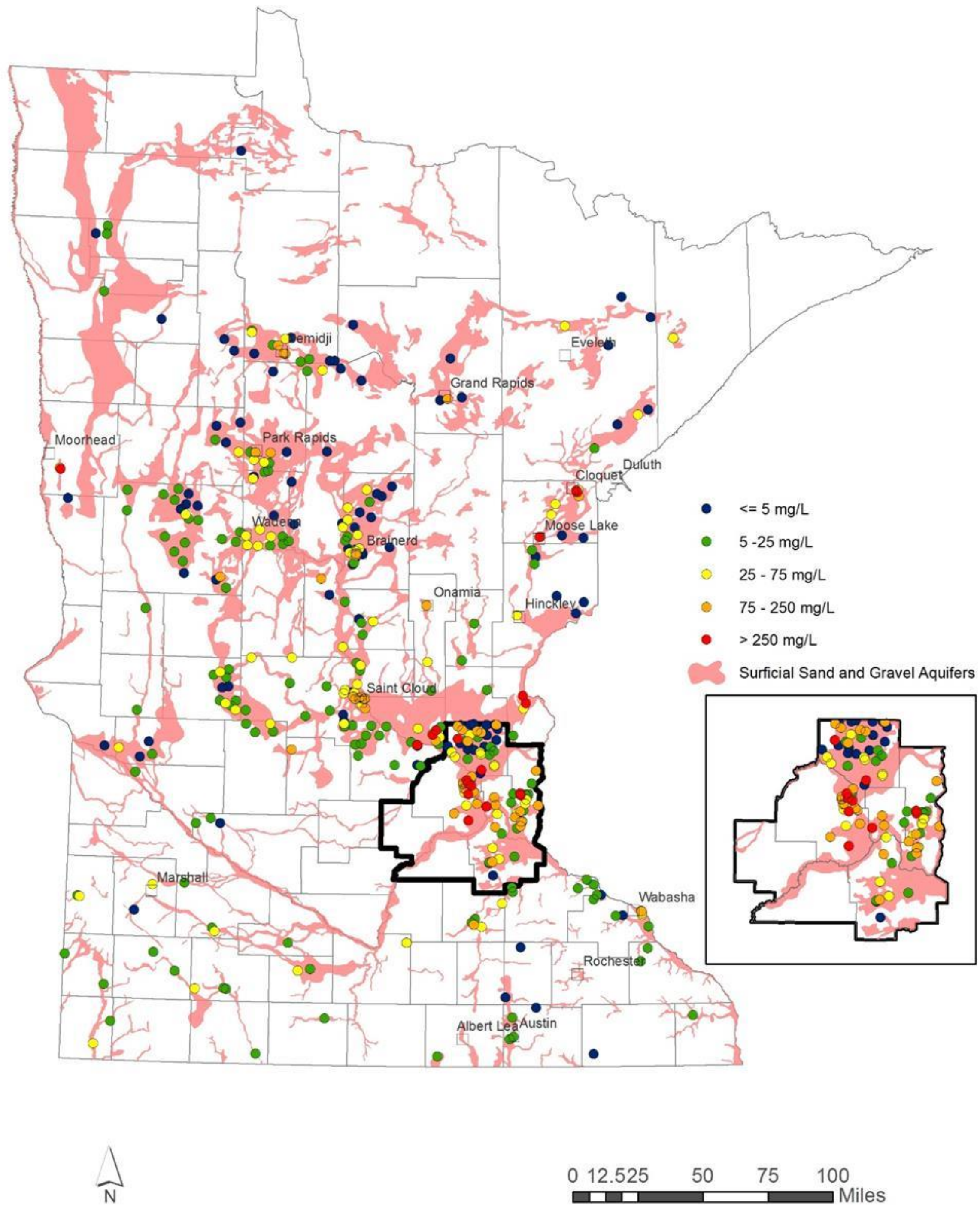


Figure 29: Chloride concentrations in ambient groundwater from the sand and gravel aquifers

The Dakota County Environmental Resources Department conducted an Ambient Groundwater Quality Study that looked at a 20 year period to evaluate groundwater conditions across Dakota County in three principal drinking water aquifers (Demuth and Scott 2020). The study confirms elevated chloride levels in groundwater in urbanized areas where de-icer and water softener use is greater. It was also found that concentrations of chloride generally decrease with well depth, with many wells (28 of 70) showing an upward trend in chloride concentration (Figure 30). This study is a good resource for understanding the conditions and trends of ambient groundwater data at a county level, and only a small component of the study is provided here. https://www.co.dakota.mn.us/Environment/WaterResources/WellsDrinkingWater/Documents/AmbientGroundwaterStudy2019.pdf

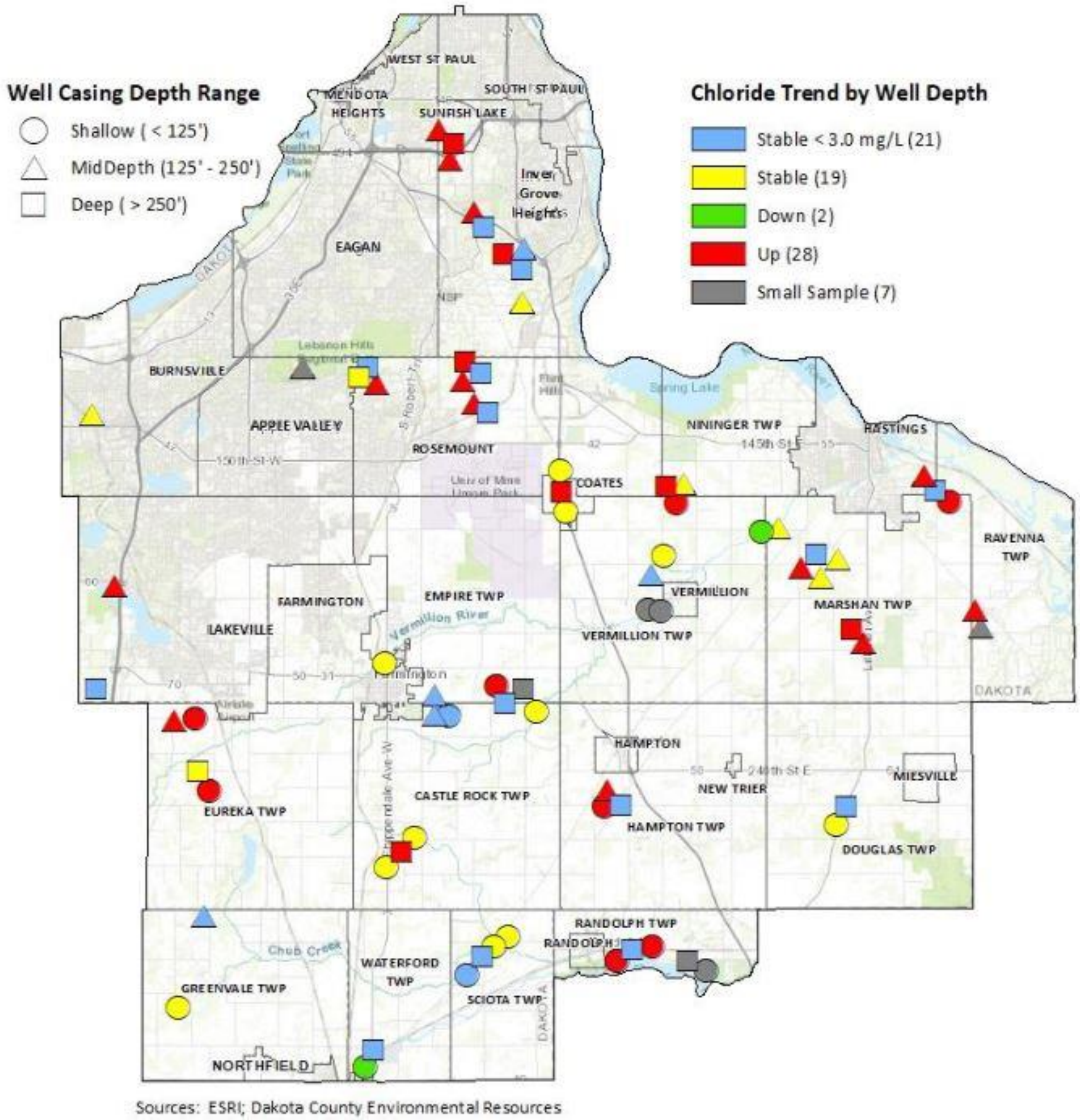


Figure 30: Chloride Trends (Demuth and Scott 2020)

4.3. Chloride Trends

This section presents evaluations of chloride water quality conditions in Minnesota considering:

- Seasonal chloride trends in surface waters
- Long-term chloride trends
    - Chloride trends within lakes
    - Chloride trends within streams and rivers
    - Chloride trends in groundwater
- Chloride relationships to watershed characteristics
- Chloride relationships within ecoregions
- Chloride concentrations in stormwater
- Chloride relationships between surface and groundwater

This information is intended to help inform management decisions, such as where and when to focus monitoring efforts and where to prioritize implementation activities.

Seasonal Chloride Variation in Surface Waters

Chloride data were evaluated for seasonal variation by looking at monthly chloride concentrations. Seasonal variation can help determine the cause of elevated chloride concentrations. Causes can be direct runoff from winter maintenance practices using chloride, dust control areas using chloride based dust suppressants, agricultural areas using chloride based fertilizers, groundwater inputs (primarily from infiltrated chloride containing deicers) during low flow, septic inputs, and WWTP inputs.

For the majority of lakes with adequate sampling coverage (30 or more total samples, collected in at least five calendar years and in at least seven months), chloride concentrations were most often highest in February through May Figure 31. In the majority of these lakes, monthly average concentrations in January through June were above the overall average, while July through November monthly averages were below the overall average. No December data was available for the 82 lakes meeting this coverage criteria.

Figure 32 presents an example of the seasonal variability observed in Powderhorn Lake (27-0014-00) in Minneapolis. Powderhorn Lake does not have a natural outlet and has little opportunity to flush chloride from the lake. In this particular lake, measured chloride concentrations indicate an under-ice chemical gradient, as concentrations were significantly less in surface samples than those taken 3 meters or more below the surface in January and February (Wilcox Mann Whitney test, $p < 0.05$). For streams, chloride concentrations were highest December through April in many cases, but there were also a number of streams with concentration peaks during summer months. Lakes tended to show less variation seasonally than streams, as would be expected due to the longer residence time and mixing that occurs in a lake.

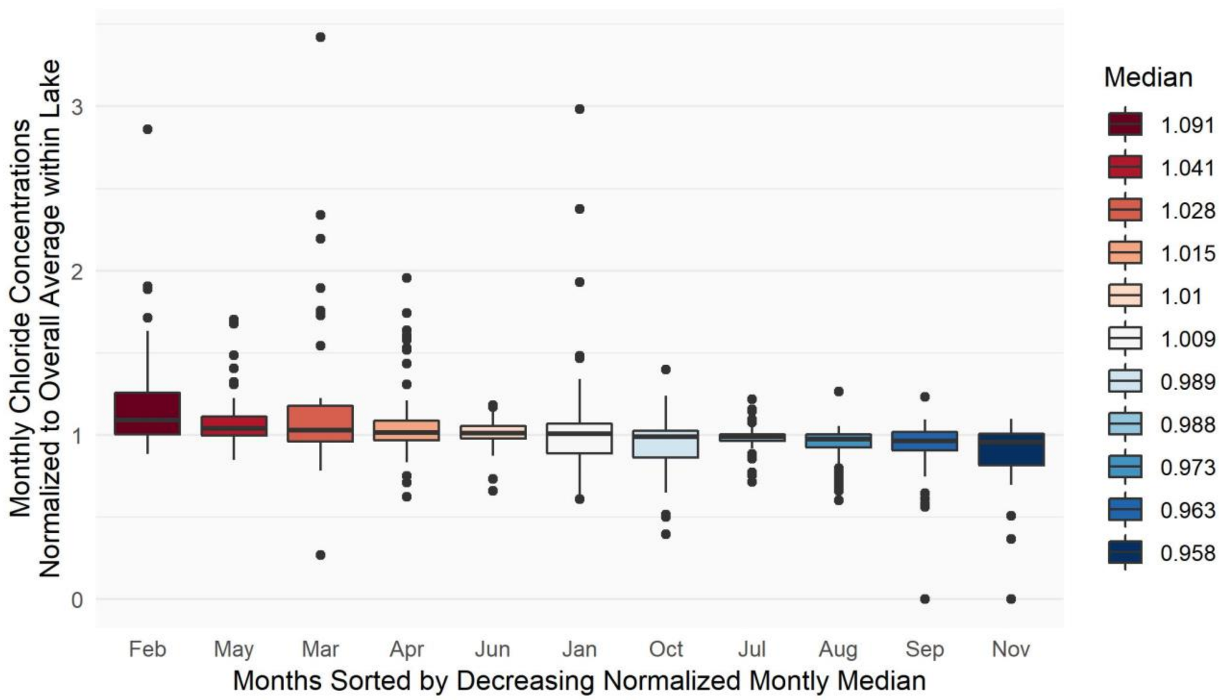


Figure 31: Distribution of Monthly Surface Cl Concentrations in Lakes Normalized by Total Mean Lake Concentrations. Only lakes with 30 or more total samples, collected in at least five calendar years and in at least 7 months, were included. Averages include samples taken at any depth throughout the water column.

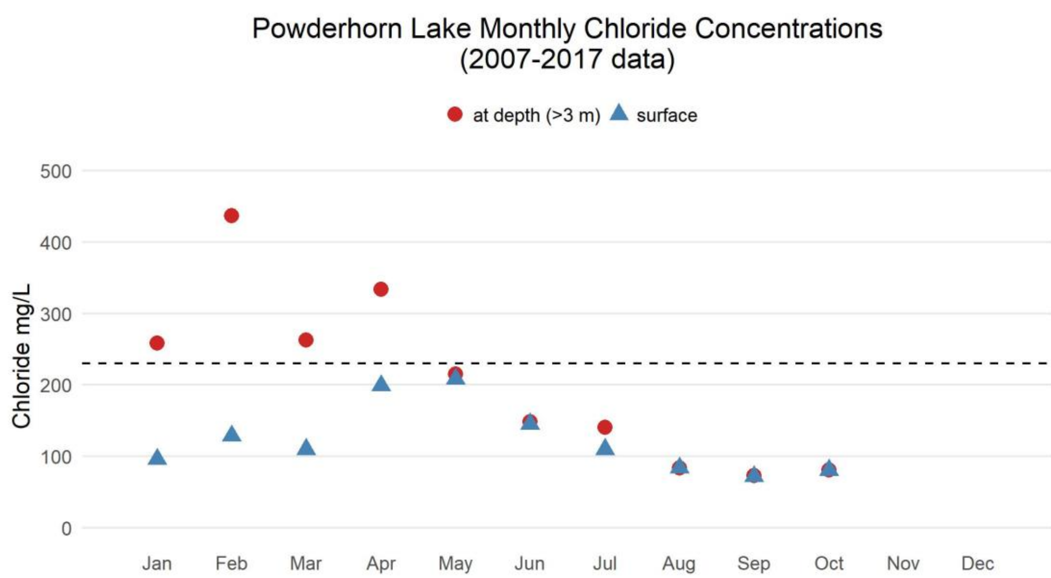


Figure 32: Monthly average chloride concentrations in Powderhorn Lake (27-0014-00). Surface concentrations were significantly less in January and February (Wilcox Mann Whitney test, $p < 0.05$).

Figure 33 and Figure 34 present examples of the seasonal variability observed in Buffalo River and Battle Creek, respectively. These two streams are in very different watersheds, with the Buffalo River being in a more rural and less developed watershed than the largely urban Battle Creek. The increased levels of observed concentrations of chloride in both streams are present during the winter months (November through February). The sources and factors affecting the chloride concentrations in these streams are anticipated to be different given the differences in watershed characteristic. As such, each should be evaluated and discussed with these differences in mind.

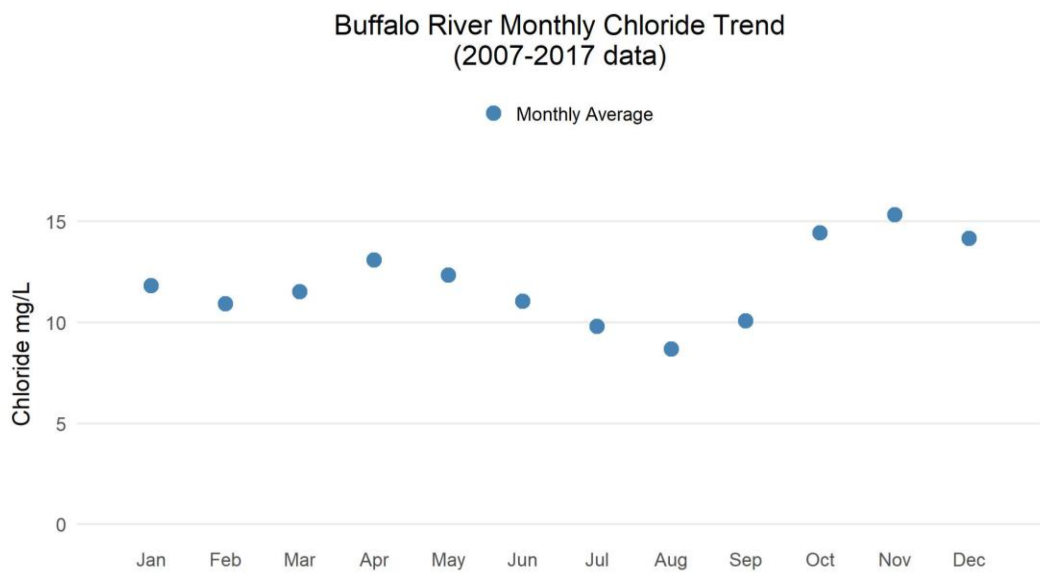


Figure 33: Monthly average chloride concentrations in the Buffalo River (09020106-501) in the South Fork Crow River Watershed

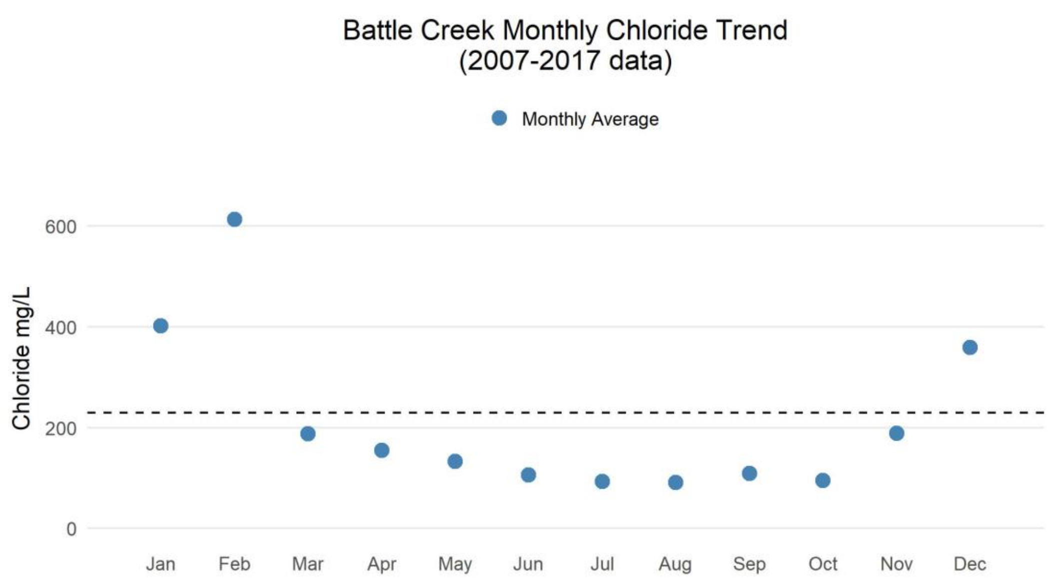


Figure 34: Monthly average chloride concentrations in Battle Creek (07010206-592) in St. Paul.

There are some streams where chloride concentrations are influenced significantly by sources other than winter maintenance activities, such as WWTPs. These streams tended to show the highest chloride concentrations when flows were low. Low flows generally occur during winter months and dry summer months (July through September) when runoff is low. Sand Creek is an example and is shown in Figure 35. Chloride concentrations in Sand Creek were highest in late summer and winter and lowest in spring and early summer. Limited chloride data from the WWTPs discharging to Sand Creek (07020012-513, 07020012-840, 07020012-839) confirm this as a significant source of chloride. Beaver River (04010102-501) is another waterbody that exhibits high chloride concentrations in summer, as shown in Figure 36.

There are several wastewater discharge permits located near the Beaver River sampling location, suggesting there are likely point source discharges of chloride along the river. Specific investigation would be required in order to fully understand the chloride detailed sources at this location.

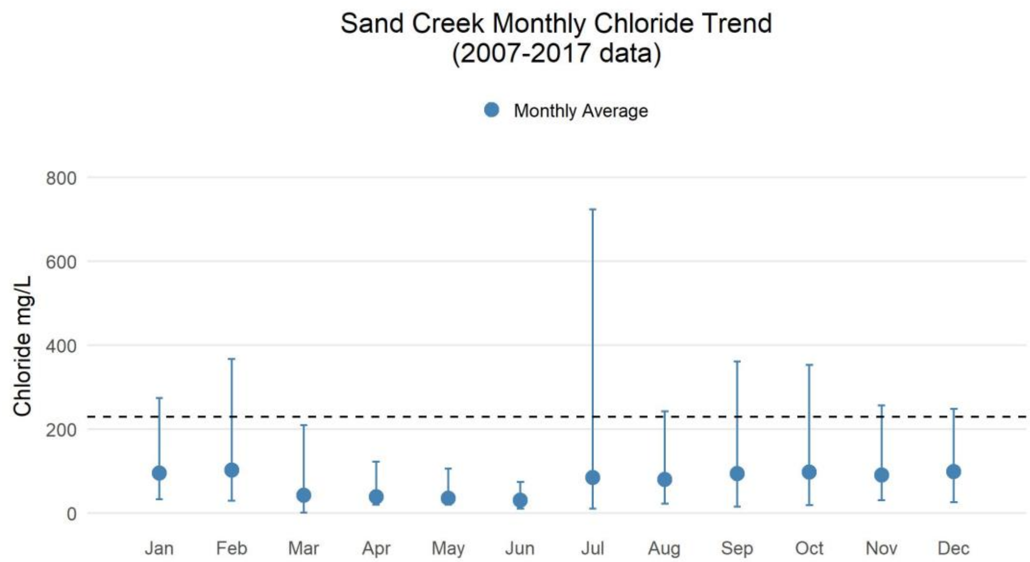


Figure 35: Monthly chloride concentrations (average, maximum, and minimum) in Sand Creek *(data from two consecutive reaches, AUID 07020012-513 and 07020012-840, were aggregated)*

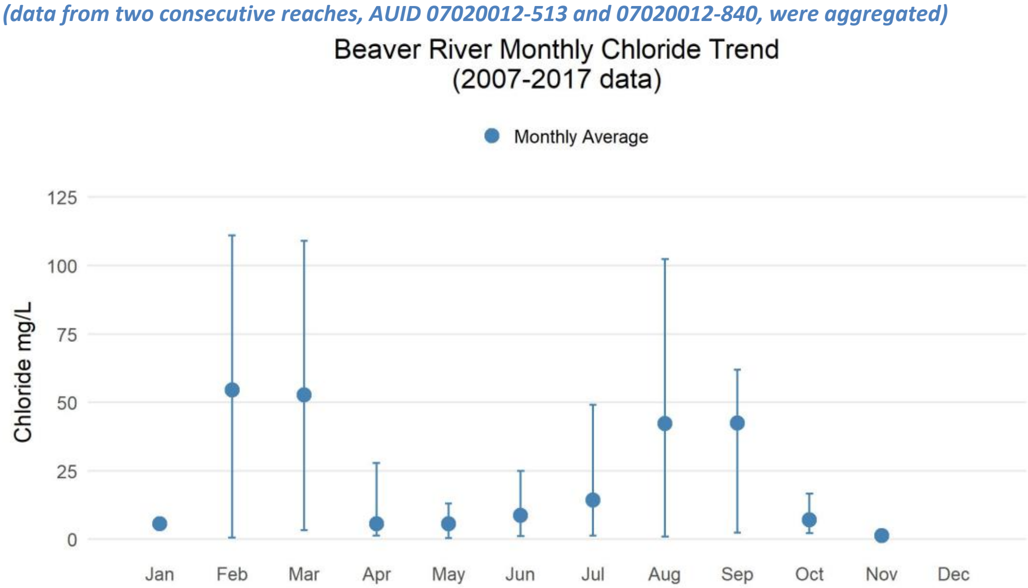


Figure 36: Monthly chloride concentrations (average, maximum, and minimum) in Beaver River (04010102-501)

Chloride Trends in Surface Waters

Chloride trends in lakes

Statistical trend analyses require a long, mostly continuous, monitoring record. Sufficient data were available to conduct statistical trend analysis for 114 lakes or lake bays, 69 of which were in the TCMA. Trends were determined using the Seasonal Mann Kendall Trend Test with R Statistical Software and are presented in Table 5 (TCMA) and Table 6 (statewide). Lakes with a minimum of 10 years of data were analyzed and only samples collected from the surface were used in the analyses. Sixty lakes showed a significant ($p < 0.05$) increasing trend in chloride, 46 of which were located in the TCMA while 14 were outstate. Fifty-three lakes did not have a significant trend, and a single lake (Sand Lake in Carlton County) had a decreasing trend. Figure 38 shows an increasing trend in chloride concentration in Gervais Lake in the TCMA. Figure 40 and Figure 41 show the increasing trend in chloride concentration in Zumwalde and Horseshoe. The other lakes in Table 5 and Table 6 show similar trends.

Table 5: Chloride Trends in Lakes in the TCMA.
The Seasonal Mann-Kendall test indicates whether the chloride concentrations versus time are increasing (positive value) or decreasing (negative value).

Lake	Lake ID Number	Period	Condition	Median [Cl] (mg/L)	Percent change/year (%)	Trend Description
Snail	62-0073-00	1974-2016	Not Exceeding	31	6.8%	Increasing
Armstrong-South Portion	62-0073-00	2002-2014	Not Exceeding	88	5.4%	Increasing
Powers	82-0092-00	2003-2014	Not Exceeding	40	5.3%	Increasing
Valentine	62-0071-00	1980-2016	Exceeds Criteria	114	5.0%	Increasing
Spring	27-0654-00	1994-2015	Exceeds Criteria	752	4.4%	Increasing
Big Marine (Main Lake)	82-0052-04	1969-2011	Not Exceeding	11	4.1%	Increasing
Kohlman	62-0006-00	1981-2016	Exceeds Criteria	67	3.7%	Increasing
Gervais	62-0007-00	1981-2016	Exceeds Criteria	94	3.6%	Increasing
Keller (main bay)	62-0010-02	1976-2016	Not Exceeding, High Risk	84	3.6%	Increasing
Round	62-0012-00	1981-2016	Exceeds Criteria	88	3.6%	Increasing
Phalen	62-0013-00	1971-2016	Not Exceeding	78	3.5%	Increasing
Upper Prior	70-0072-00	1969-2016	Not Exceeding	49	3.5%	Increasing
Piersons	10-0053-00	1988-2016	Not Exceeding	26	3.4%	Increasing
South Long	62-0067-02	1971-2016	Exceeds Criteria	108	3.4%	Increasing
Square	82-0046-00	1972-2009	Not Exceeding	6	3.3%	Increasing
Johanna	62-0078-00	1971-2016	Exceeds Criteria	121	3.2%	Increasing
Silver	62-0001-00	1971-2016	Exceeds Criteria	82	3.1%	Increasing
Tanners	82-0115-00	1989-2016	Exceeds Criteria	154	3.0%	Increasing
Turtle	62-0061-00	1980-2016	Not Exceeding	28	3.0%	Increasing
North Long	62-0067-01	1985-2016	Not Exceeding	55	2.9%	Increasing
Otter	02-0003-00	1980-2016	Not Exceeding	32	2.9%	Increasing
Brownie	27-0038-00	1978-2016	Exceeds Criteria	210	2.8%	Increasing
Josephine	62-0057-00	1971-2016	Not Exceeding	53	2.8%	Increasing
Wirth	27-0037-00	1975-2016	Exceeds Criteria	152	2.8%	Increasing
Christmas	27-0137-00	1963-2016	Not Exceeding	28	2.5%	Increasing
Nokomis	27-0019-00	1971-2016	Not Exceeding	88	2.5%	Increasing
Silver	62-0001-00	1971-2016	Not Exceeding	75	2.5%	Increasing
White Bear	82-0167-00	1962-2016	Not Exceeding	30	2.5%	Increasing
Beaver	62-0016-00	1984-2016	Not Exceeding, High Risk	77	2.4%	Increasing
Bald Eagle	62-0002-00	1971-2016	Not Exceeding	30	2.3%	Increasing

Lake	Lake ID Number	Period	Condition	Median [Cl] (mg/L)	Percent change/year (%)	Trend Description
Medicine	27-0104-00	1969-2016	Exceeds Criteria	136	2.3%	Increasing
Minnewashta	10-0009-00	1978-2016	Not Exceeding	42	2.3%	Increasing
Cedar	27-0039-00	1988-2016	Not Exceeding	124	2.2%	Increasing
Owasso	62-0056-00	1971-2016	Not Exceeding	44	2.2%	Increasing
McCarron	62-0054-00	1971-2016	Exceeds Criteria	92	2.1%	Increasing
Hiawatha	27-0018-00	1988-2016	Exceeds Criteria	82	1.9%	Increasing
Wabasso	62-0082-00	1980-2016	Not Exceeding, High Risk	38	1.9%	Increasing
St. Croix	82-0001-00	1953-2017	Not Exceeding	5	1.8%	Increasing
Calhoun	27-0031-00	1971-2016	Exceeds Criteria	134	1.7%	Increasing
Harriet	27-0016-00	1988-2016	Not Exceeding	114	1.7%	Increasing
Minnetonka-Grays Bay	27-0133-01	1958-2016	Not Exceeding	53	1.6%	Increasing
ISLAND (BASIN N. OF I-694)	62-0075-02	1984-2016	Not Exceeding	70	1.5%	Increasing
Lake of the Isles	27-0040-00	1988-2016	Exceeds Criteria	130	1.4%	Increasing
Minnetonka-Upper Lake	27-0133-05	1949-2016	Not Exceeding	43	1.2%	Increasing
Island (Basin S. of I-694)	62-0075-01	1984-2016	Not Exceeding	59	1.1%	Increasing
Minnetonka-Lower Lake	27-0133-02	1949-2016	Not Exceeding	50	1.1%	Increasing

Note that the percent change is an estimate of the historic rate of change and is not intended to be a predictive tool for future change.

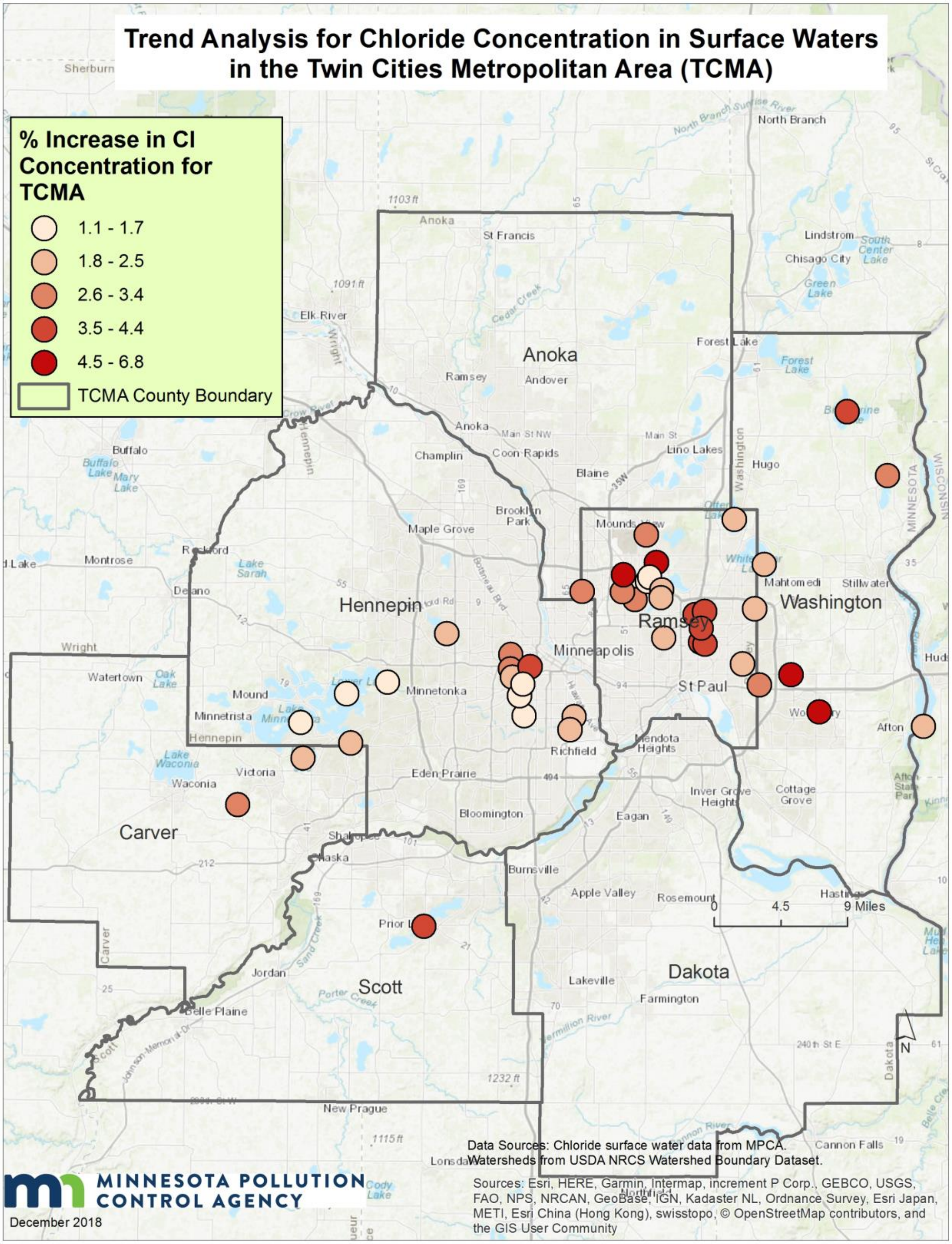


Figure 37: Trend Analysis for % Increase in Chloride Concentration per year in TCMA Surface Waters (Lakes) with at least 10 years of data.

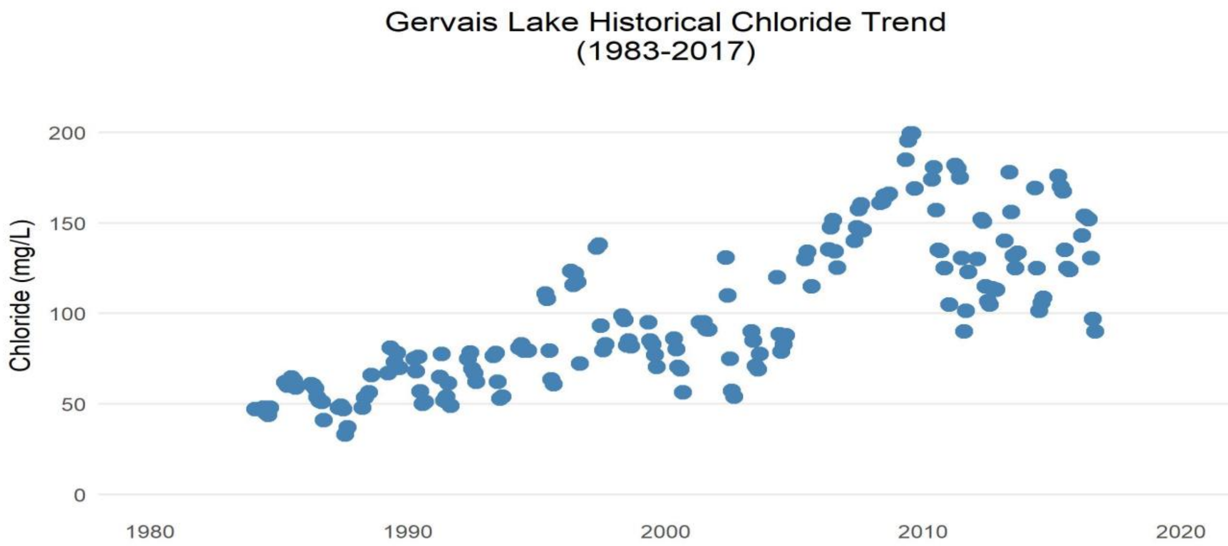


Figure 38. Increasing chloride concentration in surface samples in Gervais Lake from 1983-2016.

Table 6: Chloride Trends in Statewide Lakes (excluding TCMA).
The Seasonal Mann-Kendall test indicates whether the chloride concentrations versus time are increasing (positive value) or decreasing (negative value).

Lake	Lake ID Number	Period	Condition	Median [Cl] (mg/L)	Percent change/year (%)	Trend Description
Clearwater	69-0397-00	1988-1997	Not Exceeding	2	11.6%	Increasing
Big Birch (S portion)	77-0084-02	1949-2013	Not Exceeding	8	3.6%	Increasing
Becker	73-0156-00	1997-2009	Not Exceeding	20	3.3%	Increasing
East Vermilion	69-0378-01	1960-2015	Not Exceeding	6	3.2%	Increasing
Big Birch (NE portion)	77-0084-01	1971-2013	Not Exceeding	9	3.1%	Increasing
Zumwalde	73-0089-00	1978-2009	Not Exceeding	28	2.7%	Increasing
Shagawa	69-0069-00	1981-2009	Not Exceeding	4	2.6%	Increasing
Horseshoe	73-0157-00	1978-2009	Not Exceeding	21	2.3%	Increasing
Cedar Island (Main Bay)	73-0133-01	1978-2009	Not Exceeding	26	2.1%	Increasing
Osakis	77-0215-00	1985-2009	Not Exceeding	18	1.9%	Increasing
Ten Mile	11-0413-00	1989-2017	Not Exceeding	1	1.8%	Increasing
Shaokatan	41-0089-00	1985-2017	Not Exceeding	9	1.6%	Increasing
Trout	31-0216-00	1978-2015	Not Exceeding	7	1.1%	Increasing
Sand	09-0016-00	1980-1997	Not Exceeding	0.5	-1.3%	Decreasing

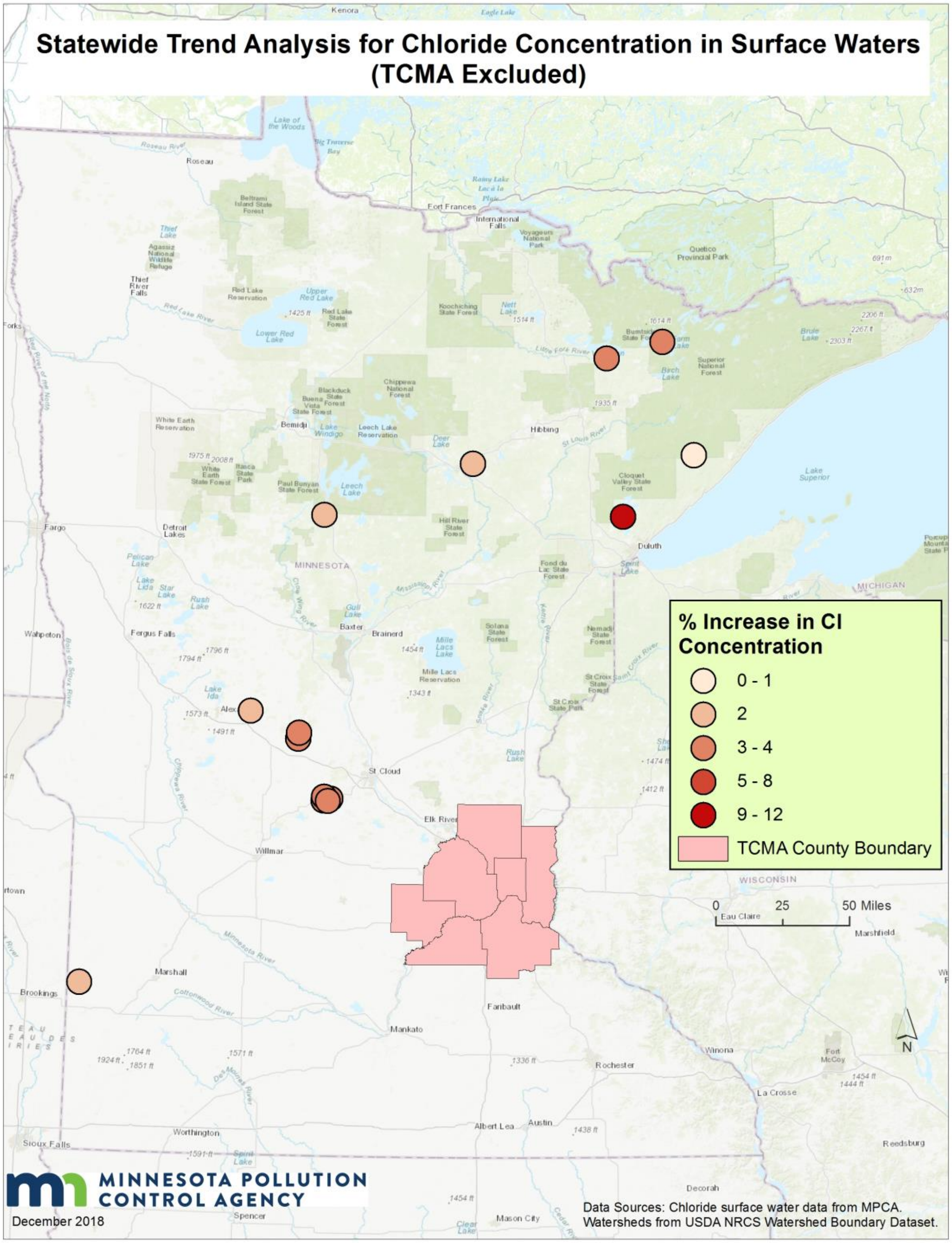


Figure 39: Trend Analysis for % Increase in Chloride Concentration per year in Minnesota Lakes with at least 10 years of data. (Excluding the TCMA)

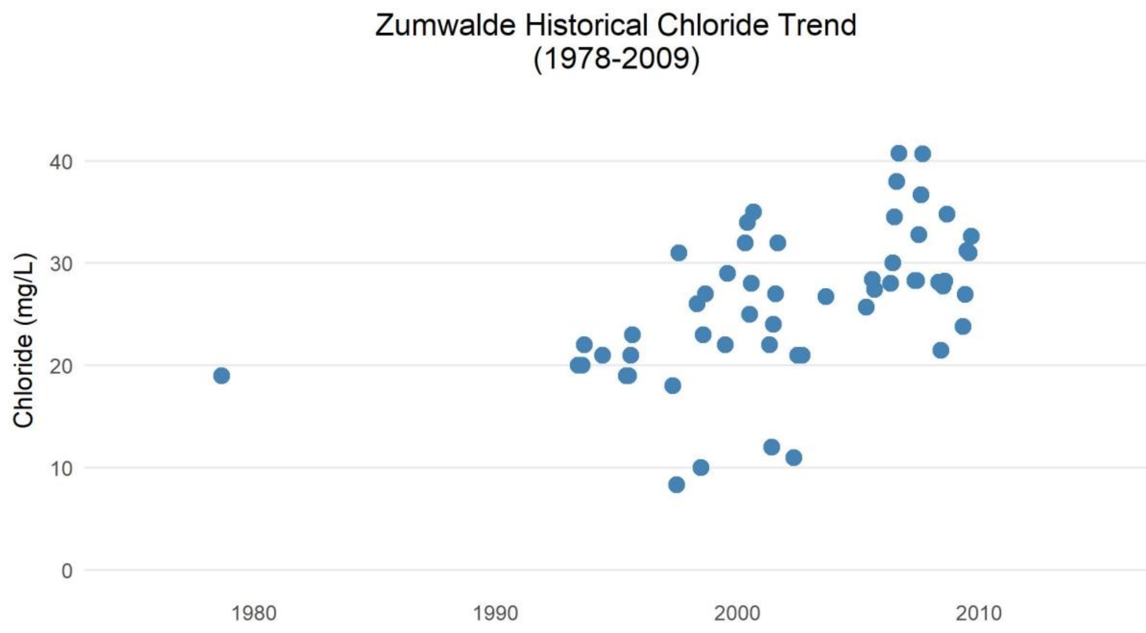


Figure 40. Increasing chloride concentration in surface samples in Zumwalde Lake (73-0089-00) from 1978-2009.

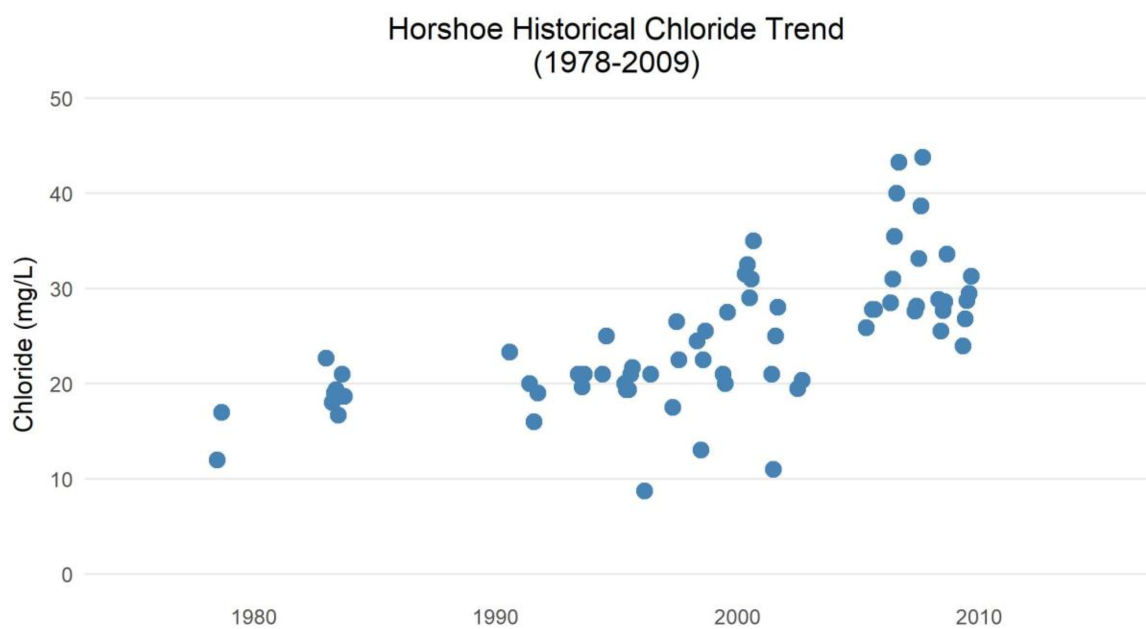


Figure 41. Increasing chloride concentration in surface samples in Horseshoe Lake (73-0157-00) from 1978-2009.

Some lakes exhibit meromictic conditions or incomplete mixing and/or circulation, which can mean turn-over of the lake is limited, delayed, or nonexistent. Mixing is an important process in a lake as it prevents reduced dissolved oxygen levels in the hypolimnion or lower level of the lake. Factors such as hydraulic residence time, fetch, groundwater inputs, colored fraction of dissolved organic carbon, and lake depth all influence the mixing conditions in a lake. Meromictic conditions are more likely to occur in lakes with higher depth to surface area ratios, as measured by the Osgood Index. High chloride concentrations in a lake may result in an increased risk of meromictic conditions. Brownie Lake and Spring Lake have been identified as being meromictic. The meromictic conditions in Brownie Lake may be due to alterations to the watershed and outlet that occurred prior to the practice of winter salt application.

A number of the monitored lakes had substantial differences in the chloride concentrations between the top (surface) and bottom (subsurface) of the water column. Brownie Lake exhibits this characteristic most dramatically, as shown in Figure 42. Peavey Lake, Powderhorn Lake, and Spring Lake also exhibit a clear pattern of higher chloride concentrations at depth as shown in Figure 43, Figure 32, and Figure 44 respectively.

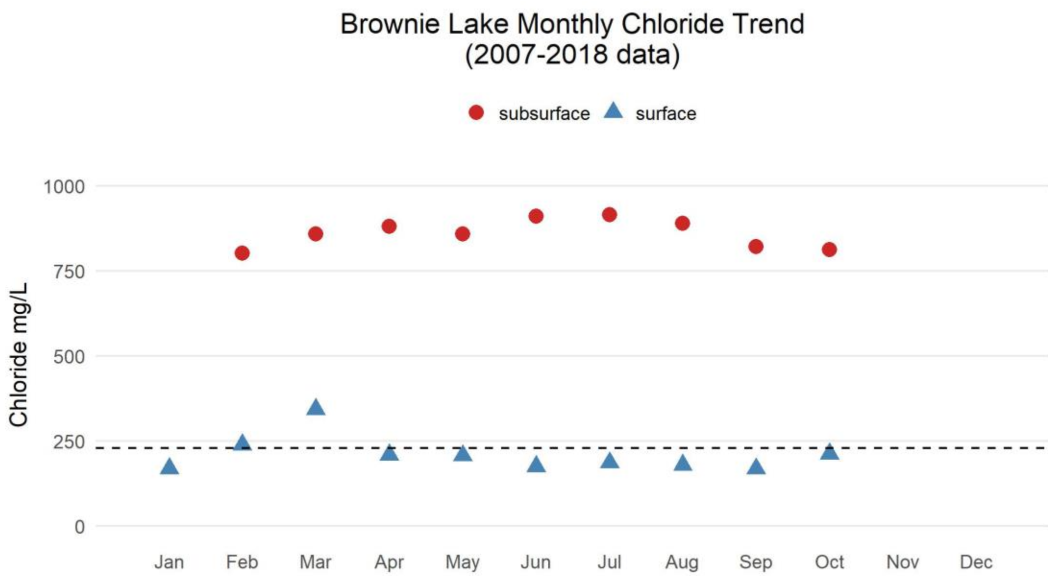


Figure 42. Average monthly chloride concentrations in surface and subsurface samples in Brownie Lake (27-0038-00)

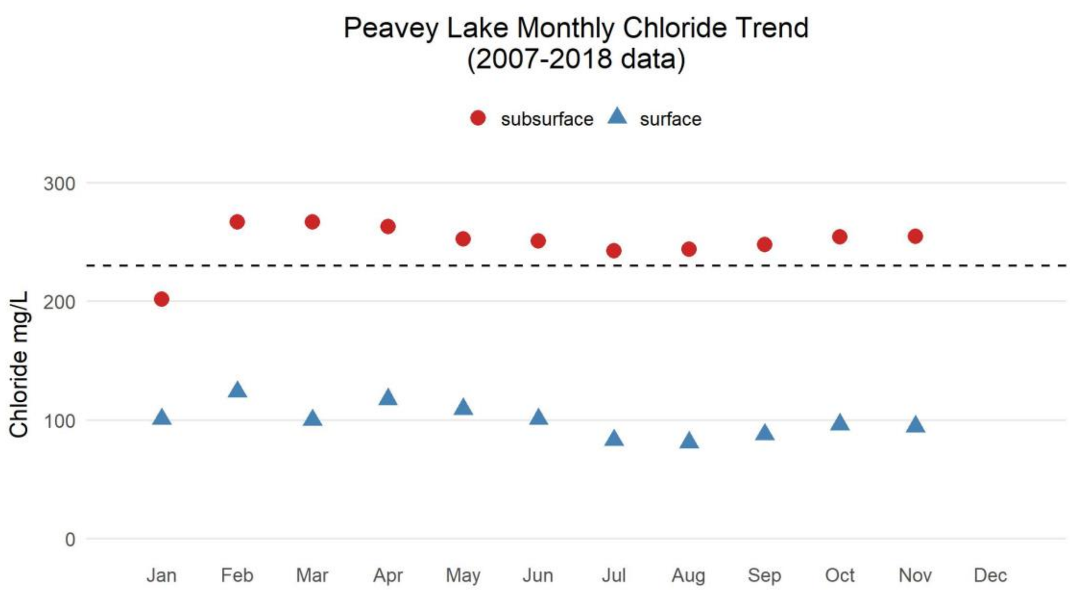


Figure 43. Average monthly chloride concentrations in surface and subsurface samples in Peavey Lake (27-0138-00)

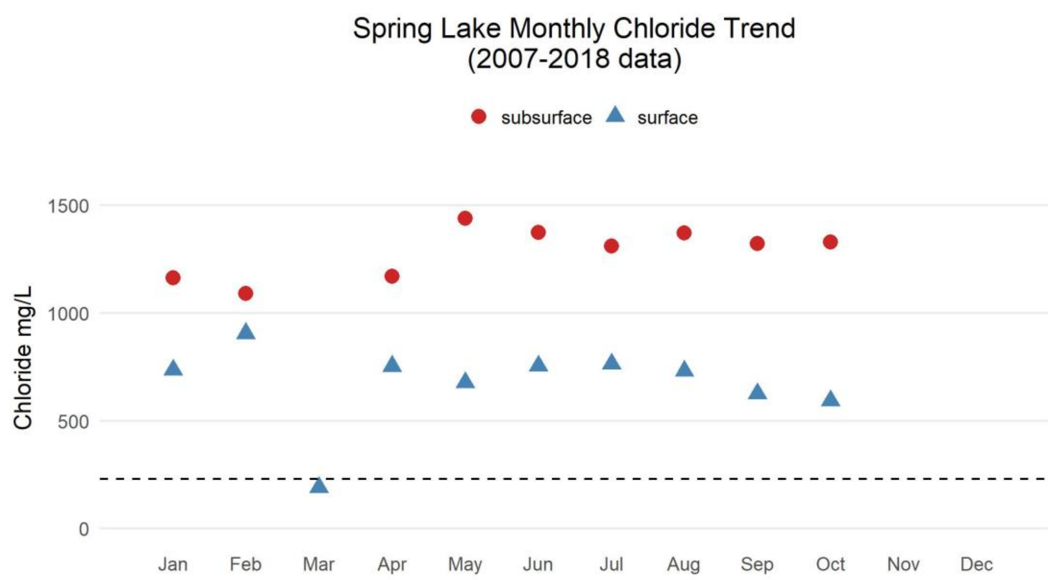


Figure 44. Average monthly chloride concentrations in surface and subsurface samples in Spring Lake (27-0654-00)

The trends observed in Minnesota are also being observed across other states and territories, which apply road salts for winter maintenance. A recent analysis of lakes across North America demonstrated increasing chloride concentrations in a large number of lakes, including 60 of 62 assessed lakes in Minnesota. The 60 observed trends were based on statewide data collected between 1970 and 2015 (Dugan, et al. 2017). This assessment was largely biased by urban lakes, but it also predicted that 34 Minnesota lakes in the TCMA would exceed a concentration of 100 mg/L by 2050 and 13 of those lakes would exceed 230 mg/L by 2050.

Another area of more recent interest is that of the potential negative impacts that increasing chloride concentrations may have on stormwater ponds. Recent research at the U of MN St. Anthony Falls Laboratory and through the Minnesota Stormwater Research Council is investigating how stormwater ponds may be stratifying due to increasing chloride accumulation and how this may have in impact on their function at capturing and storing phosphorus in sediments. This accumulation of chloride may set the deeper ponds up for early stratification, right after ice-out in the spring as a results of lack of turnover in the ponds. There is some evidence that early onset of stratification often causes persistent anoxia, which could have consequences for phosphorus release and retention in stormwater ponds. According to researchers, chloride may remain in these ponds for months when stratified and could have a potential impact on the release of phosphorus, though more research is needed. http://www.mnltap.umn.edu/publications/exchange/2019/June/roadsalt/index.html. Direct chloride toxicity, mobilization of heavy metals, and the creation of anoxic conditions are some of the anticipated effects of increasing chloride levels in stormwater ponds.

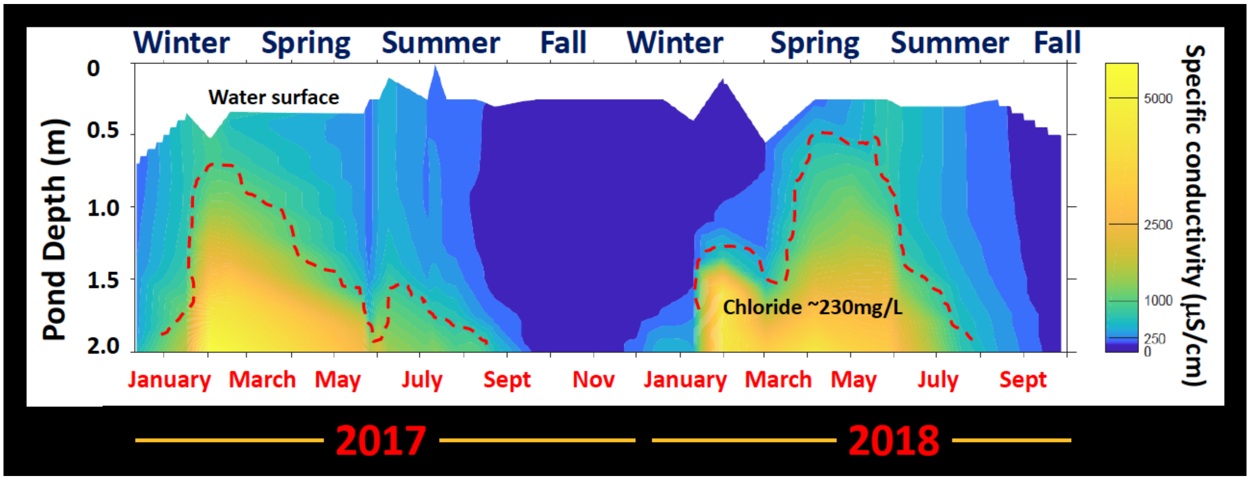


Figure 45: Seasonal patterns of salt accumulation and flushing. (Photo courtesy of Dr. Jacques Finlay at 2019 Annual Salt Symposium)

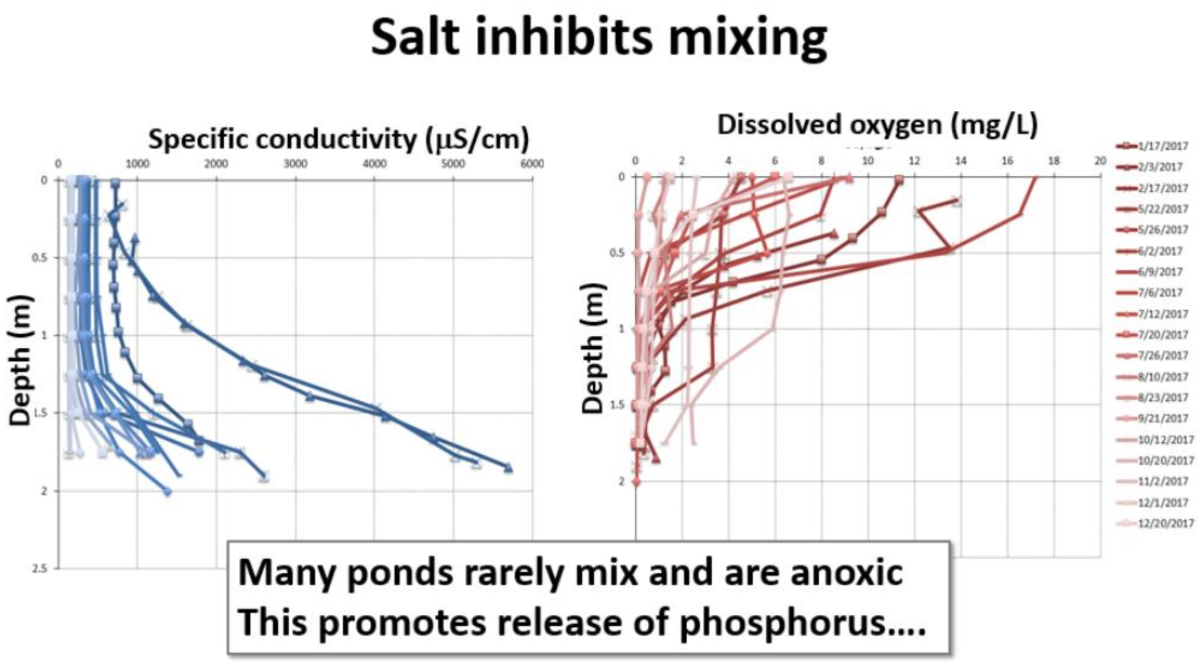


Figure 46: Salt inhibits mixing of Stormwater ponds. (Photo courtesy of Dr. Jacques Finlay at 2019 Annual Salt Symposium)

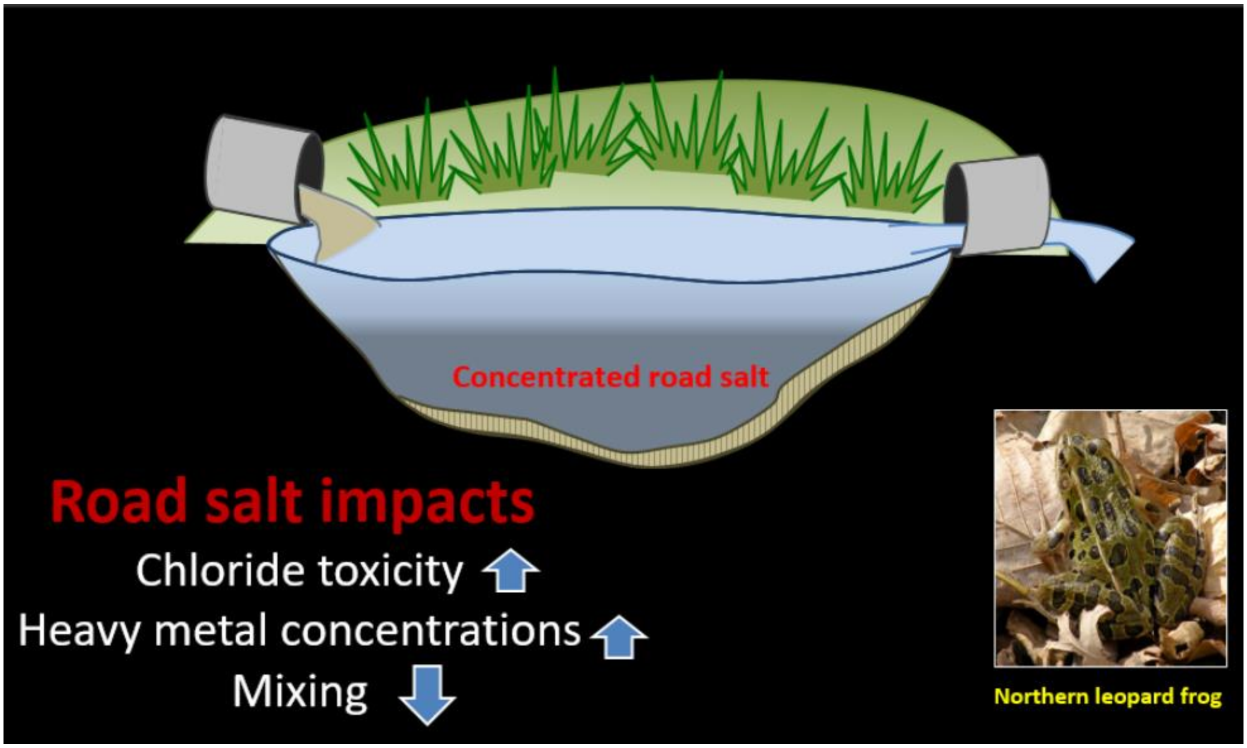


Figure 47: Diagram of potential impacts of increased chloride concentrations to stormwater ponds. (Photo courtesy of Dr. Jacques Finlay at 2019 Annual Salt Symposium)

Chloride Trends in Streams

The now discontinued Minnesota Milestone Monitoring Program maintained a network of 80 monitoring sites on rivers and streams locations around the state for the purpose of recording long term water quality data. A unique and useful feature of this program was that it collected 30 years' worth of chloride monitoring data to allow for a statewide summary of chloride trends in streams. The results of this program, published in 2014, show that there is an upward trend in chloride concentrations in both long term and recent timescales for a majority of monitoring sites (Figure 48) (Christopherson 2014). The increasing trends in chloride and nitrate/nitrite were contrasted by the reducing trends observed in other pollutants of interest (Figure 49).

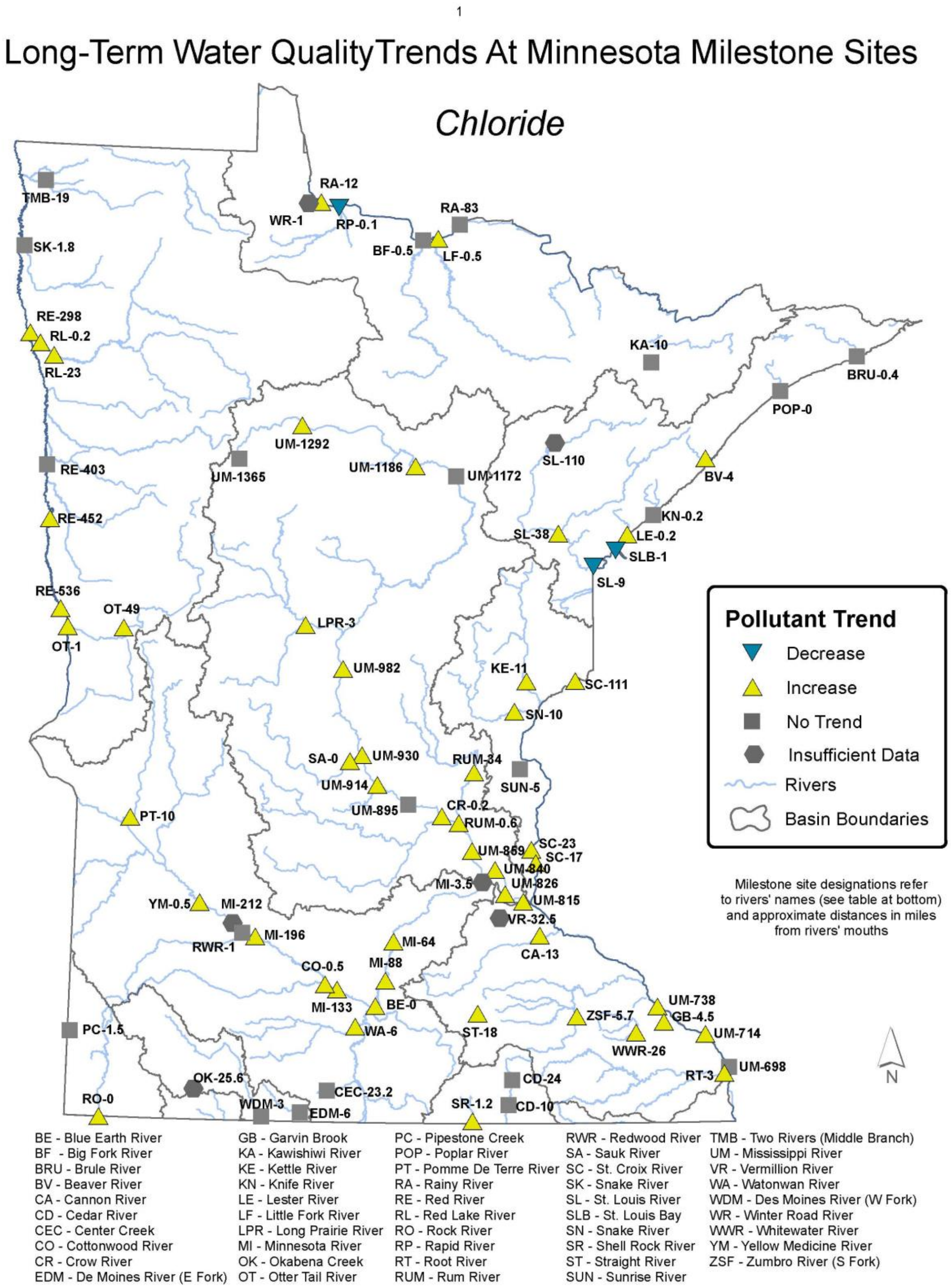


Figure 48: Long Term Water Quality Trends at Minnesota Milestone Sites - Chloride

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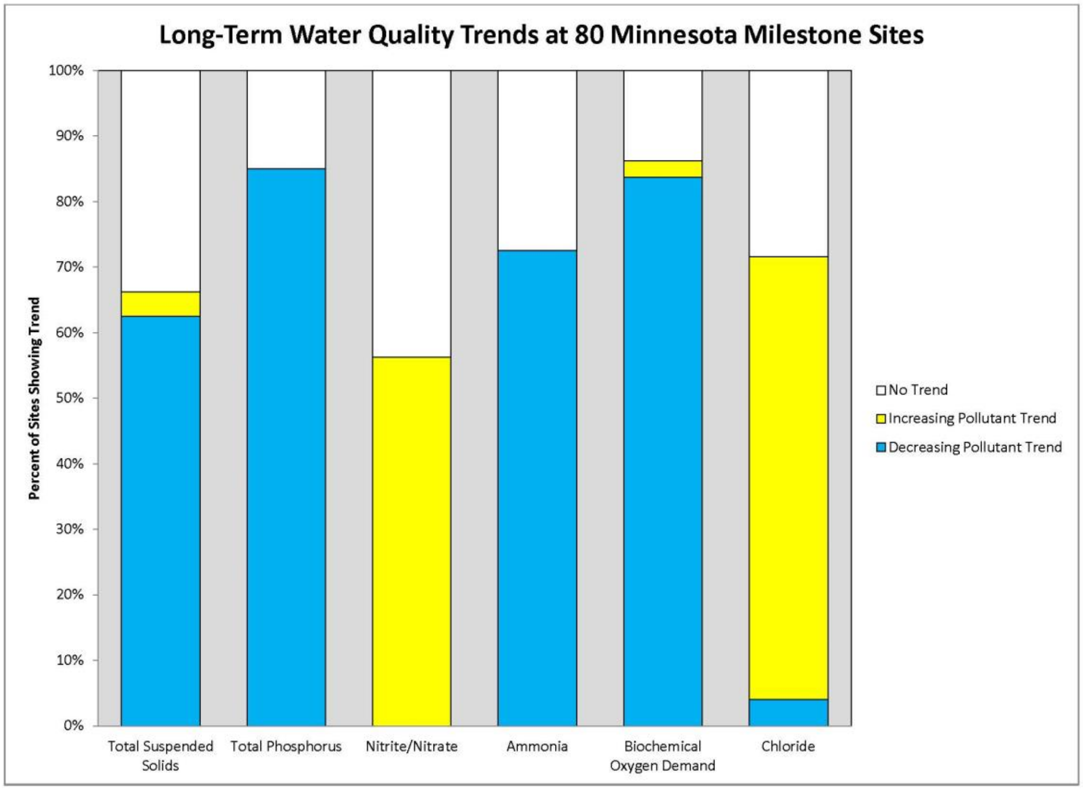


Figure 49: Long-Term Water Quality Trends at 80 Minnesota Milestone Sites

The Metropolitan Council published trends in chloride concentrations for major rivers in the metro area in June of 2018 in their Regional Assessment of River Water Quality in the Twin Cities Metropolitan Area 1976-2015 Report. Specifically, the chloride monitoring data from 2006 through 2015 was reviewed at several locations in the Minnesota River, the St. Croix River, and the Mississippi River. There were increasing trends found in each of these rivers, and in 9 of 10 sampling locations throughout the TCMA (Figure 50). The trends ranged from an 8% increase to a 143% increase, with no decreasing trends reported. The report also documents that chloride concentrations have significantly increased over a 31 year period in metro area streams (Metropolitan Council 2018).

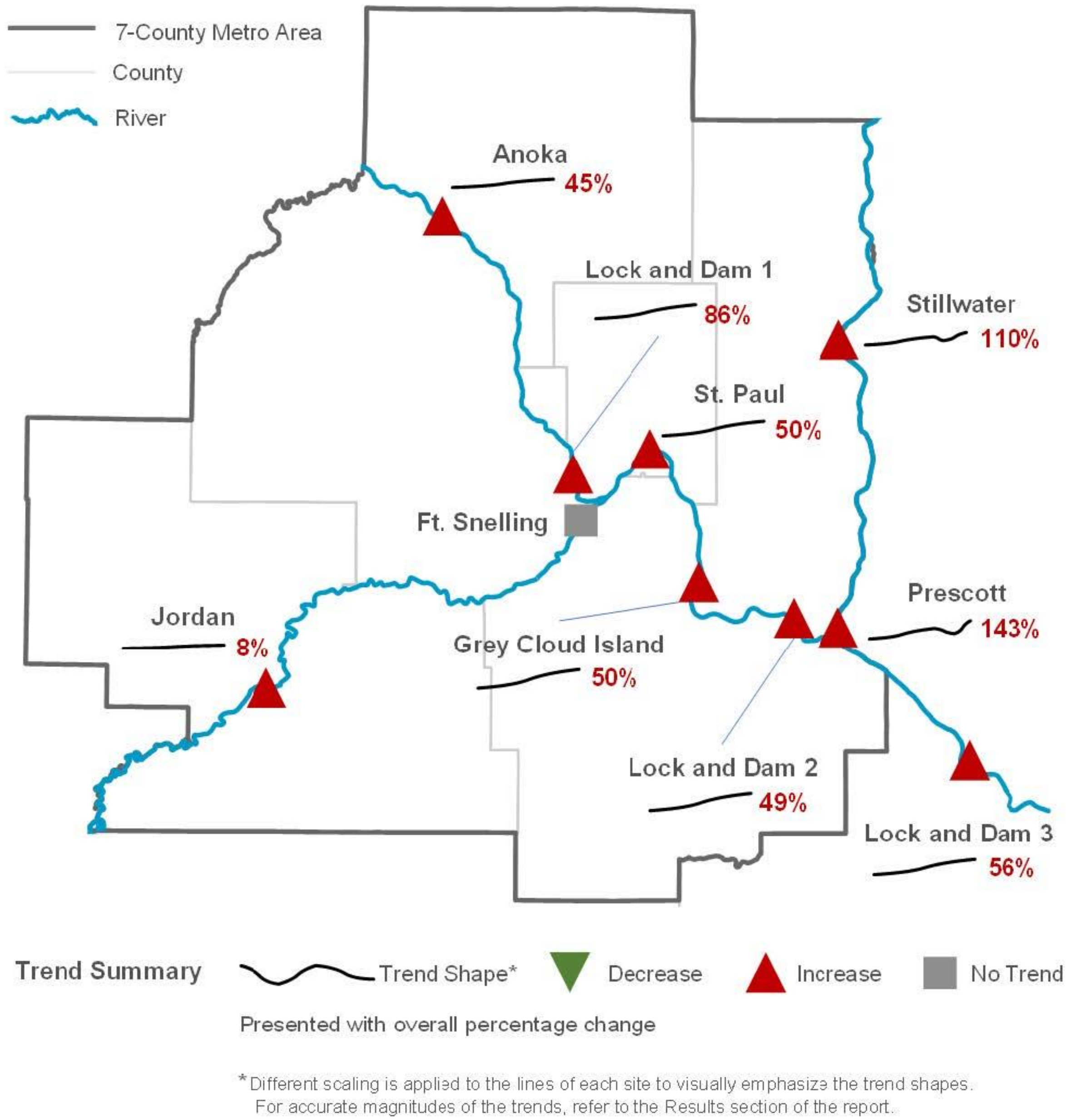


Figure 50: Flow-Adjusted Chloride Concentration Trends in the Mississippi, Minnesota, and St. Croix Rivers, 1985-2015

Chloride trends in groundwater

Longer term trends in groundwater chloride concentrations have also been evaluated (Figure 28). Chloride concentrations in the TCMA groundwater have increased in about one-third of the wells that had sufficient data for trend analysis (MPCA 2013). Upward trends in chloride concentrations were not just restricted to shallow wells that tapped the sand and gravel aquifers. Concentrations also significantly increased in two deep wells in the TCMA. One of these wells was 190 feet deep and tapped the Jordan aquifer in the vicinity of Cottage Grove. The other well was 72 feet deep and tapped a buried sand and gravel aquifer in Hennepin County. The Chloride/Bromide ratios in both of these wells - 803 and 822, respectively - also was considerably greater than those expected in groundwater unaffected by human-caused contamination. In these two wells, chloride concentrations increased on average 1.8 mg/L each year. This translated into an increase of about 15-30 mg/L over approximately the past 15 years. Concentrations in the Jordan aquifer well increased from about 12 mg/L in 1999 to 41 mg/L in 2011, and concentrations in the buried sand and gravel aquifer wells increased from about 30 mg/L in 1996 to 46 mg/L in 2011 (MPCA 2013)

In a newer analysis 14 of 35 wells (40%) tested across the state had a statistically significant upward trend in chloride concentrations from 2005 through 2017 (MPCA 2019). In some wells, chloride concentrations have increased by about 100 mg/L in the last 15 to 20 years. Many of the wells with increasing trends were shallow wells tapping the sand and gravel aquifers; however, more recent analysis show that increasing concentrations are increasingly being found in deeper aquifers. The recent analysis found that 10 of the 14 wells with increasing chloride trends were in bedrock aquifers, ranging from 90 to 340 feet deep. The high concentrations of chloride found in the shallow sand and gravel aquifers in the TCMA are likely a result of winter deicing materials (MPCA 2019).

Shallow groundwater will eventually either discharge to surface waters or move down to deeper aquifers that contain water that is used for Minnesota's drinking water supplies. If continued trends of increasing chloride in shallow groundwater persist, higher concentrations in deep aquifers will eventually occur, which could result in higher water treatment costs or restrict its use for drinking water supplies (MPCA 2013) (MPCA 2019). Based on the chloride data and associated analyses, chloride concentrations continue to increase in both the surface water and groundwater.

Chloride Relationships to Watershed and Waterbody Characteristics

Relationships were evaluated between the average winter chloride concentrations to watershed size, percent impervious surface, lake volume, and the lake Osgood Index. No strong relationships were identified with the exception of the Osgood Index and road density in this analysis. The Osgood Index relates the mean depth of a lake to the surface area (Osgood Index = Mean Depth (m) ÷ Surface Area $(km^2)^{0.5}$). Lake chloride concentrations significantly increase with increasing Osgood Index, as shown in Figure 51 ($p<0.05$). This is likely because waterbodies are generally less prone to mixing as the Osgood Index increases. This inverse mixing effect may be magnified by the presence of chloride, which increases density and the amount of energy required to mix deep layers within a lake. Thus, the Osgood Index may be used to prioritize monitoring efforts for lakes with no or limited data, since these lakes could be more prone to becoming meromictic.

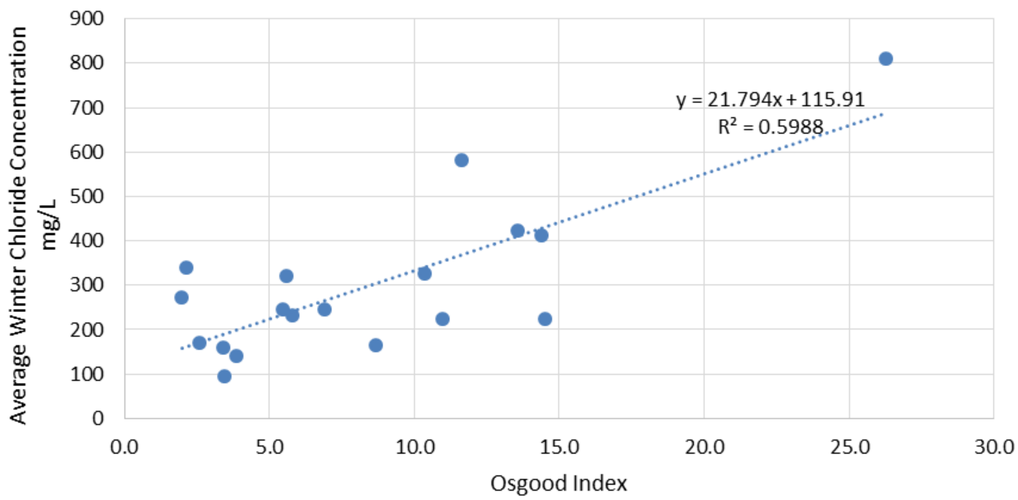


Figure 51. Winter chloride concentrations (November-March) in TCMA lakes versus Osgood Index ($p < 0.05$)

Salt applied to impervious surfaces as a deicer is considered a primary source of chloride to many lakes and streams in Minnesota. Researchers from the Center for Limnology, University of Wisconsin–Madison, found that impervious surface and road density in a subwatershed were the strongest predictors of chloride concentrations in Northeast and Midwest North American (Dugan et al.2017).

Winter stream chloride concentrations have also been positively correlated with annual winter salt application. Watersheds with less than 15 tons per square mile of chloride varied in winter stream median chloride concentration ranging from 18 to 89 mg/L (Wenck 2009). Road density was also positively correlated with median winter chloride concentrations. The deicing salt load was highly dependent on road density. Median winter chloride concentrations appear to increase with road densities greater than 25 lane miles per square mile (Wenck 2009). A road density map for the TCMA is presented in Figure 54.

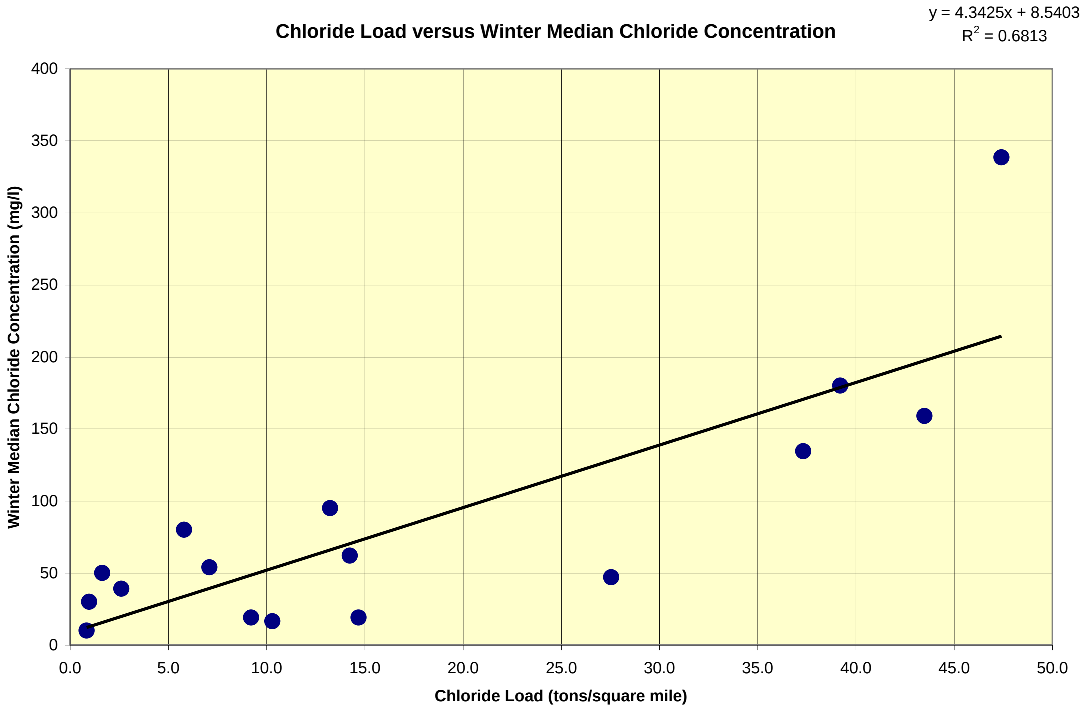


Figure 52: Relationship between road salt load and median winter stream chloride concentration. (Wenck 2009)

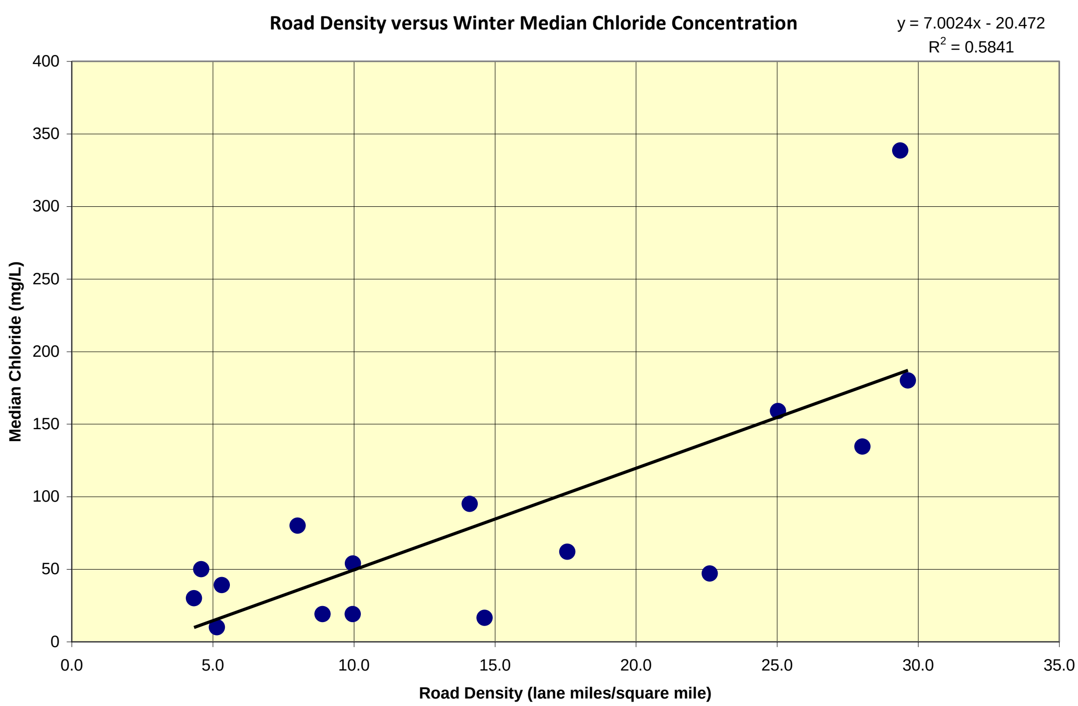


Figure 53. Relationship between road density and median winter chloride concentration. ***(Wenck 2009)***

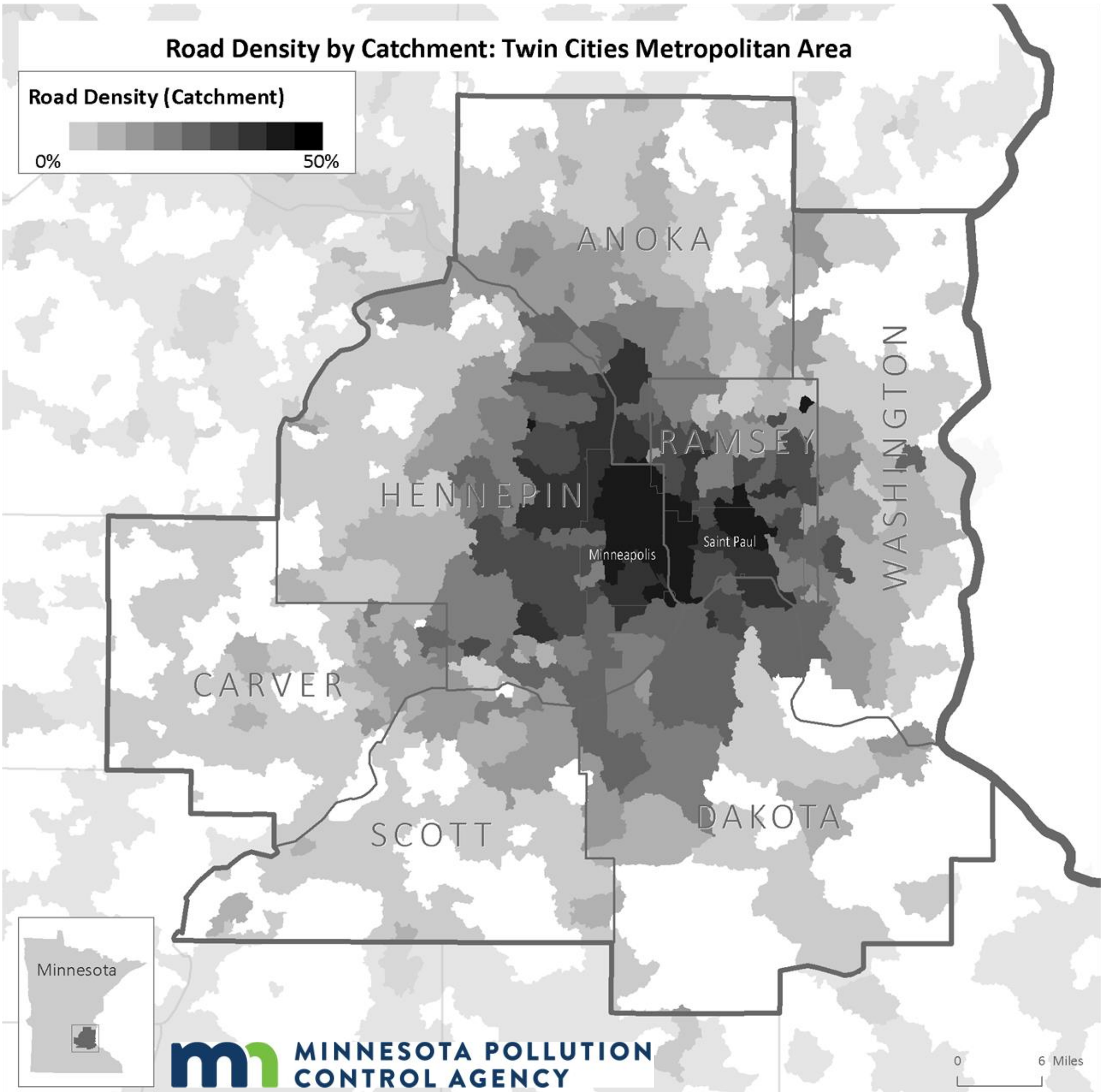


Figure 54. 2010 Road Density in the TCMA

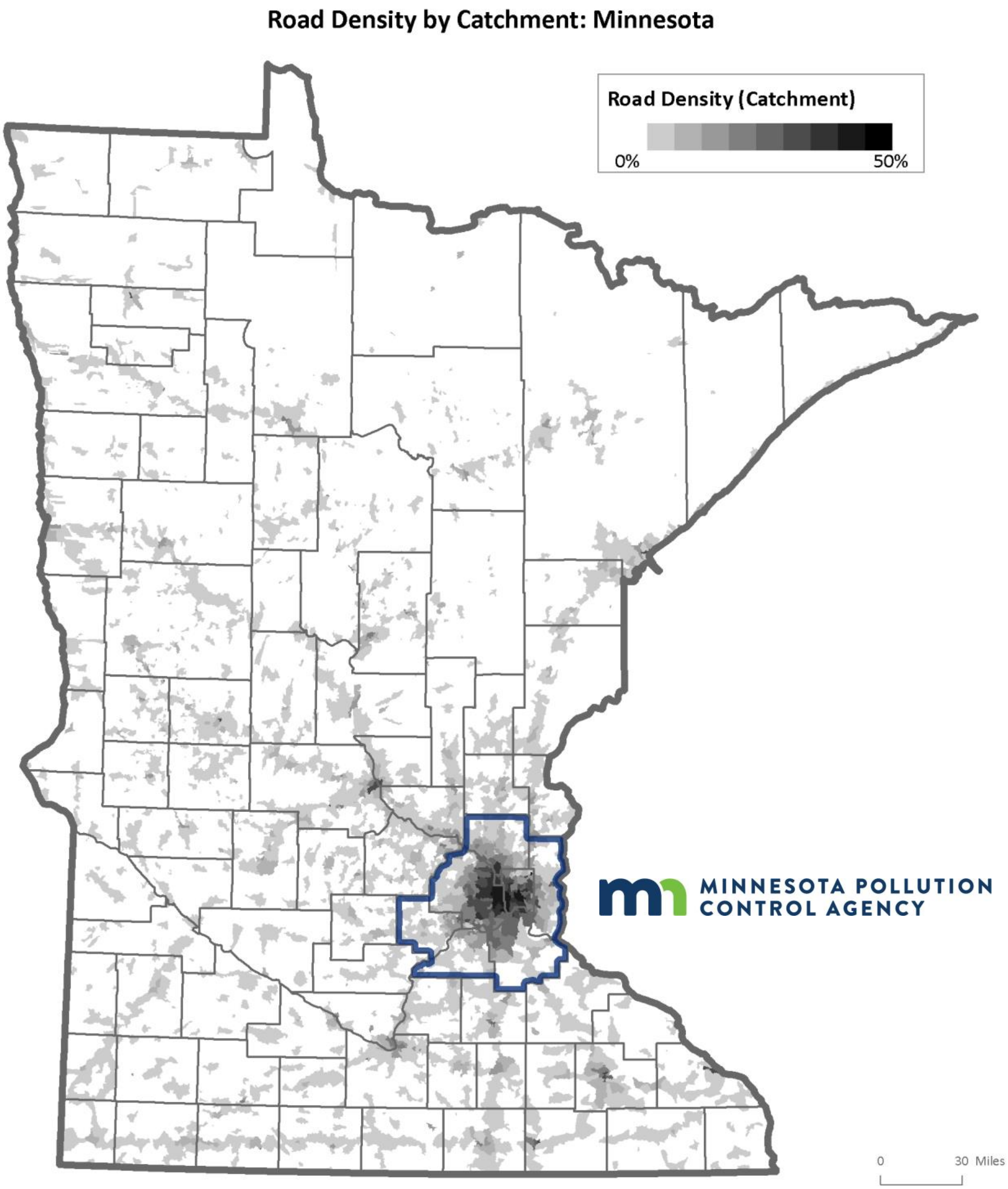


Figure 55. 2010 Statewide Road Density: (Road density from MPCA based on roads from MnDOT and catchment watersheds from DNR)
(Road density from MPCA based on roads from MnDOT and catchment watersheds from DNR)

Chloride Relationships to Ecoregion

An Ecoregion is an EPA classification of a geographic area, which is made up by relatively homogenous ecological conditions. There are four hierarchical levels of ecoregion, where level I is the broadest, and level IV is the most refined. In Minnesota, there are there are three level I ecoregions, which are further comprised of three level II, seven level III, and thirty level IV ecoregion subclasses.

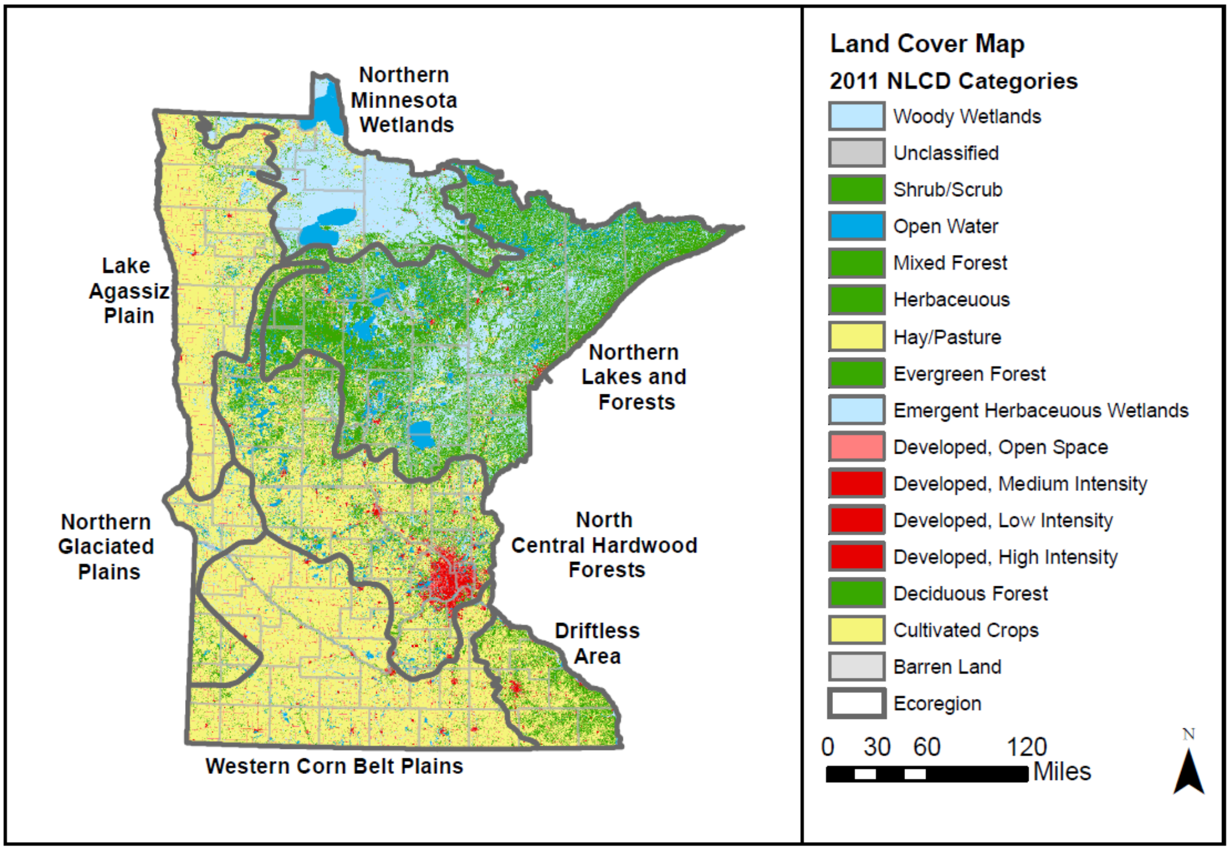


Figure 56: Ecoregions and Land Cover in Minnesota

Ecoregions can be used to make inferences about spatial chloride patterns, since the ecoregions geologic and morphologic characteristics are factored into the ecoregion classifications. Chloride concentrations in lakes within four of the six level III ecoregions have previously been assessed and found to be highest in the western part of the state (MPCA 2005). In this study, median chloride concentrations were highest in the Western Corn Belt Plains (13-22 mg/L), were slightly lower in the Northern Glaciated Plains (11 to 18 mg/L) and Central Hardwood Forests (4-10 mg/L), and lowest in the Northern Lakes and Forests (0.6-1.2 mg/L). The total number of lakes in these summaries (13-43) were not necessarily a representative sample of the entire ecoregion or an indication of natural background concentrations.

The natural background of chloride in groundwater is largely due to the weathering of bedrocks, which vary across the state and are a factor of the ecoregion classification. In Minnesota, naturally high chloride concentrations have been documented in certain aquifers throughout the Western portions of the state, where depending on the underlying geology concentrations have been observed as high as 1500 to 2000 mg/L (MPCA 2013).

In the analysis produced for the plan, the differences in chloride concentrations among level III ecoregions were evaluated using all surface water samples collected after 2007. This analysis was inclusive of all samples, regardless of the land use characteristics in the surrounding watershed. Median concentrations across ecoregions follow similar trends for both lake and stream samples; median values were highest in the North Central Hardwood Forests (which includes the TCMA) and least in the Northern Minnesota Wetlands. Concentrations were also relatively high in the Driftless and Western Corn Belt, which span across the entire southern border. To see complete results of the Ecoregion Analysis, please see Appendix C - Chloride Relationships to Ecoregion. A deeper look into the land use characteristics, beyond the influence of ecoregions, suggests that development and agriculture have a greater influence on the magnitude of chloride concentrations. Given that detailed chloride source assessments are tied to land use and that natural background chloride concentrations are well below at-risk levels, ecoregions may be better suited as a surrogate for land use characteristics than a direct predictor of impairment likelihood. For example, the Western Corn Belt is dominated by agricultural lands, thus an investigation into the source of an at-risk waterbody may begin with an assessment of possible agricultural sources of chloride

Chloride Concentrations in Stormwater

In comparison to chloride samples taken from lakes, wetlands, and streams, winter stormwater runoff contains some of the highest chloride concentrations found in the TCMA. The data indicates a high degree of seasonal variability, which is a result of winter maintenance activities and the direct connection to impervious surfaces. Figure 57 shows storm sewer chloride concentration data collected in the TCMA from 1980 through 2013. Sample set sizes ranged from 19 to 288 samples per month, for a total of 1,569 samples. The data indicate that higher chloride concentrations are found during the winter maintenance season and increase as the winter season progresses with the peak occurring in February.

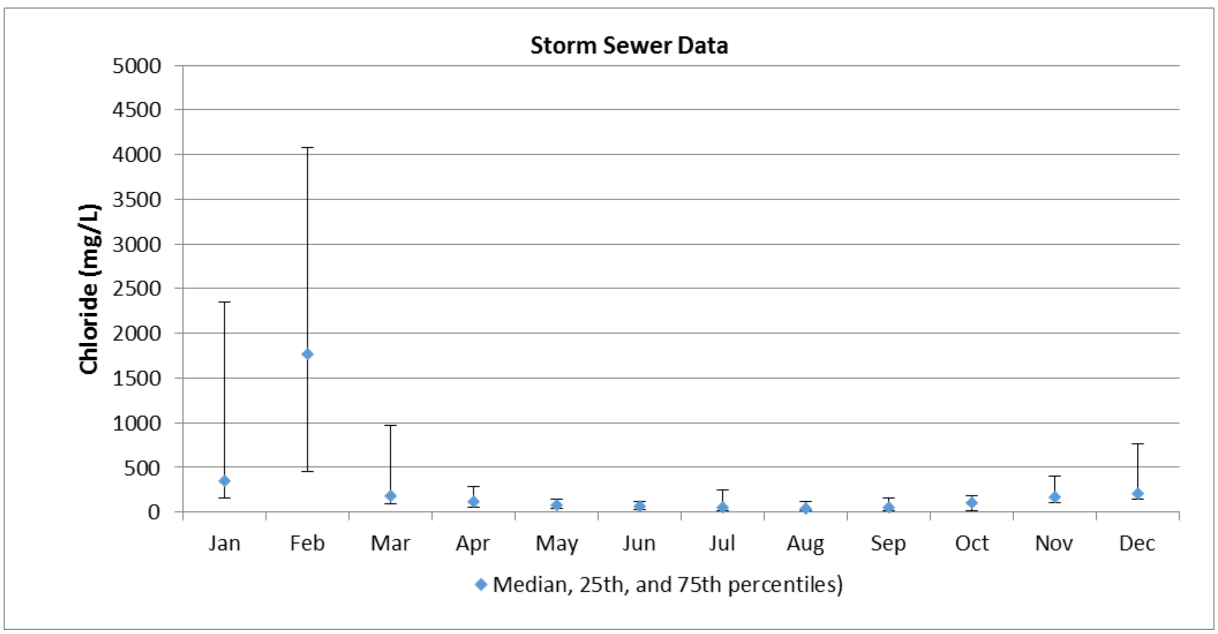


Figure 57. Storm sewer monthly chloride concentrations
(Data from TCMA between 1980-2013; median, 25th, and 75th percentiles)

This general seasonal pattern of greatest chloride loading and concentrations observed during the winter months in surface water runoff (November through March) is reiterated in an in depth MnDOT study of chloride accumulation and transport through watershed (Herb 2017). At one particular study site, Alameda Pond, chloride loading was highest from December through February (Figure 58).

Continuous monitoring at this site suggested that retention of winter and spring loads may be contributing to stronger density gradients and stratification during summer months. Chloride loading and retention patterns were comparable at two other sites that were monitored, although these were roadsides ditches.

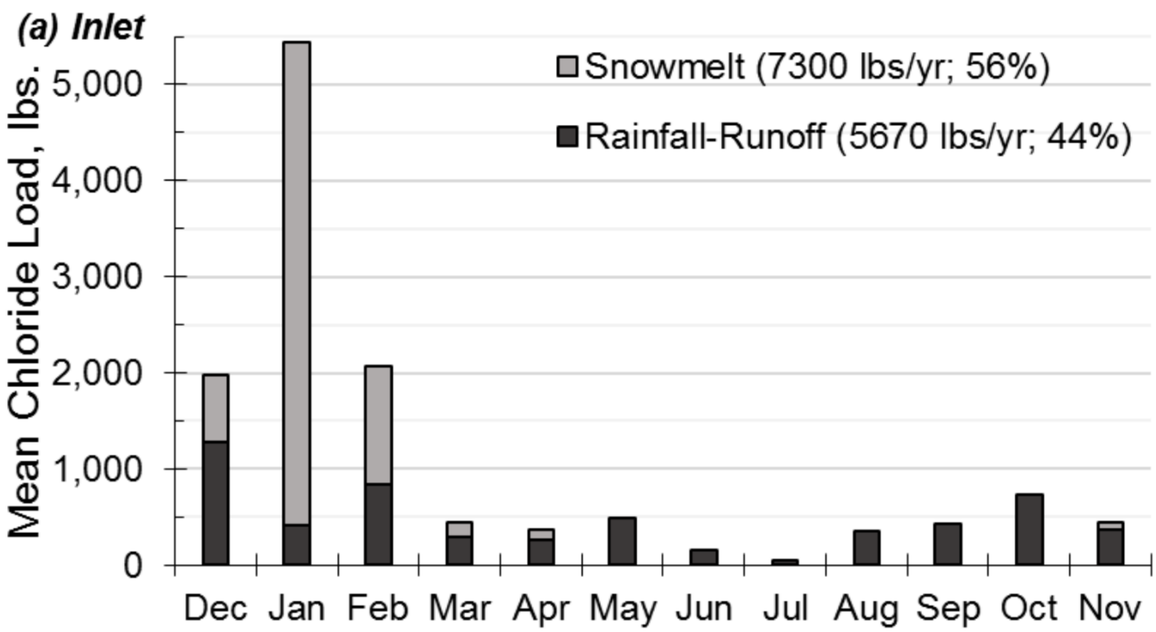


Figure 58: Mean monthly loading of chloride (lbs.) by flow regime (snowmelt vs. rainfall-runoff) observed at Alameda Pond Inlet over two years of continuous monitoring from Aug 1, 2015 to Jul 31, 2017 (Herb 2017).

Chloride Relationships between Surface and Groundwater

Concentrations of chloride in shallow groundwater are increasing. Shallow groundwater contributes flow to lakes, wetlands, and streams. In the TCMA, average chloride concentrations in shallow monitoring wells located within watersheds that contain one or more impaired surface waters were higher (141 mg/L) compared to wells in watersheds without an impaired lake, stream, or wetland (48 mg/L) (Figure 59 and Figure 60).

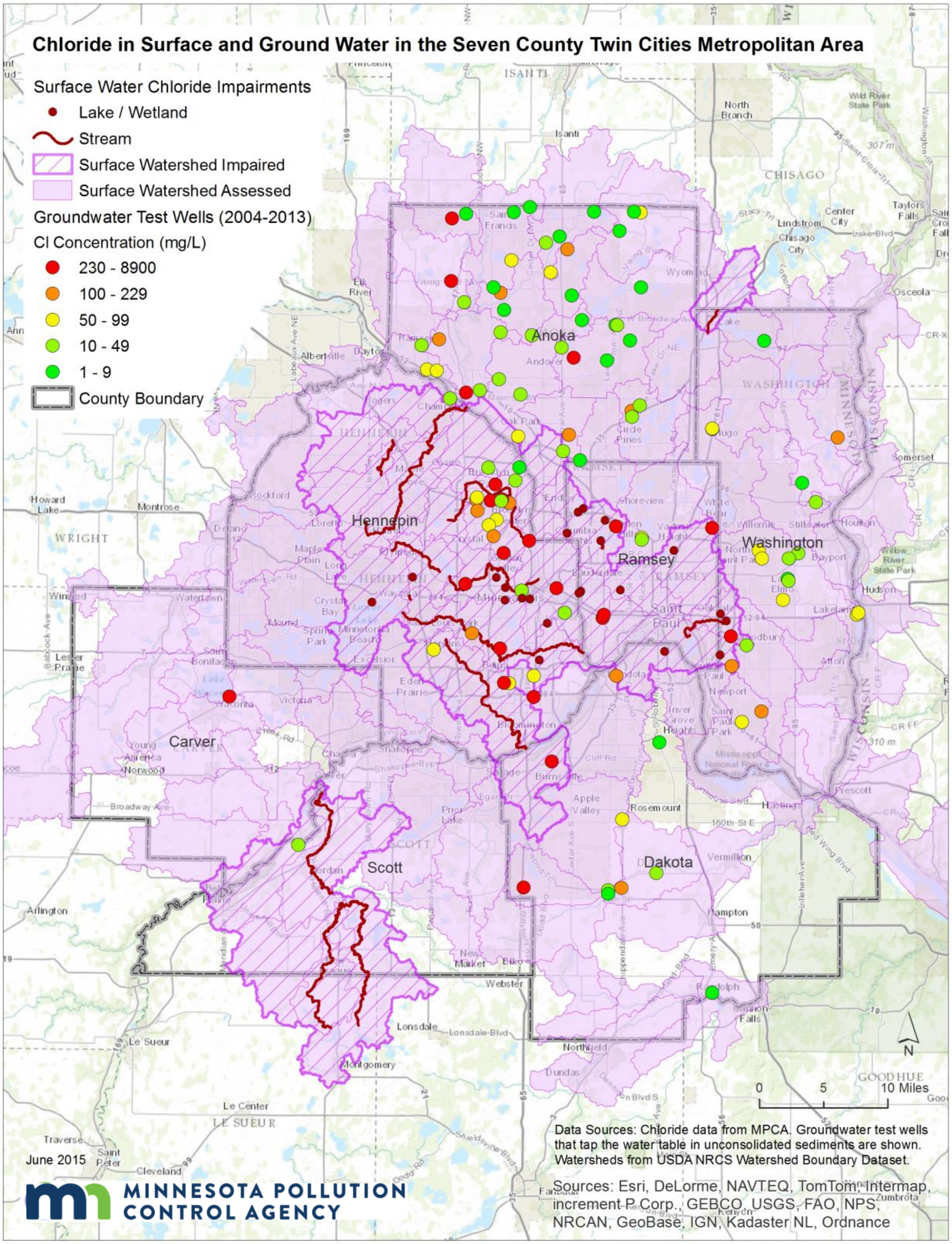


Figure 59. Chloride in Surface and Ground Water in the TCMA

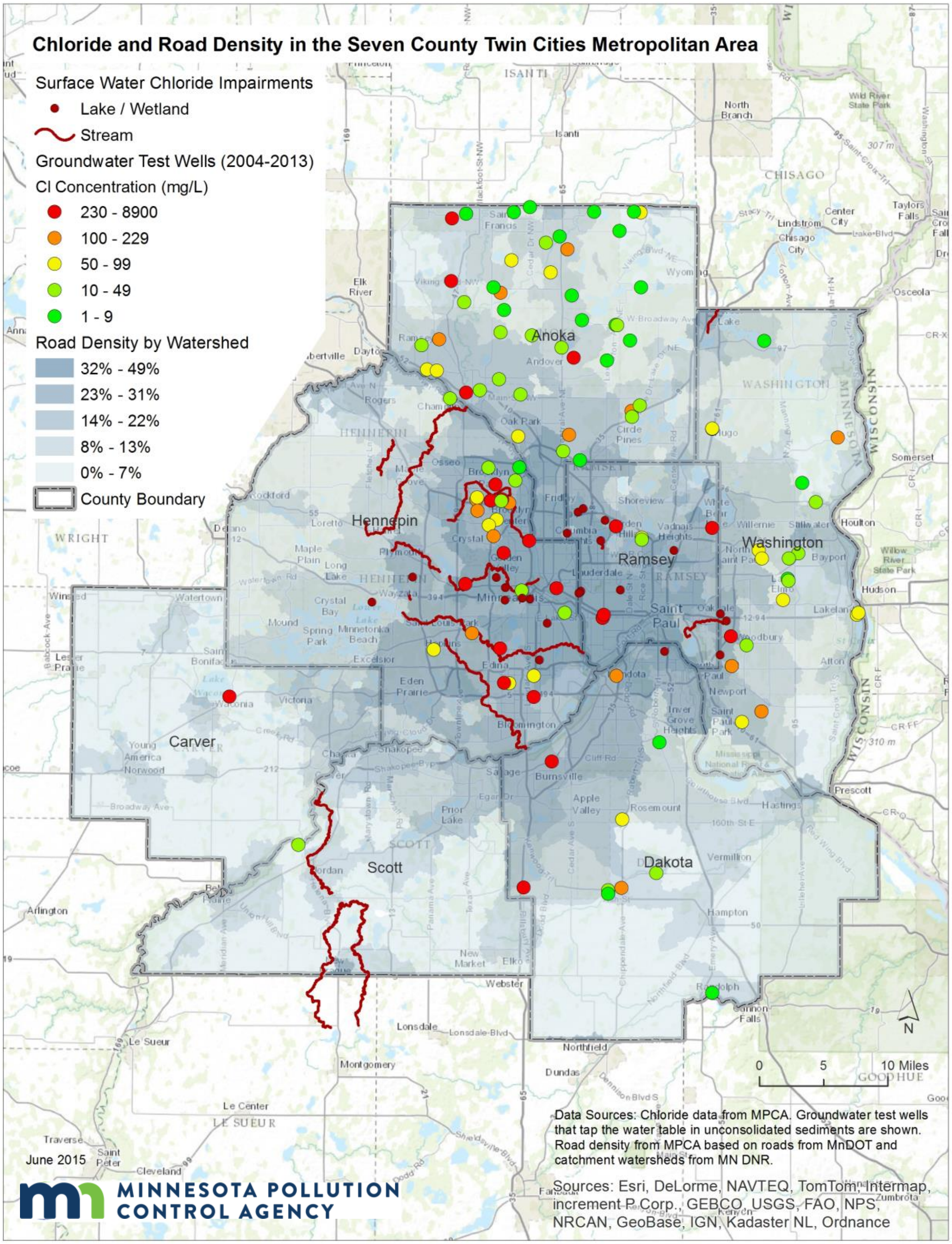


Figure 60. Chloride and Road Density in the TCMA

Several studies of streams in the Upper Midwest have found that higher chloride levels in shallow groundwater have, in part, contributed to an increase in concentration in streams during low flow conditions, when stream flow is dominated by groundwater inputs (Kelly 2008; Eyles et al. 2013; Corsi et al. 2015). This pattern of increased chloride concentrations during low flow conditions, typically during the summer months, is also evident in streams in the TCMA. Chloride concentrations exceeding the 230 mg/L standard have been observed in Bassett Creek in June and Shingle Creek in August. This issue is not isolated to the TCMA. For example, chloride levels in Miller Creek, a trout stream located in Duluth, have also consistently exceeded the 230 mg/L standard in July and August.

Eagle Creek is located in the city of Savage (Scott County) near the Highway 13/Highway 101 crossroads and is a Class 2A cold-water trout stream, meaning that it is a self-producing trout stream and is primarily fed by groundwater year round. Chloride concentrations have always been below the chronic chloride water quality standard of 230 mg/L; however, chloride concentrations have increased over time. The median chloride concentration in 2012 was 36 mg/L, which is more than twice the median concentration in 2001, 16 mg/L (Figure 61). In 2017, the median chloride concentration rose to 43 mg/L. The increased chloride concentrations in Eagle Creek, and likely many other streams in the TCMA, suggest that chloride from deicing activities may be infiltrating into shallow groundwater, resulting in elevated chloride concentrations in streams during summer baseflow conditions.

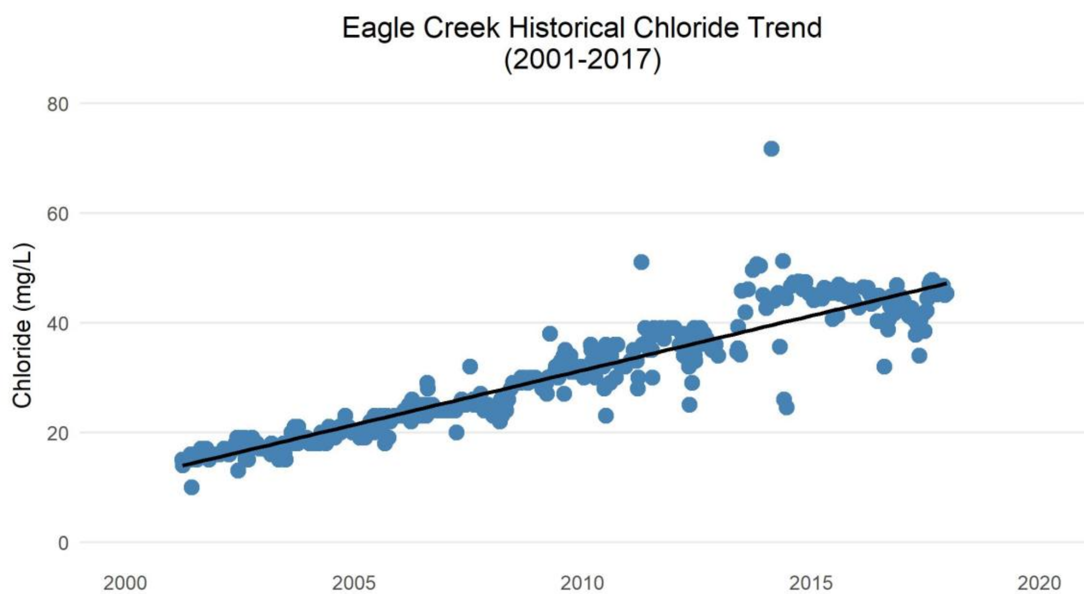


Figure 61. Increasing chloride concentrations in Eagle Creek from 2001-2017
(Data collected by MCES)

Shingle Creek, a tributary to the Mississippi River, is an urban stream that runs through Brooklyn Park, Brooklyn Center, and Minneapolis. The creek typically has numerous exceedances of the 230 mg/L standard each year, particularly during winter months. However, average chloride levels in the stream during summer months have also increased over time (Figure 62). The estimated increase in average summer (July through October) chloride concentration in Shingle Creek from 1996 to 2014 was 53 mg/L, based on a linear regression.

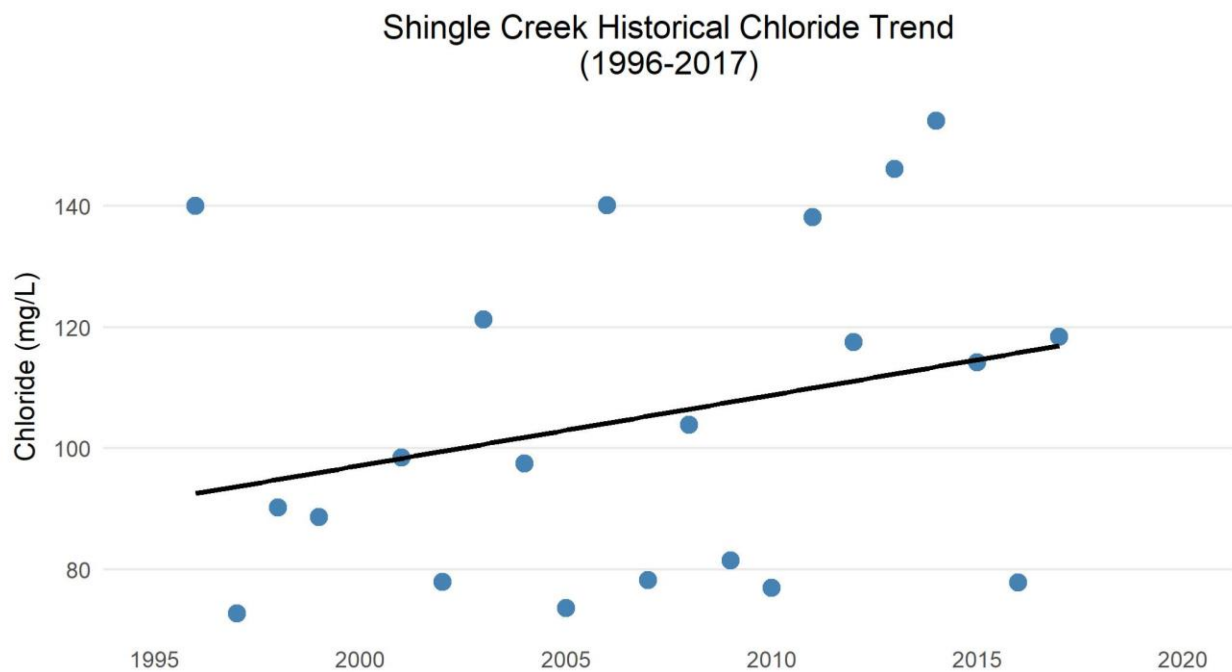


Figure 62. Average chloride concentrations (July-October) in Shingle Creek from 1996-2017
(Data collected by the USGS at Queen Avenue in Minneapolis)

Similar to other studies (Kelly 2008; Eyles et al. 2013; Corsi et al. 2015), streams in statewide Minnesota are experiencing high chloride concentrations during summer baseflow conditions. This trend is attributed to high chloride concentrations in shallow groundwater discharging to streams as baseflow.

Summary of Data Analysis

Based on the water quality data collected and the above data analyses, the following conclusions can be made:

1. Chloride use increased in Minnesota in the latter half of the 20th century, 1950 to 2000.
2. Levels of chloride are continuing to increase in both groundwater and surface waterbodies in Minnesota.
3. The highest chloride concentrations in surface waters occur during snowmelt conditions during winter months and low flow periods in streams.
4. Chloride levels tend to be higher in the bottom of a lake versus the surface, particularly in deeper lakes and lakes that are not well mixed.
5. Chloride concentrations in Minnesota waterbodies are positively correlated to road density in the contributing watersheds.
6. Winter maintenance activities in urban areas and WWTPs in rural areas tend to be the primary sources of chloride to Minnesota waters.
7. There are rural and agriculture areas that receive chloride contribution from fertilizers and/or from manure that could potentially be a load to surface water and/or shallow groundwater.

8. There are rural areas in the state with gravel roads and other gravel surfaces that receive chloride-based dust suppressants that could potentially be a load to surface water or shallow groundwater.
9. Historically, natural background and atmospheric deposition sources of chloride are generally not significant components of chloride loading to impaired water bodies.
10. There are existing data gaps of chloride concentrations in Minnesota waterbodies, as many have limited to no data and lack data that would represent critical conditions.

4.4. TMDL Summary

What are TMDLs?

A TMDL quantifies the allowable pollutant loading to a lake, wetland, or stream that will result in water quality standards being attained. The water quality target for the TMDLs was set to the chronic water quality criterion for chloride of 230 mg/L. The total allowable load, or TMDL, is allocated to the various sources contributing chloride including natural background sources, permitted wastewater, non-permitted aggregate, categorical MS4 sources, as well as consideration of a margin of safety and reserve capacity. Margin of safety is intended to account for uncertainty in the development of the TMDL. Reserve capacity is intended to set-aside a portion of the TMDL for future growth.

Many chloride TMDLs have been completed in Minnesota. In February of 2016 the MPCA completed 37 chloride TMDLs for the TCMA. This addressed all the lakes, streams and wetlands that were at that time listed as impaired by chloride. The complete details of the TMDL development are presented in the TCMA Chloride TMDL Report.

Chloride TMDLs have also been prepared for Shingle Creek, Nine Mile Creek, and Cannon River. Summaries of the TMDLs are presented in Table 7, Table 8 and Table 9 for lakes and wetlands and streams.

Lake/Wetland	AUID	Watershed Area (ac)	TMDL and Components (all values in lb/yr of chloride)					
			Loading Capacity (TMDL)	WLA		LA		Margin of Safety
				MS4 Categorical	Wastewater Sources[1]	Non-Permitted Aggregate	Natural Background	
Battle Creek Lake	82-0091-00	4,326	2,153,699	1,766,033	0	0	172,296	215,370
Brownie Lake	27-0038-00	452	341,418	279,963	0	0	27,313	34,142
Carver Lake	82-0166-00	2,242	1,071,123	878,321	0	0	85,690	107,112
Como Lake	62-0055-00	1,850	994,078	815,144	0	0	79,526	99,408
Diamond Lake	27-0022-00	744	486,017	398,534	0	0	38,881	48,602
Kasota Ponds North	62-0280-00	10	6,234	5,112	0	0	499	623
Kasota Ponds West	62-0281-00	6	5,742	4,708	0	0	459	574
Kohlman Lake	62-0006-00	7,533	4,839,183	3,106,733	1,050,484	0	303,096	378,870
Little Johanna Lake	62-0058-00	1,703	1,224,242	1,003,879	0	0	97,939	122,424
Loring Pond (South Bay)	27-0655-02	34	9,764	8,007	0	0	781	976
Mallard Marsh	62-0259-00	16	9,851	8,077	0	0	788	985
Parkers Lake	27-0107-00	1,064	1,431,262	528,161	787,163	0	51,528	64,410
Peavey Lake	27-0138-00	776	205,995	165,889	3,692	0	16,184	20,230
Pike Lake	62-0069-00	5,735	3,591,268	2,943,971	1,059	0	287,217	359,021
Powderhorn Lake	27-0014-00	332	218,588	179,242	0	0	17,487	21,859
Silver Lake	62-0083-00	655	370,011	303,409	0	0	29,601	37,001
South Long Lake	62-0067-02	114,785	26,334,624	21,534,261	4,030	0	2,106,448	2,633,059
Spring Lake	27-0654-00	39	15,600	12,792	0	0	1,248	1,560
Sweeney Lake	27-0035-01	2,439	1,456,271	1,194,142	0	0	116,502	145,627
Tanners Lake	82-0115-00	1,732	826,520	677,746	0	0	66,122	82,652
Thompson Lake	19-0048-00	178	134,340	110,159	0	0	10,747	13,434
Valentine Lake	62-0071-00	2,404	1,165,072	955,359	0	0	93,206	116,507
Wirth Lake	27-0037-00	426	1,095,000	897,900	0	0	87,600	109,500

Table 7: Summary of TMDL and Components for Statewide Impaired Lakes and Wetlands.

[1] WLA=0 in the wastewater sources column means that there is no wastewater discharges in that watershed

Table 8: Summary of TMDL and Load and Wasteload Allocations

Stream	Watershed	AUID	Watershed Area (ac)	TMDL and Components (all values in lb/yr of chloride)					
				Loading Capacity (TMDL)	WLA		LA		Margin of Safety
					MS4 Categorical	Wastewater Sources[1]	Non-Permitted Aggregate	Natural Background	
Bass Creek	Mississippi River - Twin Cities	07010206-784	5,434	1,746,399	1,432,047	0	0	139,712	174,640
Bassett Creek	Mississippi River - Twin Cities	07010206-538	25,209	9,334,219	6,642,961	1,233,048	0	648,094	810,117
Battle Creek	Mississippi River - Twin Cities	07010206-592	7,246	2,328,721	1,909,551	0	0	186,298	232,872
Elm Creek	Mississippi River - Twin Cities	07010206-508	66,382	21,332,410	17,386,888	0	105,688	1,706,593	2,133,241
Judicial Ditch 2	Lower St. Croix River	07030005-525	1,587	510,115	418,294	0	0	40,809	51,011
Minnehaha Creek	Mississippi River - Twin Cities	07010206-539	109,151	35,997,083	28,679,140	1,004,128	0	2,806,140	3,507,675
Ninemile Creek	Lower Minnesota River	07020012-809	28,480	5,086,000	4,690,000	0	0	396,000	implicit
Raven Stream	Lower Minnesota River	07020012-716	42,750	15,023,193	442,771	1,284,983	10,822,561	1,099,057	1,373,821
Raven Stream, East Branc	Lower Minnesota River	07020012-543	14,751	6,025,349	442,093	1,284,983	3,445,007	379,229	474,037
Rush Creek, South Fork	Mississippi River - Twin Cities	07010206-732	13,844	4,470,069	3,646,696	21,010	1,532	355,925	444,906
Sand Creek (South)	Lower Minnesota River	07020012-513, 07020012-840, 07020012-839	175,578	59,480,179	4,402,547	3,056,425	41,864,932	4,513,900	5,642,375
Shingle Creek (County Ditch 13)	Mississippi River - Twin Cities	07010206-506	28,771	3,285,0002	2,117,0002	0	0	11680002	implicit
Unnamed creek	Mississippi River - Twin Cities	07010206-526	6,447	2,071,959	1,699,006	0	0	165,757	207,196

(Headwaters to Medicine Lk)									
Unnamed creek (Unnamed ditch to wetland)	Mississippi River - Twin Cities	07010206-718	793	254,852	208,979	0	0	20,388	25,485
Unnamed Stream (Unnamed lk 62-0205-00 to Little Lk Johanna)	Mississippi River - Twin Cities	07010206-909	1,627	522,817	428,710	0	0	41,825	52,282
Unnamed ditch (T111 R22W S1, north line to Unnamed cr)	Cannon River	07040002-555	2,144	970,9002	481,8002	0	0	386,9002	94,9002

[1] WLA=0 in the wastewater sources column means that there is no wastewater discharges in that watershed

[2]Loading capacities, WLA, and LA are reported ay the 50% load duration interval if load durations were calculated based on varying flow regimes.

Table 9: Waterbodies Impaired for Chloride without a TMDL Developed at the time of this document

Water body name	Water body description	Water body type	Year added to List	AUID	County	HUC 8	Watershed name
Okabena Creek	Elk Cr to Division Cr	Stream	2018	07100001-602	Jackson	07100001	Des Moines River - Headwaters
Miller Creek	Headwaters to St Louis R	Stream	2010	04010201-512	St. Louis	04010201	St. Louis River
Credit River	-93.3526 44.7059 to Minnesota R	Stream	2018	07020012-811	Scott	07020012	Lower Minnesota River
Redwood River	T111 R42W S33, west line to Threemile Cr	Stream	2008	07020006-502	Lyon	07020006	Redwood River
Joe River	Salt Coulee to MN/Canada border	Stream	2006	09020311-513	Kittson	09020311	Red River of the North - Tamarack River
Agnes	Lake or Reservoir	Lake	2010	21-0053-00	Douglas	07010108	Long Prairie River
Henry	Lake or Reservoir	Lake	2010	21-0051-00	Douglas	07010108	Long Prairie River
Winona	Lake or Reservoir	Lake	2010	21-0081-00	Douglas	07010108	Long Prairie River
Jewitts Creek (County Ditch 19, 18, and 17)	Headwaters (Lk Ripley 47-0134-00) to N Fk Crow R	Stream	2010	07010204-585	Meeker	07010204	North Fork Crow River

4.5. Protection of Surface and Groundwater

Protection is an opportunity to prevent waters from continued degradation, which may result in impairment. Prevention or protection is more easily accomplished than the restoration of an impaired waterbody. Protection efforts also may eliminate the need for additional permit and other regulatory requirements to reduce pollution. Successful protection efforts rely on understanding how current practices or conditions may be contributing to water quality conditions.

High Risk Surface Waters

Preventing a waterbody from being contaminated with chloride is easier and more cost effective than restoration. Chloride is a conservative ion and will not break down over time, but rather it accumulates in waters. Therefore, efforts should be made to protect waters that show an increasing trend in chloride concentration or have been shown to have chloride concentrations approaching the water quality criteria. Lakes, wetlands, or streams with at least one sample within 10% of the chronic water quality standard within the last 10 years have been identified as a high risk waterbody (one exceedance of 207 mg/L chloride). Proactive actions to reduce chloride loads to these high risk waterbodies should be pursued. Proactive actions similar to actions listed for impaired waters should be explored to protect high risk waters. These waters are considered to be approaching the water quality standard and if no actions are taken, they will likely reach impairment status in the near future. The lakes and streams identified as being at high risk for potential chloride impairment are shown in Table 10 and Table 11, respectively.

It should be noted that there are potentially other impaired and high risk waters that have not been identified because there is limited or no monitoring data available for those waters. For this reason, similar proactive approaches to chloride management for those waters should be taken to prevent chloride contamination.

All Surface Waters and Groundwater

In addition to the high risk waters listed above, protecting all surface waters and groundwater from further degradation due to chloride is important. By implementing salt-reducing practices throughout the Minnesota, both the need to restore those waters already impaired and also protect those waters not yet exceeding the standard are addressed. The practices necessary for protection of groundwater are the same as those for restoring and protecting surface waters. Through targeting and prioritization a starting point can be established. Management practices and BMPs used for impaired and high risk waters can be the same for all waterbodies and should provide the same level of protection and chloride reduction.

Table 10: High-Risk and Impaired Lakes in Minnesota

Lake Name	AUID	Highest Measured Cl concentration (mg/L)	Lake Name	AUID	Highest Measured Cl concentration (mg/L)
Unnamed Lake	27-0015-00	321	**McCarron**	62-0054-00	296
Unnamed Lake	27-0022-00	460	**Medicine**	27-0104-00	375
Unnamed Lake	27-0186-00	231	**Parkers**	27-0107-00	716
Unnamed Lake	27-0675-00	292	**Peavey**	27-0138-00	278
Unnamed Lake	62-0141-00	210	**Pike**	62-0069-00	710
Agnes	21-0053-00	515	**Powderhorn**	27-0014-00	660
Battle Creek	82-0091-00	555	**Rice Marsh**	10-0001-00	220
Beaver	62-0016-00	211	**Ryan**	27-0058-00	207
Bennett	62-0048-00	235	**Sandy**	02-0080-00	372
Brownie	27-0038-00	1250	**Silver**	62-0083-00	276
Calhoun	27-0031-00	268	**South**	43-0014-00	310
Carver	82-0166-00	850	**South Long**	62-0067-02	298
Centerville	02-0006-00	386	**Spring**	27-0654-00	1881
Como	62-0055-00	261	**Sunrise**	13-0031-00	220
Crosby	62-0047-00	322	**Sweeney**	27-0035-01	341
Crystal	27-0034-00	526	**Taft**	27-0683-00	259
Fish	19-0057-00	230	**Tanners**	82-0115-00	530
Gervais	62-0007-00	290	**Thompson**	19-0048-00	460
Henry	21-0051-00	536	**Unnamed**	62-0278-00	248
Hiawatha	27-0018-00	558	**Valentine**	62-0071-00	400
Johanna	62-0078-00	289	**Wabasso**	62-0082-00	225
Keller (main bay)	62-0010-02	223	**Wakefield**	62-0011-00	350
Kohlman	62-0006-00	1100	**Wilmes**	82-0090-00	235
Lake of the Isles	27-0040-00	250	**Winona**	21-0081-00	593
Little Johanna	62-0058-00	1060	**Wirth**	27-0037-00	815
Loring (South Bay)	27-0655-02	1273			

Table 11: High-Risk and Impaired Streams in Minnesota

Stream Name	AUID	Highest Measured Cl Concentration (mg/L)	Stream Name	AUID	Highest Measured Cl Concentration (mg/L)
Bassett Creek - Medicine Lk	07010206-811	250	**Redwood River**	07020006-502	366
Bass Creek	07010206-784	1930	**Rice Creek**	07010206-584	301
Bassett Creek	07010206-538	587	**Rush Creek**	07010206-528	405
Battle Creek	07010206-592	2248	**Rush Creek, South Fork**	07010206-732	750
Bevens Creek	07020012-514	247	**Rush River, North Branch**	07020012-558	428
Bevens Creek	07020012-848	374	**Sand Creek**	07020012-513	367
Bluff Creek	07020012-710	717	**Sand Creek**	07020012-839	1297
Buffalo Creek	07010205-638	338	**Sand Creek**	07020012-840	724
Chester Creek	04010102-545	330	**Sarah Creek**	07010204-628	290
Clearwater Creek	07010206-519	213	**Shingle Creek**	07010206-506	3600
Cottonwood Creek	07020005-511	290	**Snake River**	07030004-587	211
County Ditch 17	07010206-557	253	**St James Creek**	07020010-502	533
County Ditch 2	07010206-522	755	**Sunrise River**	07030005-526	468
Credit River	07020012-811	389	**Sunrise River, South Branch**	07030005-528	214
Diamond Creek	07010206-525	390	**Tischer Creek**	04010102-544	436
Eagle Creek	07020012-519	437	**Unnamed**	07010204-667	260
Elm Creek	07010206-508	1600	**Unnamed**	07010206-526	405
Fish Creek	07010206-606	244	**Unnamed**	07010206-678	232
Hawk Creek	07020004-587	250	**Unnamed**	07010206-704	382
Jewitts Creek (County Ditch 19, 18, and 17)	07010204-585	320	**Unnamed**	07010206-718	688
Joe River	09020311-513		**Unnamed**	07010206-738	630
Judicial Ditch 2	07030005-525	499	**Unnamed**	07010206-740	415
Keene Creek	04010201-627	215	**Unnamed**	07010206-909	1140
Kettle River	07030003-528	209	**Unnamed**	07030005-612	284
Miller Creek	04010201-512	440	**Unnamed**	07030005-765	588
Minnehaha Creek	07010206-539	3457	**Unnamed**	04010201-A83	230
Minnesota River	07020012-505	366	**Unnamed**	07010206-801	310
Ninemile Creek	07020012-809	796	**Unnamed**	04010201-987	295
Okabena Creek	07100001-512	413	**Unnamed**	07010206-594	246
Okabena Creek	07100001-540	376	**Unnamed**	07010206-744	279
Okabena Creek	07100001-602	344	**Unnamed**	07020012-533	248
Painter Creek	07010206-700	300	**Unnamed**	07040002-530	538
Purgatory Creek	07020012-828	221	**Unnamed**	07040002-555	417
Raven Stream	07020012-716	781	**Unnamed**	07010206-559	211
Raven Stream, East Branch	07020012-819	399	**Unnamed creek - to Long Lk**	07010206-914	600

5. Prioritizing and Implementing Restoration and Protection

Reducing chloride at the source is needed throughout the state of Minnesota, not only to reduce loading to already impacted waters but also to protect all water resources. There are multiple sources to consider, a variety of options to reduce chloride, and a large geographical area to address. This section is intended to provide guidance, resources, and information to assist in making the important decisions for managing chloride. The available data indicates that surface waters and groundwater in developed watersheds, as well as those with very hard drinking water sources are considered to be at risk for chloride impairment. Many lakes, streams, wetlands, and groundwater have limited or no data available, especially during critical times of the year, which makes it difficult to determine the current chloride status. Reductions in chloride loads not only benefit surface and groundwater quality, but may also reduce damage to infrastructure and vehicles due to corrosion, and reduce impacts to vegetation along roadways. Finally, reduced use of salt is likely to result in direct cost-savings to winter maintenance organizations and private applicators, while improved efficiency and adjusted water softening practices can have economic benefits on a residential and municipal scale. The trend of increasing chloride concentrations in lakes, wetlands, streams, and groundwater is continuing throughout Minnesota. This management plan provides the framework to reduce salt use and minimize continued chloride contamination of water resources.

Performance-Based Approach for Reducing Chloride

Reducing chloride use comes with the challenge of meeting the public's winter travel expectations, providing potable water suitable for public preferences and appliance operations, and economic benefits in agricultural and industrial settings. There are currently no environmentally safe and cost-effective chemical alternatives that are effective at melting ice on paved surfaces, and few considerable options to eliminate chloride use in water softening, and agriculture. Therefore, the continued use of salt as the predominant deicing agent for public safety and its use in water softening and agricultural settings is expected, but it is also expected that BMPs are implemented to reduce waste in these industries. New innovation is necessary to get us out of the everyday use of salt, but innovations are slow in developing and even slower at being tested and implemented. Good progress has been shown in winter maintenance innovation to reduce salt without reducing safety, but very few innovations have been implemented in the design of surfaces that require low/no salt, or innovation to recycle or recover salt. Setting a specific chloride load reduction target for each individual chloride source is challenging, as is measuring actual chloride loads entering our surface and groundwater from deicing salt and other nonpoint sources. Priority should be put on improving winter maintenance practices, dust control applications, and water softening efficiency, all together referred to as Smart Salting. With these considerations in mind, the implementation approach for achieving chloride TMDLs and protecting all waters is to focus on reducing salt at the source. In addition, continued and expanded chloride monitoring of surface and ground waters is critical to track progress and evaluate the effectiveness of implementation.

A standard approach to TMDL implementation is to translate the wasteload allocation (WLA) component of the TMDL directly to a numeric permit limit, which is typical for permitted facilities with monitoring requirements. In the case of urban stormwater regulated through a Municipal Separate Storm Sewer System (MS4) Permit, chloride reduction requirements may be present in the form of performance-based requirements, where numeric WLA would be translated to a performance criterion. This can include the development and implementation of winter maintenance plan, which identifies a desired level of the BMP implementation and a schedule for achieving specific implementation activities. Progress made towards those goals are documented and reported, along with annual estimates of salt usage and reductions achieved through BMPs implemented.

In cases where it is not feasible to calculate a numeric effluent limit, federal regulations allow for the use of the BMPs as effluent limits (40 CFR § 122.44(k)). Such a performance-based or BMP approach to compliance with WLAs is being taken by states to address the Chesapeake Bay TMDL for nutrients. The TMDL is being implemented through state Implementation Plans. Some states are taking a performance-based approach to addressing urban stormwater sources, requiring minimum levels of the BMP implementation rather than requiring specific levels of pollutant load reductions.

A performance-based approach will be tracked through documentation of existing winter maintenance practices, changes in water-softening activities, dust control practices, goals for implementing improved practices including schedules, and reporting on progress made. Entities may choose to use the Smart Salting Assessment tool (SSAt), which is a BMP tracking tool, to assess and document practices and set goals, or another approach of their choice. For an information about the tool, see Appendix A. Entities should track progress and document efforts, including, to the extent possible, estimates of reduced salt usage as a result of improved practices. Entities that have achieved their goals will have documented their practices in a winter maintenance plan or chloride minimization plan. Entities that have already made significant progress will be able to demonstrate this through their documentation of existing practices. This plan should be reviewed annually and evaluated against the latest knowledge and technologies.

The performance-based approach doesn't focus on specific numbers to meet, but rather on making progress through the use of BMPs. Progress is measured by degree of implementation and trends in ambient monitoring. In a traditional approach with numeric targets, progress would be measured by accounting for salt use and loadings and comparing to the targets. The performance-based approach is intended to allow for flexibility in implementation and recognize the complexities involved with winter maintenance, water softening, dust control, fertilizer, and other sources of chloride. Because the performance-based approach does not provide a specific numeric target, a limitation of the approach is that it is not definitive on when enough progress has been made. This can only be determined by continued ambient monitoring that demonstrates compliance with water quality standards.

5.1 Prioritization and Critical Areas

This plan has been developed for many different audiences and organizations. Organizations interested in reducing the amount of salt entering our water resources should begin with an effort to fully understand the problem, identify the sources of chloride impacting or having the potential to impact a water resource, and determine what role the organization plays in contributing, preventing, or slowing the growing trend of increased chloride in surface and groundwater.

Where do I start?

Every organization will have different priorities based on their local watershed conditions, the role of their organization in the watershed or state, and their organizations specific needs or goals. This plan cannot help you determine all of the important factors that will influence a specific organizations chloride reduction priorities, but it does provide some important considerations to make.

First and foremost, know what the primary sources of chloride are in your area of interest (city, county, watershed, sewershed, campus…). This plan has laid out all the known sources of chloride in Minnesota (Section 1. Sources of Chloride), but understanding the local conditions is the most important consideration. This step can range from a simple exploration of land use maps, or an evaluation of local impervious area along with wastewater and industrial facilities located in the community, to a comprehensive chloride source assessment project. At the time of publication, the MCPA has a contract to develop a chloride source assessment model and BMP tool that will allow Minnesota communities to fully evaluate their specific sources and magnitude of chloride and develop a community specific chloride reduction plan.

The next consideration is your organization's relationship with the primary sources of chloride in your area of interest. Perhaps it is a direct relationship and chloride reduction actions are clear, or it may be an indirect relationship making it difficult to clearly identify specific actions. This would be a great opportunity to collaborate with other organizations within your area to share ideas, challenges, successes, and find ways to work together.

Another important consideration in determining where to begin with reducing chloride is local water resources. This report provides important statewide chloride conditions and trends (Section 4. Chloride Water Quality Conditions and Trends), but the specific water resources in each community needs to be considered when determining what the best actions are for each watershed. Both surface waters and groundwater should be considered. It may be best to protect local lakes from chloride contamination, or maybe an important local stream is in the high risk category for chloride. Preventing local drinking water supplies from chloride contamination may be the top priority in your area of interest. It may be that there are many important and vulnerable water resources needing protection from multiple chloride sources. Ideally a long-term plan will be developed with specific actions that will be taken to address all the key sources. This may mean starting with easier sources for you to do first and then working towards the tougher sources over a 10 year period.

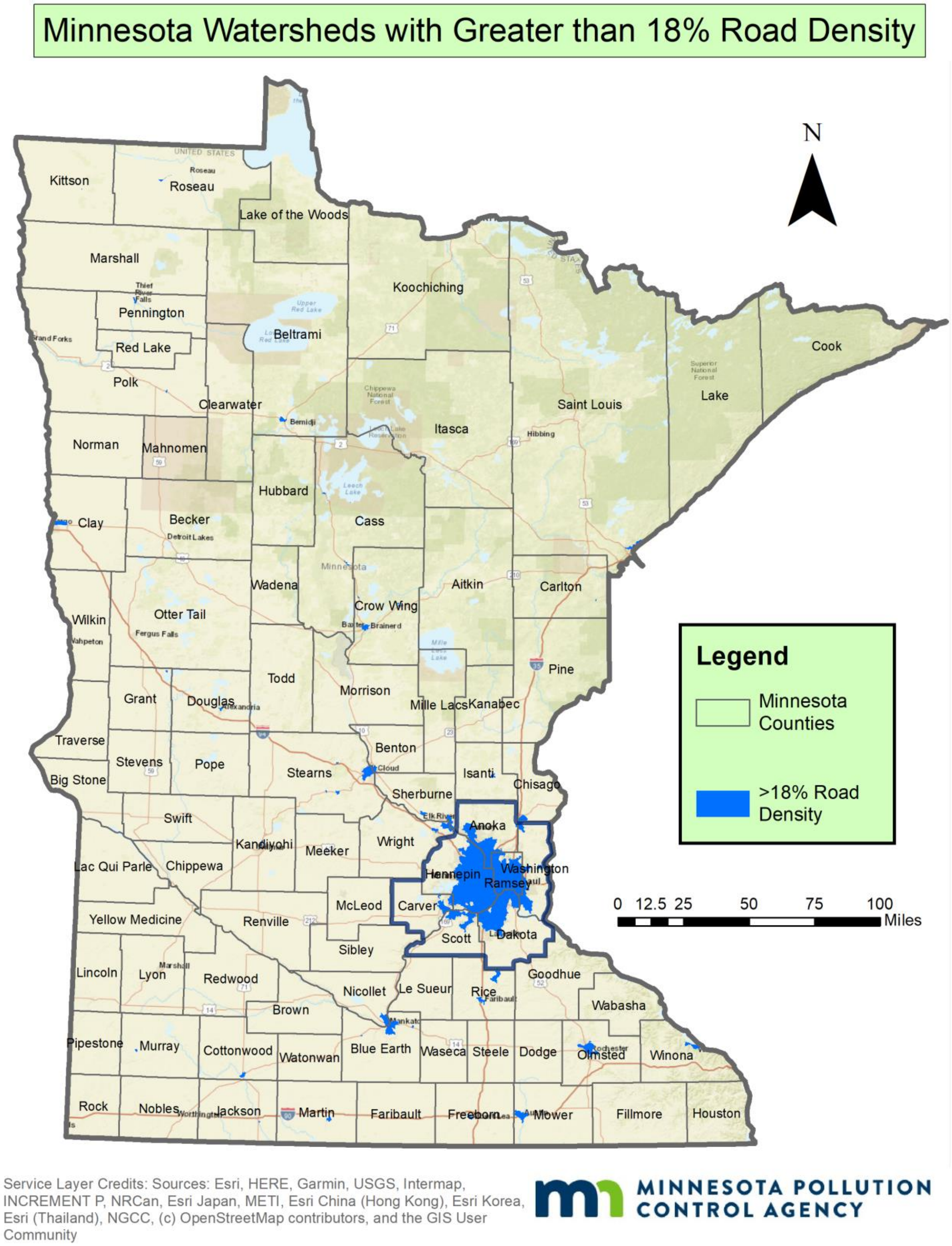
To aid in the important task of determining specific, local priorities for chloride reduction, the MPCA has defined critical areas for the primary sources of chloride causing water quality problems across the state. The goal is to provide a starting point for determining what chloride reduction efforts are most needed to achieve state water quality goals. Three separate methods were used based on the source of chloride to identify critical watershed.

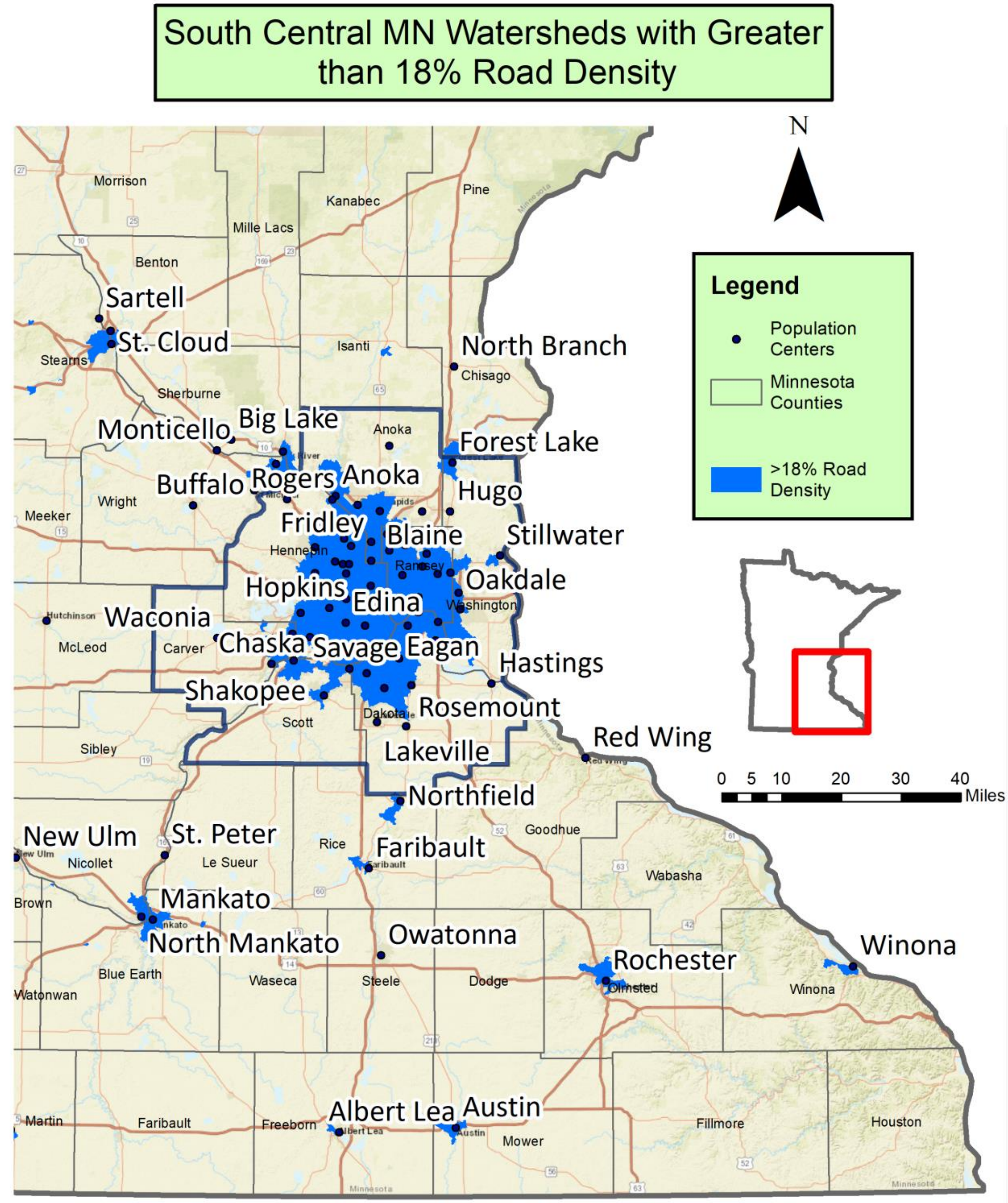
- The first method identifies watersheds with road densities of 18% or greater to identify watersheds where chloride concentrations are typically and most likely to be above water quality standards. Figure 63 depicts the critical watersheds statewide; Figure 64 highlights the critical watersheds in southern Minnesota; and Figure 65 shows the critical watershed in the northern part of Minnesota. An interactive map showing these critical areas is available on the MPCA Chloride website.
- The second method used to identify critical areas for chloride reduction focuses on areas with drinking water supply wells with hard and very hard water (Figure 7), and wastewater facilities with reasonable potential (RP) for chloride (Figure 66). Federal regulations require the MPCA to evaluate the discharge from waste water permit holders to determine whether the discharge has the "reasonable potential" to cause or contribute to a violation of water quality standards. Through these two methods, critical areas have been identified across the state where chloride

loadings are to be expected high, and therefore implementation efforts to reduce chloride should be focused. For the protection of surface and ground waters implementation is encouraged statewide.

- The third method is a new consideration given the significant source of chloride from agricultural fertilizer application. KCl or potash applications may be used in areas where soil amendments of potassium are recommended for increased yields, typically for soybean or corn production. These rates should be based on recommendations from University extension nutrient guidelines or expert guidance. Figure 67 is a map that shows regions throughout Minnesota where chloride application from KCl may be greatest based on annual potash sales. More research is still needed to determine the fate and potential impact.

Figure 63. Watershed with road densities 18% and greater in Minnesota





Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

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Figure 64. Watershed with road densities 18% and greater in Southern Eastern Minnesota

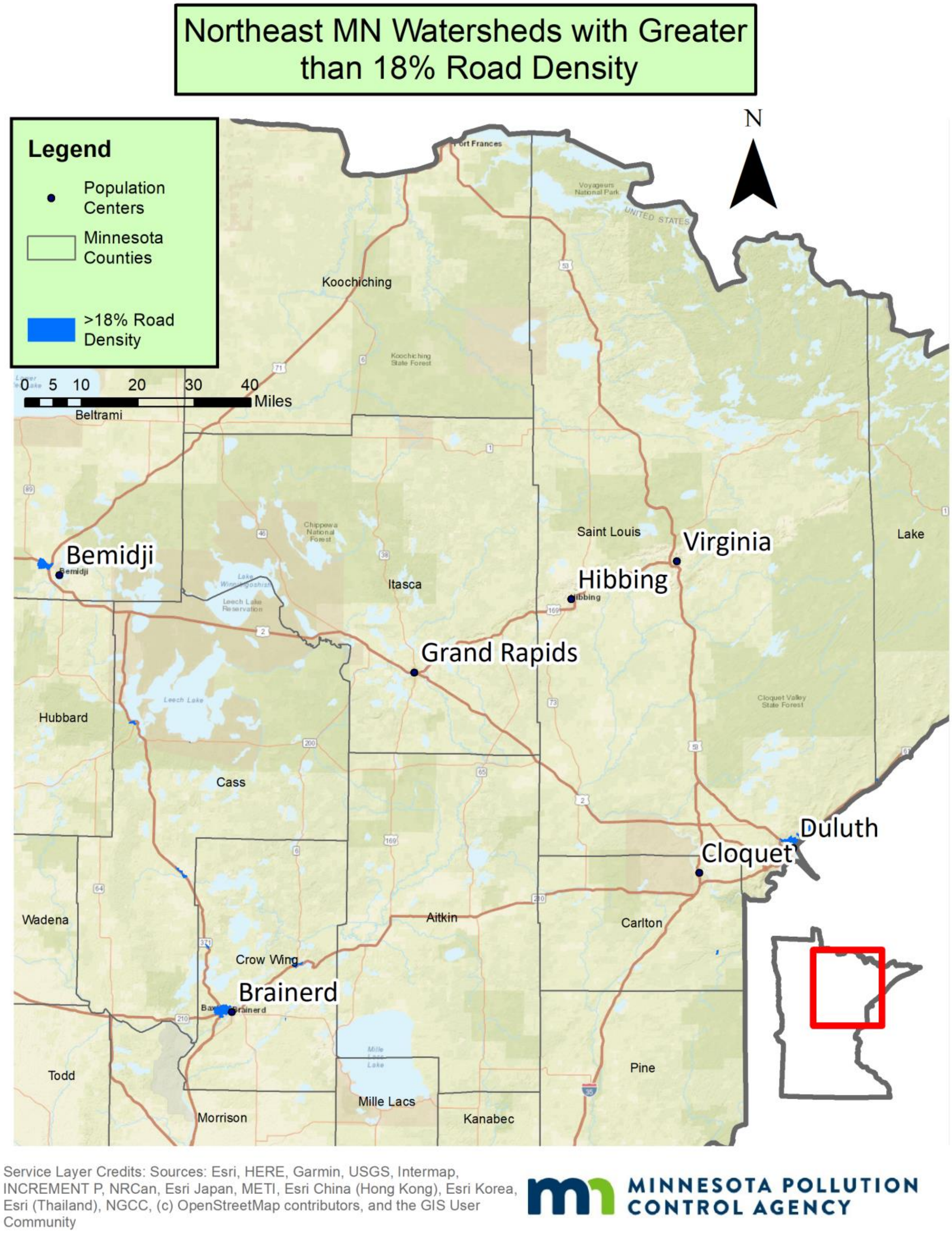

Figure 65. Watershed with road densities 18% and greater in Northeastern Minnesota

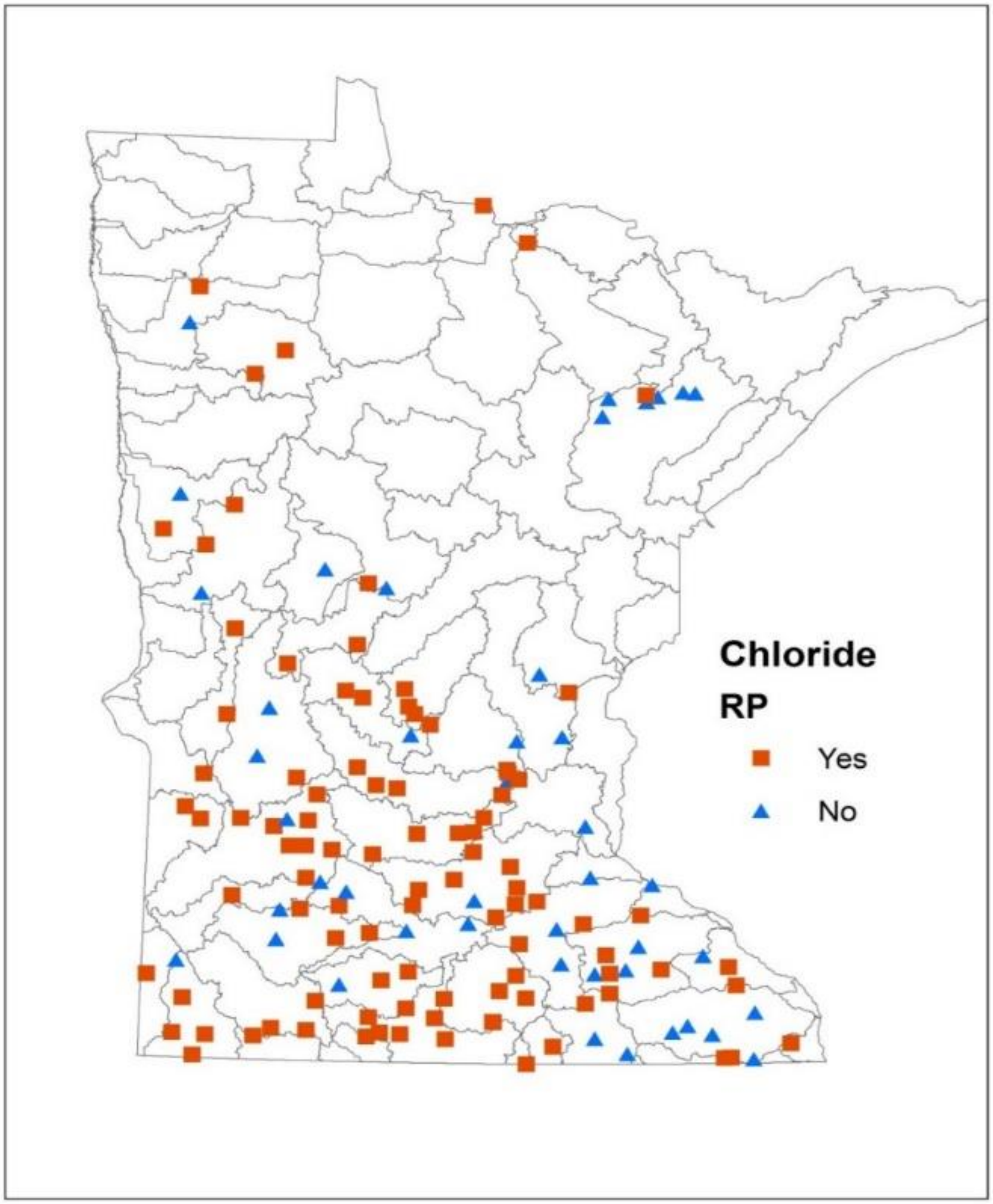

Figure 66: Prevalence of Minnesota communities with WWTPs having Reasonable Potential

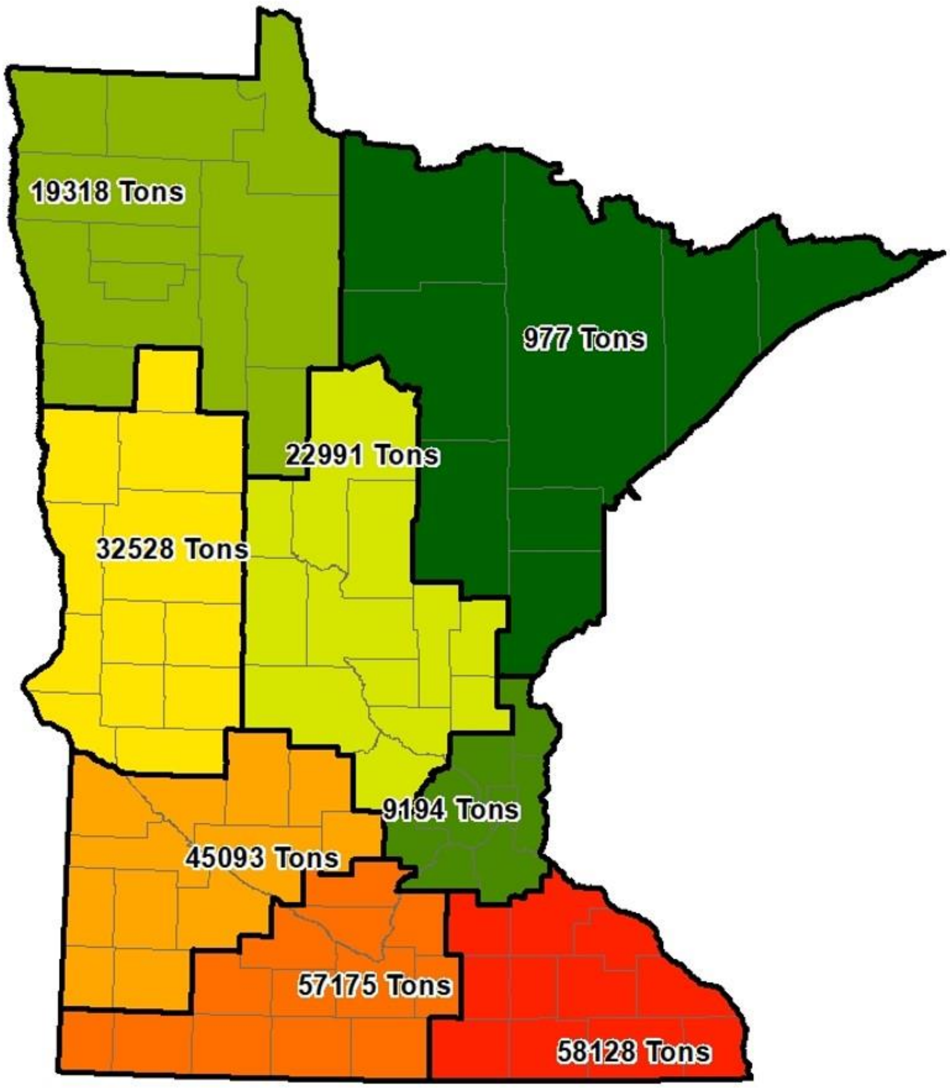

Figure 67: Annual chloride (tons) estimated from potash sales by district (Aicam 2020)

5.2 Implementation Strategies

This section provides the overall framework for the implementation strategies that are necessary to protect and restore our water resources. This section provides more detailed implementation activities for specific audiences and all sources of chloride. The over-arching implementation strategy is a performance-based approach. This approach allows stakeholders and regulators flexibility in the type of BMPs and the timing of implementation, and allows individuals an opportunity to develop specific chloride management strategies that are practical for their individual situation. Success under the performance-based approach will be measured in terms of BMPs implemented.

Figure 68: General performance-based timeline for chloride management, applicable to all stakeholders.

The overall performance-based implementation approach for the primary audiences and a suggested timeframe is presented in the figure above, with a more detailed set of strategies in Table 12. Secondary audiences are described at the end of this section and are not presented in a table. In short, local priorities should be set with a plan in place within 1 to 2 years after this Statewide CMP is released. Local priorities will vary by various stakeholder groups and audiences. By years 3 to 5, a local and organization specific implementation plan should be set and successes and progress should begin to be monitored. Years 6 to 10 should be spent sharing successes and revising any necessary components of the localized plan. Example activities for each of these steps for primary audiences are presented in Table 12.

To aid in the tracking and planning process, a Smart Salting Assessment tool (SSAt) has been developed by the MPCA and is available for use across the state. The SSAt is currently targeted to gravel road and winter maintenance professionals, however the tool will be expanded to include new sources of chloride such as water softening, fertilizer and industrial. The new expansion of the tool will also include a new GIS-interface for a variety of professionals to evaluate the estimated contribution of chloride from all sources within the selected defined watershed or other boundaries such as city/county. This will make the SSAt a comprehensive planning tool for reducing salt from all sources within a given community. Future updates to the SSAt will also include streamlining use of the tool with various permit reporting requirements for those with a NPDES permit with the MPCA. The current SSAt can be used voluntarily to understand current practices, identify areas of improvement, and track progress. It can also be utilized to fulfill new MS4 permit requirements for MS4s with a Chloride WLA. The tool is intended to streamline and simplify implementation goals and strategies. The tool can also be used to compare practices with other entities and learn from each other in order to achieve the greatest chloride reductions while maintaining the desired level of service. Utilization of this tool will allow the user to track their progress over time and show the results of their efforts. The tool can serve as both a reporting mechanism to understand the current practices and as a planning tool to project future practices. The planning side of the tool will help understand the challenges and costs associated with improved practices.

Table 12. Performance-Based Chloride Reduction Strategies

CMP Performance-Based Implementation Audience	years 1-2	years 3-5	years 6-10	Beyond year 10
Winter Maintenance Leadership (state, county, city, schools, private): those not involved in day to day operations of maintenance crew.	- Review responsibilities - Develop policies - Assess the situation - Create goals - Set priorities - Implement changes - Use SSAt - Communicate with your customers the chloride problem - Communicate with your staff the chloride problem	- Follow organizational implementation plan - Share successes - Communicate with your customers the chloride problem - Communicate with your staff the chloride problem	- Re-assess operations - Revise goals - Continue to implement changes - Share successes - Communicate with your customers the chloride problem - Communicate with your staff the chloride problem	- Re-assess operations - Revise goals - Continue to implement changes - Share successes. - Communicate with your customers the chloride problem - Communicate with your staff the chloride problem
Winter Maintenance Professionals (state, county, city, schools, private): plow drivers, mechanics, supervisors of crew.	- Attend training - Keep an open mind towards change - Look for ways to make salt use more efficient - Use SSAt - Create list with the desired changes - Prioritize the action plan - Implement changes - Use less salt	- Follow plan - Eliminate poor practices - Share successes - Use less salt	- Re-assess operations - Adjust goals - Follow plan - Eliminate all poor practices - Share successes - Use less salt	- Re-assess operations - Revise goals - Continue to implement changes - Share successes - Use less salt
WMOs/WDs, Environmental Organizations and Institutions, and Educators	- Modify plan - Put salt education and outreach goals in the operating plans - Develop/modify grant program - Develop a cost share program - If there is an existing grant program, modify - Monitor for chlorides in surface water, understand optimal times of year and locations to monitor for chlorides as this sampling is different than other pollutants. - Monitor for chlorides in shallow wells and surface waters near heavy dust control areas, high de-icing salt use and salt storage areas. - Communicate with your customers the chloride problem - Communicate with your staff the chloride problem	- Implement plan - Educate	- Implement plan - Educate	- Review and revise the outreach plan - Continue to educate - Encourage testing of new technologies
Municipalities	- Create a plan - Start implementing the plan - Track progress - Use the SSAt - Prioritize actions - Continue monitoring	- Follow plan - Continue to improve practices - MS4s report progress to MPCA	- Review and revise plan - Continue to improve practices - MS4s report progress to MPCA	- Follow plan - Continue to improve practices - MS4s report progress to MPCA
Wastewater Treatment Plants and Industrial Dischargers	- Understand the sources - Create a plan to reduce and remove chloride - Monitor chloride in effluent	- Implement plan - Discharge less salt	- Continue implementing plan for lower salt discharge - Share successes - Discharge less salt	- Review and revise plan - Continue making progress - Discharge less salt
Water Treatment Facilities (water supply)	- Research to determine if central treatment plant upgrades and optimized individual softening would be a lower salt solution. Develop plan for minimal salt use in water distribution area.	- Implement plan	- Implement plan	- Continue to work towards lower salt solutions.
Citizens	- Follow recommendations - Use less salt - Encourage others to use less salt	- Reduce salt use	- Reduce salt use - Encourage others to reduce salt use.	- Continue to reduce salt use.

CMP Performance-Based Implementation Audience	years 1-2	years 3-5	years 6-10	Beyond year 10
		- Encourage others to reduce salt use		
Citizens with private wells	- If you have a water softener, if you are a farmer that frequently applies a chloride based fertilizer or live on a gravel road that is frequently sprayed with dust suppressants, monitor your shallow wells for chlorides. - Opt out of dust control if it is an option - Considering your input water, adjust your water softener settings for efficiency, replace your softener with a higher efficiency model, or consider if removal is an option. Add an iron filter to your water softener if you are using softening as a strategy for iron removal. - Look for alternate fertilizers with less or no chloride.	- Reduce salt use - Encourage others to reduce salt use	- Reduce salt use - Encourage others to reduce salt use.	- Continue to reduce salt use.
MPCA	- Create and share the CMP for the TCMA - Continue monitoring chloride - Update chloride monitoring protocol as needed - Help various groups better understand the salt problem - Educate and promote lower salt solutions - Spearhead effort to update winter roads training manual used in smart salting training. Manual was written in 2005 with minor updates in 2012	- Support Statewide and TCMA CMP - Follow internal chloride reduction plan - Expand chloride monitoring, encourage others to monitor chloride - Collect and analyze and publish monitoring data - Create Statewide CMP - Share chloride monitoring protocol broadly as monitoring efforts across the state increase.	- Support TCMA CMP and statewide CMP - Follow internal chloride reduction plan - Expand chloride monitoring, encourage others to monitor chloride - Collect and analyze and publish monitoring data - Share chloride monitoring protocol broadly as monitoring efforts across the state increase. -	- Determine if TCMA CMP was effective - Adjust as needed - Re-evaluate chloride reduction efforts - Continue monitoring chlorides and encouraging others to monitor chlorides - Collect and analyze and publish monitoring data - Support statewide CMP - Share chloride monitoring protocol broadly as monitoring efforts across the state increase.
Policy Makers (city, county, state, other)	- Understand why we use salt - Understand what the options are for lower salt use In areas of concern research what other states/agencies have put into place to reduce salt use - Consider reduced speed limits on local roads	- Improve policy	- Improve policy	- Improve policy
Agriculture	- Inventory use of chlorides (ie.KCl in fertilizer, dust control on farm roads, NaCl in water softeners…) - Understand how chlorides affect shallow wells - Research Potassium needs and only apply KCl if needed - Research dust control in nonchloride form, or ways to reduce dust control chemicals. - Research lower salt use water softeners, install iron filter instead of softening water to remove iron. - Create farming strategies to reduce chloride use - Test wells for chloride, compare to drinking water standard of 250 mg/l - Investigate lower chloride supplements and food for livestock	- Implement chloride reduction strategies - Explain your strategies to other farmers - Work with suppliers to get lower chloride products - Monitor wells - Experiment with nonchloride sources of potassium in fertilizer - Understand chloride load in manure	- Implement chloride reduction strategies - Explain your strategies to other farmers - Monitor wells - Work with suppliers to get lower chloride products - Improve manure management to reduce chloride loading near well head, rivers, surface water	- Implement chloride reduction strategies - Explain your strategies to other farmers - Monitor wells - Work with suppliers to get lower chloride products - Explore lower chloride feed for livestock

CMP Performance-Based Implementation Audience	years 1-2	years 3-5	years 6-10	Beyond year 10
Gravel road maintenance, (city, county, state, other) Mining and others industries involved in outdoor dust control	- Hire dust control contractors that have done the free gravel road maintenance assessment on SSAt and who are educated on ways to minimize chloride dust control products. - Look for ways to control dust without chlorides - Determine what level of service is needed vs wanted. - Seek out strategies to minimize amount of chloride dust suppressant required to accomplish your various goals. - Educate crew and customers about the long term impacts of using chloride based dust suppressants - Road maintenance industry. Use SSAt - Understand your risk of applying dust suppressants near shallow wells. Consider informing well owners of the risk and giving them an option to opt out of the chloride treatments. - Avoid applying dust suppressants as a “favor” to home owners consider making them sign off on the risk they are taking to their water source. - Consider shallow well chloride monitoring near areas of heavy or long term dust control activities. - Create list with the desired changes - Prioritize the action plan - Implement changes - Use less salt	- Follow plan - Share successes - Use less calcium and magnesium chloride.	- Re-assess operations - Adjust goals - Follow plan - Share successes - Use less calcium and magnesium chloride.	- Re-assess operations - Revise goals - Continue to implement changes - Share successes - Use less calcium and magnesium chloride.
Turf maintenance professionals and those maintaining lawns	- Soil test to see what nutrients are needed for your turf - Don’t add potassium unless soil test indicates a need - Professionals attend MPCA level 1 turf certification course - Avoid fertilizing on frozen ground - Avoid fertilizing any hard surfaces - Leave grass clippings to reduce one fertilizer application - Use MPCA turf matrix to guide practices https://www.pca.state.mn.us/sites/default/files/p-tr1-05.pdf	- Implement BMPS in MPCA turf course for example: calibrate your spreaders or hire professionals who calibrate their equipment - Research possibility of nonchloride K source. - Hire trained and certified turf managers if you don’t maintain your own turf area	- Implement BMPs such as - Mow higher - separate weed and feed - Apply proper amount - Apply at proper times of year - Aerate - Use MPCA turf matrix to guide practices https://www.pca.state.mn.us/sites/default/files/p-tr1-05.pdf	- Re-assess operations - Revise goals - Continue to implement changes - Share successes

5.3 Chloride Reduction Strategy

Implementation Strategies: General Considerations

Chloride management is a challenging issue in Minnesota and requires a balance between public safety, public preference, industrial and agricultural performance, and the environment. In addition to the balance, chloride management is complex because demand may vary. This is particularly true regarding how different winter seasons require varying levels of maintenance. Different winter events can be a result of the type of precipitation, temperature, longevity of the event, timing of the event, etc. In addition to variations in each event, winter seasons can be highly variable from year to year. Other sources (water softening, agricultural, etc.) may be more predictable on an annual basis, but are also dependent upon socio-economic factors.

Implementation Strategies for Winter Maintenance: Traditional Framework

Snow and ice maintenance practices vary between road authorities and private applicators. Training, equipment, available resources, client expectations, and political pressure all factor into the amount of deicer being applied. There is no single BMP that can cost-effectively remove snow and ice and maintain an appropriate level of service for all of the various situations. Chloride management can only be achieved through implementation of an array of different BMPs. The BMPs vary by effectiveness in reducing chloride application and cost of implementing the BMP.

This document includes an arsenal of BMPs, which give maintenance professionals many ways to reduce chloride. It provides BMPs that can be used by high-use/high-experience entities all the way to low-use/low-experience entities. A wide range of BMPs allows greater flexibility in the timing and extent of implementation of BMPs.

The primary recommended winter maintenance strategies include, but are not limited to:

1. Shift from granular products to liquid products
2. Improved physical snow and ice removal
3. Snow and ice pavement bond prevention
4. Training for maintenance professionals
5. Education for the public and elected officials on chloride problems and reduction strategies

These strategies are centered on the continued use of chloride containing products in the most efficient and effective manner possible. This approach assumes maintaining the same level of service. There are several industry shifts that are needed to reduce salt waste. These changes are applicable to all winter maintenance areas in which a high level of service is expected: roads, parking lots, and sidewalks. Implementing the strategies above will lower salt use, will slow down chloride loading to the waters, but it may not be reduced enough to protect or restore all water resources.

As part of the stakeholder process to develop the CMP, a Technical Expert Group (TechEx) was developed and consists of hands-on winter maintenance professionals and industry representatives. The TechEx was engaged to better understand the state of the practices and the BMPs available to the winter maintenance industry. The TechEx provided valuable information on specific BMPs that are currently being used by various entities and the benefits of implementing these salt reducing strategies.

This team has been instrumental in the development and revisions of the SSAt, which is designed to assist winter maintenance organizations in developing their own customized salt reduction plan. The TechEx's knowledge, experience, and dedication to using smart salting techniques has been utilized to create this first ever comprehensive evaluation of all available chloride BMPs. Utilization of this planning tool will allow the user to track progress over time and show the results of their efforts.

The tool can serve as both a reporting mechanism to understand the current practices and as a planning tool to understand future practices. The planning part of the tool will help the user understand the challenges and costs associated with improved practices. The SSAt provides a more detailed and comprehensive list of the BMPs available to winter maintenance professionals. SSAt is undergoing enhancements so that in the future it will be a tool to help manage sources of chloride beyond deicing and dust control.

A few salt saving BMPs for winter maintenance programs

While the preferred and most effective approach for developing a chloride reduction plan for individual winter maintenance programs is to utilize the SSAt, here are a few BMPs that have been proven to reduce salt use.

1. Calibrate all equipment regularly (both liquid and granular systems).
2. Integrate liquids (avoid applying dry material).
3. Develop a Winter Maintenance Policy/Plan and share it with supervisors, crew, and customers.
4. Provide state-of-the-art Smart Salting training, education, and professional development for all who work in the industry.
5. Store salt indoors and on an impermeable pad.
6. Anti-ice before events to reduce bonding of snow to pavement, when conditions are appropriate.
7. Use ground speed controllers.
8. Upgrade to equipment that can deliver low application rates.
9. Select products that will work well given the pavement temperatures and conditions.
10. Select application rates based on road temperatures and trends, the product used, cycle time and other factors.
11. Start mechanical removal as soon as possible and keep at it throughout the storm.
12. Use a variety of methods to reduce bounce and scatter of sal
    - Reduce speed
    - Higher liquid to granular ratio
    - Lower spinner elevation
    - Chutes or skirts
    - Reduced spinner speed
    - Target center of road.

13. Refine application rates charts and continually test lower rates.

These BMPs may not be practical for all winter maintenance programs and should not be considered the best or only options for salt reducing activities, but rather a list of BMPs that many programs have already begun implementing, and are seeing reduced salt use as a result. To determine the activities appropriate for each organization please visit the MPCA's Stormwater Manual to utilize the SSAt.

The MnDOT is a leader in winter maintenance related research in the state. Research reports and technical summaries on the latest research can be found on the MnDOT Research Services website.

Implementation Strategies for Winter Maintenance: Nontraditional Framework

The continued use of chloride-containing deicing materials to provide safe winter conditions may not be a sustainable long-term solution. Therefore, considering practices that fall outside the current and common methods for winter maintenance are worth evaluating. When evaluating nontraditional methods, it is important to consider the environmental impacts of the methods.

Nontraditional approaches require public acceptance in terms of costs, expectations, and changes in behavior. Implementation of these practices will require messaging to the public, which includes discussion of the potentially significant costs to individuals and government. Five of the main areas where change may be considered include:

1. Adopt a lower level of service for roadways, parking lots, and/or sidewalks during snow and ice conditions, while still providing adequate safety.

In this scenario, the public would be given a lower level of service on the roadways, parking lots, and/or sidewalks. Physical removal of snow would likely remain the same but the salting would diminish. There are many ways in which winter maintenance professionals could change their level of service. For example, roads could be salted less frequently or perhaps less of the road could be salted. Instead of roads free of ice and snow from shoulder to shoulder, the melted zone could be reduced, perhaps to the middle of the drive lane. Salting could be restricted to critical areas such as intersections, ramps, hills, and high speed roads. De-icing salt would still be used, but to a lesser extent.

Winter speed limits – alter the speed limits to match the driving conditions during winter storm events or super cold weather times when black ice is present. The MnDOT currently uses a managed traffic lane approach for dealing with high traffic volumes and congestion on the interstate system within the state. It provides a way for the MnDOT to suggest a speed that will reduce braking and further congestion. This same approach could be utilized to manage the expectations of drivers in terms of speed during snow and ice conditions. The temporary winter speed limit approach has been taken in several states including Illinois, Pennsylvania, Colorado, Maine, and Oregon.

The use or possible requirement of snow tires is also a potential tactic, but not without its own problems. Some types of snow tires have been associated with increased road wear and subsequent pollution, and Minn. Stat. 169.72, prohibits studded tires. The challenge with this approach lies again with public acceptance and driver education on how to safely use winter tires. There would also be a direct cost to consumers and costs for the enforcement of such a requirement. Increased maintenance to roads would likely be an indirect cost associated with this approach, which the resulting salt savings would be modest at best.

- *Primary challenges:* Changing the public's behavior and would require acceptance from the public. The cost of longer commute times and perceived less safe travel conditions, as well as savings from fewer accidents and possible increased telecommuting, in winter months are unknown with this approach however. This would affect nonmotorized commuters as well (i.e. pedestrians and bicyclists).
- *Benefits:* Potential to immediately reduce the amount of chloride entering our waters and would save money in salt purchases. This strategy would be easy to implement from a technical perspective but challenging to implement without political and public support.

2. Alternative pavement types and urban design

In this scenario, government transportation agencies and private industry would adopt different forms of pavement that can be kept clear with less, or without the use of, salt. This could include various forms of heated roadways, new types of improved traction surfaces, surfaces constructed with internal anti-icing features, solar roadways, which could generate heat as well as electricity, permeable pavements, and flexible pavements. Narrower roadways may also allow for less application of deicing material.

Urban design methods such as parking ramps and covered parking, skyways or covered walkways, porous paving, public transit, transit-oriented development, and higher density development may also help to reduce impervious surfaces, reduce impervious surfaces requiring deicing, and reduce the overall chloride use.

- *Primary challenges:* would require large-scale public funding, and substantial rework of existing roadways. May result in much higher direct costs making its adoption less desirable and practical. This would be difficult to implement on a large scale due to funds, but may be feasible at a smaller, watershed scale. This approach may take a significant amount of time to convert traditional roads to high performance roads. It will be important to educate entities on permeable pavements and the importance in reducing chloride application since the runoff from permeable pavement surfaces will enter the groundwater.
- *Benefits:* No drastic change in the public expectations for winter travel conditions. Could implement as infrastructure is redeveloped. Would allow for treatment of other pollutants as well.

3. Driver behavior changes

Voluntary use of winter tires or other types of tires with improved traction, driving at lower speeds in winter, maintaining greater following distances, attentive driving, reduced expectations on level-of-service, and increased chances for telecommuting are examples of behavioral changes that drivers may adopt that could reduce chloride use. There remain concerns that driver behavior would not change enough to allow less salt use.

Work with employers to establish a work from home policy during snow events for employees who have suitable jobs. The work force is already experiencing an increase in remote worksites, timing is right to encourage this type of proactive winter storm behavior with employers. Possibly this will reduce traffic enough during critical times to allow maintenance to be more effective with less salt.

- *Primary challenges:* need to advertise to employers the opportunity they have to engage in the more sustainable practice of remote workforce during snow events. Some types of winter tires may increase damage to roads although tire technology for winter tires is excellent and offers much improved traction. The problem is maintenance crews try to make it safe for everyone including those with bald and low functioning tires. Need widespread education on winter conditions and easy to get advice for drivers to slow down during winter events. The trend is in less attentive driving so this opportunity seems smaller than others.
- *Benefits:* Driver changes would allow for easier and continued reduction in salt use.

4. Nonchloride deicers

There is a fairly wide variety of other chemicals, which do not contain chloride that can be used for anti-icing and/or deicing. However, there are significant environmental concerns with most of the existing alterative products. In general, the toxicity of nonchloride based deicers is often more severe to surface water organisms in the short term as the chemicals breakdown. There are fewer long-term concerns with nonchloride deicers, which should be evaluated against the long-term permanency with chloride. Of the four strategies, this may be the easiest to implement, but the possible negative environmental impacts of these alternatives are the highest of the options listed and needs to be better understood.

- *Primary challenge:* in general, the costs of alternative products that work as well at melting ice are more expensive than chloride containing products. The environmental consequences of alternative products are relatively unknown.
- *Benefits:* no requirement for public acceptance or changes in behavior. Easy to begin implementing and only requires minor adaptations from maintenance professionals to understand how to effectively and appropriately use these new chemicals.

See MnDOTs Transportation Research Synthesis Report: Chloride Free Snow and Ice Control Material for further information on nonchloride deicers and other nontraditional strategies such as permeable pavement, reducing road widths, solar, and others.

5. Snow melting equipment

Snow melting equipment may be a viable solution in some cases. However, the costs, practicalities, and other environmental consequences of snow melting equipment should be explored further before implementing this method.

Implementation Strategies for Water Softening

Chloride management related to water softening presents a challenge of balancing environmental protection with socio-economic factors. Water hardness is greatly variable geographically, and the amount of salt used in the softening process depends on the hardness of the local source. Municipalities have an opportunity for centralized municipal hardness reduction prior to distribution, but this is a local decision based on economic considerations and community feedback.

There is no single best approach to meet softening needs for localized industrial uses and residential preferences. Within commercial and residential settings, softness can be necessary to prevent scaling on appliances and household items. Softening can also be driven by taste and hygiene preferences, though there is no specific health issues related to hard water. Communities with drinking water hardness that is greater than 7 grains per gallon or 120 mg/L, may consider hardness reduction treatment to ensure appliances run well and to improve the taste, smell, or look of the water (MDH, https://www.health.state.mn.us/communities/environment/water/factsheet/softening.html). Industrially, softening may be necessary for certain manufacturing or chemical processes. Thus, individual communities must balance the particular hardness in their source water with the particular uses and preferences when deciding on a management strategy.

This document includes a collection of BMPs, which give professionals, municipalities, and community stakeholders many ways to reduce chloride. This provides BMPs that can be used by high-use/high-experience entities all the way down to low-use/low-experience entities. A wide range of BMPs allows greater flexibility in the timing and extent of implementation of BMPs.

The primary recommended water softening strategies include, but are not limited to:

1. Improve understanding of local chloride budget.
2. Upgrade in-home and on-site softening equipment to equipment with a salt efficiency rating of no less than 4,000 grains of hardness removed per pound of salt used in regeneration. This may affect older water softeners (>10 years old)
3. Offer inspection and calibration services for existing newer water softeners (<10 years old) to achieve greater efficiency.
4. Evaluate the option of centralized municipal hardness reduction or RO to determine if this strategy is appropriate.
5. Education for the public and elected officials on chloride problems and reduction strategies.

These water softening strategies are built upon two principals, improving understanding of the local options, and leveraging opportunities to reduce use with more efficient technologies. Alone, these changes may not fully restore or protect all water resources, but will help communities make strides towards understanding and addressing the broader chloride issue.

Implementation Strategies for Dust Suppressants

Dust suppressants provide a number of benefits, which must be balanced when considering the goals of chloride management. Dust management on gravel roads extend the lifespan of aggregate surfaces, increase driving safety, ensure better health for citizens in the area, and prevent excessive dust and sediment from being deposited into surface waterbodies. Consequently, these factors, as they relate to local needs and roadway use patterns, may be of variable importance to a particular community.

Primary recommended dust suppressant strategies for local communities include, but are not limited to:

1. Tracking application rates and locations
2. Reviewing appropriate level of service
3. Reviewing alternative suppressants without chlorides Current alternatives can be found in an MPCA report: https://www.pca.state.mn.us/sites/default/files/aq1-15.pdf

4. Educating crew and customers about the long-term impacts of using chloride based dust suppressants

Implementation Strategies for Agriculture – Production and Research Needs

Agricultural practices involve salt or chloride applications to meet the biological needs of both plants and animals, thus chloride management needs to consider the best opportunities to reduce use and or export without harming yields. Chloride can be introduced to the environment through fertilizers and land application of manure.

Primary recommended chloride management practices in agriculture include, but are not limited to:

1. Inventory use of chlorides
2. Testing chloride in wells
3. Test soils for Potassium needs prior to KCl fertilization, and apply at agronomic rates
4. Follow suggested application and management practices for K application
5. Identifying chloride transport pathways
6. Development of nutrient and CMPs

Implementation Strategies for Turf management

A common ingredient in turfgrass fertilizer is KCl. With many untrained users of turf fertilizer, the potential to drop KCl use with education is promising. Soil testing will provide guidance to professional turf managers who might still be able to reduce KCl use with Integrate Pest Management strategies and implementation of Best Practices.

Recommended chloride management practices in turf management include, but are not limited to:

1. Professionals to be trained and certified in turf management.
2. Determine K amendment requirements based on soil test
3. Implement BMPs from MPCA turf matrix and other reliable sources
4. Educate residents on fertilizer use and lower use strategies (i.e. leave lawn clippings to reduce one fertilizer application per year).
5. Explore alternative nonchloride based potassium sources for fertilizers in areas with high chloride concentrations in ground or surface water.
6. Include more education about potassium use in MPCA turf training program.
7. Monitor for chlorides during peak fertilizer times to better understand their contribution to chloride loading.

One of the challenges for fertilizer control is the ease of availability to obtain fertilizer and the lack of education and training for the nonprofessional users of turf fertilizer. It is likely that fertilizer is commonly over applied or misapplied by the nonprofessional users of turf fertilizer.

Another challenge is the KCl is the most commonly used and least expensive source of Potassium in most turf fertilizers. Its link to the chloride problem has gone unnoticed and unexplored until recently.

More work is needed in this area to explore adjusting fertilizer contents, use and recommendations based on the chloride dilemma.

Training and Professional Development Opportunities

- MPCA Level 1 Smart Salting Training and Certification
  - This training program teaches practices for effectively managing snow and ice while protecting Minnesota's environment. These classes are designed for private applicators and for city, county and state winter maintenance professionals, and property managers. There are several classes offered:
    - Winter Parking Lot and Sidewalk Maintenance
    - Winter Road maintenance. The Field Handbook for snowplow operators is given to each participant.
    - Property Management
    - The training schedule for the MPCA Smart Salting trainings can be found at https://www.pca.state.mn.us/water/smart-salting-training
- MPCA Level 2 Smart Salting Training and Certification
  - This on-line program is for the organization to evaluate its operations program and plan for changes to reduce salt use.
  - The training classes are available that provide winter maintenance professionals an opportunity to learn how to utilize the SSAt.
- SSAt
  - The SSAt has been developed as a resource of all known salt saving BMPs in winter maintenance and dust control (additional features coming soon).
  - The SSAt is a free, web-based tool that can be used to assist public and private winter maintenance organizations in determining where opportunities exist to improve practices, make reductions in salt use, and track progress.
  - https://smartsaltingtool.com
- MPCA Property Management Certification
  - This training will help management-level property managers or local government decision-makers learn how to save money and protect water resources using less salt and still maintain safe paved surfaces. The tons of salt used every year to manage snow and ice damages infrastructure and vegetation and pollutes our lakes, streams and groundwater.
  - This is a 3-year certification; to become Smart Salting certified:
    - Attend training
    - Pass test
    - Pledge to hire certified contractors

        - Pledge to certify your staff
        - Pledge to reduce salt use on your properties
- Minnesota Local Technical Assistance Program (LTAP)
    - Snow and Ice Control Material Application
        - This training is aimed at determining proper application rates during various conditions in order to use salt and sand effectively and efficiently.
    - Snowplow Salt and Sander Controller Calibration Hands-on Workshop
        - This workshop is aimed at calibrating salt and sander controllers. Attendees receive hands-on calibration instruction.
    - Gravel Road Maintenance and Design Course
        - This training is aimed at providing supervisors and operators with information on how to best maintain all aspects of gravel roads, including dust control.
- Fortin Consulting's Annual Salt Symposium
    - The symposium brings together environmental and transportation professionals to learn about the latest research on the environmental impacts of salt and innovations that are helping overcome the problems. Environmental leadership awards are presented to local organizations that are making progress in reducing salt.
- American Public Works Association (APWA)
    - Offer training at APWA meetings and conferences: https://www.apwa.net/
        - List of those certified by the MPCA Smart Salting trainings can be found at:

          http://stormwater.pca.state.mn.us/index.php/Smart_Salting_(S2)_training_certificate_holders
- Small site Smart Salting training video and homeowner Smart Salting training video can be found at https://www.pca.state.mn.us/water/educational-resources.
- MPCA Level 1: Summer Turfgrass Maintenance Training https://www.pca.state.mn.us/water/summer-turf-grass-maintenance-training
    - This training program is aimed at high level BMPs for Professionals such as private applicators, city and county park departments.
        - Turf Maintenance Manual is given to each participant.
        - Turf Maintenance Matrix is given to each participant
        - The training schedule for the MPCA turf trainings can be found at https://www.pca.state.mn.us/sites/default/files/p-tr1-02.pdf
- Other professional turf training programs that encourage IPM

Road Authorities

One of the challenges for public road authorities is the variability in road types, conditions, and meeting driver expectations. Each municipality is faced with unique challenges and circumstances that will play a role in determining the specific BMPs implemented. Development of winter maintenance policies/plans that are proactive and aim to minimize salt use is a critical first step for all winter maintenance programs to begin implementing the BMPs in an effective and strategic way. Training and regular professional development for all applicators is another key strategy to allow winter maintenance programs to reduce overall chloride use while providing an appropriate level of service.

Another valuable resource for public road authorities is their peer group. Several public road authorities have improved practices, significantly reduced chloride use, and have recognized cost savings by implementing BMPs. These success stories, when shared between entities can be a great way to demonstrate specifically how chloride reductions have been successfully achieved. Case studies describing some of these local success stories and specific areas of improvement are discussed below in Section 6 Success Stories.

Stormwater Authorities

A MS4 is a means of transportation, individually or in a system, (e.g. roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains, etc.) that are owned or operated by a public entity (e.g. cities, townships, counties, military bases, hospitals, prison complexes, highway departments, universities, etc.). These systems are designed or used for collecting or transporting stormwater. A small MS4 permit authorizes the Permittee to operate a small MS4 and to discharge from the small MS4 to receiving waters, in accordance with the requirements of the General Permit under the NPDES/SDS program. The MPCA's general permit for small MS4s (commonly referred to as the MS4 general permit) was issued in November 2020. For more information about the MS4 general permit, please visit: https://www.pca.state.mn.us/water/municipal-stormwater-ms4

The MS4 general permit contains minimum control measure (MCM) requirements that are to be included in the permittees Stormwater Pollution Prevention Program (SWPPP). New for this permit, three of the six MCMs include requirements to address chloride reduction specifically. Some of these provisions include:

- Distribution of educational materials or equivalent outreach to residents, businesses, and commercial facilities on topics of impacts, reduction methods, and proper storage (MCM 1)
- Proper salt storage at commercial, institutional, and non-NPDES permitted industrial facilities (MCM 3)
- Proper salt storage at permittee owned/operated facilities (MCM 6)
- Implementation of a snow and ice management policy (MCM 6)
- Annual training for winter maintenance staff (MCM 6)
- In addition to the MCMs, there are additional requirements to address discharges to impaired waters with a EPA-approved TMDL that includes an applicable WLA (Section 22 of the MS4 General Permit):

- If the permittee has an applicable WLA where a reduction in pollutant loading is required for chloride, the permittee must document the amount of deicer applied each winter maintenance season to all permittee owned/operated surfaces
- If the permittee has an applicable WLA where a reduction in pollutant loading is required for chloride, each calendar year the permittee must conduct an assessment of the permittee's winter maintenance operations to reduce the amount of deicing salt applied to permittee owned/operated surfaces and determine current and future opportunities to improve BMPs

The complete permit and all requirements can be found at:
https://www.pca.state.mn.us/sites/default/files/wq-strm4-94.pdf

The SSAt is a valuable resource to MS4s in terms of prioritizing and implementing the BMPs. Use of the SSAt is not a requirement but will allow each MS4 to determine their own priorities that may be based on cost, location, ease of acceptance, or other important factors unique to the MS4's particular situation. The SSAt provides the specific BMPs related to all areas of winter maintenance to aid in the development in a detailed plan that meets the unique conditions of each individual program and can be prioritized and implemented according specific needs and constraints.

Wastewater Authorities

Guidance from the EPA sets water quality standards for chloride to protect aquatic life. Chronic exposure limits are set at 230 mg/L (four-day average) and acute exposure limits are set at (860 mg/L). When MPCA determines reasonable potential to exceed a standard, it assigns a Water Quality Based Effluent Limit (WQBEL) to the WWTP permittee. The MPCA and permittee will work together to determine the best permit approach to meet any subsequent numeric standard.

When a WQBEL is established, MPCA and the permittee will work through the following decision tree together:

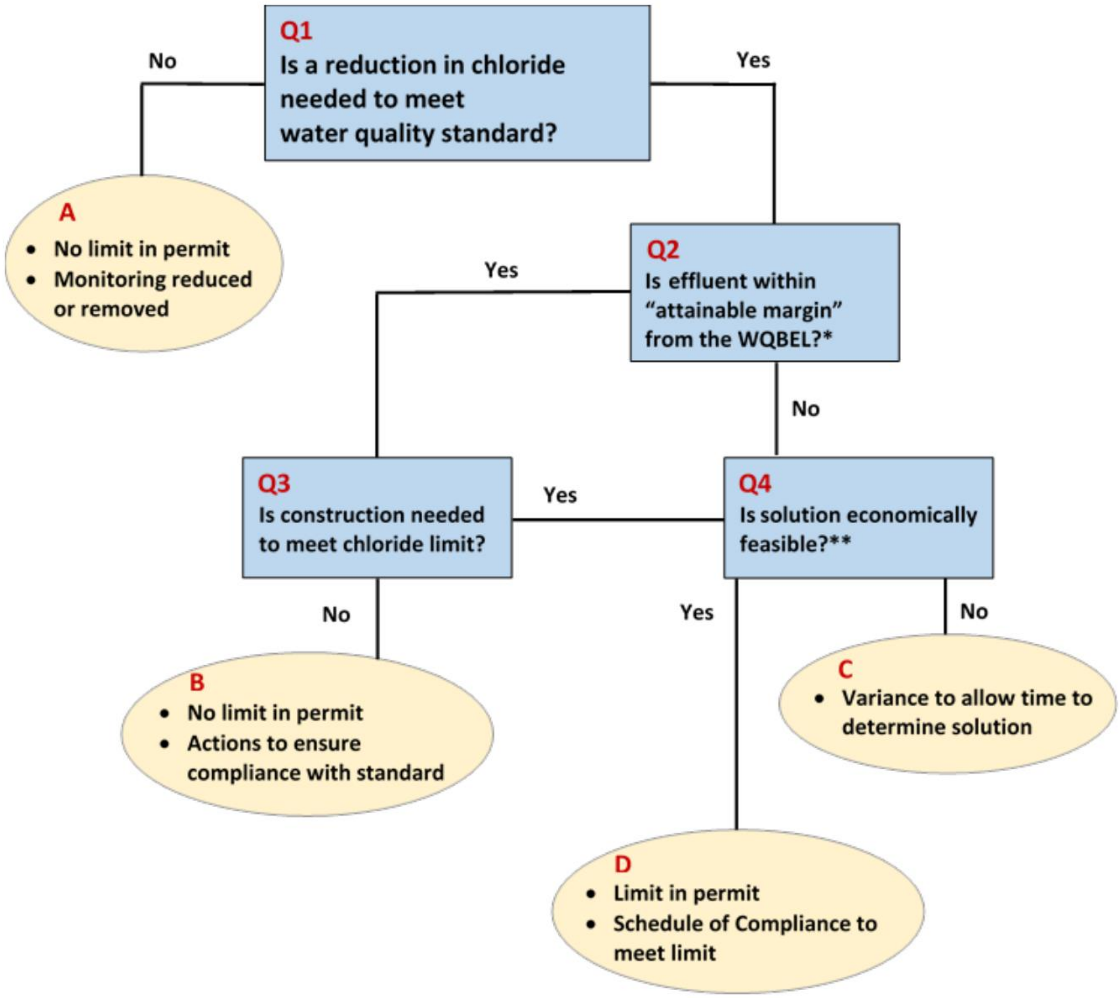

Figure 69: Chloride Decision Tree for implementing Minnesota's chloride water quality standard in wastewater discharge permits *(MPCA 2017).*

This process will establish whether an effluent limit is required, what any necessary numeric effluent limit should be, and what the permittee's most feasible approach to meeting the standard will be. Permittees may use the MPCA's variance screening calculator to determine economic feasibility of treating chloride to the effluent limit using a number of possible solutions.

If the solution is not economically feasible, the permittee may apply for a variance. The variance provides time for wastewater permittees to move toward attainment of a WQBEL. A variance allows the permittee to discharge in excess of the designated WQBEL for the period of time specified in the control document. A variance will contain an interim limit and a CMP as directed through a "schedule of compliance activities":

- The interim limit will be equivalent to the maximum effluent chloride concentration recorded in discharge monitoring reports during the previous period of record. The interim limit reduces the authorized load of chloride to the receiving water and ensures that pollutant loading does not increase.

- The schedule of compliance activities, or CMP, will require the permittee to explore chloride sources and the potential for reductions throughout the course of the variance.

For chloride, the MPCA is exploring a streamlined variance process in which applicability criteria are made available at a public meeting. For most communities, chloride sources and potential solutions are similar, and costs are reasonably scalable by population. Predetermined eligibility criteria will provide more certainty for communities and lower administrative costs for permittees and the MPCA. The schedule of compliance activities will also be standardized to the extent possible (MPCA 2017).

Private Winter Maintenance (Commercial, Industrial, Residential)

A major challenge in the overall reduction of chloride use is getting private applicators to reduce winter maintenance chloride usage. There are six primary hurdles related to this effort:

1. Liability concerns for applicators and property owners
2. Education and training for applicators, including cost
3. Contracting practices and incentives for applicators
4. Diversity in personnel experience
5. Private companies often are excluded from grant opportunities
6. Difficult bare pavement demands by their customers and the public

Two potential approaches to educating/training private applicators include a required training approach and a voluntary training approach, both discussed further below. A required training assumes that an ordinance or other regulatory mechanism is adopted by a governing body that requires training. A voluntary approach assumes that there is no ordinance or regulatory mechanism in place.

Potential Required Training Approach: for watersheds with chloride impairments (or suggested reductions)

1. Consider requiring the MPCA’s Smart Salting certification program statewide.
2. Watershed organizations to require the MPCA Smart Salting training for anyone performing professional level winter maintenance in the watershed.
3. Cities within those watersheds create an ordinance requiring Smart Salting training certification to work in their cities.
4. Cities ask commercial property owners in their city to become trained. They award contracts only to certified applicators.
5. All government organizations (state/counties/parks/schools/cities) to hire only Smart Salting certified contractors to maintain government properties.
6. The MPCA, watershed organizations, and cities all help advertise the training.

Voluntary Training Approach:

1. The MPCA to continue offering Smart Salting training statewide.
    a. Increase the number of classes

   b. Expand locations of classes
   c. Incorporate alternative methods for certification (e.g., Webinars)
   d. Increase advertising about the availability and importance of being "certified" winter maintenance professionals
2. Watershed organizations and cities host and advertise classes in their area.
3. Ask cities/watershed organizations to host and advertise Smart Salting training classes in their area.
4. Improve communications with contractors by advertising training and following the research recommendations:
   a. Email
   b. Mail
   c. Websites (the MPCA, watersheds, cities)
   d. In-person at trainings, seminars, and conferences (both winter and summer maintenance)
   e. Via other professional organizations (MNLA was commonly referenced)
   f. Posting in newsletters of other professional organizations
   g. Telephone

The winter maintenance industry has changed since the MPCA Smart Salting training program started in 2006. The training itself has also changed. By making the training certification valid for five years, this will encourage on-going awareness of the winter maintenance BMPs, keep the industry current with regulations, and strengthen communication between maintenance organizations and strengthen communication between the environment and maintenance. For optimal success these considerations should be made:

- Have certification valid for a five or fewer of years.
- Notify training participants when certification expires.
- Inform training participants that names/companies will be removed from the MPCA Smart. Salting certification list when expiration occurs.
- Provide a schedule for upcoming trainings.

In addition to education, legislation that limits liability for private applicators that are certified under the Smart Salting training program would enable them to use less deicer without fear of litigation. An important aspect to a statute like this is requiring training in order to maintain an appropriate level of service. The State of New Hampshire passed a new law, RSA 489-C effective November 1, 2013, which limits the liability of business owners who contract for snowplowing and deicing as long as the applicator is certified through the New Hampshire Green SnowPro Program. The entire law can be found at: www.gencourt.state.nh.us/rsa/html/NHTOC/NHTOC-L-489-C.htm.

Feedback from stakeholders in Minnesota has indicated that many of the private applicators over-apply salt because of concerns about litigation. A law like New Hampshire's RSA 489-C could change salt application behaviors of private applicators by limiting their liability.

In some cases, compensation for winter maintenance is based on the amount of salt used, which can incentivize over-application of salt. In this case, a boilerplate should be developed and performance based contract for private entities to use when contracting for winter maintenance services. Performance based contracting methods and the boilerplate contract could be part of the education and training programs for private applicators.

Homeowners and Small Business Owners

A clear message on why reducing chloride is important for the environment, important for saving money, and how to effectively use chloride will be the key to changing salt application behaviors by homeowners and small businesses. This messaging should be carried out by various state and local governmental entities in order to reach a broad range of people. It is important to note the impact residents and small businesses can have by reducing salt from both, winter maintenance activities and softening.

Nine Mile Creek approached this by providing a measuring cup type salt scooper to homeowners and small businesses in order to raise awareness of the amount of salt they are using. Homeowners currently not using salt should be encouraged to continue without salt. See MPCA's Chloride website for Statewide Educational resources.

5.4 Statewide CMP Elements for Specific Audiences

Winter Maintenance Leadership (State, County, City, Schools and Private)

Winter maintenance leadership is the group responsible for operation management. This group includes the individuals in charge of the shop facilities, selling winter maintenance services, determining the type of pavement overlays, or organizing the "getting ready for winter" refresher training. This group does not include the plow drivers or their direct supervisors.

Winter maintenance leadership is a very diverse group that plays a variety of roles across many organizations. Their influence is significant and they have great potential to positively impact reductions in salt use. This group can advocate for change by understanding the economic benefits of salt reduction, including the direct cost savings as a result of using less salt.

Table 13 presents example activities and timelines for winter maintenance leadership to consider. Throughout implementation, goals and practices should be reviewed, assessed, and adaptively updated to reduce the use of chloride. Examples presented in this section include specific possible actions. However, these actions are intended to be examples and are not meant to put emphasis on the specific actions. Each entity will need to assess the most relevant and cost-effective actions to take in their situation to reduce salt loadings.

Table 13. Considerations for Implementation Strategies to Include for Winter Maintenance Leadership

Assessment Items	Goals	Actions
Does salt leave storage sites in ways not intended?	No salty runoff water from salt sheds.	Storage sheds 1, 2, 4 are ok. Re-grade floor of storage shed 3 so water that enters the shed stays in shed.
Do customers know that salt harms the environment and that improved practices are being implemented to reduce salt use yet provide great service?	Give all customers the opportunity to learn about efforts to reduce salt.	Meet or talk to all customers when bidding on work explaining approaches to winter maintenance and environmental protection (private contractors) or run cable TV infomercials about salt reduction reasons and strategies during November (municipal).
Do trucks contribute salt to the truck wash water?	Re-use 50% of winter truck wash water for brine making or have less salt on truck prior to entering the wash.	Install filter system to remove wash water oils and solids, install tank to capture wash water, integrate filtered wash water in brine making system or Install a truck cleaning station before the truck wash to encourage thorough truck emptying in an area where granular salt can be easily reclaimed.
Which organizations have been most successful in reducing salt and what are the lessons learned?	Identify outstanding success in areas of interest (i.e. storage buildings, contracts that don't bill by the ton, using nontraditional plow drivers to get 24 hour coverage).	Look at Clear Roads research, Snow and Ice Management Association (SIMA) research, APWA research, AASHTO research, attend the annual Salt Symposium and other winter maintenance conferences to identify the leaders. Talk to them directly.
Are lower salt use pavements being tested or installed	Find some sort of pavement surface that requires 20% less salt on it.	Install heated concrete at doorway to public buildings. Consider installing a drain between heated and unheated surfaces to avoid ice dams
Is payment based on amount of salt applied?	Have a profitable contract without billing by the ton which encourages overuse of salt.	Look at MPCA model contracts for example contracts that do not charge by volume.
Do train your crew and hire certified contractors>	Have an educated workforce.	MPCA voluntary certification program for smart salting.
Is concern over liability resulting in over applying salt?	See if other states have a law to reduce liability for private companies doing winter maintenance.	Encourage legislators to look at New Hampshire's law that limits liability of private contractors in winter maintenance.
Do you sell equipment that can deliver salt at lower rates?	Look at MPCA Application Rates, charts, and design equipment that can deliver those rates.	Get new and improved salt saving equipment on the market.

EXAMPLE: YEARS 1-2

- Better understand the impacts of salt on the environment and how your organization may contribute.
- Create a chart of items to investigate that may reduce salt use/waste. Consider creating a list of items to be assessed, including goals, actions, and priorities.
- Visit the MPCA website for example low salt contract templates that do not charge by volume.
- Encourage legislators to look at New Hampshire's law that limits liability of private contractors in winter maintenance.

Watch a video: This video, produced by the MWMO and the UMN, is used to train seasonal and full-time property employees as well as business owners, front desk staff and anyone else who needs to control snow and ice in or near entrances and on sidewalks- https://www.youtube.com/watch?v=-xMt1kyzIcg

EXAMPLE: YEARS 3-5

- Install truck cleaning station before truck wash and provide training for proper use.
- Provide training for crew on how to monitor pavement temperatures, calibrate equipment, chose deicer's that will work best based on pavement temperatures.
- Revise contracts to avoid billing by the ton and stay profitable, meet with them for ideas.
- Educate customers about winter maintenance strategies.

EXAMPLE: YEARS 6-10

- Re-grade floor of storage shed #3.
- Install heated concrete at public building entrance.

Winter Maintenance Professionals (State, County, City, Schools, Parks, Private)

Winter maintenance professionals are responsible for performing outdoor, hands-on winter maintenance and those who supervise them. The primary duties include snow and ice removal from roads, sidewalks, parking lots, and trails, and applying a variety of deicers and abrasives. Some are part of emergency services and have exemption for laws that may cover weight restrictions on trucks or hours of consecutive work.

Winter maintenance professionals are employed by the public and private sectors, working for very small organizations to large organizations. Unusual hours and working in a variety of difficult winter weather conditions are typical in this industry. All of these professionals are under public scrutiny and receive comments about their work, because it directly and visibly impacts the public. There is a lot of pride within this sector as they are called on repeatedly, in the most difficult weather, to get the travelling public to their destinations safely.

The state, county, and city winter maintenance operations in the TCMA and in other population centers are under the extreme pressure of moving people safely on high volume, high speed roads, during all times of the day and night. Although their job is difficult, they often have the advantages of more sophisticated equipment, bigger support staff, less staff turn-over, and access to better and more frequent training than their private or more rural counterparts.

Private winter maintenance companies are very diverse and have a unique set of challenges. They often assume legal liability for “slip and falls” at their customer sites. They cannot bill clients when they attend training and have fewer incentives for training their crews. It can be difficult to locate this segment to invite them to Smart Salting trainings. The equipment used for small sites is less sophisticated and prone to over application of material. Their customers are spread out geographically, creating problems for proper and efficient storage and the transport of materials. Part-time seasonal workers fill many of the positions in these companies, which makes proper training an additional challenge for the employer.

The areas of maintenance vary greatly from seldom used sidewalks to the interstate. It ranges from concrete bridge decks, a country road, to the marble steps of the capitol building. Each maintenance area has unique challenges that must be understood and mastered. The public generally does not understand or appreciate the difficulty of winter maintenance, and certainly does not understand the increasing challenges and changes coming to this industry as it moves towards conservative use of salt.

Maintenance professionals should become educated on the environmental impacts of salt and how their practices contribute to it. Maintenance professionals should attend training on lower salt use strategies, keep an open mind towards change, and look for ways to make salt use more efficient.

Operators should attend training and learn about changes that can be made on an individual basis. Many salt saving strategies do not need the cooperation of an entire agency; they can be incorporated into daily work, such as applying salt at lower speeds to help keep the salt from bouncing off of the road, or not dumping left over salt at the end of a winter maintenance season. Other salt savings actions can be led by supervisors that will involve teamwork within the department, such as moving from manual controlled spreaders to computer controlled spreaders.

Supervisors may assess their current maintenance program using the SSAt, or other assessment techniques, to assess advanced, standard, and remedial practices. The remedial practices could be prioritized then followed by working towards improving good practices to make excellent practices.

Training opportunities, tools, and other resources for winter maintenance professionals can be found on the [MPCA Statewide Chloride Resources webpage.]

EXAMPLE: YEARS 1-2

- Clean out salt from truck thoroughly before washing truck.
- Avoid plowing off other's salt, communicate with other drivers.
- Bring extra salt back to the pile, do not use it up on the route if not needed.
- Add tanks to 5 trucks a year starting now.
- Work out agreement to buy brine from neighboring agency.
- Supervisors and senior crew attend Smart Salting training.
- Speed up physical removal of snow by changing our call out policy to 2 inches of snow.
- Reduce speed of application on high speed roads to 30mph.
- Calibrate most equipment yearly.

EXAMPLE: YEARS 3-5

- Speed up physical removal of snow by changing call out policy to 1 inch of snow.
- Work out salt building agreement for salt storage with neighboring agency.
- Calibrate all equipment yearly.

EXAMPLE: YEARS 6-10

- Push snow across bridges and/or truck it away.
- Adjust to selecting the appropriate material for the pavement temperature all of the time.
- All personnel will attend training.

Watershed Management Organizations (WMOs), Watershed Districts (WDs), and Soil and Water Conservation Districts (SWCD)

The WMOs, WDs, and Soil and Water Conservation Districts (SWCDs) play a significant role in the management of the state's waters and provide an opportunity to combine the goals and recommendations of the Statewide CMP into watershed plans. This important group, together with environmental organizations, agencies and educators are the key organizations to help increase awareness of the problem and encourage reduced salt use across the State. Much of the changes in attitudes and environmental awareness has stemmed from this group of organizations. There are a wide range of possibilities for incorporating key elements of this Statewide CMP into watershed plans, as well as important roles that the WMO/WDs can take to help reduce salt use.

The WMOs/WDs/SWCDs play an important role in developing funding programs specifically for private entities, who may have limited funding options.

EXAMPLE: YEARS 1-2

- Partner with the MPCA to offer the Smart Salting winter maintenance training for local private and public winter maintenance professionals each winter.
- Educate 50% of constituents on the benefits of smart salt use.
- Create awareness about the environmental impacts of chloride through education, outreach, and other activities to local residents, applicators, elected officials and businesses.
- Monitor local surface waters for chloride concentrations to track trends, track progress and understand the movement of chloride through the watershed.
- Develop incentive based program for chloride reduction strategies.
- Host yearly workshops for local winter maintenance professionals to encourage the use of the SSAt and track progress of BMPs implemented.
- Coordinate end of winter excess salt drop off locations for private contractors.
- Provide a measuring cup type salt scooper to homeowners and small businesses at the point of sale of salt in order to raise awareness of the amount of salt they are using.
- Work with famers to reduce chloride use in fertilizers and content in manure.

EXAMPLE: YEARS 3-5

- Educate 75% of constituents on the benefits of smart salt use.
- Offer grants to private and public winter maintenance organizations for upgrading equipment or implementing innovating practices.
- Implement a rebate program for residents to have a water treatment professional optimize their current water softener, replace their old softener with a high efficiency on-demand model, or consider removal where appropriate.
- Provide “free” advertising to private applicators who meet “smart salting” criteria.
- Encourage local businesses and public buildings to reduce salt use through improved insurance benefits and liability protection.
- Partner with local stakeholder on innovative projects to reduce chloride at the source and alternatives for deicing and water softening.
- Investigate way to reduce chloride content in manure.

EXAMPLE: YEARS 6-10

- Educate 100% of constituents on the benefits of smart salt use.
- Create model ordinances, educational materials, or incentives for the organization or others to use and/or adopt. The MPCA has developed chloride reduction model ordinance language that serves as guidance for municipal officials who want direction in regulating the use of deicers to protect water quality, animals, human health and infrastructure.
- For example:
  - Restrict the application of salt within a city to trained winter maintenance professionals.
  - Citizens are asked to prove their knowledge of salt impacts on the environment and sign a pledge to use less salt, in return for a stormwater fee credit.
  - Create consumer awareness materials available at participating stores (promoting the sales of shovels and snow blowers instead of ice melt).
  - Encourage hazardous household waste centers to accept ice-melt products.
  - Encourage development/redevelopment in your jurisdiction to specify a % of lower salt dependent surfaces (heated, permeable, other).
  - Promote nonchloride solution for dust control.

Municipalities

Municipalities should conduct a source assessment study to determine all the sources of chloride in their community, including winter maintenance, water hardness reduction, agricultural production, and dust suppressants. This could also include identification of what sources may be contributing to impaired, high risk, or vulnerable water bodies. If winter de-icing salt is identified as contributing source of chloride, expectations for all will begin with an assessment of the existing winter maintenance practices and designing a plan to improve practices. The MS4s will have an additional requirement to report progress on the use of improved winter maintenance practices to the MPCA.

The purpose of the maintenance assessment is to determine where opportunities exist to make reductions in salt use. The SSAt is an easy-to-use web-based tool. This tool will allow municipalities to evaluate their current winter maintenance program and their dust control of gravel roads program at a very detailed level and create a customized plan for implementing salt savings. The tool will allow an individual to assess their current practices and speculate on potential future practices to understand how to reduce the use of chlorides while still providing an acceptable level of service.

SSAt is developed for maintenance professionals with a broad and detailed understanding of winter maintenance operations and dust control of gravel roads. Maintenance leadership should conduct the assessment, then set and share the goals so that the organization can work to meet the goals. Municipalities can choose to assess existing practices using any means. Municipalities should identify practices to improve winter maintenance activities and dust control activities, with priority on eliminating remedial or unacceptable practices. The implementation goal for each MS4 will be specific to the MS4.

Each municipality will have a unique implementation goal. Some municipalities have already made substantial improvements in practices and require minor effort to improve practices. For leading edge operations it is worthwhile to note the technology and tools for further reductions of salt use are constantly evolving and changing. Organizations currently demonstrating the best practices will still have to dedicate time and resources to stay current with the industry. Leading edge operations could consider sharing their experiences with other organizations that are attempting to lower salt use. For organizations that are just beginning reductions, it may be worthwhile to observe the operations and equipment of those who have already made progress on reducing salt. Networking with other operators could be part of the organization's plan. Organizations outside of Minnesota may also have valuable insights. Many municipalities in the Midwest and Canada have developed expertise in different areas of winter maintenance and are recognized by their peers across the nations. An example of a question and response for a municipality to consider when implementing a chloride reduction policy BMP can be seen in Table 14.

Table 14: Example of Considerations for Municipality Policy Adoption BMPs

Does your city have any ordinances to encourage smarter salting?	Adopt at least 1 model ordinances https://www.pca.state.mn.us/sites/default/files/p-tr1-54.pdf	Notify all those operating in your city about your new ordinance. Provide them the training and resources they need to understand the ordinance. Finds ways to help them comply with the ordinance in the first year as it may take resources they have not planned for.

EXAMPLE: YEARS 1-2

- Conduct a chloride source assessment to determine source of chloride in the community.
- Educate civic leaders on the benefits to reducing chloride and its importance.
- Partner with the MPCA to offer the Smart Salting winter maintenance training for local private winter maintenance professionals in the area each winter.
- Educate 50% of constituents on the benefits of smart salt use.
- Create awareness about the environmental impacts of chloride through education, outreach, and other activities to local residents, applicators, elected officials, and businesses.
- Attend trainings, workshops, and events to learn about new technology and strategies for reduced salt use.
- Create a local plan to reduce chloride.

EXAMPLE: YEARS 3-5

- Educate 75% of constituents on the benefits of smart salt use.
- Recognize private winter maintenance organizations for upgrading equipment or implementing innovating practices.
- Implement a rebate program to residents to install on-demand water softeners and remove old, inefficient water softeners.
- Provide "free" advertising to private applicators who meet Smart Salting criteria.
- Encourage local businesses and public buildings to reduce salt use through improved insurance benefits and liability protection.
- Partner with state and local stakeholders on projects to reduce chloride at the source.
- Evaluate chloride containing dust control practices, consider alternative options.

EXAMPLE: YEARS 6-10

- Educate 100% of constituents on the benefits of smart salt use.
- The MPCA has developed chloride reduction model ordinance language that serves as guidance for municipal officials who want direction in regulating the use of deicers to protect water quality, animals, human health and infrastructure. If model ordinance has already been adopted, the timeline for this element may be completed in earlier years.
  Create model ordinances, educational materials, or incentives for the organization or others to use and/or adopt. For example:
  - Require all salt applicators to be trained and certified
  - Citizens are asked to prove their knowledge of salt problems in the water and sign a pledge to use less salt, in return for a stormwater fee credit.
  - Create consumer awareness materials available at participating stores (promoting the sales of shovels and snow blowers instead of ice melt).
  - Encourage hazardous household waste centers to accept ice-melt products.
- Host MPCA turf training for professionals operating within your city limits.
  - Most K sources contain chloride. Turf management best practices will reduce fertilizer use and thus Potassium Chloride use.
  - Promote use of turfgrass fertilizer that is chloride free.

Wastewater Treatment Facilities and Industrial Dischargers

This section addresses municipal and industrial WWTPs that either create saline water in their operations or receive and discharge saline water. The concentration of chloride present in the waste stream will vary for every facility and is dependent on the source of chloride. The major source of chloride to municipal WWTPs is from water softeners (>90% in some municipalities).

If WWTPs effluent chloride concentrations demonstrate a reasonable potential to exceed 230 mg/L (Figure 66), the MPCA will work with the permitted entity to include appropriate permit conditions, including monitoring requirements, compliance schedules, and possible effluent limits. If a permitted facility receives a chloride limit they will be required to identify sources of chloride.

For municipal wastewater facilities, technologies capable of removing chloride from wastewater are either cost-prohibitive, technologically infeasible, or a mix of the two. The RO and evaporation of the resulting brine is the most technically viable option for removal of chloride at the WWTP. The MPCA analyzed the cost and implementation concerns of using RO treatment and evaporation to remove chloride for WWTPs in 2012 (Henningsgaard 2012), which is also summarized in Section 5.8 - Cost Considerations and Funding Opportunities. Based on the assessment, RO treatment and evaporation are cost prohibitive and pose significant implementation concerns.

The most feasible option for reducing chloride loading to the WWTPs is upstream source reduction. The two primary sources of chloride to WWTPs are industrial users and water softeners. If a facility has a chloride limit or would like to voluntarily reduce chloride, WWTPs should work through their Industrial

Pretreatment Program (IPP) to identify significant users who may be contributing chloride. The WWTPs can review existing data from industrial users or can require industrial users to collect chloride data. If industrial users are identified as a significant source of chloride, the WWTP can work with the industrial user through the IPP to develop and implement a plan to reduce chloride loads.

In the future the SSAt will be a valuable resource for evaluating all chloride sources impacting a community with recommendations and strategies for reducing it at the source.

Municipal Wastewater Treatment Facilities

Water softening and industrial discharge are likely the biggest source of chloride entering WWTPs, however winter deicing salts also contribute by entering cracks and gaps in the infrastructure. This contribution can be significant in winter months. Engaging in education and supporting sewershed-wide improvements in winter maintenance can reduce this chloride source in winter months. (See Madison Metropolitan Sewerage District for example of grant program they have to lower salt in winter maintenance operations https://www.madsewer.org/Programs-Initiatives/Chloride-Reduction)

One option for municipalities includes the potential of providing centralized municipal hardness reduction at the water treatment plant (WTP) in an attempt to decrease the load of hardness residential water softeners are treating, thus increasing their efficiency and lowering the chloride. In these cases, removal of water softeners based on post-treatment hardness may be an option. This option assumes that all WTP users would optimize, upgrade, or remove their water softener to reflect the input water and individual softening requirements. Centralized municipal hardness reduction at the WTP may be the best option for WWTP to reduce their chloride discharge enough to meet possible chloride permit limits. Each WWTP must do an evaluation of their sources of chloride and other important factors to determine the best option for meeting permit limits.

The MPCA supports any effort to reduce chloride loading to the WWTPs, including encouraging residential users to switch to high efficiency ion exchange softeners. However, the MPCA does not believe that switching residents to high efficiency softeners will automatically allow a WWTP to come into compliance with chloride permit limits. The MPCA has guidance that provides WWTPs chloride source reduction methods, treatment alternatives, and permitting strategies that will help WWTPs to come into compliance with the chloride water quality standard. See the MPCA's Chloride water permit holder website for details: https://www.pca.state.mn.us/water/water-permit-holders-and-chloride.

The steps suggested in the "Residential" water softening section below will help to reduce the amount of salt being discharged to a WWTP.

Commercial and Industrial Dischargers

For direct dischargers of industrial wastewater, the individual permittee will need to work with the MPCA to develop and implement a plan to reduce chloride if effluent concentrations have reasonable potential to exceed 230 mg/L. Each industrial discharger will have unique circumstances and will need to consider whether source reduction, treatment, or another approach would be most effective in their specific situation.

Water softening is used in some commercial businesses and industries to prevent scale build-up, minimize staining or spotting, or to improve water quality for manufacturing processes or products. Many of the same options exist for commercial and industrial softening as for residential, but at a larger scale.

- Soften water only for applications that require the use of hot water (boilers, cooling towers, commercial dishwasher, car-washes, etc.).
- Twin or multiple tank softeners reduce regeneration since a reserve is not needed.
- Counter-current regeneration moves water up through the brine so that the ion exchange occurs more efficiently.
- RO uses a membrane along with pre and post filters to remove dissolved solids, hardness, and other contaminants from water. It is more commonly used by industries. No salt is used, but it is expensive and has high water and energy use.
- Nonsalt water conditioning is available for commercial uses. There are several different methods, which may reduce scale build-up to varying levels. Many are not well proven or widely used, but may be a possibility for some businesses.
- Chloride reduction efforts should also be investigated for chlorides added to the wastewater beyond those associated with waters softening. These could include chlorides or chloride containing materials used in processing or those in winter maintenance at the facility.

The following softening methods are used in commercial/industrial businesses but not residential.

- Brine reclamation systems.
- Zero liquid discharge facilities are used in industries such as the oil and gas, biofuel, mining, power, and petrochemical industries. The process includes brine concentrating, crystallization and dewatering. Resulting solid salts can be disposed or potentially reused.

EXAMPLE: YEARS 1-2

- Cities
  - Monitor chloride in effluent and review past monitoring reports for chloride concentrations.
  - Evaluate chloride data and determine if reasonable potential to exceed 230 mg/L exist.
  - If potential to exceed 230 mg/L work with MPCA permit staff and create a plan to reduce upstream chloride sources.
  - Educate residents in cities that reduce hardness at WTP that they may not need water softeners, or could use more efficient models (replace with higher efficiency)
- Commercial and Industrial
  - Verify hardness of incoming water and check settings on softening system.
  - Evaluate if 0 gpg hardness is needed, or if a higher hardness would be acceptable. Make adjustments if possible.
  - Conduct chloride source assessment to better understand sources of chloride (processing, softening, grounds maintenance).
  - Create a chloride reduction plan for all sources.

EXAMPLE: YEARS 3-5

- Cities
  - Identify goals for chloride reductions.
  - Develop a compliance schedule if chloride limits are established through NPDES permit.
  - Educate industrial dischargers on the importance of reducing chloride in waste stream.
- Commercial and Industrial
  - Consider upgrading to a high efficiency softening system.
  - Evaluate if brine reclamation is feasible.
  - Conduct a chloride source assessment to better understand sources.
  - Reduce chloride in processes.

EXAMPLE: YEARS 6-10

- Cities
  - Work with water softening companies to offer a trade-in program to optimize softener settings or upgrade to high efficiency residential water softeners.
  - Offer a credit to a city or industrial discharger for reducing chloride concentrations in wastewater.
  - Install centralized municipal hardness reduction
- Commercial and Industrial
  - Add brine reclamation.
  - Update to a high efficiency system or possible nonsalt alternative.
  - Reduce salt use in outdoor winter maintenance.

Drinking Water Treatment Plants (Water Supply)

This sector draws water from groundwater or surface water sources and tests and treats it before distributing it to residents. Municipalities that use centralized hardness reduction processes before it is distributed to households or municipalities that are considering this should take care to minimize salt use and salt waste and assess the needs for soft water in the area and look for non-salt approaches. Consider the mass balance of how much salt is used by individual water softeners versus centralized water softening. Several non-salt approaches are suggested by the MPCA Chloride Working group, such as centralized municipal lime or RO hardness reduction (MPCA 2017). Residents should be informed if additional softening is required. Municipalities can also evaluate how high saline water is disposed of in the cleaning and flushing process. An article published in 2021 by MPCA staff estimated lifetime costs of three alternative solutions: centralized softening, home-based softening, and a baseline alternative (Bakshi et al. 2021). Using data from cities across Minnesota, the report found that centralized softening using RO or lime-softening technologies are the more cost-effective treatment options, compared to the alternative of home-based softening with chloride treatment at the end of pipe in WWTPs.

EXAMPLE: YEARS 1-2

- Assess hardness level of water and need for softening.
- Determine if non-chloride source hardness reduction is a viable option.
- Survey homeowners on the use of residential water softening.
- Educate customers on water conservation and the benefits related to chloride reduction.

EXAMPLE: YEARS 3-5

- Encourage residents to install high efficiency water softeners.
- Encourage home by-pass of soft water for irrigation and drinking water. Create cost share program to encourage plumbing changes needed to accommodate this.
- For those with RO systems, explore ways to capture RO wastewater, which is saline and route to water softener.
- Invent lower salt strategies to manage winter water main breaks.

EXAMPLE: YEARS 6-10
• Reuse salt from cleaning municipal hardness reduction equipment. • Use non-chloride techniques for reducing source water hardness.

Citizens

This group includes everyone living or working in Minnesota. Each person contributes to the attitudes and practices that have created a high and steadily growing volume of salt to be used each year. In order to reverse this situation each person must contribute to changing attitudes and practices that are more sustainable and require less salt. The list of actions that this group can take is extensive. Citizens form public policy, set the expectations that our maintenance crews must live up to, and use salt on their own property such as water softening and salting their sidewalks in the winter. Engaging the citizenry in Minnesota offers the best chance to get salt use under control.

There are many ways to reduce salt use. Below are a few simple steps that residents can take to help reduce the amount of chloride entering waters. More ideas are listed on the MPCA's website: https://www.pca.state.mn.us/featured/snow-removal-do-it-better-cheaper-and-pollution-free and https://www.pca.state.mn.us/living-green/skinny-water-softeners

Every teaspoon of salt reduction prevents five gallons of water from being polluted. Small changes can have big results. In urban/suburban areas the biggest salt uses are sidewalk/driveway/steps (winter maintenance) salt and water softeners. In other areas of the state fertilizer and dust control may be significant contributors.

Winter Safety:

- Support local and state winter maintenance crews in their efforts to reduce their salt use.
- Work together with local government, businesses, schools, churches, and nonprofits to find ways to reduce salt use in the community.
- Inform and educate local and state policy makers on the importance of this issue.
- Shovel. The more snow and ice removed manually, the less salt is needed and the more effective it can be. Whether through shoveling, blowing, plowing or scraping, get out early and keep up with the storm. Salt may not be needed.
- Clear snow before applying salt.
- A coffee mug (approximately 12 ounces) of salt is all you need for a 20-foot driveway or 10 sidewalk squares (roughly 1,000 square feet). Consider using a hand-held spreader to apply salt consistently and only applying salt to critical areas.

- Deicing chemicals work best when the sun is shining, or the temperatures are warming, so less salt will be needed. Below 15°F pavement temperatures it is too cold for our most common deicer (NaCl) salt to work, and on very cold winter days even the deicers designed to work at colder temperatures lose their ability to perform.
- Consider using sand instead of salt for traction, but remember that sand does not melt ice.
- Slow down. Drive for the conditions and make sure to give plow drivers plenty of space to do their work. Consider purchasing winter (snow) tires.
- Be patient. If the salt is not visible on the road, it doesn't mean it hasn't been applied. These products take time to work. Drive according to conditions and allow ample time to get to your destination.
- There are no labeling laws for bags of deicers. Therefore the information on the bag may be accurate or misleading; it may contain a list of all ingredients, a partial list, or no ingredient list.
- Choose the appropriate deicer for the conditions. Salts are used because they are able to decrease the freezing point of water. Whatever product selected, know at what temperature it stops working.
- Sweep up extra salt and sand. If salt or sand is visible on dry pavement it is no longer doing any work and will be washed away. Reuse this salt or sand somewhere else.
- See the MPCA salt and water quality website for information on common deicers and the practical melting ranges, additional education resources and information

Dust Suppression:

- Dust control of gravel roads is often done by applying a liquid chloride product at high application rates. The chloride from these treatments will migrate into the ground and groundwater. Consider how much and how often dust control is needed in your area before you ask for it.

Water Softening:

- Know the source of your drinking water.
- Find out the hardness of our drinking water. If you use city water call the city or check consumer reports to find out. If you are on a private well, send a sample of your water to a lab or have a local water quality professional do a test.
- Many communities implement centralized municipal hardness reduction at the drinking water treatment facility. Reduction, removal, or use of higher efficient residential and commercial softening processes should be considered in these situations. .
- Determine what an acceptable level of hardness is for your home, business, and local community buildings. Acceptable levels of hardness vary depending on how water is used.
- If water is at an acceptable level of hardness, consider if softening is necessary.

- Over-softening wastes salt and water and results in excess chloride. Check your unit's settings and adjust to lower salt use if possible. The factory settings on most equipment is set at highest salt use setting.
- Don't soften water to outside spigots or to cold drinking water taps. For households that use private wells, consideration should be made for manganese in the well water. Water softeners have been found to be effective at reducing the level of manganese in drinking water. The MDH Home Water Treatment Factsheet lists water softening as a treatment option to reduce copper, calcium, magnesium, manganese, and radium. https://www.health.state.mn.us/communities/environment/water/docs/factsheet/hometreatment.pdf
- Know your equipment and maintain it. If your household softener uses more than one 40 lb. bag of salt per month, work with a water quality professional to evaluate and optimize the efficiency of your water softener. Water softening systems are complex and changes in water use and water chemistry can impact its efficiency.
- Upgrade to a high-efficiency water softener that has a salt efficiency rating of no less than 4,000 grains of hardness removed per pound of salt used in regeneration. If you're buying or upgrading to a demand-initiated water softener.

Citizens with private wells

Much of the advice given to the "citizens" above also applies to "citizens with private wells" but in addition to that advice, there are some special considerations for this group to consider. Chlorides are found in de-icing salt, dust control products, fertilizers, water softening salt, manure and other sources. Many private wells are exposed to many of these sources of chloride. The groundwater is the source of your drinking water. The chloride standard for drinking water is 250 mg/l and your well can be tested for chlorides.

If a water softener is used, consider investing in a salt-efficient model that is programmed to your incoming water hardness and in proper working order. Avoid using your water softener as the primary means to remove iron, manganese and hydrogen sulfide as there are other lower salt methods to remove these, such as iron filters, and these filters will extend the life of your water softener. For homeowners with water softeners understand that all of the salt you put into your softener will end up being discharged. If you have a drain field the salt will be released and will filter through the soils into the groundwater.

Minnesota Pollution Control Agency

The MPCA will continue to provide support to stakeholders to address chloride impacts on surface water and groundwater resources, as resources allow. The MPCA will continue to monitor lakes, streams, and groundwater for chloride, in cooperation with the statewide partners, to track progress and better understand water quality trends. The MPCA recognizes the importance of the MPCA Smart Salting training program and will continue to support and improve the training as new technologies and resources are available. The MPCA will also continue providing necessary technical assistance, resources, tools including supporting and hosting the SSAt, to its permittees, stakeholders and local partners.

Since the completion of the TCMA CMP, the MPCA has taken several actions to address chloride. In January of 2017, the MPCA finalized an internal document that is the Agency's Chloride Implementation Strategy. This plan lays out a process to integrate and align the various water programs efforts to address chloride in a collaborative and strategic approach. This plan also highlights some critical services that the Agency will restore, expand, or create to provide support to local stakeholders. The MPCA accomplished the important first step of developing a detailed, specific chloride strategy for the organization.

EXAMPLE: YEARS 1-2

- Explore ways to support a sustainable MPCA Smart Salting Program.
- Host, support and update the SSAt on the MPCA website.
- Continue to monitor lakes, rivers, and groundwater for chloride.
- Solicit assistance in statewide chloride monitoring through partnerships and grant programs.
- Promote engagement, coordination, and dissemination of the latest information in BMPs for salt use. The annual salt symposium is one an example of an event of such a promotion.
- Support and provide access to the "Salt Dilemma" and water softening educational displays at various events and venues.
- Provide technical assistance to permittee for reducing chloride.
- Create guidance on salt storage/deicers (Liquid and Granular).
- Consider coordinated statewide campaign about chloride pollution with other state agencies.

EXAMPLE: YEARS 3-5

- Continue to monitor lakes, rivers, and groundwater for chloride.
- Continue to update impaired waters list with waterbodies exceeding the state's chloride standard.
- Collaborate with local partners and stakeholders on important chloride related activities.
- Expand and support a Statewide Smart Salting training program.
- Support and provide access to the "Salt Dilemma" display at various events and develop a water softening display for the State Fair.
- Continue to provide technical assistance to permittees for reducing chloride and fulfilling permit requirements for Chloride TMDLs.
- Integrate chloride reduction opportunities into other MPCA programs.
- Include chloride reduction as a priority at the MPCA where possible.
- Educate internal staff working on other environmental issues about chloride reduce their use
- Create a way for organizations to identify the sources of local chloride pollution.
- Update turf training to include more reduction strategies for potash (Potassium Chloride).

EXAMPLE: YEARS 6-10

- Continue to monitor lakes, rivers, and groundwater for chloride.
- Continue to update impaired waters list with waterbodies exceeding the state's chloride standard.
- Continue to support the implementation of the Statewide CMP.
- Continue to support and improve the Smart Salting training program.
- Continue to work collaboratively with local partners, stakeholders, permittees, and citizens on reducing chloride at the source.
- Continue to create new educational resources and tools regarding chloride's impact on water resources.
- Continue to provide technical assistance to permittees for reducing chloride.
- Create new programs and services to meet the needs of chloride reduction.
- Expand SSAt to include assessments on other source chloride.

Policy Makers

State, county, city policy makers, and those that make policy to govern other entities have an important role to play in chloride management. Policy is the tool that helps speed up behavior change in areas where behavior change is not progressing or progressing fast enough. In order to enable policy makers to be more active in this area, information about the environmental impacts of salt and awareness of the existing voluntarily efforts to improve salt reductions is necessary. There are many policies and actions that can be considered to assist with reducing salt use.

EXAMPLE: YEARS 1-2

- Better understand environmental impacts of salt use and ways the constituents contribute.
- Understand options for reducing chloride use.
- Support the implementation of the Statewide CMP.
- Develop a limited liability law to protect private contractors if they are following BMPs under the Smart Salting (S2) training, similar to New Hampshire. Fear of law-suits often drives over application of salt.
- Implement an ordinance that requires all salt and salt/sand piles must be stored indoors and on an impermeable surface.
- Advocate for an accurate label on deicers similar to that of pesticides or food products.
- Consider development/redevelopment requirements for % of the hard surfaces to be of the type that do not require salt or require much less salt (heated, permeable, non-stick, flexible, different texture).
- Consider requirements for resale of houses/buildings for updated softening at point of sale.

EXAMPLE: YEARS 3-5

- Require statewide certification of salt applicators similar to the Department of Agriculture's pesticide applicator certification program.
- Require all new construction to have irrigation water and drinking water plumbed to avoid the water softener, if appropriate for the drinking water supply.
- Ban sales of water softeners that recharge by the time of day and not by the salinity of water.
- Provide funding, to agencies, to support implementation of salt reduction practices.
- Discuss lower levels of service with constituents.
- Consider a ban on sales of water softeners that recharge by the time of day and not by the salinity of water.

EXAMPLE: YEARS 6-10

- Develop labeling laws for deicers sold in Minnesota so ingredients are listed along with practical melting range and includes warning about the environmental impacts of using the material.
- Policies should be reviewed to determine effectiveness in chloride reductions.
- Work with other policy makers to understand the most effective low salt policies.
- Investigate work-at-home options during snow events to reduce pressure on public works.

Agriculture

The primary source of chloride from agricultural lands in Minnesota is from fertilizers, manure, land application of food processing waste, and biosolids from municipal sewage treatment. Excessive chloride concentrations on agricultural lands can be harmful to crop growth in addition to contributing to elevated levels of chloride in surface runoff and groundwater infiltration. Conservation practices and nutrient management not only protect water resources, but can save farmers money. Development and implementation of nutrient management plans should be conducted for agricultural lands. Conservation practices and nutrient management planning information and guidance can be found at the Minnesota Department of Agriculture website as well as through BWSR and local SWCDs.

EXAMPLE: YEARS 1-2

- Complete an assessment to see if you need to apply potassium or how often it is needed. [University of Minnesota Extension]
- Evaluate other forms of fertilizers containing potassium.
- Practice proper manure management.
- Investigate lower salt diet for farm animals.
- Test your well, or other freshwater sources like ponds or creeks for chloride.
- Determine chloride sources used on the farm (fertilizer, animal feed, dust control, biowaste).
- Explore using non-chloride sources of potassium (K) in fertilizer.

EXAMPLE: YEARS 3-5

- Implement manure management plan.
- If lower salt diet looks feasible, test lower salt diet for farm animals.
- Develop whole farm chloride management plan.

EXAMPLE: YEARS 6-10

- Test substitute for Potassium Chloride.
- Count chloride from manure into total chloride budget.
- Count chloride from biowaste into total chloride budget.
- Tell others how to reduce chloride in agricultural settings.
- Implement whole farm chloride management plan.

Gravel Surface Maintenance and Dust Control (Rural Road Authority, Construction, Mining, Forestry and Industries)

Dust suppressants come in several varieties, but chloride-based dust suppressants are most commonly used. For those using dust control products, we recommend taking a close look at the frequency, volume and type of dust suppressants used, and seek strategies to minimize chloride use. Dust control measures such as proper gravel road composition and grading introduce less chlorides into our freshwater system and should be considered the first approach to managing dust on gravel road management. Speed limits, considerations for paving, and other nonchemical approaches to dust control should be evaluated and implemented if possible. Maintenance supervisors and operators will benefit from use of the SSAt, which includes guidelines such as, understanding reapplication frequencies, avoiding application near wells or drainage tiles, and planning around weather forecasts.

EXAMPLE: YEARS 1-2

- Make a list of physical or structural changes that would reduce need for dust control.
- Explore options for non-chloride dust suppressants.
- Assess applicability of lowering speed limits.
- Identify opportunities for structural barriers (fences, trees, etc.) along roadways.
- Use SSAt and assess your gravel road dust control practices.
- Inform landowners near dust control areas of the side effects of chlorides and allow them to opt out of dust control in front of their home/farm/business.

EXAMPLE: YEARS 3-5

- Change remedial dust suppressant practices shown in SSAt reports (red colored).
- Educate residents about side effects of dust control products.
- Search for stabilization techniques that are chloride free.
- Assess traffic redirection.

EXAMPLE: YEARS 6-10
• Re-assess gravel road dust control practices through SSAt. • Become better educated on the side effects of Chloride based products. • Evaluate total salt use of gravel vs paved roads.

Turf maintenance professionals and those maintaining lawns

Potassium (K) is one of the 3 key nutrients in fertilizers. KCl is the most commonly used potassium source. It is also called Potash. To reduce overall chloride loading from this source, soil testing should be integrated into turf maintenance strategies. Applying the proper mix of fertilizer, the proper amount of fertilizer, and applying at the proper time of year all will reduce overall fertilizer use and reduce the waste of these macronutrients not needed or not able to be used by the turf. The MPCA has a turfgrass maintenance course designed to reduce the environmental impacts of turf maintenance. This course is recommended for all professionals doing general purpose turf maintenance in Minnesota. The course does not cover turf maintenance of athletic fields, golf courses or specialty turfs. To learn more about MPCA's turf maintenance course visit: https://www.pca.state.mn.us/water/summer-turf-grass-maintenance-training. The MPCA course recommends the use of best practices in mowing and aeration, fertilizing, weed control and irrigation. Other sources of Potassium exist and may be used as a substitute for Potash. Further study is recommended to determine how much chloride can be reduced by integrating best practices vs switching to an alternate potassium source.

EXAMPLE: YEARS 1-2
• Professional turf managers attend MPCA turf class, read MPCA turf manual, and follow MPCA turf matrix. • Implement soil testing to determine Potassium needs at each site. • Apply only needed amount of Potassium. • Avoid applying fertilizer to frozen ground. • Avoid applying fertilizer to hard surfaces (sidewalks, roads). • Leave grass clippings on lawn, to reduce fertilizer use.

EXAMPLE: YEARS 3-5

• Professional turf managers understand IPM concept.
• Research alternate Potassium source that does not contain chloride.
• Test alternate Potassium source.
• Integrate BMPS such as:
  ○ Calibrate spreaders.
  ○ Apply fertilizer at recommended rates.
  ○ Apply fertilizer at recommended times of year.
  ○ Mow at higher heights.
  ○ Don't use up the bag to get rid of it. Only apply what is needed.
  ○ Separate weed control from fertilizer.

EXAMPLE: YEARS 6-10
• Tell others about MPCA training and ways to reduce Potassium use. • Continue to refine and improve practices.

5.5 Secondary Audiences

This group includes those that have a smaller, but important, role in reducing the amount of salt entering surface and ground water.

Those awarding maintenance contracts

- The property manager or contracts department for any organization hiring winter maintenance services should consider requiring those bidding on work to have successfully completed the MPCA Smart Salting training. When crews are on-site conducting maintenance work, a high percentage (to be determined by contracts department) should have successfully completed the training within the past five years. Here are things to consider when negotiating a contract for winter maintenance services:
- Have all contracted and in-house winter maintenance workers applying salt attend the MPCA Smart Salting training. The MPCA has developed a property manager's specific smart salting training. The MPCA sponsored Smart Salting training specifically tailored to Property Managers (https://www.pca.state.mn.us/water/smart-salting-training).

- Charge for level of service (i.e., hourly, event-based or seasonally), not per pound of product.
- Develop a Snow and Ice Policy and set clear expectations (see Smart Salting training website for Minnesota model policy).
- Clean up spilled piles of salt, loading areas, excess on sidewalks and parking lots.
- Use mechanical methods of snow and ice removal (plow, shovel, brush, blow) prior to using any chemical control.
- If using sand, conduct year-around sweeping to remove products on dry pavements.
- Record what and how much product is applied for each event.
- Calibrate all equipment at least annually and document the results.
- Use dry salt (NaCl) only if pavement temperature is above 15 degrees Fahrenheit.
- Find ways to wet salt – 30% less material can be used, it works faster and stays in place
- Show progress towards lower application rates based on the MPCA's training program.

Some example language to consider:

> *Snow plowing and deicing of parking lots will be done in a manner similar to guidelines provided under both the Minnesota Pollution Control Agency and the Minnesota Department of Transportation "Winter Parking Lot and Sidewalk Maintenance" manual provided to LESSOR.*
>
> *LESSOR shall request LESSOR'S vendor to attend Smart Salting training offered by the Minnesota Pollution Control Agency. The following link provides information about the Minnesota Pollution Control Agency's Salt Education Program:*
> http://stormwater.pca.state.mn.us/index.php/Smart_Salting_(S2)_training_information

Grant-giving organizations

Ensure that grant opportunities are available to invent and implement lower salt solutions. The private sector is a significant contributor to chloride pollution. Change grant eligibility language to make private companies eligible to apply. Consider ways to ensure a simple application process and equal access to funds for nontraditional source reduction (pollution prevention) projects addressing chloride. Possible areas include:

- Provide assistance for state of the art storage facilities, snow removal equipment, brine-making equipment, liquid application equipment, and pavement temperature monitoring equipment or education and training.
- Cost share implementation of lower salt use pavements (heated, permeable, flexible…).
- Research or implementation of reduced-salt strategies to winter maintenance.
- Research or implementation of lower or no salt pavement or gravel road strategies.
- Citizen involvement on environmental impacts and solutions.
- Research or implementation of changing winter driver behavior and expectations.

- Research or implementation of softener setting adjustments, high efficiency residential water softening, or nonchloride based options Cost saving testing of re-using waste stream products for deicing and dust control.
- Research or implementation of urban design solutions that reduce salt use. (Examples: parking ramps/covered parking as an alternative to vast parking lots, skyways or covered walkways, transit-oriented development so people have alternatives to driving.)

Driver Education Programs and Division of Driver and Vehicle Services

For all new drivers, those getting additional licenses such as commercial or motorcycle licenses, and those moving into Minnesota, consider educating about winter tires, appropriate winter driving, and the environmental impacts of salt. Include training on winter driving, the temperature range at which salt does not work, how bridge decks and ramps freeze before the roads, and other tips for safe winter driving. Teach drivers to respect the plowing operations and take pressure off of public works departments for instantly cleared surfaces. Send information with driver license renewals to current drivers on tips for winter driving. ClearRoads research consortium has a training module developed for those that teach drivers training about winter driving. http://clearroads.org/project/12-04/ (Module 22).

Pavement designers, researchers, engineers

Become educated on the issues with high-salt-use surfaces and the impacts to water resources. Look for opportunities to invent, test, and implement lower-salt-use pavement surfaces. This includes sidewalks, parking lots, roads, bridges, ramps, trails, parking ramps, steps, or other highly salted surfaces in the winter months. Possible areas include, but are not limited to:

- Permeable surfaces
- Flexible surfaces
- Heated surfaces
- Different color or texture of surfaces
- Smaller surfaces
- Pavement overlays

Water experts in most any field including limnologists, hydrologists, biologists, chemists

Understand the impacts of chloride to water resources and the pathways it takes to get there. Look for opportunities to invent, test, and implement techniques to prevent salt from entering water resources after application or for strategies to mitigate for it. Problem areas to consider include:

- Recovering salt after application to paved surfaces
- Options for treating chloride in stormwater ponds
- Research the impacts of infiltration into ground water versus surface flow to surface waters
- Options for mitigating chloride already present in surface waters
- Capturing and reusing salt water (truck wash, runoff, water softening, waste water discharge)

Other State Organizations

The MDH should continue to monitor chloride in drinking water, as resources allow. The Metropolitan Council Environmental Services (MCES) may continue to monitor chloride in lakes, wetlands, streams, and groundwater, as well as chloride in wastewater discharges in the TCMA. The Minnesota Department of Natural Resources (DNR) could continue to monitor chloride impacts on aquatic life, plants, and animals. The Minnesota Department of Administration could evaluate chloride reduction potential at all state owned buildings. This could include both winter maintenance services and water softening. The MDA could work with farmers to develop nutrient management plans, which include methods to reduce chloride-based fertilizers. The MDA could continue and expand the monitoring of chloride in the agricultural wells and correlate the amount of KCl purchased and chloride levels in wells. With the historical purchase records a trend line could be established for chloride concentrations in rural Minnesota wells. The MDA could help educate farmers on the sources of chloride and lower salt solutions. The Board of Water and Soil Resources (BWSR) will continue to administer grant programs to protect, enhance, and restore water quality in lakes, rivers, and streams in addition to protecting groundwater and drinking water sources from degradation, as resources allow. The State may consider moving towards utilizing surface water as a drinking water source where feasible.

The MnDOT should continue to provide in-house training and leadership throughout the state in an effort to enable the implementation of effective chloride-reducing BMPs. This includes research on innovative technology and passing the knowledge on to others.

5.6 Chloride Policy Considerations

Policy considerations for chloride reductions from de-icing, water hardness reduction, and dust suppressant activities are listed in Table 15. These policy considerations are focused at state and local level implementation and may include recommendations for possible funding opportunities, ordinances, outreach and education, and continued research and technical support. Many policy considerations can be found in the Minnesota Clean Water Council Clean Water Fund and Policy recommendations to the legislature (https://www.pca.state.mn.us/about-mpca/clean-water-council). Other considerations have been developed in adherence to already established best management practices. This list represents a snap-shot of policy considerations at the time of publication of this plan. The development of new and effective policy considerations is an ongoing process.

Table 15: Chloride Policy Considerations

Source	Type	Policy
De-icing	Ordinance	Require that contractors providing snow and ice management services within community have MPCA Smart Salting certification.
De-icing	State	Liability protection legislation: Reduction of liability for snow and ice private applicators who become certified under the Smart Salting training program and implement practices.
De-icing	State	Require all state entities to only hire Smart Salting certified winter maintenance contractors on their owned/leased properties.
De-icing	State	Fund the Smart Salting applicator training and certification program, and the MPCA's chloride reduction budget to support the development and maintenance of tools, resources, policies, trainings and assistance programs to reduce chloride pollution.
De-icing	State	Request that the Legislature give the MPCA the authority to charge a fee for chloride training.
De-icing	State	Provide research funds to develop new technology and alternatives to chloride-containing de-icing chemicals, and best management practices.
De-icing	State	Develop labeling laws for deicers sold in Minnesota that requires ingredients are listed along with practical melting range. Also require third party verification for environmental and pet safety claims. The goal of this effort could be to convene a knowledgeable group of stakeholders from a variety of sectors to create language that will ensure that consumers are provided accurate and necessary information about the de-icing products they are purchasing and applying to Minnesota's environment. This could also include: reporting possible negative impacts of the product on surfaces, vegetation, water quality, providing safety protocols for handling the products, and providing guidance for proper application.

Source	Type	Policy
De-icing	State	Make research funds available to develop new technology and alternatives to chloride-containing de-icing chemicals. Research on new technologies and alternative de-icing solutions may allow for a shift in snow and ice management that protects water resources while maintaining public safety.
De-icing	State	Encourage and support the adoption of the MPCA's Chloride Reduction Model Ordinance Language by local governmental entities. The model ordinances provide guidance for creating and implementing ordinances that will assist with reducing chloride pollution. The four focus areas in the guidance include a) Occupational Licensure for Winter Maintenance Professionals b) De-icer Bulk Storage Facility Regulations c) Land Disturbance Activities d) Parking Lot, Sidewalk and Private Road Sweeping Requirements
De-icing	Construction/ Land Disturbance	Encourage the consideration of alternative pavement types and improved urban design for new construction and re-construction. Pavements that require lower or no salt for winter maintenance. Involve winter maintenance professionals into the design process for heavily salted pavements like parking lots.
De-icing	Ordinance	Create an ordinance that all salt and salt/sand piles must be stored properly; indoors or on an impervious surface, covered.
De-icing	State	Require statewide certification of salt applicators similar to the Department of Agriculture's pesticide applicator licensing program.
De-icing	Ordinance	Require a land disturbance permit applicant to provide chloride use information and Smart Salting Certification when conducting new or redevelopment activities.
De-icing	Ordinance	If salt and other deicing materials applied by private or public entities remain on surfaces after a winter event, a municipality may include sweeping requirements in their zoning regulations.
De-icing	Rebate	Encourage municipalities to collect residential deicers at the end of the winter and offer a trade with a bag of mulch, tree, bag of compost. This salt can be added to their salt or sand pile.
De-icing	State/Ordinance	Utilize a regulatory mechanism to prohibit the use of salt to open frozen storm drains or other water conveyance systems.
Water softening	Rebate	Create a rebate program offered to residents/businesses to install on-demand water softeners.
Water softening	Rebate	Create a rebate program offered to residents/businesses to have water treatment professional optimize currently installed hardness reduction system or remove individual home softening systems when appropriate.
Water softening	Cost Share	Encourage home by-pass of soft water for irrigation and drinking water. Create a cost share program to encourage plumbing changes needed to accommodate this.
Water softening	State/Ordinance /Rebate	Encourage or require reuse of softened cooling water or other manufacturing water not mixed into products.

Source	Type	Policy
Water softening	Ordinance or Plumbing Code	Require all new construction to install on-demand softeners and only have irrigation water and drinking water plumbed so as to not pass through the water softening. Drinking water sources and health based guidance should be considered when implementing this type of policy as sources with elevated manganese, copper, and radium may utilize in-home ion exchange water softeners to reduced concentrations of these dissolved ions.
Water softening	Ordinance or Plumbing Code	Require that Ion Exchange water softeners used primarily for water hardness reduction that, during regeneration, discharge a brine solution shall be of a demand initiated regeneration type equipped with a water meter or a sensor.
Water softening	State	Ban the sale of timer-based water softening system in the state of Minnesota.
Water softening	State	Provide financial support and technical assistance to municipalities to reduce chloride discharges and allow flexibility for how municipalities achieve these reductions.
Water softening	State	Update the state plumbing code to effectively prohibit the installation of new water softeners in Minnesota that use timers rather than on-demand regeneration systems.
Water softening	State	Fund a program for activities, training, and grants that reduce chloride pollution. Grants should support upgrading, optimizing, or replacing water softener units.
Dust Suppressant	State/Ordinance	Restrict the use of chloride containing dust suppressants in areas with Chloride impairments.

5.7 Citizen Attitudes and Practices

The average Minnesotan values having clean, healthy water resources. The same Minnesotans value safe driving conditions on roads and bridges and the quality of potable water in their homes. These public goods are in direct conflict and create a serious dilemma for local government and businesses. Driving in difficult winter road conditions is a problem that directly impacts daily life for nearly all members of the public. It is immediately recognized and felt. Potable water that softened is critical for the preservation of industrial, commercial, and residential equipment. Conversely, the problem of chloride pollution causing permanent damage to local waters is something that is not readily seen and may not be felt until much later. Extreme public pressure is often brought to bear on local officials to address the immediate problem of icy roads, in spite of the long-term consequences of permanent damage to water resources that will have severe and wide impacts.

When confronted with this dilemma, most citizens will acknowledge this challenge needs to be resolved. However, the expectation is this is government's problem to solve. This dynamic – the government must solve this problem, while the public simply observes – is at the root of this challenge. Changing this expectation is needed to change the over-use of chloride to manage chloride use in winter maintenance, dust control, agricultural applications, turf management and water softening.

The question is how?

Traditional information and education campaigns are important tools in raising awareness about chloride impairments in lakes, rivers, and groundwater. However, if the goal is to create long-term, sustainable change in the practices surrounding the use of salt and other chloride products (e.g., sidewalk deicers, water softening agents, fertilizers), additional strategies will be needed. Research shows that education may be effective in altering some citizens' behaviors for the short-term, but these changes are not likely to be widespread or sustained unless they are coupled with organizing strategies that provide supportive structures for citizen collaboration and public action (Dietz and Stern 2002).

In order to ensure that a new mindset and social norm are achieved around the use of chloride, a long-term approach to organizing stakeholders will be needed. Changing attitudes will require significant, long-term, and small-scale organizing of homeowners to work in partnership with WDs, WMOs, lake associations, and neighborhood organizations. These community-based organizations are best poised to deliver outreach and programs.

Outreach and education programs remove the barrier of lack of information and encourage people to make changes in their day-to-day practices. However, research has found that there are often other barriers that keep people from changing their existing practices. One effective strategy for overcoming these barriers is to couple information with relationship-building and collaboration support systems in small-scale settings. Community associations, civic groups, and lake associations that already organize neighbors around the issue of water quality can expand their learning and strategies to include addressing chloride pollution. The trusting relationships that develop in these contexts and citizens openness to learn and act, increases the possibility they will consider new information and assistance.

Trusted local leaders delivering information will likely have greater impact than blanket media campaigns, fact sheets, or other educational materials. This approach can be especially effective when coupled with an effort to develop a sense of citizenship and common good while addressing water quality as part of an overall outreach and organizing strategy. Inspiring citizenship and caring for the common good and community, is showing promise in sparking interest in participation.

Development and implementation of public education and involvement is critical and necessary to the success of chloride management in Minnesota. Based on feedback from stakeholders, a multi-agency approach to public education and involvement is needed to reach a large and diverse group of salt applicators, the public, gravel road maintenance staff, agricultural professionals, turf managers, and municipalities with a range of motivations related to salt application. Public education and involvement can be accomplished through multiple venues such as mainstream news media, social media, permanent and variable message signs, elementary and high school education, and other resources aimed at reaching the general public. The MPCA Chloride website maintains a list of available educational resources.

Changes in personal practices and attitudes can be the most challenging and time consuming and require short- and long-term strategies. Current winter driving and gravel road expectations are a result of decades of increasing de-icing salt use and improvements to the level of service. The improved level of service has allowed the traveling public to drive faster with greater confidence during snow and ice events. Similarly, inefficient water softening practices remain an issue where chloride could be reduced by upgrading/replacing low-efficient systems, optimization of current systems or removal where input water is suitable without additional hardness treatment. A long-term strategy is needed to reverse these expectations. Education of young drivers could be an important starting point in changing driver behaviors to expect a lower level of service during snow and ice events.

As part of the TCMA Chloride Project, an education committee was created to identify the principal audiences for education and discuss potential opportunities and strategies to increase awareness about salt use and associated water quality issues. The Educational Outreach Committee (EOC) included state and local education specialists from the MPCA, counties, the UMN, The Freshwater Society, WDs, WMOs, conservation districts, and MnDOT, which met four times over the duration of the TCMA Chloride Project.

The following is a summary of recommendations provided by the EOC and other stakeholders. These recommendations should be considered by professionals in relevant organizations and roles. In addition to the great information and recommendations gathered from local education specialists, there is a need for government and citizens to collaborate to make effective policy choices for reducing salt use. While EOC has focused on winter maintenance, these principals can and should be applied to other salt using professionals and citizens.

Strategies for Education and Outreach

- Share winter maintenance success stories that reflect people who have made positive and measurable changes. Create a recognition award program to acknowledge organizations that have made efforts to improve winter maintenance practices.
- Share Smart Salting training for Small Sites, and Improved Winter Maintenance: Good Choices for Clean Water videos.

- Provide information on hiring certified winter maintenance contractors to condominium associations, townhouse developments, etc. The NMCWD (ninemilecreek.org) created "Hiring a Snow Removal Service" brochure.
- Develop seasonal salt messages for radio public service announcements.
- Create targeted messaging such as information wheels or videos for gas stations, home improvement stores, hardware stores, and other stores that sell deicers; create winter maintenance tips for products, like shovels.
- Create a system for the public to report excessive salt use. The system could be used to notify users of excessive use reports.
- Incorporate education on chloride into pre-existing community events (e.g., National Night Out) as much as possible, rather than expecting the public to attend a separate event about de-icing salt.

Winter Maintenance Training

- Provide Smart Salting training for school maintenance and grounds directors. The NMCWD developed Winter Maintenance on School Grounds Workshop to train building and grounds directors on proper winter maintenance techniques for entrances, sidewalks, and parking lots.
- Provide training for private applicators and offer it at events such as the Northern Green Expo.
- Develop and implement a train-the-trainer and/or mentorship program. Provide opportunities for winter maintenance professionals to share changed practices and lessons learned at expos, trainings, etc.
- Create and implement a program similar to the Canadian program "Smart about Salt": www.smartaboutsalt.com. A similar program would allow schools, apartment complexes, condominiums, government, commercial properties, etc. to become certified. Benefits are cited as quality for insurance premium discounts and stormwater credits offered to certified sites within certain municipalities.

Strategies for Recruiting for Training

- Include a letter or a link to a short online video with the training brochure explaining the importance of the training and include a list of example BMPs.
- Prioritize recruiting individuals who perform winter maintenance activities on large parking lots, such as malls, hospitals, universities, etc. that drain to waterbodies.
- Promote trainings at events such as the Northern Green Expo, and at nonenvironmental events to target different audiences. Adjust emphasis and message (e.g., cost savings, habitat, etc.) depending on event and audience.
- Recruit individuals who have received funding for past projects (e.g., rain gardens) and/or individuals that have applied for permits for construction activities.

Demonstration Projects

Demonstration projects can be used to test the organizing approaches for building partnerships between citizens and government or property owners to work together to solve the challenge of chloride use and water resource impairments. The demonstrations will likely be most successful where community capacity around environmental issues exists. Local leaders should be supported to experiment with building partnerships across sectors to co-develop strategies for chloride reductions by municipalities, businesses, and households. The demonstrations can employ pre- and post-evaluation to determine whether the approach achieves meaningful outcomes over time. The outcomes will determine whether the efforts should expand past the pilot stage. If defined outcomes are significant, the plan should be developed to scale to metro-wide and beyond application.

5.8 Cost Considerations and Funding Opportunities

The potential costs of reducing chloride loads and potential funding opportunities are discussed in this section.

Winter Salt (applied to Roads, Parking Lots, and Sidewalks)

The assessment of costs and economic benefits associated with chloride uses and its impacts is complex. Removing chloride from impaired lakes, wetlands, and streams through RO or distillation is impractical and cost-prohibitive; therefore, prevention or source control is the logical approach.

Application of salt in winter months is currently the most commonly used method of maintaining safe roads, parking lots, and sidewalks. The economic benefit of safe travel is hard to measure. Economic benefits are also from reduced work-loss time. The various economic impacts and benefits are shown in Figure 70 and discussed briefly below. Though salt is one means of reducing accidents and work-loss time resulting from winter weather, other means are available, such as

- Slower speed limits during winter events
- Working from remote locations during winter events
- Acceptance of lower level of service adjusting with winter tires, better footwear, non-distracted driving and walking to compensate for safety
- Installation of new pavement innovations that require less salt
- More winter driving instruction in drivers training classes
- More winter driving/walking/biking and winter maintenance classes available to the general public, and
- Public service information to keep more people off roads, bridges and ramps during critical maintenance times.

The economic impact of salt use goes beyond the environmental and includes costs associated with damage to transportation infrastructure, vehicle corrosion, and vegetation damage (Fortin 2014).

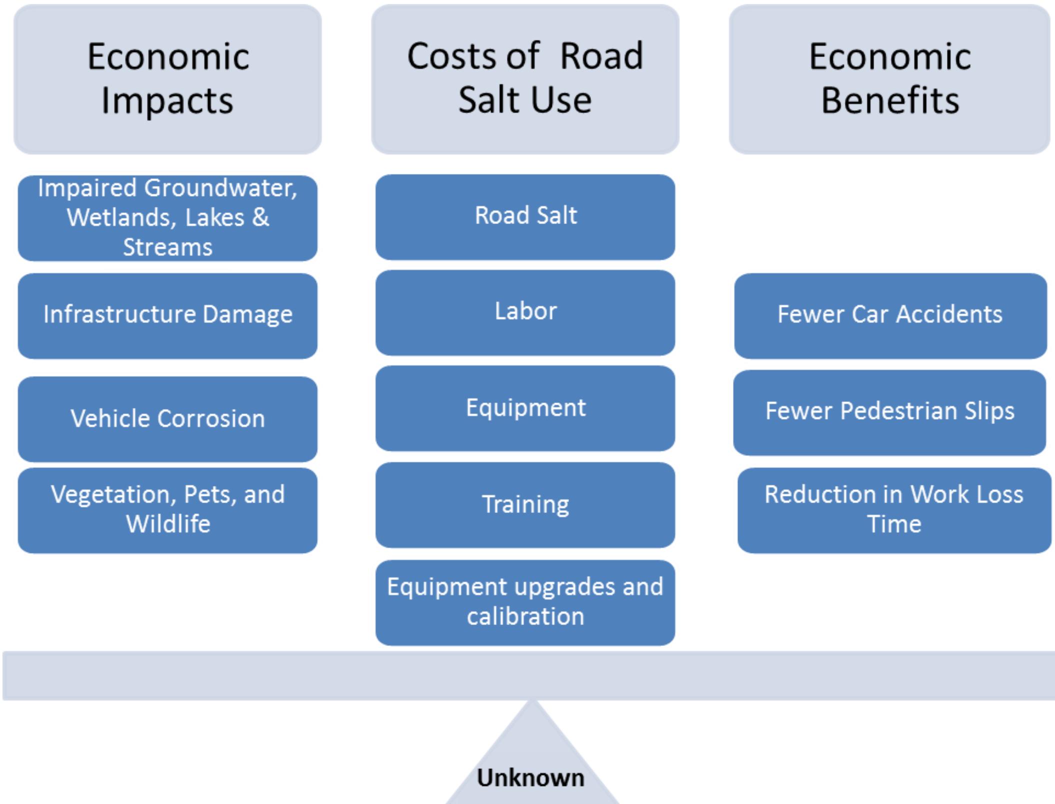

Figure 70. Cost Considerations Related to Salt Use

Efficient winter maintenance practices can reduce salt use without lowering the level of service. The SSAt BMP survey shows how well an organization is doing as far as optimizing the BMPs for winter maintenance. So far no organization in Minnesota has submitted a report with 100% BMPs optimized. This indicates all organizations performing winter maintenance in Minnesota still have room to improve in optimizing salt use.

The improved practices are intended to maintain a consistent level of service in terms of safe roads, parking lots, and sidewalks with lower salt use. Implementation of improved winter maintenance activities may come with an initial investment cost to address training, new equipment, and public outreach. However, as a result of reduced salt usage, a cost savings is expected based on information provided by several local winter maintenance organizations. A net cost-savings has been shown by many organizations who have tracked cost before and after the implementation of winter maintenance BMPs. Table 16 provides examples of tracked cost savings associated with the implementation of various salt reducing BMPs by local winter maintenance organizations. Detailed descriptions of these cost savings examples can be found in Section 5.8 of the CMP. The cost estimates provided in Table 16 reflect implementation of a variety of BMPs, with multiple activities applied simultaneously. The information provided in Table 16. Examples of Municipal and Private Cost Savings is not intended to be a reflection of cost for any one practice, but rather an overall estimate. Section 6: Success Stories highlights examples of additional cost reductions associated with de-icer reduction initiatives. Each organization will implement practices that are most appropriate for their individual operations and there is not a one-size-fits-all approach when it comes to winter maintenance; therefore, the costs will vary greatly across organizations.

Table 16. Examples of Municipal and Private Cost Savings

Entity	Implementation Period	Main Actions Implemented	Salt Reduction	Cost Savings
University of Minnesota, Twin Cities	Start 2006	Began making salt brine and anti-icing and adopted several other salt reduction BMPs.	48%	New equipment cost $10,000 $55,000 cost savings first year
City of Waconia	Start 2010	Switch from 1:1 sand:salt to straight salt and liquid anti-icing; calibration; equipment changes; use of air and pavement temperatures.	70%	$8,600 yearly cost savings ($1.80 per lane-mile)
City of Prior Lake	2003-2010	Upgrade to precision controllers and sanders; anti-icing and pre-wetting; use of ground temperatures, best available weather data; on-site pre-mix liquid and bulk-ingredient storage, mixing and transfer equipment; staff education.	42%	$2,000 per event estimated cost savings; 20 – 40 mg/L decrease in receiving-water chloride (liquid app-only watershed)
City of Richfield	Start 2010	All-staff Training*; yearly sander calibration; use of low-pavement-temp deicers; road crown-only application; minor-arterial-road policy adjustments.	> 50%	$30,000: 2010-2011 $70,000: 2011-2012
Rice Creek Watershed District Cities	2012-2013	Staff training; purchased shared anti-icing equipment	32%	$26,400 in one winter
City of Cottage Grove	2011-2012	Staff training	Not available	$40,000 in one winter
City of Shoreview	Start 2006	Stopped using a salt/sand mixture and moved on with straight salt; set up all its large plow trucks with state of the art salt spreading controls, pre-wetting tanks and controls and pavement sensors; use of calcium chloride in the pre-wetting tanks reduced the amount of rock salt as well; all applicators and supervisors annually attend *Training; crews attend an annual snowplow meeting to review procedures and talk about salt use and conservation methods; trucks	44% since 2006	$24,468 in 2014

Entity	Implementation Period	Main Actions Implemented	Salt Reduction	Cost Savings
		set up for anti-icing main roads with calcium chloride.		
City of Eagan	Start 2005	Moved from a 50/50 salt/sand mix to straight salt; eliminated purchase of safety grit; EPOKE winter chemical application technology; use AVL; pre-wet at spinner.	Not available	$70,000 annual savings
Joe's Lawn and Snow, Minneapolis	Start 2013-2014	Owner and staff Training*; purchase of new spreader, temperature sensors; equipment calibration; use of temperature data; on-going experimentation.	50%	$770 estimated cost savings in 2014 Expected to use 20 tons, only use 9 tons

* Training - MPCA Smart Salting Training (All entities described above have attending the MPCA Smart Salting Training.)

Municipal Wastewater (primarily from Water Softening)

The cost for point source wastewater dischargers to remove chloride from their waste stream is very high and is cost prohibitive for most facilities. Below is an estimate of the cost to treat effluent from a WWTP (MPCA 2018):

Estimates for the total cost of various technologies are shown below:

- Fine filtration - $1.5 million per million gallons treated
- RO and Evaporation and Crystallization - $30 million per million gallons treated

Annualized cost for construction (assuming 20 year term at a market rate of 2.25%) is between $250,568 and $328,871 per year (Henningsgaard 2012).

Annual Operation and Maintenance costs:

- Fine filtration – $100 to $150 per million gallons treatment
- RO and Evaporation and Crystallization - $10 per MGD per annum

Based on specifics from each community, this cost could be considered to have "substantial and widespread economic and social impact" (40 CFR 131.10 (g) (6)), and could be justification for a variance that would not require this type of expensive treatment. There is no reasonable (environmental and economic) way to dispose of the highly concentrated sludge produced by RO treatment.

The high cost of end-of-pipe treatment for chloride, and the high cost and difficulty of final disposal of the brine, makes source reduction a critical element to wastewater treatment of chloride-containing waste streams. In most municipal situations, a major source of chloride is water softeners. NaCl or KCl is commonly used in the softening process at the WTP and in residential or commercial softeners.

Funding Opportunities

There are available sources of money to offset some of the costs of implementing practices that reduce chloride from entering surface and groundwater. Several programs, listed below, have web links to the programs and contacts for each entity. The contacts for each grant program can assist in the determination of eligibility for each program and funding requirements.

On November 4, 2008, Minnesota voters approved the Clean Water, Land and Legacy Amendment to the constitution to:

- *protect drinking water sources;*
- *protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat;*
- *preserve arts and cultural heritage;*
- *support parks and trails;*
- *and protect, enhance, and restore lakes, rivers, streams, and groundwater.*

There are a variety of grant and loan funding programs that can be used to address chloride pollution. The Clean Water, Land, and Legacy Amendment (CWLLA) funds have several grant and loan programs that can be used for implementation of the BMPs, education and outreach, and WWTP modifications. There are other funding sources beyond the CWLLA. The various programs and sponsoring agencies related to chloride pollution are:

- Agriculture BMP Loan Program (Minnesota Department of Agriculture)
- Clean Water Fund Grants (BWSR)
- Clean Water Partnership 0% Interest Loan Program (MPCA)
- Environment and Natural Resources Trust Fund (Legislative-Citizen Commission on Minnesota Resources)
- Environmental Assistance Grants Program (MPCA)
- Environmental Low-interest Loan program (MPCA)
- Phosphorus Reduction Grant Program (Minnesota Public Facilities Authority)
- Clean Water Act Section 319 Grant Program (MPCA)
- Small Community Wastewater Treatment Construction Loans & Grants (Minnesota Public Facilities Authority)
- Source Water Protection Grant Program (MDH)
- Surface Water Assessment Grants (MPCA)
- TMDL Grant Program (Minnesota Public Facilities Authority)
- Wastewater and storm water financial assistance (MPCA)

The WDs and WMOs may have individual grant opportunities for implementation of the BMPs and education and outreach activities.

The MPCA offers a variety of grants and loans that benefit the environment. Check the MPCA's financial assistance website for current opportunities that may be available for chloride reduction activities.

The Minnesota Local Road Research Board's Local Operational Research Assistance (OPERA) Program helps develop innovations in the construction and maintenance operations of local government transportation organizations and share those ideas statewide. The OPERA program encourages maintenance employees from all cities and counties to get involved in operational or hands-on research. The program funds projects up to $10,000 through an annual request-for-proposal process. (http://www.mntap.umn.edu/)

The Water Environment Research Foundation (WERF) funds water quality research that is funded through a competitive process. Apply for grants for research related projects at: www.werf.org.

The MPCA administers several programs that can provide technical assistance to organizations looking to address salt use and chloride pollution:

- Minnesota GreenCorps – Places AmeriCorps members with host organizations around the state to assist with a variety of environmental efforts, including reducing salt use and minimizing chloride pollution
- GreenStep Cities – A free, voluntary challenge, assistance, and recognition program to help cities achieve their sustainability and quality-of-life goals. Reducing salt use is one of the recommended best practices.
- Small Business Environmental Assistance – MPCA's program for helping small businesses meet regulatory obligations and reduce their impact on the environment.

There are several grant and loan programs through the federal government for education and outreach and purchasing equipment and implementation of the BMPs. A list of federal grant programs can be found at: water.epa.gov/grants_funding/.

6. Success Stories

Reductions in the use of deicing salt are possible through smart salt use and adoption of BMPs. Many organizations have already begun implementing salt reduction practices across the state. Examples of local efforts to implement smart salting strategies from water softening successes and winter maintenance successes are included in this section to provide ideas that may work for others and to highlight the great work already being done.

6.1. Municipal Water Softening Successes

Reductions in the discharge of chloride due to municipal water softening are often possible after a review of the major sources. It is difficult to completely eliminate municipal sources, as residents and commercial and industrial properties often have decentralized on-site and in-home softening units, but it is possible to greatly increase the efficiency of municipal softening with comprehensive strategies and improved equipment. Examples of local efforts to reduce municipal chloride discharge are included in this section to provide ideas that may work for other municipalities around the state.

City of Marshall

The City of Marshall discharges wastewater into Redwood River, and as of 2016 the chloride concentration in the discharge was 470 mg/L to 689 mg/L (AE2S, 2016). The proposed limit for the City of Marshall was 261 mg/L. To address this reduction, the City hired a consultant to identify the major sources of chloride in wastewater and found that 75% came from residential, commercial, or industrial softening waste, which residential sources suspected as being the primary source.

Given the source, Marshall Municipal Utilities (MMU) evaluated options to soften water at the plant beyond its current effort to reduce hardness from 53 to 31 grains. MMU determined that updating lime slacking and providing soda ash treatment could reduce the hardness to 5 to 7 grains prior to distribution. The City of Marshall performed outreach to educate residents about the change and earned support for reduced in-home softening. This proposed level, 5 to 7 grains, was supported by a considerable enough proportion for residents who would turn off or reduce use of less efficient in-home or on-site equipment (https://www.wrc.umn.edu/sites/wrc.umn.edu/files/ostpfactsheetmarshall.pdf). In the fall of 2019, the City of Marshall began construction of the WTP Softening Enhancement Project.

City of Morris

The City of Morris WWTP discharges wastewater into the Pomme de Terre River, and recently has discharge chloride concentrations consistently near 800 mg/L for chloride. The water quality standard that the City of Morris is required to achieve by December 31, 2020, is approximately 400 mg/L. A review of the distribution system demonstrated that the water hardness enters homes at 40 to 45 grains and that more than 90% of households use a water softener. Individual home water softeners were identified as the largest source of chloride. The Center for Small Towns constructed a model for Morris to evaluate the potential chloride reductions possible if every household switched to a high-efficiency softener with on-demand settings. The results demonstrated that the City would need to use one-third less water and reduce salt usage by 72% with the high-efficient units.

In the spring of 2019, the City of Morris began operation of a new WTP that uses a lime and soda ash based system to centrally soften the city’s municipal drinking water. The cost of the plant was $18 million, $12 million of which was provided through state aid. The plant has been able to reduce hardness to between 5 to 7 grains of hardness. In May 2019, the City of Morris City Council voted to adopt an ordinance that would limit the discharge of briny wastewater from water softeners from entering the municipal sanitary system from homes. This would effectively restrict the use of the older timer-based water softeners and encourage residents to have their softening systems inspected. The City of Morris also worked with a Minnesota GreenCorps member in 2018 to facilitate the reduction of chloride pollution in local waters.

Figure 71: City of Morris Water Treatment and Central Softening Facility

Shakopee Mdewakanton Sioux Community

The Shakopee Mdewakanton Sioux Community (SMSC) irrigates crops with a reuse pond, which receives highly chlorinated (>200 mg/L) stormwater and wastewater effluent. The high chloride concentrations were rendering the pond water unusable for the purpose of irrigation. SMSC identified winter maintenance salt and wastewater as major chloride sources to the reuse pond. SMSC trained their salt applicators according to the MPCA Smart Salting certification program, but still needed to identify an option for reducing chloride in wastewater.

SMSC determined that a RO system for the drinking water treatment was the best option to reduce chloride. Pre- and post-installation monitoring demonstrated that the hardness in distributed water dropped from 17 to 22 grains to 4.5 to 5.0 grains.

6.2. De-icing Reduction Successes

Reductions in the use of salt are possible through smart salt use and adoption of winter maintenance BMPs. Many winter maintenance organizations have already begun implementing salt reduction practices across the state, and many municipalities have begun to assess cost-effective ways to reduce chloride loads from water softening. Examples of local efforts to implement smart salting strategies are included in this section to provide ideas that may work for other entities and to highlight the great work already being done.

Maintenance Decision Support System and Automatic Vehicle Location -- MnDOT

The MnDOT Road Weather Technology (RWT) Team is made up of a cross section of professionals that bring a great deal of knowledge and experience to MnDOT's Salt Sustainability effort. The team's responsibilities include: Road Weather Information Systems, Automated Vehicle Location System, Maintenance Decision Support System (MDSS) Salt Sustainability Project, Pathfinder, and many other projects associated with these programs. MnDOT's RWT Program is focused on the most responsible use of winter resources using technology to enhance decision making. Each RWT Coordinator brings skills that provide valuable input and experience, to form a comprehensive well-rounded team approach to the Salt Sustainability effort. As snow and ice control technology evolves, MnDOT tries to stay on the cutting edge by developing new strategies and techniques. By using expertise gained in Integrating Mobile Observation projects, in conjunction with Federal Highway Association and partnering states, MnDOT has moved forward with innovative applications such as Web MDSS. MDSS has been valuable in predicting weather and road conditions and providing operators with a tool for better decision-making during winter events. MnDOT, along with its contracted weather provider, Iteris, have developed a matrix within the MDSS application. This matrix disseminates usage data and recommendations, to help MnDOT gauge how they are doing. It has provided MnDOT with a sustainability goal measure to help determine areas that need improvement. Overall the goal of RWT is to provide data-driven decisions that help operators in the field meet sustainability goals. RWT provides information and training on the right material, the right amount, at the right time, in the right place. By using the latest technology, the expertise of the RWT Team, good data, and proper training, MnDOT strives to efficiently manage its snow and ice operations by using resources effectively.

Minnesota Department of Transportation and the University of Minnesota Extension: Snow Fencing

Blowing and drifting snow on Minnesota's roadways is a concern for safety and efficiency reasons. Establishing snow fences improves visibility for drivers and helps maintain good road surface conditions. Snow fences have the potential to lower the costs of road maintenance, reduce salt applications and decrease crashes attributed to blowing and drifting snow. Snow fences are a non-chemical approach to improve driving conditions, they require maintenance or design crews to be proactive and by being proactive can be a positive, sustainable addition to winter maintenance. Snow fences can be used in any part of our state from large metropolitan areas to small rural communities. Anywhere there is blowing drifting snow; snow fences should be part of the maintenance strategy. Snow fences can protect more than just roadways: some examples include walk or bike paths, parks, businesses, parking lots, blowing snow coming off of lakes, and much more. Over the past several years, the MnDOT has partnered with the University of Minnesota Extension to conduct snow fence research. Together, they have created a state of the art, web-based snow control tool and a snow fence design tool helps road authorities and conservation organizations promote the use of snow fences. They have also launched a program that offers incentives for snow fence establishment by farmers and landowners and they are continuing their research on snow fence innovations. Snow fences promoted and supported by MnDOT include: Standing corn rows are 6 to 12 rows of corn left by the farmer a proper distance from and parallel to the highway. Corn can be harvested but stalks must remain standing.

Living snow fences (LSFs) are rows of trees and/or shrubs that are strategically placed to control drifting snow. LSFs are an agroforestry practice that provides a range of environmental benefits, including wildlife habitat and carbon sequestration. Structural snow fences are 8 foot tall poly fencing that is placed the proper distance from the highway to catch blowing snow. A narrow strip of land is purchased from the farmer who can farm close to the fence during the growing season. The team developed a website to host the two snow fence web tools, webinars and resources. If you need help or guidance in creating or enhancing your snow fence operations you have come to the right place. http://snowcontroltools.umn.edu/. There are many types of snow fences. We encourage you to be proactive and creative. Use snow fences and use the type of snow fence that will work best for your site. The advice on the U of M Extension website will help you be more successful with your snow fence project. Fact sheets, additional research and resources are also available.

Carver County

Carver County has reduced salt use by about 800 tons per year and here is how we did it. Beginning in the winter of 2011-2012, we began to focus on smart salting. We calibrated all of our equipment, retrofitted all of our trucks with tanks, reduced the use of salt/sand mix and started using treated salt. To gear up for liquids, we purchased a 5,000 gallon tank.

In 2012 to 2013, we wrote and the Board adopted a Snow and Ice Policy. We calibrated all of our equipment and made this a standard practice moving ahead. We again reduced the salt/sand use and began buying trucks equipped with side tanks. Three new tandems were purchased and we eliminated more of our manual controllers.

We began placing a priority on educating our drivers. All of them were sent to the MPCA Road Maintenance workshops. We reviewed salt use amounts on routes.

We began to experiment with different cutting edges to reduce the amount of snow and ice left on the road to “melt”. This same year, we added a second 5000 gallon tank at the main public works location and 750 gallon storage tanks at our Watertown and Young America locations.

In 2013 to 2014, we purchased a new water truck that allowed us to spray brine for anti-icing applications and we purchased a brine slurry tank system for one of our trucks as a way to reduce salt use even more in sensitive areas. We replaced two more tandems and reduced manual controllers to two.

The following year we replaced one tandem axle truck. Using the water truck we began anti-icing before the storm. The operator assigned to the slurry truck also experimented with brine only applications when conditions would allow.

We now purchase all treated salt and no white salt. The benefits of treated salt are the ability to melt at lower temperatures along with better adhesion to the road surface. We have seen tremendous improvements with the growing knowledge and education of our plow drivers. They see the same results with less salt in town, and rural users now salt only were needed--on hills, curves and intersections. Supervisors have purchased totes of Road Guard 8 to be blended with our salt brine and used when temps are below zero.

This year we have again returned to education. We hosted the MPCA certification training, invited our local cities and all of our plow staff. We have switched to a new A.V.L. vendor and hope to get better data to track salt usage and get real-time reporting of plow activities. This will allow the plow drivers to be aware of the materials they are using. We think this will benefit taxpayers and the waterways of

Minnesota. We plan to have a link on our web site to inform the residents of current plow route status in real time.

We are proud of the work we do at Carver County. We will continue to provide excellent service to our customers and do our best to protect the waters of Minnesota.

Dakota County

This information was taken from the *Dakota County Smart Salting training KAP Study Report* (Eckman et al. 2011).

The snowplow drivers in Dakota County, Minnesota, attended the MPCA sponsored Smart Salting training course presented by Fortin Consulting and the Minnesota LTAP in 2008. To test the effectiveness and impact of the course, a knowledge, attitudes, and practices (KAP) was administered to these drivers before the course to establish how the snowplow drivers approached the job. After two winter seasons, approximately 14 months after the initial training, the same KAP test was administered again to measure any change. Steps were taken to maintain confidentiality of the respondent and to ensure the same people were compared. Seasonal and temporary employees were not used in the comparison.

Results: In September 2008, the results of the survey showed that Dakota County plow drivers had good general knowledge and good practices, but they were in need of some improvement. While the drivers were aware of the county's winter maintenance policy, the independent judgement factor was a little more difficult. For example, only 60% agreed they "minimize the use of deicers during a snow storm." Although this type of information is useful, the goal was to evaluate how effective the training was to actually make a difference in all three facets of knowledge, attitudes, and practice.

The follow up survey in November 2010 showed mixed results. Most importantly, some of the significant improvements were under knowledge and practices.

Question	**2008 Response (Yes)**	**2010 Response (Yes)**	**+/- percentage change**
I minimize the use of deicers during a snow storm	60%	96%	+36%
During calibration I have set the computer speedometer to match my trucks speedometer.	40%	73%	+33%
I use an application rate chart to determine the amount of salt/sand to apply	35%	76%	+41%
I avoid using de-icing salt when pavement temperature is below 15 degrees F	27%	88%	+60%
I document my winter maintenance actions	73%	69%	-4%
The policy encourages plowing before two inches of snow accumulation	92%	84%	-8%
Equipment is calibrated for each type of deicing material used	92%	88%	-4%

Question	2008 Response (Yes)	2010 Response (Yes)	+/- percentage change
I have ground-speed controlled sanders-the auger is installed and working	84%	77%	-7%
I plow before applying deicers to minimize the dilution of the chemical	96%	92%	-4%
I avoid salt/sand mixes	72%	68%	-4%

The areas that showed declines were areas that either additional training or clearer policies could produce better outcomes. The majority of the questions indicate there has been a positive shift in knowledge, attitudes, and practices since attending training. In addition to the KAP survey, the amount of actual salt has been reduced to further underscore the success of the training. The county used an average of 405 tons of salt per snow event in 2007, the winter season before attending the training. Post training, the county reduced their usage by about 50 tons per event to 355 tons of salt per snow event. This reduction correlates to about 40 million gallons of freshwater protected from chloride contamination per snow event.

Goodhue County Department of Public Works

The population in Goodhue County has increased, along with the expectation for clear roads during the winter months. Today the whole plow crew is mobilized on weekends for snow that would have generated no plow activity a few years back. Additionally, the public expects the roads to be cleared soon and to stay clear regardless of the weather. Fortunately, Goodhue County Public Works has been updating their snow and ice fighting equipment and methods during that same period.

The crews are dispatched earlier in the morning to attack the snow before it is packed by traffic. Additional belly blades and rear mounted wings help remove the snow so less chemical is needed to finish the job. The plow trucks have been equipped with onboard thermometers to monitor outside air and road temperatures so the operators know exactly what the conditions are and they can adjust their attack to these specific conditions. Pre-wetting tanks have been installed to help the salt stick to the road, increase the efficiency and reduce the loss of this valuable snow fighting material, and the sanders have been calibrated so the operator can monitor what he puts out. Additional sheds have been made available to the crews so they can customize their sand salt mixture to meet the specific storm at hand. If it makes sense to use more salt to cut a layer of snow before an arctic clipper descends upon the county, then the loads are modified and the sand that doesn’t really help much in this event is greatly reduced or eliminated for this particular fight. Or if it is too cold for salt to help, then less salt and more sand can be used in that situation.

The latest technology employed this year is use of an anti-icing agent, which is spread in critical stretches of the system to prevent the snow and ice from sticking to the road in the first place. This year the county was able to fight frozen rain on the roads in these critical stretches before sending out the morning plow crew.

Results: Even though the traffic and number of hours that the crew works is up, material usage has not increased with the additional work because of the use of these new materials, technology and equipment. They are not using more materials; they're using the same amount smarter.

Scott County

This information was supplied by Scott County.

The past practice of Scott County was to use a mixture of 1:1 sand and salt that was applied with noncalibrated spreaders. No policy or guidelines were in place for mixture ratios or spread rates.

The county started a training program for the supervisors and operators to familiarize them with the effectiveness of salt depending on pavement and air temperatures. After attending the training, treated salt was added to the county's material options. Each plow truck was supplied with information about the route, how many lane miles, and tables for each material and its spread rate based on the temperature.

It took several events to convince the members of the team of the effectiveness. There was not an instant buy-in from the drivers, but after several events, most of the drivers were impressed with the results using the treated salt. During the course of 8 to 10 events, the usage of the sand and salt declined. The winter maintenance teams stopped using the sand/salt mixture, although small cities and townships continued to purchase the sand/salt mixture from Scott County.

Results: By implementing the new practices and policies, the drivers found a single load, or less, was enough to treat the route. Anecdotally, the drivers reported the usual practice would be to apply three or four truckloads of the sand/salt mixture in a single event. The County estimates that 1,500 to 2,000 pounds of the sand/salt mixture was applied per mile lane each event. After the change, the usage dropped to about 424 pounds per lane mile per event. The savings of over 1,000 pounds per lane mile paid for the increased costs of the treated salt. This correlates to a 25% to 30% reduction of chloride entering lakes, streams, wetlands, and groundwater. Scott County maintenance believes this is the most economical and environmentally sound approach available.

Three Rivers Park District, Baker Park

The mission of the Three Rivers Park District is to promote environmental stewardship through recreation and education in a natural resources-based park system. The Park District is located in the west suburban Minneapolis/St. Paul metro area of Minnesota. We manage 27,000 acres of park reserves, regional parks, and special-use facilities. The name "Three Rivers" comes from our park geography, situated within watersheds that flow into three significant rivers: the Mississippi, the Minnesota and the Crow.

As a natural resource-based park system we are expected to be role models in preserving and protecting the natural resources. We also need to manage the park for active recreational use. The Park District has a natural resources department with Water Resources being one of its divisions. Another division is Parks and Trails Maintenance. Roads, trails, and parking lots fall within their area of responsibility. Understanding the effects that salt use has on the environment, the Maintenance Crew at Baker Park Reserve set a goal to improve how they use salt for de-icing.

Before 2000, we applied salt/sand, with each person deciding how much to spread in a given area. Over time we weaned off of the use of sand and went to straight salt. Initial calibration efforts began after staff attended a 2007 Winter Parking Lot and Sidewalk Maintenance workshop funded through the MPCA. We learned that we were wasting time and money on the sand-salt mixture, as well having to sweep up the sand in the spring. By calibrating our spreaders, we were able to reduce our salt use by 25%.

A few years ago Hennepin County Public Works offered to provide us with treated salt. We found it was far more effective in colder temps and we could lower overall salt use. From 2007 to 2012, we were also able to reduce the use of treated salt 33% to 50%.

The maintenance crew at Baker Park saw county trucks spreading brine on nearby roads and started doing internet research to figure out how they could engineer some in-house equipment and for brine-making formulas. They built a mixing station and spray equipment using discarded tanks, pumps, and other re-purposed materials. The Baker crew tests each batch of brine with a simple hydrometer and controls the amount of brine applied by calibrating the equipment. Most recently we were able to purchase a manufactured spray applicator. Our goal is to expand what we have learned at Baker to other Park District locations as funds become available. With the introduction of brining in 2012, we have seen a significant decrease in the use of regular dry salt at Baker over the last several years.

We found that in most situations where anti-icing takes place, bonding ice is prevented and crew time can be saved. This allows snow removal with one pass. The younger generation has new ideas and the older generation has years of experience; this puts some friendly competition into our maintenance efforts and makes us better at what we do. The maintenance staff at Baker Park is leading the way for sustainable winter maintenance at Three Rivers Parks and we are proud of our achievements thus far.

St. Louis County Public Works Department

The St. Louis County Public Works Department in northern Minnesota does not have a bare road policy. Because of this the county has been able to stay with a program based on abrasives for traction. They do try to get to bare pavement but it is through mechanical removal such as underbody scrapers and graders to scrape off blacktops when time allows. The county uses carbide pick blades to help break up the ice on packed roads and gravel roads. Because they have this type of program, they also have an aggressive sand recovery program that begins in early spring. The crew works throughout the spring to try to recover as much material as possible. This is hard work but unlike programs that use mostly salt, they have a chance to recover the material before it enters our lakes and streams.

Both salt and sand have environmental issues and they have been actively working on reducing our impact from salt and sand since the early 1990s. They first step was to erect dome buildings and coverall type buildings at all facilities where salt and sand are stored. The county partnered with other government entities such as the Nett Lake Indian reservation, the cities of Hibbing and Ely, and with the State of Minnesota. They now cover 100% of the material.

The county started their calibration program two years ago when we began buying trucks with ground speed oriented controllers. This gave them the ability to more accurately calibrate trucks and gives better control over application rates. They also completed a $250,000 initiative to retrofit 46 additional units from the fleet with ground speed controllers and pre wetting equipment. In the future, they intend to add GPS/AVL capabilities to these trucks.

Although they have more of a traction than a melting program, they have found that by incorporating liquid deicers to their material there is less sand bouncing off the road. The county has expanded their salt brine making facilities to include 5 additional facilities, sharing capabilities with the MnDOT at Hibbing and Pike Lake.

Results: Currently, they use approximately 19,265 tons of salt and 67,440 cubic yards of sand per year valued at $1,200,000 and $202,000 per year respectively. It is a goal to reduce salt/sand usage by as much as 45% by using calibrated equipment, ground speed controllers, and pre wetting equipment. This will help the environment by keeping the 8,669 tons of salt out of the water, protecting about 7 billion gallons of freshwater, and by keeping 30,348 cubic yards of sand from entering our rivers and streams. These reductions are projected to save up to $634,000 per year in this time of tight budgets. It is because of their recent and large effort to update equipment resulting in a reduction the amount of materials applied to county roads that St. Louis County is able to minimize their salt and sand pollution.

Chisago City

Chisago City has three plow trucks, two with open loop sanding set-ups and one with a closed loop system. There are about 46 miles of asphalt roads and about 16 miles of gravel roads. At first, the whole road width was salted including at stop signs, hills and curves. Initially, a 50/50 sand salt mix was used and stored in the open. Starting in 2009 sand use was cut back until, in 2012, only salt was used. After the sand was removed from operations the spreaders started being calibrated.

Initially, the trucks were set at very high rates. One truck with a closed loop sanding system was used in “blast mode” because the code to calibrate and program it was missing. There were also two open loop trucks in use. The three trucks were feeding at 1800, 720, and 675 lbs/LM at 20 mph minimum, which resulted in 15 to 20 tons of salt per event for 46 miles of road (average feed rate of about 740 lbs/LM).

The first step was to address the closed loop truck. After experimenting with feeding rates, a 300 to 400 lbs/LM rate was reached to use less salt and produce better results. Adjusting the other two trucks reduced salt use by and estimated 33% to 50%. The auger speeds were also analyzed and reduced to achieve a new lower minimum setting of 100lbs/LM.

In addition to calibration, salt spread was also examined at different speeds. After watching the salt scatter it was determined that above 20 mph on rural roadways resulted in salt bouncing into ditches. Plow drivers adjusted their speeds on those roads accordingly to keep salt on the roads.

A salt shed was purchased and the salt is stored in a covered building on an impervious surface.

Results: Chisago City was able to greatly reduce their trucks’ rates by changing their flow valves and testing the speed dial knobs. At 20 mph one truck was reduced from a minimum setting of 675 lbs/LM to a minimum setting of 54 lbs/LM, with the flexibility of several settings in between.

The second truck’s minimum setting was reduced to 150 lbs/LM from 720 lbs/LM minimum at 20 mph previously.

The third truck with the closed loop system was reduced to a minimum of 100 lbs/LM.

The ability to adjust to consistent rates and the knowledge of the amount of salt being put down will help Chisago City to achieve the best results on their roads. They hope to cut salt use in half with better and more consistent results.

City of Cottage Grove

Cottage Grove saw a significant decline in salt usage after attending training. Their usages for the past few years, per event have declined steadily.

- 2009/2010 = 1,987 tons of salt used (71 tons/event)
- 2010/2011 = 2,083 tons of salt used (75.9 tons/event)
- 2011/2012 = 1,320 tons of salt used (57 tons/event)
- 2012/2013 = 3,019 tons of salt used (67.1 tons/event)

Results: The City realized a savings of 694 tons of salt for the 2011-2012 winter season. This translates into a savings of $40,000 in one season. The rate increased in 2012-2013, but was still lower than earlier years.

City of Eagan

This information was gathered from Tom Struve's presentation notes, 2011.

The City of Eagan discontinued mixing sand and salt in the 2005-2006 winter season. Without dropping the level of service to residents, the City was able to eliminate a five year average purchase of safety grit. The elimination of the 3,249 tons of grit led to a 65% reduction in spring street sweeping hours. This elimination saved Eagan $70,000 per year.

In 2008, Eagan began using EPOKE winter chemical application technology. This enabled the city to use a precise chemical application of up to 90 gallons of brine per one ton of salt and realize immediate improvements. Also, the addition of AVL allows snowplow drivers to inform the police of the location of cars remaining on the streets during snow emergencies. The police receive a map by 8:00 a.m. showing the exact location of the cars, which makes the mechanical removal of snow much more efficient and effective for the snowplow drivers.

The City of Eagan implemented additional practices including: pre-wetting material at the spinner; using salt brine to 10 to 15 degrees and substituting MgCl when the temperature falls below 10 degrees; limited uses of Clear Lane for severely cold temperatures; and, managers directing the lane mile calibrated application rates. Eagan still has a stockpile of sand, which they rarely apply. Most importantly, Eagan has the buy-in of the operations staff, which has been very important for their success.

Despite the new practices, the level of service that Eagan provides for residents remains high. The residents have high expectations for winter road maintenance and Eagan has been able to make changes to reduce salt use, while also meeting the expectations of the community.

City of Edina

The City of Edina convened a diverse advisory committee of service providers, property managers, and other interested representatives to develop a model contract for snow and ice management services.

The main focus of this work is to offer a model contract that embraces best practices to minimize environmental impacts from sand, salts and other chemicals, while also maintaining safety and addressing liability risk allocation. The city considers safety, service, and the environment when developing strategies for chloride management. The city has developed strategies under the regulatory, technological, and education/knowledge category of strategies. Under the regulatory category, the city has supported limited liability legislation and developed a model contract for snow and ice management that embraces best practices to minimize environmental impacts from salt and other chemicals. Property owners can adapt the model contract to suit their needs and to ensure their contractors are protecting Minnesota waters from chloride pollution. From a technological perspective, the city uses calibration of equipment, brine mixing, pre-wetting, anti-icing, AVL technology, segmented plow blades for winter maintenance activities, and is considering an adaptive management approach to improve deicing operations. The city has provided staff with level I and level II training, hosted smart salting training for property managers, developed model contracts, and created a chloride PSA: "More Isnt Always Better" video among other knowledge based initiatives.
https://www.youtube.com/watch?v=pYm1aTn_AgE

City of Cambridge

The City of Cambridge, Minnesota Public Works and Utilities Department have adopted best management practice to apply reduced amounts of chloride based deicers while also achieving safe surfaces. Cambridge staff have been certified in the MPCA Smart Salting Training Program. They have increased sand to salt ratios, purchased equipment that applies salt brine for deicing purposes, which reduces salt use, and intend to use pre-treating methods before snow events to additionally save on salt use.

City of Jordan

In 2014, the City of Jordan made a goal to reduce salt use by half while maintaining the same results. The first step to achieving this goal was to talk to other municipalities about their prewet programs. The city knew of the high upfront costs associated outfitting trucks for a prewet system. A plan was put in place and the city was able to save $18,500 in upfront equipment costs. The next steps to implementing prewet strategies were purchasing an old farm sprayer, using old tanks, and manufacturing brine. After contacting a metal fabrication company to hang the system on the trucks the overall cost for the city was $1,500. The next step was trying out the new brine system. The first year the city relied on gravity to wet the salt. The results were good but the second year they added small pumps on the truck to pressurize the system and get more liquid onto the salt. Next, Jordan is trying to upgrade the pre-wet system by adding a second spray tip, which will add even more brine to the salt.

Results: With the improved pre-wet system the City of Jordan was able to reduce salt by only salting hills and intersections till after the snow has stopped, only open the main roads if it's still snowing up to 4 inches, and adding Road Guard 8 to the salt brine when temperatures get below 10 degrees.

These changes have not only cut the salt use in half but also saved the department on equipment wear and tear and thousands of dollars in fuel. What has helped their crew find new innovative ways to do our jobs is to always keep an open mind and to not be afraid to try new ideas.

They plan on adding a new truck to their fleet, which will have a prewet system inside the box, plus an anti-ice bar for treating the roads before the storm hits.

City of Roseville Public Works Department

The Roseville Public Works Department saved money, reduced application rates and improved our level of service by plowing more, anti-icing, increasing pre-wet rates and modifying our brine. We have reduced application rates by 100-200 pounds per lane mile. Our snow policy specifically calls out our duty to provide “safe winter driving conditions,” not to provide bare pavement. Also, all of our winter operators have been through the MPCA training. They see the benefits of less salt and are committed to this goal by using the right amount of salt for the conditions. We increased how often we plow to reduce the amount of hard pack and ice to be melted. We find plowed roads require about 1/3 less salt than unplowed roads, assuming approximately 1.5 inches of snow on them. Many suburbs still have a 3 inch call out in their snow policy. We are going out more often at 1 inch on residential and ½ inch to 1 inch on main roads. This has been one of the most important ways to use less salt and provide better service.

One of our best tools for anti-icing is a spreadsheet. We have recorded all our anti-icing applications. Forecast, pavement temps, application rate, material used, and effectiveness are all recorded. This lets us see when anti-icing will be helpful and when it is not. We have created a guide with a series of questions that help us decide whether or not to anti-ice. In 2008, after attending an MPCA winter maintenance class, we built a small walk behind brine applicator from an old Earthway spreader. A 5 gal bucket was the tank and a 4 feet section of PVC was the spray bar. We treated City Hall sidewalks for the season and quickly realized it could lead to reduced salt use. The next year we bought a 275 gal tote tank and rigged up a system on 3/4 ton pickup. We could only do 12 lane miles and had to drive very slowly to maintain our desired application rate. Equipment upgrades over the last 7 years allow us now to apply the correct rate while moving at traffic speed, and cover within a day the 60 miles we anti-ice when conditions are appropriate.

We increased the amount of brine applied at the spinner, and incorporated Ice Bite 55 brine mixtures into pre-wet and anti-icing operations. Most of our trucks had a very small, fan nozzle for pre-wetting. After the MPCA class, we checked how much brine was actually coming out. It was only 2 gal per ton, likely the reason our seasoned veterans doubted the value of pre-wetting. We removed the nozzles and let the quarter-inch hose spray directly onto the salt. This gets us 10 to 15 gal per ton. We now purchase our plow trucks with hydraulic pumps that can be calibrated. Higher pre-wet application rates show a better spread pattern and less bounce, and operators agree on its value. We blend salt brine with Ice Bite 55. It is both cost and space effective. We do not have the space for a brine making system. We put up a large rack that holds 4 tote tanks at a time and one on the floor. This is plumbed to a large pump with 2” hoses. We fill totes with salt brine from the county, and then blend it with Ice Bite 55. We generally blend 90/10 for anti-icing, greatly improving adhesion to the road surface. For pre-wet, we blend around 70/30.

We are always discussing our rates amongst ourselves during an event, talking about pavement temp, what we're all seeing in different parts of town, trying to make sure we're using just enough to do the job and nothing more. Our goal in winter is simple, continue to earn and exceed our reputation for exceptional winter road maintenance without significant cost to tax payers or the environment.

City of Wyoming

The City of Wyoming Public Works is proactively reducing the environmental impacts from the use of salt in 2017. Their goal is to minimize salt loss and salt usage by storage, handling and spreading. Past salting practices were disorganized and undocumented. No records of salt usage were track. They began improving salt loss by implementing the use of an enclosed 500 ton salt shed with an asphalt floor. In the past Wyoming public works stored salt and salt/sand outside under tarps without containment or a hard surface. An asphalt mixing pad was installed in front of the new salt shed where the salt can be dumped, mixed and loaded. The excess or spilled material can quickly be cleaned up and placed back in the shed protected from the elements. The implementation of the shed and pad has minimized salt leaching and salt loss dramatically from rain events and spillage.

Wyoming Public Works has also began the calibration of salt sanders on trucks to reduce salt waste. Staff calibrates each truck to effectively put down the desired amount of salt to efficiently melt ice. Wyoming Public Works now rarely applies salt until the snow event stops. Wyoming Public Works starts plowing operations sooner than in past. If a snow event ends during the night, staff are called in earlier to clear the roads before the snow becomes packed down. This minimizes the amount of salt needed to cut or break the snow pack. A rubber cutting edge is being tested on trucks. The rubber edge reduces noise, damage to curbs, iron structures, and follows the contours of the road-way better, which results in a cleaner surface to minimize salt use. Wyoming Public Works is working on rewriting its snow and ice control policy reduce salt use, meet community expectations for road safety and reduce environmental impacts. Wyoming Public Works will continue to search and implement best practice methods to reduce salt use, protect our city's water resources and improve the safety of our road ways.

City of Mahtomedi Public Works Department

In 2010, the City of Mahtomedi adapted from a sand/salt mix to just salt on all city streets. This was done in an effort to both improve the snow removal process and to reduce the amount of the material going into the water, and ultimately White Bear Lake. The city council authorized the purchase new equipment, which allowed the City of Mahtomedi to begin the process of greatly reducing their salt use. The list of new equipment the City of Mahtomedi used is listed below.

- **Scale for Case Loader**: To be efficient with salt use, each driver needs to know how much he is using. Drivers receive a paper print out showing exactly how much salt he/she is taking from the shed. This helps the driver make an educated decision regarding the use of the salt versus the condition of the city streets, resulting in the reduction of salt use and saving tax dollars and our water. Monthly print outs of each employee's salt use is posted for all to see. The numbers spur conversations between employees on how to further reduce salt consumption.
- **Salt Brine Making System**: This system allows the city to make a brine solution from their own salt stockpile. The brine is used in a spray unit mounted on a one ton, and also in end gate pre-wetting tanks installed on all of the single axle dump trucks in 2011.
- **Stockpile treatment:** The crews also use a product called "SOS". When needed SOS is mixed into their salt on a storm by storm basis. It provides for better adhesion, and increases the effectiveness of the salt.

- **Pre-wet tanks**: The city purchased 100 gallon tailgate tanks for 3 of the single axle trucks to enable pre-wetting of the salt with a brine solution as it comes out of the truck. Pre-wetting gives better adhesion to the ground, and makes the salt more effective.
- **Spray Unit**: This unit slides into the back of a one ton truck. The truck sprays the streets before an event occurs. Anti-icing keeps the road surface wet longer before the snow accumulates, and eases removal. It inhibits the bond snow and ice make with the pavement. When the bond is reduced, the snow is easier remove from the pavement, reducing the time needed to complete the snow removal process, and providing a better result for the traveling public. Anti-icing has reduced the number call-ins and overtime costs.
- **Infrared pavement sensors**: These sensors give the driver pavement temperatures. The information is used to adjust application rates. They annually calibrate each of the city trucks used to de-ice city streets so we are accurate on our rates.

Results: The reduction in the use of sand has resulted in an 83% reduction of sweepings picked up each year. 2009-2010 prior to the switch city crews used 700 tons of a sand/salt mix. 2010-2011 the city committed to purchase 700 tons of salt with the switch to straight salt in place, and record amounts of snow, city crews used 485 tons of salt. 2011-2012 seasons the city has committed to purchase 400 tons of salt. It is the city's goal to reduce the annual salt use 50% from the peak years. At $65 to $70 per ton, the savings are significant.

City of Mankato, City of North Mankato, and MnDOT District 7-Mankato

Collaboration between organizations sharing neighboring areas can help move progressive ideas ahead faster and more easily than "going it alone." The public works crews of City of Mankato and the City of North Mankato have been working with and alongside MnDOT Mankato to reduce the amount of salt necessary to keep the roads passable in winter. They have partnered over ideas and with technology to move ahead the best practices for saving money and reducing salt application. Points of collaboration include the use of brine and calibration, as well as sharing tips and information on what is being seen during storm events.

The City of Mankato's Public Works Department plows 432 centerline miles and uses an average of 2,400 tons of salt annually. They have two 1400-gallon brine tanks for pre-treating. The city implemented temperature compensation systems in 2003, to take the guesswork out of knowing how much salt to put down. It computes the minimal amount of salt needed to melt the maximum amount of snow and ice by calculating the road temperature and the air temperature along with the speed of the truck.

Annually, the City of Mankato's snow fighting crew prepares for the season by calibrating all equipment to be confident of how many lbs/lane mile of salt and gallons/ton of salt brine are being applied at any given time. Applications range from 90 – 540 lbs/lane mile of salt and pre-wet, at 7 to 10 gallons per ton of brine, depending upon the storm event, pavement surface temperatures and other factors. Prior to each snow event, if surface temps allow, they pre-treat many of the hills, concrete surfaces, sharp corners, bridges and other areas to decrease the likelihood of the snow and ice bonding to pavement surfaces. This then reduces the amount of granular salt required to treat after plowing. They apply brine when anti-icing at around 40 gallons/lane mile. The City of Mankato averages approximately 41,000 gals per year in anti-icing.

The City of North Mankato also utilizes brine application before a winter storm, anti-icing problem areas in advance of an event. This allows snowplows to remove the majority of the material and a reduced reliance of having to melt through it with salt or other chemicals. Consistent planned plowing during events reduces packed snow on surfaces, which in turn case reduce the amount of salt needed. The City of North Mankato attributes their reductions in salt to this use of salt brine, the use of road speed sensors to adjust application rates, and employee education. Each event is assessed individually for the appropriate techniques to use. Both the City of North Mankato and the City of Mankato now obtain brine from MnDOT District 7 – Mankato. District 7 first started making and using brine in the mid-1990s. The brine was made in old metal cattle tanks and the truck was constructed with round fiberglass tanks that another district had discarded. Once the operators saw how well brine worked, a bigger system to make brine was needed along with more tanks for the trucks. Every year more tanks were added to trucks. More liquid and less salt was the driving objective.

The Mankato subarea experimented with mixing on the fly using herbicide spraying-technology, and anti-corrosive additives were tested, along with many other deicing chemicals. The goal was for the most cost-effective method. Then in 2004-2005 Mankato purchased a more automated system capable of fine-tuning brine production and the Windom area built a bigger system to supply the southwest corner of Minnesota in 2006-2007.

When the Mankato District Headquarters was going to be replaced, the decision was made to invest in a state of the art brine production building capable of supplying not only Mankato's needs but all of the truck stations as well as cities and counties in the Mankato area. District 7 has several trucks that they anti-ice with. The first tanks were smaller, 1000 gallons, and were able to spray three lanes at a time at slow speeds. The next project was MnDOT's first semi-tanker capable of multi-lane, high speed applications. This tanker holds 6000 gallons.

Results: Thanks to some inventive and determined staff, Mankato District 7 has always been on the cutting edge of brine use, production and dispensing. As with the City of Mankato and the City of North Mankato, District 7 has identified some key techniques to reduce salt use and operate in a cost-effective manner: anti-icing prior to events, using brine to reduce salt loss, using smart application systems, doing proper calibration, and educating operators. Together these three organizations have improved service in the region and continue to support each other in progressive winter maintenance.

Edina Public Schools

Edina Public Schools serves 8,000 students and over 205 acres of property. Its 10 sites include 6 elementary schools, 2 middle schools, the Edina High School and the Edina Transportation Center. Buildings are often open 7 days a week. Edina Public Schools estimates they have reduced their salt use 88% since 2014. It has been a districtwide effort to minimize the harmful effects salt has on our groundwater and the environment. The school district has made several changes to their snow and ice practices. This includes purchasing less product, educating staff, researching and purchasing more efficient equipment, and being more conscious of the weather. The salt reduction began in 2014 as the District began the purchase of snow removal equipment such as brooms and drop spreaders that could clean more efficiently and better control salt distribution. Prior to 2014, the District was purchasing and utilizing 45 pallets of salt. Salt was freely applied throughout the winter with little or no regard to the changing weather conditions or current condition of the walkways and parking lots.

In 2016, the grounds crew began attending the MPCA's Smart Salting training. This led to discussion and planning for how they could reduce salt use on the grounds. Currently all grounds crew, along with several building staff, are certified in Smart Salting.

This winter of 2019, the District purchased 16 pallets of salt, and have used only a small portion of it. The grounds crew, transportation, building staff, and administration are all tuned into the weather and are quick to respond when steps can be taken to prepare walkways and parking lots prior to inclement weather. Two years ago, the crew created their own salt-brining system that has been used throughout the district especially on high traffic walkways. Many areas prone to refreeze and several unsafe walkways/stairways are completely closed during the season to reduce salt and risk. The building staff has been equipped with small hand spreaders that distribute salt in entryways and stairs in a responsible manner. It is the Edina Public School District's hope that they can continue to improve and minimize the negative effects their district has, on the groundwater and on the environment as a whole.

Figure 72: Ventrac Salt Drop Spreader Used by Edina Public Schools

City of Minnetonka

The winter maintenance operators and managers for the city of Minnetonka are committed to the need to reduce salt to protect the environment. This city delivers high service and the residents expect excellent service. Minnetonka Public Works maintains 254 centerline miles of streets, which includes 562 cul-de-sacs. During full scale snow events of 2 inches or greater, 20 plow trucks, 2 loaders, and 7 pickups are mobilized to perform snow removal.

Prior to the 2010-2011 winter season, Minnetonka installed a Cargill Accubrine automated brine production system. The system can blend up to two other products with the brine produced to aid in temperature suppression of the brine when needed. There are five 6,500 - gallon tanks to store the finished products or purchased additives. The City currently uses a corrosion inhibited 32% calcium chloride to pre-wet salt when temperatures are below 15 degrees F. Outside agencies, including Hennepin County and neighboring cities, purchase brine for use. The brine is used to pre-wet the salt before it is applied to the road and for anti-icing prior to a snow event.

Prior to snow events, Minnetonka uses a 2,000 gallon tanker truck and a truck with a 900 gallon tank that are used to pretreat the highest volume streets with brine at a rate of 30 to 35 gallons per lane mile. The fleet is currently being retrofitted with new technology: pre-wetting equipment, on spot chains, Force America data, and AVL.

All 20 plow trucks and 1 spare truck in the snow fleet are equipped with ground speed controllers to accurately apply and track salt used. The trucks are also equipped with brine tanks so that the salt that is discharged from the trucks is treated with brine at a rate of 10 gallons per ton of salt.

The City subscribes to a web-based weather service that provides a 48-hour weather forecast, which is updated every hour. Information provided includes air and pavement temperature, wind speed, dew point, snow and ice accumulation totals and rates/hour, when the precipitation will start and stop, and also provides recommendations for salt and liquid application rates. This information supports decisions for properly staffed crews for the event, application of anti-icing liquid, and the application of the correct liquid for pre-wetting the salt. City staff can compare information from around the state with regards to road temperatures, wind speed, and radar to see how an approaching storm will affect Minnetonka operations.

The AVL is used on all mobile snow equipment to track vehicle location and salt application. A real-time, citywide map shows progress of snow removal operations and allows movement of plows around the City to address any missed areas or areas that are running behind schedule. The system will also send an email notification if an error occurs with a salt controller on a truck. Depending on the status of the plowing and storm, staff determines whether to bring the truck in for repair. Even if in an error state, the controller is able to track salt application provided the spreader is functioning. Four trucks are equipped with air and road temperature sensors, which are monitored through the AVL system.

Results: The city of Minnetonka has achieved its goal set by the Nine Mile Creek Watershed during the 2010-2011 season. They reduced application of salt to 4.2 tons per mile from 7.022 tons per mile. This was a reduction of 40% during a normal season.

Minnetonka is focused on improving the use of liquids. For the 2012-2013 winter season, the trucks averaged 3.5 gallons/ton of brine for pre-wet and the city realized that the nozzles were not calibrated for the gravity application system. The nozzles are now calibrated along with the salt controllers before winter and the average for 2014-2015 increased to 6.2 gallons/ton. This is still below the 10 gallons/ton rate the trucks are calibrated for but it is improving.

Precision Landscaping

Precision Landscaping is making a move into using liquids. They began with one truck at one site earlier this season. They will be adding two more trucks with liquid capabilities to be able to use the technology on more sites because of the success they have had with reducing the amount of product needed. They are also working to add off site reloading locations to increase the number of properties liquids can be used on. Additionally, they are working to educate their clients about the effects of salt as part of their push to implement liquids across their sites.

In September of 2018, they held a Smart Salting training at their office for their entire staff, which has led to a team effort on salt awareness and reduction. They involved all staff in calibration this year, instead of a few people so that everyone was aware of the process and how the equipment works. They also had staff representation in the Edina winter maintenance model contract advisory committee.

In addition to regular reminders to try to use less salt, Precision Landscaping bought fewer pallets at the beginning of the season with the goal to meet site safety needs while reducing salt without needing to make another salt purchase this year. Having a smaller supply has made staff more conscious about how they are using product. From these changes, Precision has cut back 35% per event from last season. On 1, 14-acre site in particular their salt usage is down by about 60%.

Figure 73: Precision Landscaping Brine Truck

Norwood Young America

With tight budgets, the City of Norwood Young America is finding more ways to cut back on salt and help the environment and maintain safe roads. Five years ago, city employees attended an ice and snow workshop and learned the importance of calibration on city dump trucks, and found they were over salting are roads. Some of the roads in NYA where white from heavy salt residue, and this changed after doing calibration on all of our trucks.

In 2010, the city’s employees attended another workshop on snow and ice control practices. After that workshop the city purchased tanks for pre-wetting salt before applying to road surface. The liquids activated the salt faster and they used less salt per snow fall. In fact, integrating liquids almost cut usage in half.

Results: In the past five years they have seen good changes in snow plowing practices. They have saved money, they are being more environmentally positive, and they do not need to waste material to help improve safety. Every day the city employees go and clean roads. The goal is to make safe roads to drive on and provide a future of better water quality. They have reduced their salt use from an average of 600 tons to 350 tons per year. They are pleased with the progress and will continue to look for new and better ways to improve operations.

City of Plymouth

The City of Plymouth currently has a chloride impairment listed by the MPCA for Elm Creek, Bass Creek, Plymouth Creek, Bassett Creek, and Parkers Lake. The current Shingle Creek Chloride TMDL, and the TCMA CMP, mandate the city to improve its winter operations and reduce the amount of chloride entering our water resources.

Over the past several years City maintenance staff has been implementing BMPs for chloride reduction. These practices include:

- All of our plow trucks are equipped with a pre-wetting system. To make the pre-wetting process more efficient, staff has adjusted the delivery system to allow for salt to better stick to the roads when applied. Leading to 30% less salt use.
- Calibration of truck spreaders and anti-ice units twice annually
- Plymouth utilizes 2 anti-icing units to treat all roads with speeds over 35mph, which accounts for 150 lane miles. By utilizing our anti-icing units staff has found our salt usage has decreased from 400 lbs./lane mile in the year 2000 to 200 lbs. per lane mile in 2016-2017
- Temperature sensors on all plow trucks
- Practicing good housekeeping
- Promptly sweeping up spills
- Loading indoors/under roof
- Storing road salt in a separate covered building
- Equipment operators attend chloride trainings
- Utilizing a variety of materials such as brine, rock salt and calcium chloride
- To increase efficiency, the City of Plymouth purchased an Accubrine brine maker. Previously staff was able to make about 4,000 gallons of brine per day, the new system is able to produce approximately 5,000 gallons/hour.
- Tracking salt application rates with the Precise GPS system

While each winter storm and season is different, Plymouth staff has been implementing these BMPs and techniques since 2010. Staff has found that their efforts have resulted in a decrease of salt usage over time. During the 2009-2010 season Plymouth staff applied 3200 tons of salt for 17 snow events, which equates to 188 tons per snow event. In the 2016-2017 season Plymouth staff applied 1300 tons of salt (regular and treated) for 16 snow events, which equates to 81.25 tons per snow event.

City staff has four years of chloride monitoring data leading into Parkers Lake and Plymouth Creek in the southern and central parts of the City. Based on the results of this monitoring, it has been found that the practices being implemented by Plymouth maintenance staff is having a positive impact on the water quality leading into these two bodies of water. It is encouraging to see the equipment, maintenance, and education efforts that staff has completed over the past number of years is minimizing the amount of chloride getting into our surface waters.

City of Prior Lake

The information provided below is based on information provided by the City of Prior Lake for the 2010 American Public Works Association Excellence in Snow and Ice Control awards ceremony. The City of Prior Lake maintains approximately 100 center lane miles of street with 10 maintenance personnel and one supervisor.

Starting in 2003, Prior Lake implemented a winter maintenance program, which includes:

- Staff education and development
- Anti-icing before events to reduce removal time
- Pre-wetting to deliver salt more efficiently at lower concentrations
- Upgraded controllers and sanders that allow flexibility for precise applications Pre-mixed chemical storage that allows on-site storage of three ready- to-use mixes and bulk storage of critical ingredients
- Liquid mixing and transfer equipment

Education

The staff buy-in and support was critical to the success of this program. Education was important for this; they started with supervisor training and researched other programs. Various training programs were attended or used including: LTAP, CTAP, Manual of Practice for an Effective Anti-icing Program, APWA Anti-icing/RWIS CD, AASHTO Clear Roads CD Series, and attending an APWA Snow Conference.

Since 2003 to 2011, the City invested about $250,000 in the program, including a $50,000 building addition. They recognized that the right equipment is the key to providing the flexibility to apply the right chemicals, in the appropriate amounts by the most efficient method.

Chemicals and Storage

Depending on conditions, Prior Lake keeps pre-mixed chemicals ready for use and bulk materials on hand. This allows the City to pre-mix and modify operations depending on weather conditions. Using the best available weather data for preparation and monitoring actual ground temperatures during operations is critical.

- Bulk materials include brine, beet juice, magnesium or calcium chloride, and molasses
- Pre-mixes include liquids for anti-icing and pre-wetting above and below 15 degrees

Application Equipment

Equipment upgrades can be phased in over time. Prior Lake took seven years to fully upgrade the fleet. The new 5100/6100 controllers and new sanders can apply pre-wet material at rates down to 85 pounds per lane mile. Liquid application units can also apply at below 100 pounds per lane mile rates. Upgraded equipment includes:

- Controllers
- Salt Sanders

- Evaluate plow configuration to further optimize
- On-board liquids

Liquid anti-icing operations increased removal efficiency. The City found that applications are effective for 7 to 14 days after application, depending on the type of mixture and conditions. Equipment was also used for a liquid-only route with deicing application rates of less than 100 pounds per lane mile.

Efficient truck design and equipment including Elliptical Box, 200 gallons of Liquid Storage, Falls Salt Special Material Applicator, Force America 6100 Controller, and bed tarp allows for more efficiency with application rates of pre-wet salt as low as 85 pounds per lane mile.

Results: Prior Lake had a reduction of average application rates, from 500 pounds per lane mile of salt in 2005 lane to 200 to 250 pounds per lane mile using pre-wet salt in 2010.

- Added an all liquid route with application rates equivalent to 100 pounds per lane mile or less.
- Observed chloride level reduction in controlled watershed of 20 to 40 mg/l with all liquid program.
- Reduced staff time for snow removal and maintenance.
- Overall salt use reduced 42% since 2005 even with an additional 7% increase in mileage maintained.
- Minimum estimated savings per snow removal event $2,000 (salt, labor, equipment).
- Maintained safety and increased level of service.

Future Plans

- No chemical application routes, blade cutting edge technology advances
- Pre-wet application rates of 100 pounds per lane mile
- Expand liquid only routes
- High Priority Chloride Reduction Zones designations

Rice Creek Watershed Cities

This information was taken from the Six Cities Chloride Reduction Project. https://www.ricecreek.org/index.asp?SEC=F4177EED-3D43-4579-AC07-EC3B73D9F12D&Type=B_BASIC

The City of Centerville, after attending a winter maintenance workshop, collaborated with Lino Lakes, Hugo, Circle Pines, Lexington, and Columbus to purchase shared anti-icing equipment and to train the staff to use BMPs. The coalition was able to successfully apply for a Rice Creek County Watershed grant of $65,000 to offset the costs. The new anti-icing equipment was used to apply liquid salt brine to 245 miles of paved roadways before the winter storms to reduce the need to apply salt during and after the storm. The training provided to the operators, reinforced the need to apply enough salt for public safety, but to avoid applying unnecessary amounts to pollute. The coalition plans on using the savings on materials to continue to fund the operational costs and program maintenance.

Results: In the 2012-2013 winter season, the six participating cities reduced their salt use by 528 tons, or a 32% reduction based on the previous monitoring data. The six cities saved a combined total of $26,400 in a single winter, based on a conservative cost estimate of $50/ton of salt.

City of Richfield

The information provided below is based on information presented at the awards ceremony at the 2013 Road Salt Symposium (Fortin Consulting and Freshwater Society 2013).

In 2009, the NMCWD began a TMDL Analysis and Report process for the chloride impairment identified for the Nine Mile Creek. By 2010, they had prepared a draft TMDL report that called for a 62% reduction of salt application by the NMCWD MS4 cities, including Richfield. Along with other agencies, Richfield's reaction to the reduction was the requirement was not only unreasonable, but impossible. They believed that public safety would be compromised and that the goal was too far to take seriously. However, the City eventually came to accept that they had to make efforts toward reducing salt usage.

The City Engineer learned that the NMCWD was working with Fortin Consulting and the LTAP to offer the free MPCA Winter Maintenance Certification Training. After attending the training the City Engineer found the training to be excellent. The entire snowplow operations staff was immediately enrolled in the next available training and all of the snowplow operators that plow parking lots have attended the MPCA Winter Parking Lot and Sidewalk Maintenance Training.

Despite the pride and effort that Richfield's winter maintenance staff has in their work, the training showed them many ways to improve their operations. The education, along with the dedication of the staff, created a sense of urgency to change their practices and make the needed improvements. The changes needed were relatively small and simple to implement quickly.

Richfield's salt application process changes were:

- Calibrating all sanders every year
- Applying salt to the crown of the road only
- Determining application rates by road temperatures/weather conditions
- Using alternative materials for low road temperatures
- Adjusting policies for minor arterial roads

These small changes reduced the amount of salt applied to roads by over 50%. It is projected this will improve over time, bringing the city closer to the TMDL of 62%. The Richfield operators have traditionally taken great pride in their work; the additional training provided them with the understanding of the importance of reducing salt for the environment and not just cost savings shown below.

- 2010-2011--$30,000* in salt because of the trained crew, calibrated equipment, and correct application rates
- 2011-2012--$70,000* saved in salt; new addition was adding the pre-wet product, "Ice Slicer"
- 2012-2013—no savings (many more ice events than the previous years)
- 2013-2014—no savings (many more ice events than the previous years)

- 2015-2016—the operations superintendent expects to see savings compared to previous practices

*The cost savings were based on the 2009-2010 price of salt.

City of Shoreview

This information was supplied from the City of Shoreview in 2015.

In 2006, the city of Shoreview stopped using a mixture of sand and salt and began using straight salt. This was the beginning of a continuous effort to reduce chloride.

Shoreview's applicators and their supervisors each attend the annual "Snow and Ice Control Best Practices" training and are certified through the MPCA. The crew attends an annual meeting to discuss and review procedures and conservation methods. The operators are trained and allowed to make adjustments based on conditions and the pavement temperatures. The MPCA materials, guidelines, and BMPs have been successfully used throughout this effort.

A snow event begins with the city's crew monitoring the surface temperature and road conditions. This information is critical to following their BMPs and application guidelines. This practice allows for preparation for the storm and the application of anti-icing to reduce the ice that requires treatment during and after the storm.

The goal of the anti-icing procedure is to apply calcium chloride to at least 28 lane miles of roadway before the storm to reduce the buildup of ice and allow for cleaner plowing. All of the city's trucks are equipped with state-of-the-art spreading controls, pre-wetting tanks, and pavement sensors to ensure that each truck is calibrated and efficient. The use of the pre-wetting calcium chloride reduces the need for rock salt and minimizes the loss of salt from bounce or vehicle distribution. Pre-wetting allows the salt to be effective at lower temperatures.

Results: The three-year average salt use for 2006 through 2008 was 786 tons and in the period of 2009 through 2011 the average amount of salt used dropped to 437 tons. The reduction continued during 2012through 2014 to 444 tons. Although the tons of salt appear to increase, there were more snow and ice events during the 2012 through 2014 period. The total reduction of salt since 2006 is approximately 44%. The cost savings for 2014 is estimated at approximately $24,468.

City of St. Paul

This information was provided by Freshwater Society, 2014 Environmental Leadership Award on February 6, 2014.

St. Paul Street Maintenance has changed and updated its snow maintenance practices and equipment to reduce salt, increase driver safety and improve the service level. The city created its first Snow Plan in 2011 through the collaboration of the maintenance staff.

The following equipment has been upgraded:

- In 2011, the decision was made to make salt reduction a priority when selecting equipment
- The salting equipment was upgraded with electronic controls—95% of the city's trucks were equipped with electronic spreader controls (90% increase)

- Trucks were upgraded with pre-wetting systems over two years (50% increase)
- All trucks with electronic controls were equipped with AVL to monitor and correct salt usage
- All trucks are calibrated before the season

Between 2012 and 2013, the following training was completed:

- By 2012, 95%, and by 2013, 99% of the staff and leadership had successfully completed the MPCA Winter Maintenance Certification training
- In 2012, six supervisors successfully completed the APWA Winter Maintenance Supervisor Certification training. Three more were certified in 2013.
- The vendor performed small group training for 92 workers and supervisors
- In 2013, 170 employees attended a two-day snow operations training program

Results: The city has had an average salt reduction of 30% per event over the past five years. The purchase of salt was reduced over the five years from 24,000 tons to 16,000 tons.

City of Waconia

The information provided below is based on information presented at the awards ceremony at the 2013 Road Salt Symposium (Fortin Consulting and Freshwater Society 2013). The city of Waconia Public Services Department completes winter maintenance activities on 56 street center lane miles, portions of 14 miles of concrete sidewalk and 13 miles of bituminous trails. In 2012, the City of Waconia introduced their employees to pretreating streets before it snows. The City built a pre-treat distributor and with this application they saved in two areas. They saved by using less salt but also saved in personnel and over time. For small or light snow falls they did not have to call any personnel back to work. If the snow fall is more than the pre-treat can handle, it gives the city operators a little more time before going out to plow streets.

Prior to the winter season, City staff attends an annual winter preparations meeting. They review the Winter Maintenance Policy and route assignments, discuss material use, and the service level expectations. All spreaders are calibrated for liquid and solid material applications. Calibration charts are prepared and placed in each vehicle for user review.

In 2010, the staff updated their 1999 “Snow and Ice Policy” to a “Winter Maintenance Policy.” The document title expresses a different, proactive approach to events. In the past, the city had a reactive approach to storms. The City changed from a 1:1 sand/salt mixture to straight salt and liquid anti-icing practices. Additional items reflected in the policy included:

- Service level expectations for streets, sidewalks, trails, parking lots, and downtown snow removal
- Additional ordinances reflecting policy guidelines
- Right-of-Way uses, including mailbox placements
- Description of operation commencement, use of air and pavement temperatures, and anti-icing practices

- Tips on resident snow storage, or maintaining a “snow pocket,” for driveway cleaning

By implementing calibration and equipment changes, the staff has been able to reduce materials rates of salt per-pound by 70%. Using pre-wetting practices and saving material by application rates based on weather and pavement conditions have saved $1.80 per-lane-mile and a yearly savings of $8,600.

As part of the winter maintenance practices for sidewalks and trails, the staff took the initiative to switch from hand-applied and truck-applied chloride products to liquid applications only. The staff conducts anti-icing and deicing activities as needed on sidewalks and trails leading to substantial savings. The staff obtained a “Local Operational Research Assistance Program” grant for $5,000. The research found a savings of 70% for activities related to recreational critical areas through the use of liquids for trails and sidewalks.

Figure 74: City of Waconia Truck capable of dry/liquid material mix application.

University of Minnesota, Twin Cities

The information provided below is based on information presented at the awards ceremony at the 2007 Road Salt Symposium (Fortin Consulting and Freshwater Society 2007) and updated by Doug Lauer, a Landcare Supervisor with the University. The UMN Twin Cities Campus made changes to their winter maintenance program starting the winter of 2006. They began making their own salt brine and anti-icing and adopted several other salt reduction BMPs. The resulting reductions for each winter maintenance material are listed below in Table 17: UMN – Twin Cities Campus – Winter Maintenance Improvements

Table 17: UMN – Twin Cities Campus – Winter Maintenance Improvements

Material	Tons/Year Used (1997-2005)	Tons/Year Used (2006-2008)	Tons/Year Used (2008-2014)	Reduction	Notes
Rock Salt	775	262		40%	
Ice Melt ($MgCl_2$)	131	64		51%	Changed from $MgCl_2$ to $CaCl_2$ in 2008
Ice Melt ($CaCl_2$)	131 ($MgCl_2$)		59	55%	
Sand	1965	20		99%	

In addition to salt reductions, they invested about $10,000 in new and saved $55,000 the first year the BMPs were implemented. The UMN used an average of 1,965 tons of sand from 1997 through 2005; in 2006 to 2008, it was reduced to 18 tons. This is a 99% reduction. Between 2009 and 2014, the UMN used an average of 21 tons of sand in this five year period, showing a continuing decline.

The UMN continues to use brine to treat before the storm, as indicated in Table 17. The staff is aggressive with mechanical removal using blades and brooms. A change was made from MgCl to calcium chloride because it mixes better with sodium and doesn't clog their equipment when changing products. The product contains less corrosive beet juice.

Figure 75: University of Minnesota Brine Application to Sidewalk

Joe's Lawn and Snow

Joe's Lawn and Snow is a small lawn and winter maintenance company located in the TCMA. The following information was provided by Joe Mather, owner.

Joe's Lawn and Snow plows and treats both sidewalks and parking lots. Prior to attending the MPCA Winter Maintenance Certification class, the staff relied on manufacturer recommended application rates and best judgment for application rates. Joe Mather attended the certification class in the winter of 2013-2014 and sent four employees. Joe and his staff were able to implement the practices learned in the first year.

Practices implemented included:

- Purchased new spreader
- Calibrated equipment
- Made a bowl to catch any excess salt at spinner and reuse
- Adjusted the spreader to even the spread and prevent salt piles
- Reduced application rates
- Tested the results of application rates and continued to refine
- Purchased hand-held and truck mounted temperature sensors
- Used temperature to help determine rates and materials
- Identified drainage patterns and appropriate snow storage areas before the season

- Used sediment traps to contain solids in runoff and subsequently cleaned out manholes
- Experimented with anti-icing using liquids and plans to continue experimenting

Results: These changes, implemented for the last half of the 2013-2014 season, resulted in a reduction of salt by about 50% and did not reduce the level of service. Based on the 2014 cost of salt per ton, this saved Joe's Lawn and Snow $770 in material costs.

MnDOT District 6 Management Team - Nelrae Succio, Jeff Vlaminck, Mark Panek, Greg Paulson, Steve Kirsch, Judy Schmidt, Steve Lund

The District 6 Management Team has given outstanding financial support to equip all 25 truck stations and reloading sites with double wall brine storage tanks for salt brine and liquid corn salt. They have supported the purchase and installation of Brine Makers at 10 locations, a blending station, transport tanks and trailers, anti-icing units and staff to run water lines to brine makers. They have supported staff efforts to rebuild storage facilities to house the makers and tanks. District 6 has been able to acquire pavement sensors and brine units on all 98 trucks. Management has backed the maintenance crews on most anything that was needed to provide quality service to the public.

They have supported efforts to experiment with other products that could be more environmentally friendly such as sodium magnesium acetate, potassium acetate, Geo-Melt and others. They support the efforts of employee run "Salt Solutions Committees", research and development committees, post-storm review efforts, winter preparedness meetings, staff training and a many efforts to get staff to communicate and work together as a team to reduce salt consumption by using the right material, the right amount and at the right time. The program started quite a few years ago, but really got going when Steve Lund came to the District. He brought along his experience as the State Maintenance Research Engineer and recognized the need to support the program.

Results: District 6 has made significant advances in how they treat their roads. They now have the anti-icing and pre-wetting storage and application equipment available and are better able to prevent frost from forming on roads and bridges. By pre-wetting their material it helps it stick to the road and makes the salt work faster. With additional storage capacity, they are able to store different products such as MgCl and liquid corn salt for use at colder temperatures.

The salt and sand application rates are on a downward trend. Last year alone District 6 used 7,333 tons less salt than the previous four year average. That relates to a $330,000 cost savings. The sand usage has decreased from 49,000 tons a few years ago to 7,000 tons today. Because of their increased liquid use they were able to achieve overall rate reductions.

Figure 76: Inside look at MDS/MDSS of a MnDOT Plow Truck

MnDOT, University of Minnesota (Extension, Center for Transportation Studies, and Center for Integrated Natural Resources and Agricultural Management), and USDA

Blowing and drifting snow on Minnesota's roadways is a concern for safety and efficiency reasons. Establishing snow fences improves visibility for drivers and helps maintain good road surface conditions. Snow fences have the potential to lower the costs of road maintenance, reduce salt applications and decrease crashes from blowing and drifting snow. Snow fences are a nonchemical approach to improve driving conditions, they require maintenance or design crews to be proactive and by being proactive can be a positive, sustainable addition to winter maintenance. Snow fences can be used in any part of our state from large metropolitan areas to small rural communities. Anywhere there is blowing drifting snow; snow fences should be part of the maintenance strategy. Snow fences can protect more than just roadways: some examples include walk or bike paths, parks, businesses, parking lots, blowing snow coming off of lakes, and much more. Over the past several years, MnDOT has partnered with the Extension to conduct snow fence research. Together, they have created a state of the art, web-based snow control tool and a snow fence design tool that helps road authorities and conservation organizations promote the use of snow fences.

They have also launched a program that offers incentives for snow fence establishment and they are continuing their research on snow fence innovations. Snow fences promoted and supported by MnDOT include standing corn rows that are 6 to 12 rows of corn left by the farmer a proper distance from and parallel to the highway. Corn can be harvested but stalks must remain standing. Living snow fences are rows of trees and/or shrubs that are strategically placed to control drifting snow. Living snow fences are an agroforestry practice that provides environmental benefits, including wildlife habitat. Structural snow fences are eight feet tall poly fencing that is placed the proper distance from the highway to catch blowing snow. A narrow strip of land is purchased from the farmer who can farm close to the fence during the growing season.

The team developed a website to host the snow fence web tools, webinars and resources: www.snowcontroltools.umn.edu. There are many types of snow fences. We encourage you to be proactive and creative. Use snow fences and use the type of snow fence that will work best for your site. The advice on the U of M Extension website will help you be more successful with your snow fence project. Fact sheets, additional research and resources are also available.

The MnDOT District 1, North Shore Substations of Two Harbors, Illgen City, and Grand Marais

These shops in the MnDOT District 1 have worked hard the past few years updating and changing their winter maintenance practices. Each truck now has a pavement temperature sensor onboard and is calibrated each season for each material that it applies. Mechanical snow removal is always done and often the extra thin layers can be removed with the underbody plows. Application rate charts are used and all salt is applied wet. Anti-icing has also saved a lot of material use especially in frost or frost warning situations.

Many equipment changes, deicer changes and policy changes have been made, but perhaps the biggest change of all is in the attitude of the people. Crews are going above and beyond the expected to keep rates low. Each driver compares their route with other routes or other drivers on the same route to see if rates are consistent. A good line of communication is kept in regards to weather and snow totals during an event. A healthy competition has grown to see who is more accurate in recording. The more experienced operators have taken on the responsibility on their routes to co-ordinate material applications and communications between shifts. The motto “It is time to win” can be heard. This means the temperatures and sunlight are right to melt and it is the best time to regain bare pavement efficiently. Discussion takes place after every event to compare application rates and effectiveness of materials chosen for the event. Care is taken to apply very little, if any material during an event, and plan regain during the warmest pavement temperatures after the event has ended. The operators don't feel like these measures are extra steps, and should be considered common practice.

Results: Over time, salt use was steadily increasing topping out at 4,655 tons a year in the winter of 2005-2006. Since this time changes have been made and salt has been reduced to about 2,500 tons per year, a 55% reduction. Winter sand is also decreasing from years that averaged 3 to 4,000 tons to the last few winters, which averaged 1,000 tons, a 75% reduction.

St. Cloud VA Health Care System

The St. Cloud VA Health Care System campus is located on 218 acres of land in St. Cloud, Minnesota. There are 58 buildings on the campus connected by concrete sidewalks and paved roadways. There are 18 paved parking areas on the campus ranging from a few spaces to 234 parking spaces. The St. Cloud VA Healthcare System is protecting water resources by incorporating environmentally sound snow and ice control methods into its winter sidewalk, road, and parking lot maintenance program. They are using less salt and maintaining high safety standards to protect the environment and keep sidewalks, roads, and parking lots safe for staff, patients, and visitors. Salt is not just harmful to water resources it can also damage the facility's environmental surfaces. When salt gets tracked into buildings it damages tile, carpet and rugs, and creates dead weedy zones along the sides of sides of sidewalks. Reducing salt use has helped to reduce the time and expense of fixing the facility's environmental surfaces and benefits the natural environment.

Since 2011, all of Garage Operations employees have attended Winter Parking Lot and Sidewalk Maintenance Training and have become certified in snow and ice control BMPs. The St. Cloud VA also trains employees who volunteer to remove snow and ice on sidewalks, entryways, and steps during the snow season on BMPs for small spaces. Facilities Management purchased a new salt spreader after the initial Winter Parking Lot and Sidewalk Training Class in 2011. The new spreader has allowed operators to use brine to pretreat paved surfaces before storms and allows for pre-wetting rock salt before it hits paved surfaces resulting in a 50% reduction in salt use. In 2018, a new salt spreader was purchased that has more advanced control systems and settings to further improve VA's smart salting program. The St. Cloud VA Sustainable Snow and Ice Control Program can be easily replicated at other facilities and organizations. The cost of equipment and training were minimal compared to the benefits of the program. Replicating the project simply requires a commitment to sustainability, training support, and organizational leadership.

Mayo Clinic – Rochester, Minnesota Campus

At the conclusion of his first two winters as Grounds Maintenance Supervisor for Mayo Clinic, Nick Queensland was proud of what his crews had accomplished in terms of productivity and safety. On the other hand, he was extremely bothered by the amount of salt that was applied to their paved surfaces in order to obtain these results. Immediately following winter 2017-2018, he went to work determined to maintain Mayo Clinic's excellent level of service while prioritizing salt reduction.

While doing research on snow removal methods that conserve salt, Queensland continued to come across the MPCAs Smart Salt training. After some discussion with Fortin Consulting, who created and teaches this course for the MPCA, he decided to have all his in-house grounds maintenance staff attend the Parking Lot and Sidewalk training class together, including leadership. This was an excellent decision! His crew was energized about reducing salt use after learning facts about the detrimental effects of salt to our environment and fresh alternatives to current practices.

The day after the Smart Salting class Queensland gathered his crew and they made a list of methods they could implement to reduce salt use on Mayo's campus consisting of 15 miles of sidewalk, 300 doorways, and 120 acres of parking lot and roadway throughout the Mayo Clinic campus. Queensland focused primarily on the parking lot and roadway salting as he felt he could realize the greatest tonnage reduction and had the most room for improvement.

The first thing he did was calibrate the salt application equipment used on the property. Mayo Clinic had never done this in the past and was surprised that nobody knew what rate of salt was being applied. Knowing the rates of the spreaders was an important tool. When they directed the contractors to apply salt they could specify a rate instead of the contractor applying a moderately heavy blanket of salt every time.

The other big thing Mayo Clinic did was to incorporate liquid salt brine into their ice control toolkit. They had experimented with liquid salts in the past with limited success and had abandoned this method. The salt brine applied correctly allowed them to plow snow and not have to apply rock salt at all for several storms.

Calibrating contractor equipment and incorporating liquids in practice along with Smart Salt training resulted in a 60% salt reduction for Mayo Clinic in a winter where they received a record amount of snow and a normal amount of ice. This number exceeded expectations. This was not easy, change never is, but Queensland found it was well worth efforts both in environmental impact reduction and budget savings.

Since implementing these changes Nick helped develop the new Smart Salting for Property Managers training class being offered by the MCPA. They will continue to implement changes to their operations and manage their properties to reduce salt and protect the environment.

Figure 77: Snow Sweeper Clearing Snow at Mayo Clinic in Rochester, Minnesota

7. Monitoring, Tracking, Reporting and Adaptive Management

Addressing the issue of the environmental impacts of chloride in Minnesota is a long-term endeavor. Water quality improvements will take time to observe, due to historical loadings, groundwater inputs, variable residence times, and other complicating factors. Continued monitoring of lakes, wetlands, and streams for chloride is critical, along with documenting changes in winter maintenance activities, point source discharges, fertilizer use, dust suppressant use, and water softener usage. Continued water quality monitoring along with improved source tracking will allow adaptive management and inform the future steps to restore and protect Minnesota waters. This Statewide CMP is intended to be revisited and revised within 10 years, based on improved understanding. The update of the Statewide CMP will also include new waterbodies that are identified as impaired by chloride.

7.1. Water Quality Monitoring

There are a number of organizations across Minnesota that monitor water quality or partner with others to conduct monitoring. In addition the MPCA, Metropolitan Council and the USGS also collect data throughout Minnesota. Incorporating the recommendations below into existing local water monitoring programs will provide valuable data to assist with tracking progress and meeting water quality goals. Monitoring should take place at the existing sites for consistency and comparison purposes. However, monitoring activities that are lead at the local level will be dependent on available resources and local priorities. We encourage local monitoring data be shared with MPCA by routinely submitting data to the MPCA's water quality database, EQuIS. The monitoring that MPCA conducts across the state follows the 10-year monitoring strategy as described in Minnesota's Water Quality Monitoring Strategy Report.

The MPCA has worked with the Monitoring Support Group (MSG) to develop monitoring guidelines for lakes, streams, wetlands and storm sewers. Monitoring guidance documents are available on the MPCA chloride project website. The key components of continued monitoring to support the implementation of the Statewide CMP include:

- Collect samples during the critical periods for elevated chloride concentrations, and in deepest waters when sampling lakes:
    - January through May for lakes, and December through April for streams, within urban areas and locations near deicing. However, always put safety first when assessing conditions for collection of samples through the ice.
    - April through November for lakes and streams downstream of the discharge locations of WWTPs. These locations will have critical flows or volumes during this period, and chloride will likely have the greatest concentrations observed during these months.
    - April through November for lakes and streams downstream of heavy agriculture, near tile drainage systems, and in proximity to gravel roadways that receive dust management.
    - Peak turf fertilizer use (May and September) in urban/suburban runoff. There are some that still apply a late fall fertilizer, although it is not recommended. More chloride may be found in runoff if the ground is frozen, or in groundwater if the soil is not frozen.
    - Review all possible local sources (including groundwater and natural baseflow) when establishing a local or targeted sampling plan. Many locations may have several contributing chloride sources, requiring sampling at different times of the year.
- Analysis of chloride should also be included in typical summer season sampling. Analysis for chloride is relatively inexpensive and should be included if the effort is being made to collect samples for analysis of other parameters.
- In lakes with potential for stratification, collect a bottom sample and surface sample.
- Maintain consistency in sampling. Chloride concentrations may vary from year-to-year depending on the winter conditions. Assessment of long-term trends will have greater confidence with consistent, yearly datasets.
- Collect a matching conductivity reading with each sample taken for chloride analysis.

- Expand the sampling program to additional lakes, streams, and wetlands as resources allow. Many waterbodies in Minnesota have not been sampled sufficiently to make a reliable assessment of potential impairment by chloride.

High Risk Monitoring Recommendations

The MPCA has developed specific guidance for monitoring of Minnesota waters not currently impaired but showing a high risk of impairment for any organizations or entity monitoring for chloride. The chronic standard of 230 mg/L for chloride concentration applies as a four-day time average. In practice, impairment is often judged from monthly sampling results when these show a clear pattern of prolonged concentrations exceeding the standard. Weekly or twice-weekly sampling would provide the basis for a clear determination. Long-term sampling at such high frequencies is unreasonably expensive in most cases. Therefore, the MPCA suggests the following guidance for additional monitoring of high risk waters:

1. Identify dates or periods of past chloride concentrations that were either:
    a. Exceedances (exceeded the chronic chloride standard), and/or
    b. High occurrences, defining high as less than, but within, 10% of the chronic standard (thus >207 mg/L)
2. Select a four-week period centered on each such date or period, and for each:
    a. Sample for chloride weekly, always on the same day of the week
    b. Sample at the same depth or depths as in past sampling
3. If an electrical conductivity meter is available, take and record a matching conductivity reading with each lab sample taken:
    a. matching = from the same primary sample that provides the lab subsample, if the primary sample is a sufficiently larger volume than the laboratory bottle used; or otherwise
    b. matching = same location and depth as the lab sample
4. Possible expanded effort:
    a. Monitor twice weekly rather than once, always on the same days of the week (e.g., Mon and Thu) including, as resources permit:
        i. Chloride sample and conductivity measurement if possible
        ii. Chloride sample only if lacking conductivity meter
        iii. Conductivity measurement only on the increased frequency if laboratory costs limit sampling but a meter is available

To clarify, sampling for chloride at least weekly during the selected four-week period(s) is the necessary minimum effort for ensuring the value of this additional monitoring; conductivity measurements alone will not suffice at present. This could change in the future if a reliable and accurate relationship between chloride and conductivity is developed for an individual waterbody or for an area including the waterbody.

Impaired Monitoring Recommendations (Tracking Progress)

The MPCA recommends monitoring waters already identified as impaired for chloride less frequently. It is recommended that efforts focus on collecting samples during critical periods. For instance, if the impairment is a result of winter maintenance activities, chloride sampling should be conducted during January through May for lakes and wetlands, and December through April for streams. If the impairment is caused by effluent with high chloride concentrations from WWTPs, monitoring during low-flow periods in the streams should be targeted. If long-term monitoring data has already been collected, less frequent monitoring during critical conditions (monthly or twice monthly) is recommended. If monitoring efforts are limited by costs and a site-specific chloride-conductivity relationship has been established, the MPCA recommends collecting conductivity measurements during the critical period to track progress.

General Monitoring Recommendations for Waters without Data

At a minimum, collect monthly chloride and conductivity data for waters without data during the critical period. If possible, expand the effort to weekly sampling during the critical period, and include chloride in typical summer season sampling efforts. For lakes with a potential for stratification, collect a bottom and a surface chloride sample. If it is determined that these waters meet the high risk criteria, the MPCA recommends following the monitoring guidelines for high risk waters.

7.2. Tracking and Reporting Implementation Efforts

Measuring water quality in Minnesota and monitoring chloride loads in the lakes, wetlands, and streams is critical to understanding progress toward the ultimate goal of restored and protected lakes, wetlands, and streams. However, these types of measurements alone will not be sufficient to demonstrate the progress made in implementing individual salt reduction efforts and accomplishments taking place throughout Minnesota to reduce chloride. Tracking of implementation activities is needed to assess the related benefits to water quality, take credit for making progress, and identify areas where additional effort is needed.

The approach to tracking implementation efforts will vary by the source type. The SSAt will be an option available to any winter maintenance group and will support a consistent approach to tracking and reporting winter maintenance activities. In the future, SSAt is planned to be a resource beyond winter maintenance and dust control for tracking chloride BMPs. The plans include the ability to perform chloride assessments in fertilizer use, water softening, industrial discharge and more.

Treatment facilities holding an NPDES Permit will be required by permit to monitor for chloride for an initial term. If the effluent shows no reasonable potential to contribute to or cause violations of the chloride criteria, monitoring requirements may be dropped. For facilities where monitoring shows elevated chloride concentrations, the MPCA will work with the individual facility to determine a course for reducing chloride loads. Where residential water softeners are a major contributor to elevated chloride concentrations, educational and outreach efforts and implementation of water softener optimization, upgrade, or removal programs should be documented.

7.3. Adaptive Management

Implementation of a Statewide CMP, which includes several hundred cities and townships and 87 counties, as well as colleges, universities, private industries, commercial property owners, school districts, private homeowners, farmers and others, can only be accomplished by maintaining flexibility and adaptability within the overall approach. It should be understood that the water quality goals and chloride loads presented in this plan are estimates based on the best available science.

Adaptive management is an approach that allows implementation to proceed in the face of potentially large uncertainties. Adaption allows the implementation plan to be adjusted in response to information gained from future monitoring data and new or improved understanding of related issues. The adaptive implementation process begins with initial actions that have a relatively high degree of certainty associated with their water quality outcome. Future actions are then based on continued monitoring of Minnesota water resources and an assessment of the response to the actions taken.

The Statewide CMP is a prime candidate for an adaptive implementation process for a number of reasons. First, the scale, complexity, and variability of chloride sources within the state make a traditional implementation plan (i.e., one that identifies the specific implementation activities required to attain the TMDL) impractical. Second, there will likely be a time lag between reduction of external loads and the response of the system, and there will be year-to-year variability in the monitoring results. Finally, the TMDLs focused on the problem of high chloride loads and its current sources. However, restoration and protection of Minnesota water resources will require a planning framework that recognizes potential future threats such as changing deicing products, driver expectations, climate change, and population increases. For these reasons, implementation of the Statewide CMP will be conducted within an adaptive framework. The primary steps in the adaptive management framework are presented in Figure 78. Measurement and evaluation of progress in early years of implementation will be critical to success.

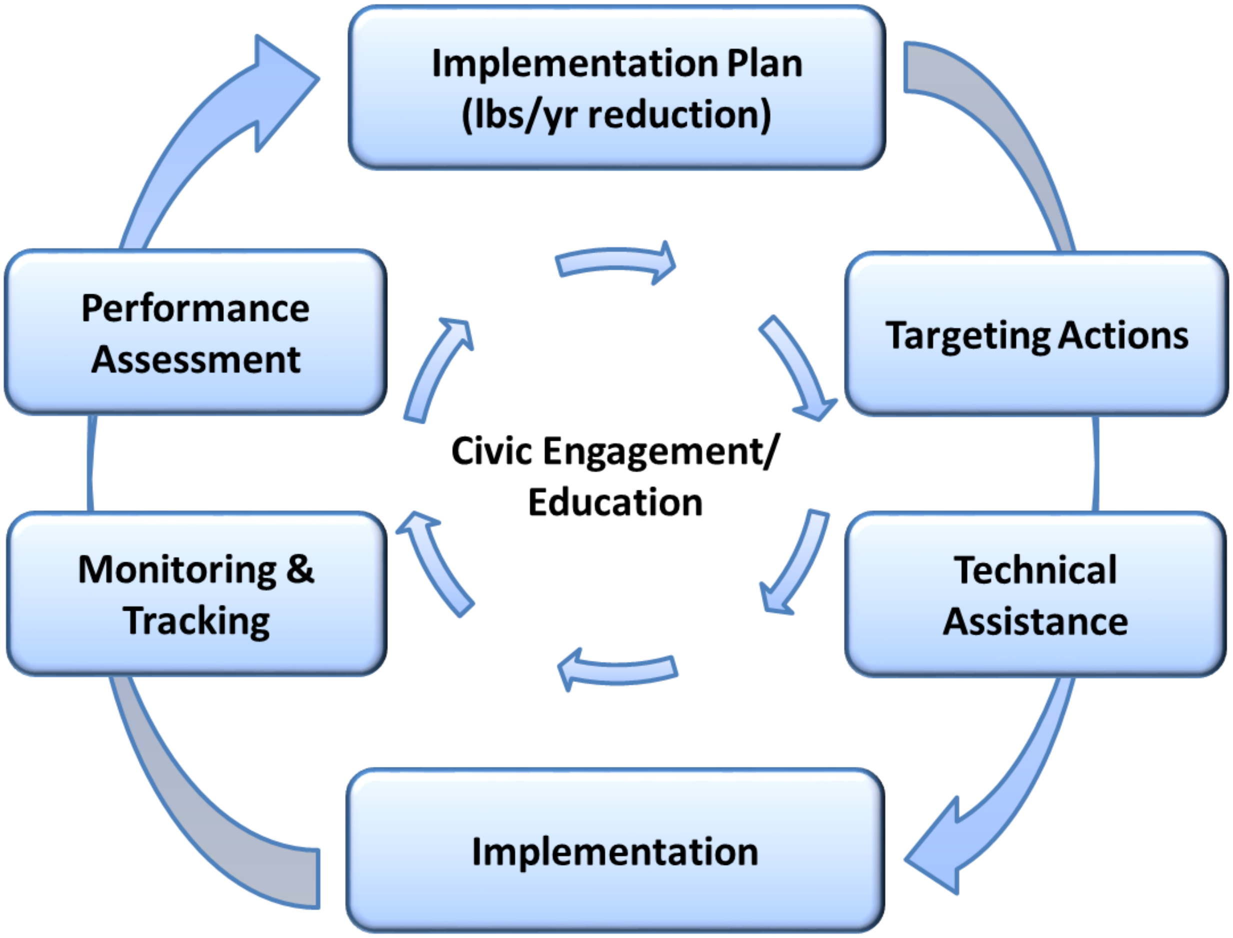

Figure 78. Adaptive Management Framework
Adapted from Washington County Conservation District

8. Research Needs

There are still many areas related to chloride where additional research and information may help to inform management decisions. There are 14 main areas that would benefit from additional information.

1. **Chloride reductions when implementing the BMPs**. The SSAt is the first ever, exhaustive resource of all known winter maintenance salt saving BMPs. The reduction potential for each BMP is largely unknown. The SSAt is limited by available research, as to how much of a reduction can be attained by improving each individual practice. More research is needed on many BMPs to understand how much salt can be saved when the BMP is implemented. The tool contains a list of over 200 winter maintenance BMPs, most of which would benefit from reduction potential research.
    a. For example, an estimated 17% of salt is lost by storing salt/sand piles uncovered over the winter. By implementing the recommended BMP of storing salt/sand piles indoors, there is an estimated 17% reduction potential for that pile
    b. For example, no information is available on the percent salt savings attained from increasing liquid to granular ratio from 8 gallons per ton to 50 gallons per ton. This information may help decision makers select those BMPs that achieve the greatest chloride reduction.

2. **Water softening options.** More information is needed on the effectiveness of various water hardness reduction systems at reducing chloride, and the relative cost for each. The current available options for reducing chloride from this source include: converting timer based water softening systems to higher efficiency on-demand softeners; replacement of ion exchange water softeners with non-chloride water conditioning in-home systems; optimizing softener settings with centralized hardness reduction; removal of individual water softening systems where centralized softening has reduced hardness to acceptable levels; and provide education on optimizing individual home softening systems settings to increase efficiency processes where centralized municipal hardness reduction is used. Developing a better understanding of the cost associated with such conversions would also aid in proper decision-making. Information on potential chloride reductions resulting from a more informed public would be beneficial. This would include a public that knows untreated hardness level, understands reasonably acceptable hardness levels for home use, and sets the water softeners appropriately.
3. **Environmental impacts of non-chloride deicers.** There are many alternative deicers that do not contain chloride; however, all have negative environmental impacts. A thorough review of all practical alternatives that exist with detailed information on the short-term and long-term environmental impacts and how it compares to chloride containing deicers in effectiveness and environmental impacts would allow more informed. Currently research about short term environmental impacts has been done on a variety of chloride and nonchloride deicers by the Clear Roads research consortium.
4. **Citizen attitudes and practices around the use of chloride.** Demonstration projects can be used to test the organizing approaches for building partnerships between citizens and government or property owners to work together to solve the challenge of chloride use and water resource impairments. The demonstrations will likely be most successful where community capacity around environmental issues exists. Local leaders should be supported to experiment with building partnerships across sectors to co-develop strategies for chloride reductions by municipalities, businesses, and households. The demonstrations can employ pre- and post-evaluation to determine whether the approach achieves meaningful outcomes over time. The outcomes will determine whether the efforts should expand past the pilot stage. If defined outcomes are significant, the plan should be developed to scale to metro-wide and beyond application. More research is needed for the most effective way to educate the public to make changes. A multi-agency approach is needed to reach the greatest public audience. The MnDOT has evaluated many different options for deicing, but some may need additional research into the effectiveness. Information can be found at "Chloride Free Snow and Ice Control Material."
5. **Effectively educate the public about environmental impacts of salt use and how they can help reduce it.** Research is needed for the most effective way to educate the public to make changes. A multi-agency approach is needed to reach the greatest public audience.
6. **Pavement alternatives.** Additional research should be done to understand pavement types and emerging pavement technologies that could reduce chloride usage while providing an adequate level of service.

7. **Reuse.** An evaluation of the feasibility of re-using wastewater with chloride for winter maintenance should be conducted, including brine from RO processes. As part of this evaluation, an understanding of the other chemicals present in the wastewater will be important in determining the feasibility of re-using wastewater.
8. **Septic Systems**. More research into septic systems and the amount of chloride loading to the groundwater needs to be better understood as well as other contributors of chloride to groundwater.
9. **Climate Change.** Additional research is needed to understand how climate change will affect precipitation patterns and temperatures and their effects on chloride. Precipitation and temperature could cause increases or decreases in chloride application. However, increased or decreased precipitation could also affect the amount of runoff available for dilution and flushing of chloride.
10. **Dust Suppressants.** Additional research is needed to understand the use of chloride containing dust suppressants and the statewide scale of its use, as well as alternatives to chloride based dust suppressants, and the chloride concentrations in runoff from areas that received chloride based dust suppressant treatments.
11. **Fertilizers.** Additional research is needed to understand the use of chloride containing fertilizers and the statewide scale of its use. A statewide chloride based fertilizer mass balance should be developed. A better understanding of the crop and type of fertilizer used and the amount of chloride in the type of fertilizer. For example turf fertilizer would be used by professionals but also used by many untrained applicators on residential lots likely producing chloride runoff and leaching into ground water from fertilizer in more urban/suburban areas. Agricultural fertilizer may come in a variety of forms from manure, industrial waste products, and chemically formulated fertilizers. The variety and amount will vary with crop and soil type and availability of fertilizer sources. Tile lines, surface runoff and leaching to groundwater should all be better understood. BMPs should be created specific to chloride use in fertilizers. The 2020 Salt Symposium, sponsored by Fortin Consulting, stressed the need for additional research on how chloride and fertilizer relates to crop nutrient management, precision agriculture and soil health.
12. **Manure.** Additional research is needed to understand the chloride concentrations in manure and the statewide scale of manure use as a fertilizer.
13. **Water experts.** Research is needed to better understand how to capture chloride before it enters the water and how to remove it once it enters our surface water or ground water. Special attention should be directed toward preserving the food chain living in surface water systems when considering filtration methods for removing chloride from lakes, rivers, and wetlands.

9. Stakeholder and Public Involvement Process

The development of this Statewide CMP and the TCMA CMP was done collaboratively with a wide variety of partners, experts and stakeholders in order to learn from others' perspectives and unique challenges, develop strong partnerships, develop a thorough foundation of potential strategies, and gain insight into the various experience and expertise across the state. This collaborative approach has allowed for the creation of a comprehensive understanding of the chloride in Minnesota with a wide range of options to reduce its impacts on Minnesota's environment.

Twin Cities Metropolitan Area – Chloride Management Plan

A robust stakeholder involvement process was undertaken to develop partnerships and gain insight into winter maintenance activities and municipal wastewater plants as a source of chloride. This process began in early 2010, and has continued throughout the project allowing the stakeholders to assist in the development of the TCMA CMP and the TMDL report, and has generated the support of local partners and created a common understanding of the challenges with balancing water quality and public safety. This effort consisted of over 115 participating stakeholders on seven teams over five years; an IAT, a TAC, a MSG, an IPC, an EOC, and Technical Experts (TechEx). Meeting information and stakeholder team membership lists are available at: http://www.pca.state.mn.us/programs/roadsalt.html.

The IAT members included water resources experts from the MPCA, MnDOT, BWSR, MDH, USGS, MCES, and the DNR. This team provided high-level oversight, support, and guidance for the project and became involved in the project during the initial feasibility study in 2009. The Committee met three times from 2010 through 2014.

The TAC members included representatives from the MPCA, MnDOT, St. Paul, Minneapolis, Shoreview, Burnsville, Plymouth, Capitol Region WD, Ramsey-Washington WD, Bassett Creek WMC, Mississippi WMO, Nine Mile Creek WD, Scott County WMO, Minnehaha Creek WD, Rice Creek WD, and the APWA. This team was responsible for providing review, guidance, and support for the technical aspects of the project. Committee meetings were held seven times from 2010 through 2014. In addition to the in-person meetings, regular updates, and gathering of input and feedback on draft documents occurred over email.

The MSG was created to provide detailed technical guidance and support regarding the water quality monitoring aspects of the project. The team not only developed monitoring guidance for chloride but also partnered with MPCA to collect additional chloride data across the TCMA to inform the TCMA CMP and TMDL. This team consisted of local and state water quality experts from the MPCA, DNR, USGS, MCES, Minneapolis Park and Recreation Board (MPRB), Three Rivers Park District, Ramsey County, Capitol Region WD, Ramsey-Washington WD, Rice Creek WD, Minnehaha Creek WD, and Mississippi WMO. The Committee met four times from 2010 through 2013.

The EOC included local education specialist throughout the TCMA representing WDs, WMOs, counties, Freshwater Society, UMN Extension, East Metro Water Resource Education Program, and the MnDOT. This team was created to provide insight, direction, and to share information and resources to develop the strategies and needs of educating and engaging the public and stakeholders. The team met four times from 2011 through 2014.

A TechEx was formed to assist in the development of the SSAt. The team included hands on leaders in the winter maintenance industry from the MnDOT, cities, counties, and private companies. This team was instrumental in developing the vision and technical details of the SSAt. This group met several times; however, much of the review, feedback, and expertise were shared electronically.

The IPC consisted of representatives from all other teams and other interested stakeholders. This team's primary responsibility was to provide oversight and guidance on the development of the TCMA CMP.

This group also received updates on the development of the TMDL and other project information. Meetings were held three times from 2012 through 2014.

In addition to the involvement of the stakeholders on the seven project teams, there were many other meetings, events, and conferences over the five-year span of the project to share progress and results. This included:

- annual presentations at the Annual Salt Symposium since 2010
- presentations at the Minnesota Water Resources conference in 2010 and 2014
- participation in the EPA's Stormwater Pollution Prevention Webinar in 2013
- presenting at the Minnesota Street Superintendent's Association meeting in 2014
- participation in the Mississippi River Forum in 2015
- attendance at numerous local meetings and events to discuss project

Two special outreach meetings were held specifically for the TCMA Chloride project. The first one was the Sand Creek Community Meeting, which was held in Jordan, Minnesota on July 30, 2014, to discuss the draft TMDL results. City, township, county representatives, and WWTP operators within the Sand and Raven Creek watersheds were invited to the meeting. Fourteen stakeholders attended the meeting. The second meeting was the Chloride Extravaganza held in St. Paul, Minnesota on April 28, 2015. Over 250 permitted and key stakeholders in the TCMA were invited to hear presentations from the various MPCA staff regarding the water quality conditions of chloride in the TCMA, results of the draft TMDL, and have discussion regarding implementation of the TMCA CMP and TMDL. About 100 stakeholders participated in the event.

Aside from collaborating, engaging, and informing local stakeholders about the TCMA Chloride project, additional efforts were made to increase the public's awareness about the environmental impacts of chloride. The primary and most effective efforts included the development of a new MPCA webpage with information and tips for the public to reduce salt use and protect water quality. A short YouTube video was created discussing the environmental concerns about deicing salt and the effort underway to develop a plan for a collaborative and effective chloride reduction strategy. A large interactive display was designed, built, and shared with the public at the Minnesota State Fair since 2012, and is available to local partners for local educational events. Finally, in 2010, the MPCA began generating press releases at the start of every winter that discusses the impacts of deicing salt on water resources and highlights new information, reports, or data available.

The official public comment period for the TCMA CMP and TMDL was held from August 3, 2015, through September 3, 2015. Eleven letters were received during the public comment period.

Statewide – Chloride Management Plan

The kickoff for the development of the Statewide CMP began in late 2016. Both Limnotech and Fortin consulting were contracted to assist converting the TCMA to a statewide plan. Limnotech compiled and analyzed statewide chloride sources and water quality data, reviewed and complied data for urban and rural BMPs, reviewed new information of water softening and WWTPs, and provided text and graphics found throughout this plan. Fortin Consulting prepared and wrote many of sections of this plan containing implementation strategies for urban-rural areas of the state. They were also critical in reviewing all aspects of the plan, as well as co-presenting for the statewide tour described below.

Just as with the TCMA CMP, this plan utilized a robust stakeholder process to ensure that winter maintenance activities, water softening and municipal wastewater plants as a source of chloride, and dust suppression activities were captured at a statewide level. In the spring and summer of 2017, the MPCA held eight meetings as part of a statewide tour to gather preliminary information from regional partners. These meetings provided an important basis for understanding what current policies, practices, equipment were in place around the state, as well as gathering ideas about what activities and BMPs should be included in any statewide chloride reduction guidance. The MPCA also conducted a workshop with the Minnesota Association of Townships to issue a survey to better understand how townships around the state manage dust suppression on unpaved roads and maintain unpaved roads during the winter maintenance season.

In the spring and summer of 2019, the MPCA revisited with four communities in Minnesota - Rochester, Twin-Cities Metropolitan Area, Duluth, Alexandria-St. Cloud - to inform and involve community members at every level in the final stages of development of this plan, as well as providing an update on other resources available in chloride reduction efforts. These meetings saw approximately 170 people participate in the presentations, questions and answers, and following discussions. The MPCA recorded these discussions and the ideas generated from them to help inform the final changes to this plan.

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Appendix A – Smart Salting Assessment tool (SSAt)

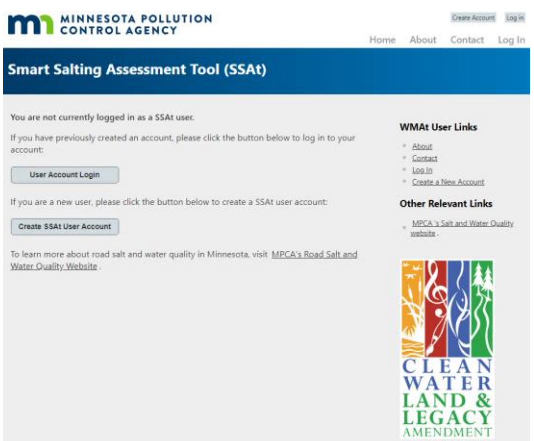
There are thousands of miles of streets and highways in Minnesota, along with parking lots and sidewalks that must be maintained to provide safe conditions throughout the winter. Winter maintenance of these surfaces currently relies heavily on the use of salt, primarily NaCl, to prevent ice build-up and remove ice where it has formed.

In response to the increase in chloride concentrations from winter maintenance activities in area lakes, streams, wetlands, and groundwater, Minnesota state agencies, local municipalities, and experts across Minnesota have partnered to create a CMP to effectively manage salt use to protect our water resources in a responsible and strategic approach.

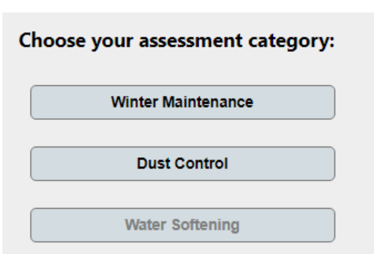
As part of the CMP development, the first of its kind, SSAt has been developed as a resource of all known salt saving BMPs for winter maintenance. The SSAt is a free, web-based tool that can be used to assist public and private winter maintenance organizations in determining where opportunities exist to improve practices, make reductions in salt use and track progress.

How to use SSAT:

You can enter SSAT via https://smartsaltingtool.com/ where you set up a free account.



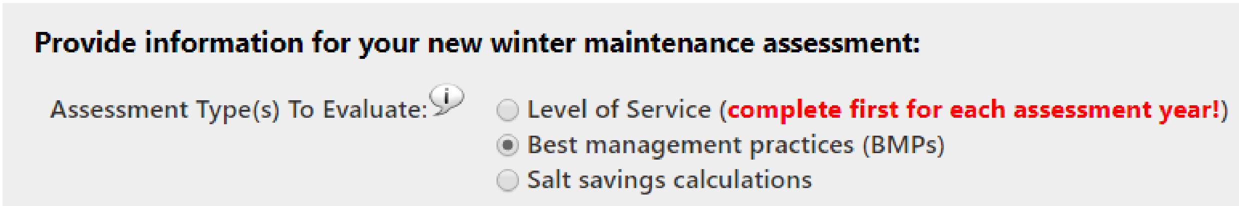
You select which area to assess:



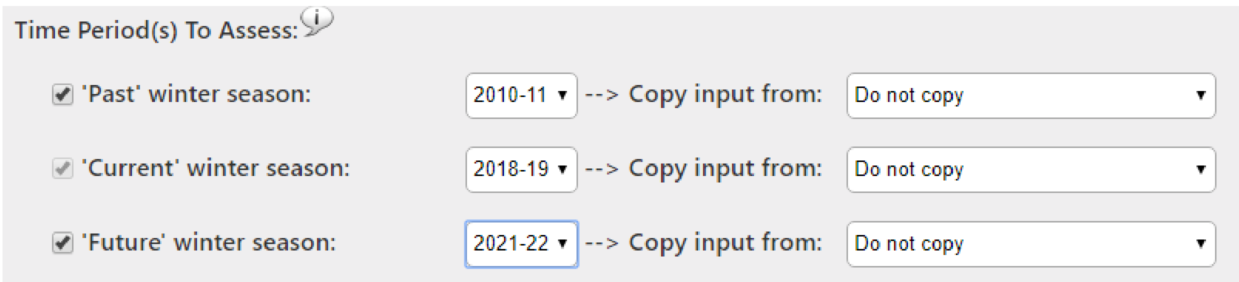
All of the assessment categories are designed to help you think about ways to reduce salt use. The water softening category is not yet available. There are various types of assessments you can choose under each category:

Setting up an assessment in Winter Maintenance

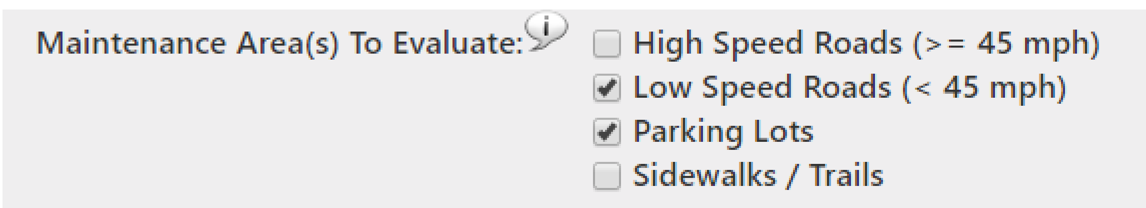
You select which type of assessment



You select the time period you want to evaluate. You can choose any past, current and/or future date. The current season is always required. You also have the ability to copy an existing assessment into a new date, which speeds up the process of creating/editing additional assessments.



You select what type of maintenance you want to assess. You may select any number of maintenance areas. However your best insight your operations would be given if you select one maintenance are per assessment. For the purpose of Level 2 certification all maintenance areas should be selected, this will give you the most general or high level report for all of your activities.

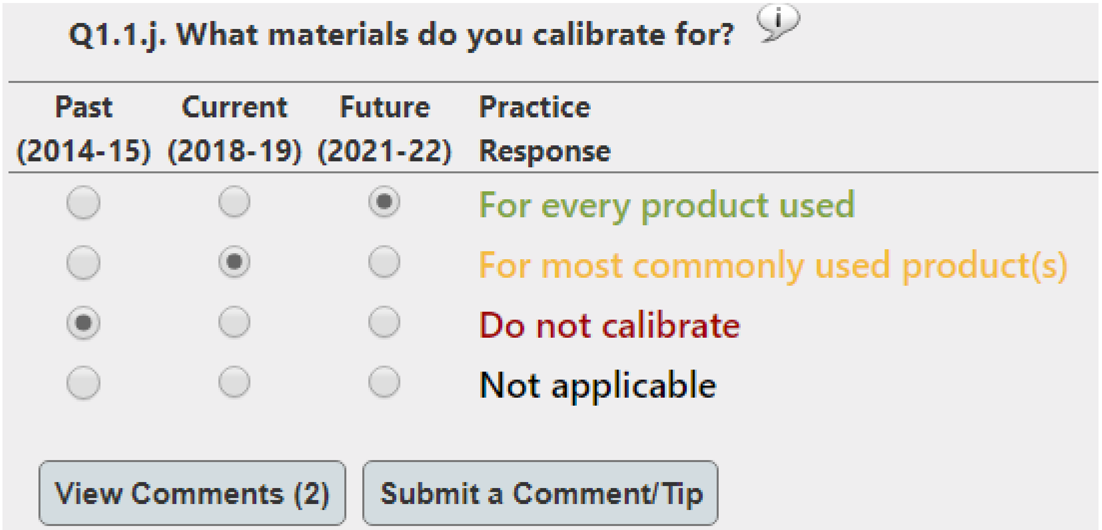


You select your level of service goal for the area(s) you want to assess.

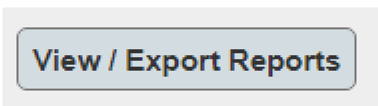
Conducting an assessment in Winter Maintenance

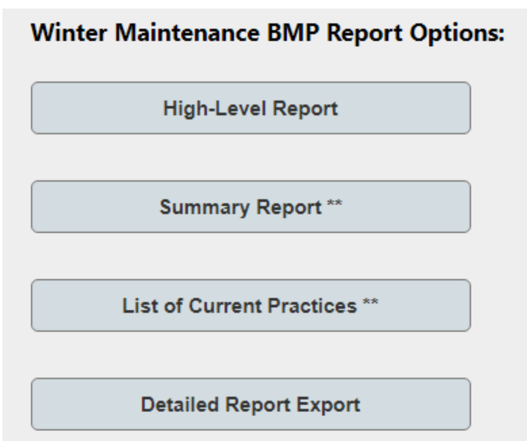
BMP Assessment (Best Management Practices)

Answer all questions that have been selected for you. For each question select the practice that best reflects your operation. Below is an example question. Depending on the criteria you have selected when setting up your assessment the number of questions will vary. There are typically over 100 multiple choice questions in a BMP assessment.

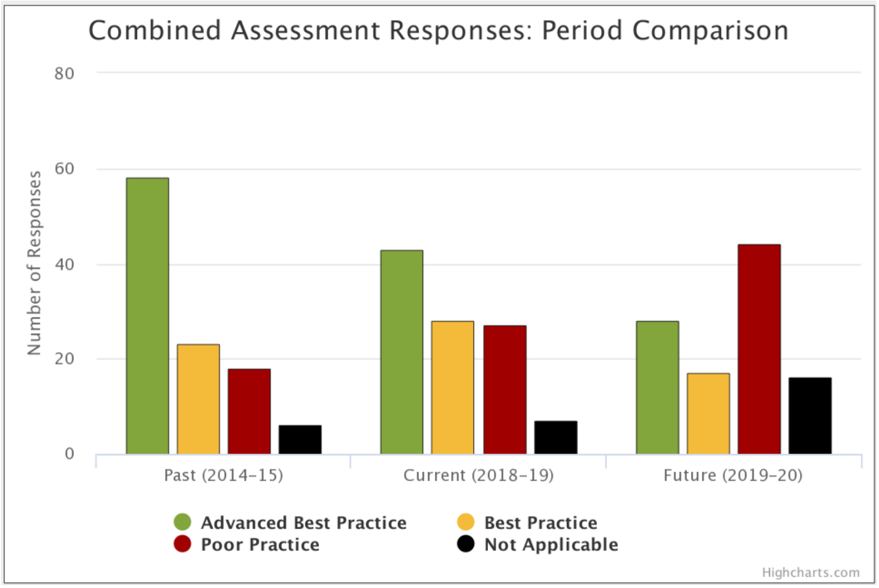


When all questions are answered SSAT will generate reports for you automatically. You can view these reports by clicking on this button.





The "High Level Report" maps out the change in practices over time. This report is color coded showing outstanding practices in green, ok practices in yellow and poor practices in red. It is our goal to grow the green practices and shrink the red practices in order to reduce our salt use.



The "List of Current Practices Report" gives detailed report of every practice and the status of those practices. These may also be exported into an Excel spreadsheet for your internal use.

Current (2018-19) Advanced Best Practice

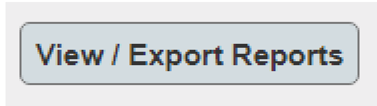
Question ID	Question	Response
1.1.e	Do you calibrate your "gator" or small vehicle granular spreaders?	Yes (for all)
1.1.h	Where are your manual spreader control calibration charts?	Always with the equipment and a backup copy in the office
1.1.i	Do your operators know how to read the calibration charts (cab cards)?	Have all electronic controls, so do not need charts
1.2.c	Do you have more than one type of liquid to choose from (for anti-icing or deicing)?	Yes
2.1.c	What is the most common way you treat frost?	Do nothing
2.1.d	Our anti-icing systems are primarily:	Electronic controls, closed loop system or ground speed system
4.5.g	Do you restrict the output of your push spreaders?	Yes, by restricting the amount of salt you give to the person applying
3.1.e	Are you working to increase liquid and decrease granular use across your entire operations?	Yes
3.1.a	Do you use a sand/salt mix as your primary deicer?	No
3.1.h	Do you stir your storage tanks to insure proper mix?	Yes
3.1.k	When pavement temperatures are below 15 degrees and expected to remain cold, how often do you use dry rock salt?	Rarely or never

LOS Assessment (Level of Service)

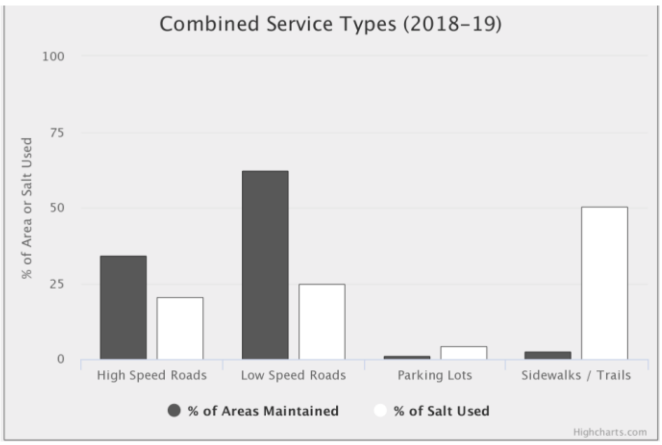
Answer all questions that have been selected for you. Below is an example question. There are very few questions in this mode but will require you to enter data about your operations.

High Speed Roads

	Bare pavement surfaces (2018-19)	Non-bare pavement surfaces (2018-19)	Gravel (winter maint. or dust control) (2018-19)
How many single lane miles of each service type are (or will be) salted (in miles)? (in lane miles)			

When all questions are answered SSAT will generate reports for you automatically. You can view these reports by clicking on this button. 

All reports in this area are designed to improve your insight into how much salt is used based on your type of maintenance goal or your surface type. One of the reports generated shows the areas maintained versus the salt used to maintain those areas. In the below chart we can see that a small amount of sidewalks are maintained (black) yet a disproportionate amount of salt (White) is used to maintain them.



SS Assessment (salt Savings)

Answer all questions that have been selected for you. There are about 30 questions in this mode most will require you to enter data about your operations. This assessment will predict how much salt you will save in the future if you make the changes you indicate. (The predictive model assumes you would have the exact same winter weather.) Below is an example question.

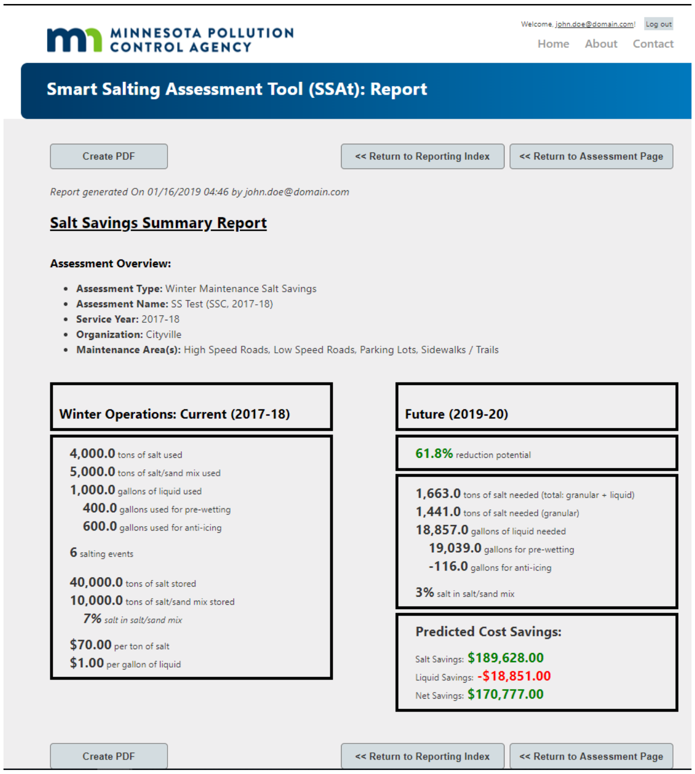
Q3.1.f. For roads, what % of the time do you use the below methods for deicing? (
to 100%)

Practice Response	% of time you use these methods (current)	(future)
Straight liquid	0	20
Slurry (> 30 gallons/ton)	0	
16-30 gallons/ton (pre-wet)	0	
7-15 gallons/ton (pre-wet)	80	60
4-6 gallons/ton (pre-wet) (i.e., pretreated stockpile)	0	
4-6 gallons/ton (On-site mixed stockpile)	0	
Dry salt	20	20
Sand/salt mix	0	
Other	0	
Do not deice		

View Comments (8) Submit a Comment/Tip

When all questions are answered SSAT will generate reports for you automatically. You can view these reports by clicking on this button.

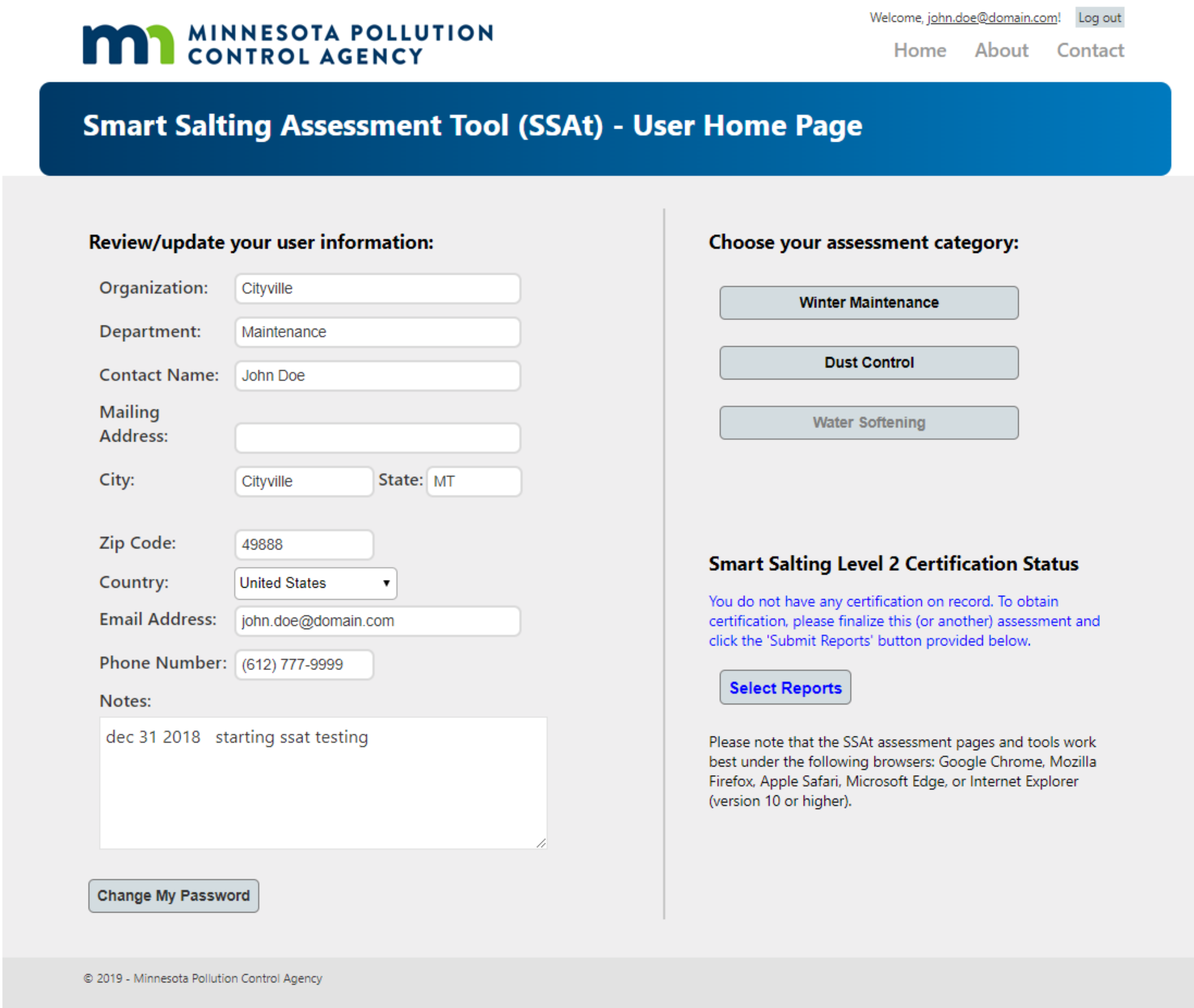
View / Export Reports



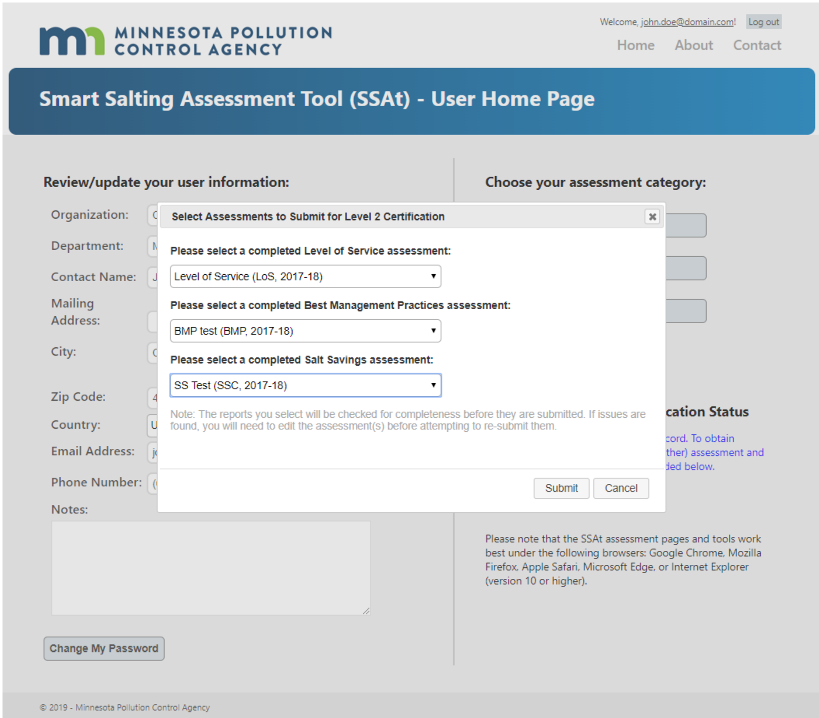
The predictive model used in Salt Savings Assessment is limited by the date we have been able to gather on where people have found changes that resulted in salt savings. Over time we expect this model to grow and be refined to include more types of changes and more data per type of change. Today's model is really more of an illustration of how this mode works with a limited data set.

Using SSAT to become Level 2 certified with the MPCA

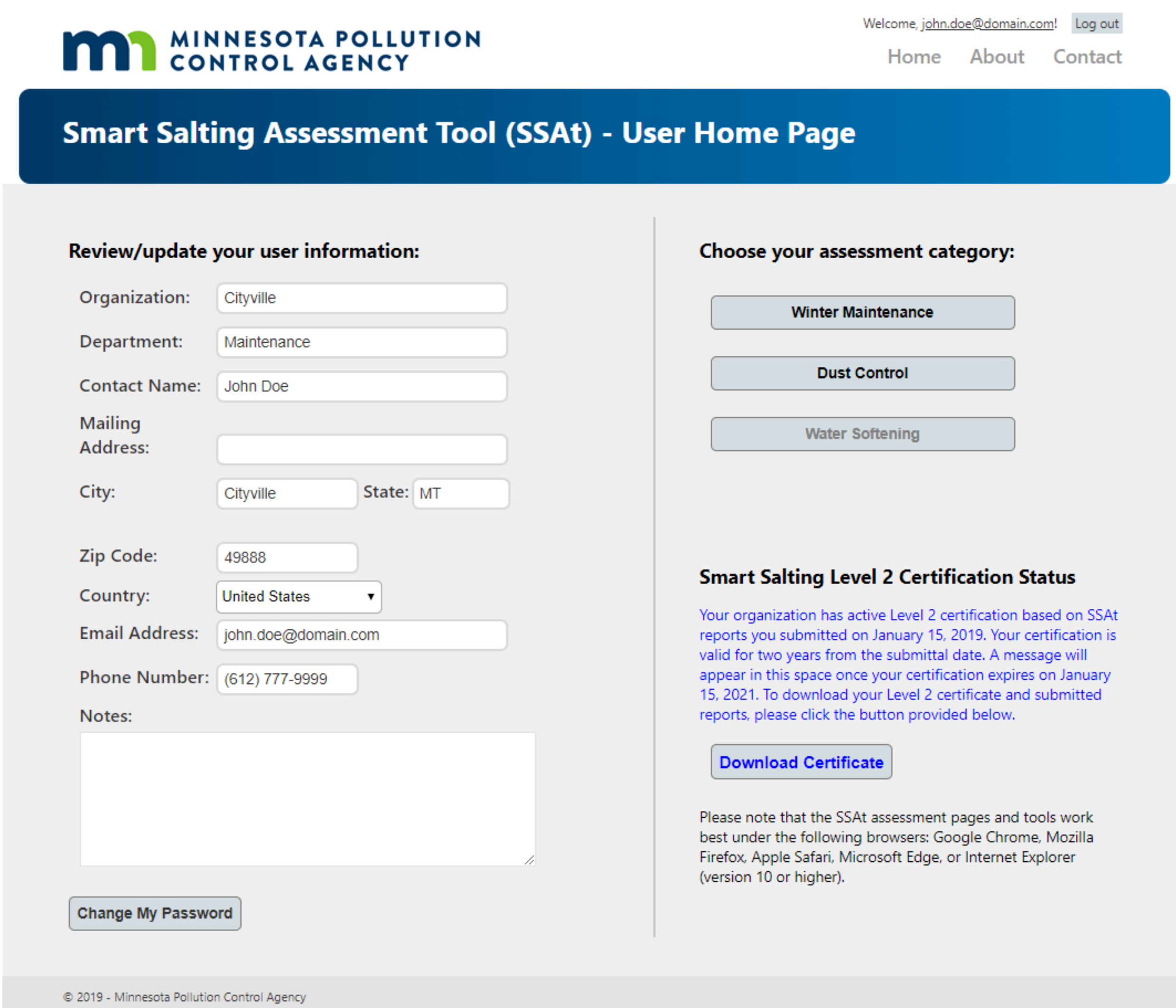
Once you have completed a LOS, BMP, and a SS assessment you may submit these reports to MPCA to become certified. You do this by clicking on the “Select Reports” button on the home page.



This will allow you to look at all of the assessments you have completed and select the most current ones to submit for certification.



Once SSAT verifies that the reports have been submitted successfully, your organization will be Level 2 certified. At this time you will be able to download and print out your certificate.



MINNESOTA POLLUTION CONTROL AGENCY

Welcome, john.doe@domain.com! Log out

Home About Contact

Smart Salting Assessment Tool (SSAt) - User Home Page

Review/update your user information:

Organization: Cityville

Department: Maintenance

Contact Name: John Doe

Mailing Address:

City: Cityville State: MT

Zip Code: 49888

Country: United States

Email Address: john.doe@domain.com

Phone Number: (612) 777-9999

Notes:

Change My Password

Choose your assessment category:

Winter Maintenance

Dust Control

Water Softening

Smart Salting Level 2 Certification Status

Your organization has active Level 2 certification based on SSAt reports you submitted on January 15, 2019. Your certification is valid for two years from the submittal date. A message will appear in this space once your certification expires on January 15, 2021. To download your Level 2 certificate and submitted reports, please click the button provided below.

Download Certificate

Please note that the SSAt assessment pages and tools work best under the following browsers: Google Chrome, Mozilla Firefox, Apple Safari, Microsoft Edge, or Internet Explorer (version 10 or higher).

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The certification is good for two years. To renew your certification, you only need to go in and update your assessments to reflect your current situation and resend them. The MPCA publishes a list of all organizations who are level 2 certified at https://www.pca.state.mn.us/sites/default/files/p-tr1-47.pdf. Below is an example of the list of those certified:

Minnesota Pollution Control Agency

Smart Salting Applicators Training - Level 2

Certificate Holders

7/1/2016

List of Organizations certified (by application date)
A voluntary environmental commitment certification was given to organizations who:
- Summary of BMP Question Responses for Current Report;
- BMP Question Responses: Summary Charts Report; and
- Salt Savings Summary 1 Report.

Expires after 2 winter seasons

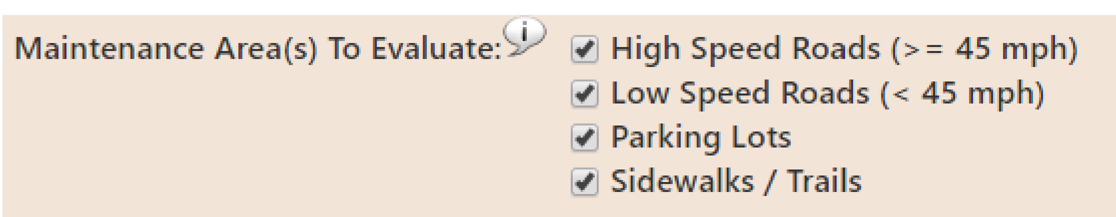
INNESOTA CERTIFIED (note: out of state at end of Minnesota Certified)

Application Date	Expiration Date	Type	MS4	Organization/ Company	Address	City	State	Zip Code	Contact Name
2/16/2016	9/1/2019	City	Yes	Roseville, Public Works	2660 Civic Center Drive	Roseville	MN	55113	Josh Dix
2/19/2016	9/1/2019	State	YES	MNDOT, Eden Prairie Truck Station	7333 Bryant Lake Drive	Eden Prairie	MN	55344	Jamie Traxler
3/1/2016	9/1/2019	City	Yes	Edina, Public Works	7450 Metro Blvd	Edina	MN	55439	Brian Olson
3/9/2016	9/1/2019	City	Yes	Cyrstal, Public Works	4141 Douglas Drive	Crystal	MN	55422	Mark Gauke
3/15/2016	9/1/2019	Private	NA	Prescription Landscaping, St Paul	481 Front Ave	St Paul	MN	55117	Rick Winter
4/13/2016	9/1/2019	County	Yes	Carver County, Public Works	11360 Highway 212	Cologne	MN	55322	John Wickenhauser
4/18/2016	9/1/2019	City	Yes	Eden Prairie, Public Works	15150 Technology Dr	Eden Prairie	MN	55344	Mike Schmidt
4/22/2016	9/1/2019	City	YES	Rochester – Public Works	4300 East River Road NE	Rochester	MN	55906	Dan Plizga
6/30/2016	9/1/2019	City	YES	White Bear Lake - Public Works	3950 Hoffman Road	White Bear Lake	MN	55110	Mark Meyer
7/1/2016	9/1/2019	City	YES	Maple Grove - Streets Dept	9030 Forestview Lane N	Maple Grove	MN	55369	Frank Mauer
8/25/2016	9/1/2019	Private	NA	Arteka Companies	8810 13th Ave East	Shakopee	MN	55379	Dan Slepica

Setting up an assessment in Dust Control

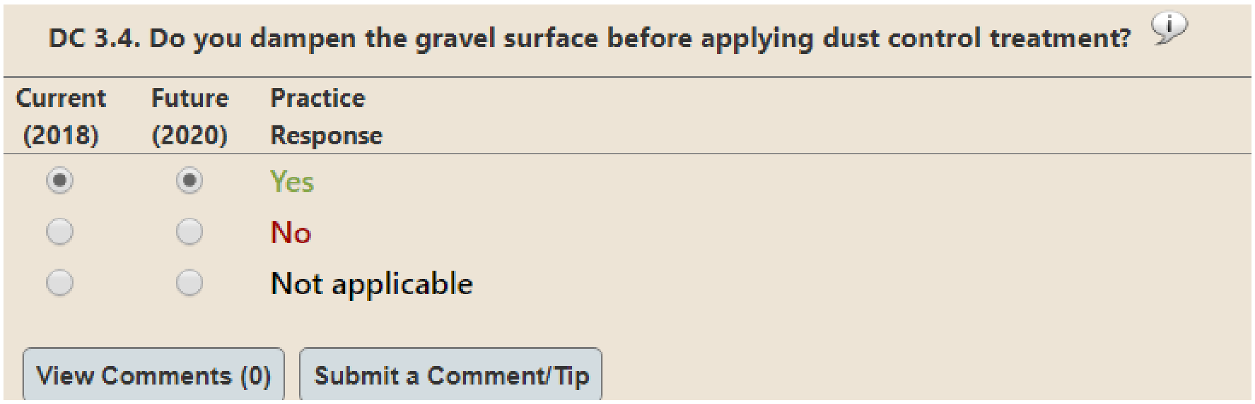
You select the time period you want to evaluate. You can choose any past, current and/or future date. The current season is always required. You also have the ability to copy an existing assessment into a new date, which speeds up the process of creating/editing additional assessments.

You select what type of maintenance you want to assess. You may select any number of maintenance areas. However your best insight your operations would be given if you select one maintenance are per assessment.

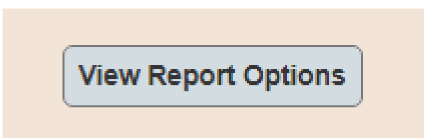


Conducting an assessment in Dust Control

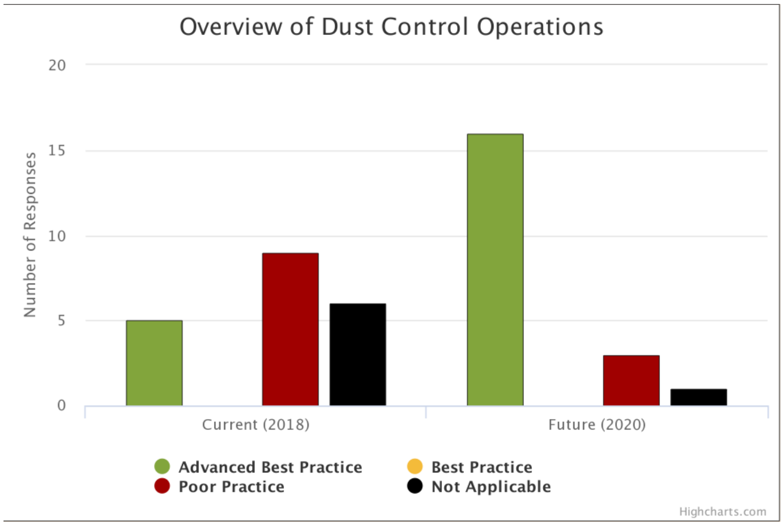
Answer all questions that have been selected for you. For each question select the practice that best reflects your operation. Below is an example question. Depending on the criteria you have selected when setting up your assessment the number of questions will vary



When all questions are answered SSAT will generate reports for you automatically. You can view these reports by clicking on this button.



The "High Level Report" maps out the change in practices over time. This report is color coded showing outstanding practices in green, ok practices in yellow and poor practices in red. It is our goal to grow the green practices and shrink the red practices in order to reduce our salt use.



The “List of Current Practices Report” gives detailed report of every practice and the status of those practices. These may also be exported into an Excel spreadsheet for your internal use.

Current (2018) Advanced Best Practice

Question ID	Question	Response
DC 1.2	Do you keep records of your applications?	Yes
DC 1.3	Does the crew understand the dust control policy?	Yes
DC 1.7	Do you restrict dust control treatment to gravel roads with higher traffic volumes?	Yes
DC 3.4	Do you dampen the gravel surface before applying dust control treatment?	Yes
DC 4.6	Where do you apply dust control products?	Spot treat or continual, dependent on use

Current (2018) Best Practice

There are no responses in this category

Current (2018) Poor Practice

Question ID	Question	Response
DC 1.1	Do you have a written dust control policy?	No
DC 1.4	Do you communicate your dust control policy to your customers?	No

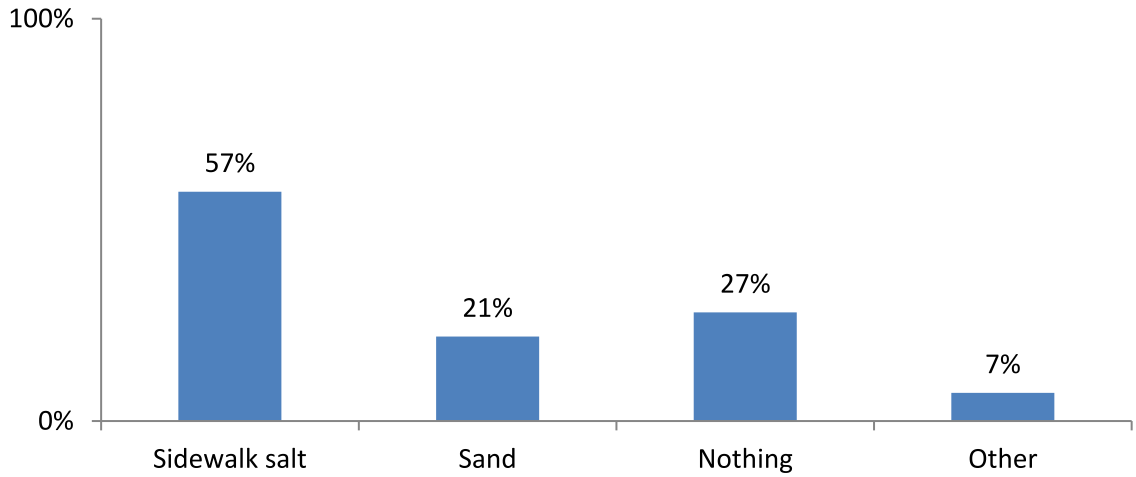
Setting up an assessment in Water Softening

This type of assessment was not yet developed by the time that the Statewide CMP was completed. It will be implemented in the future.

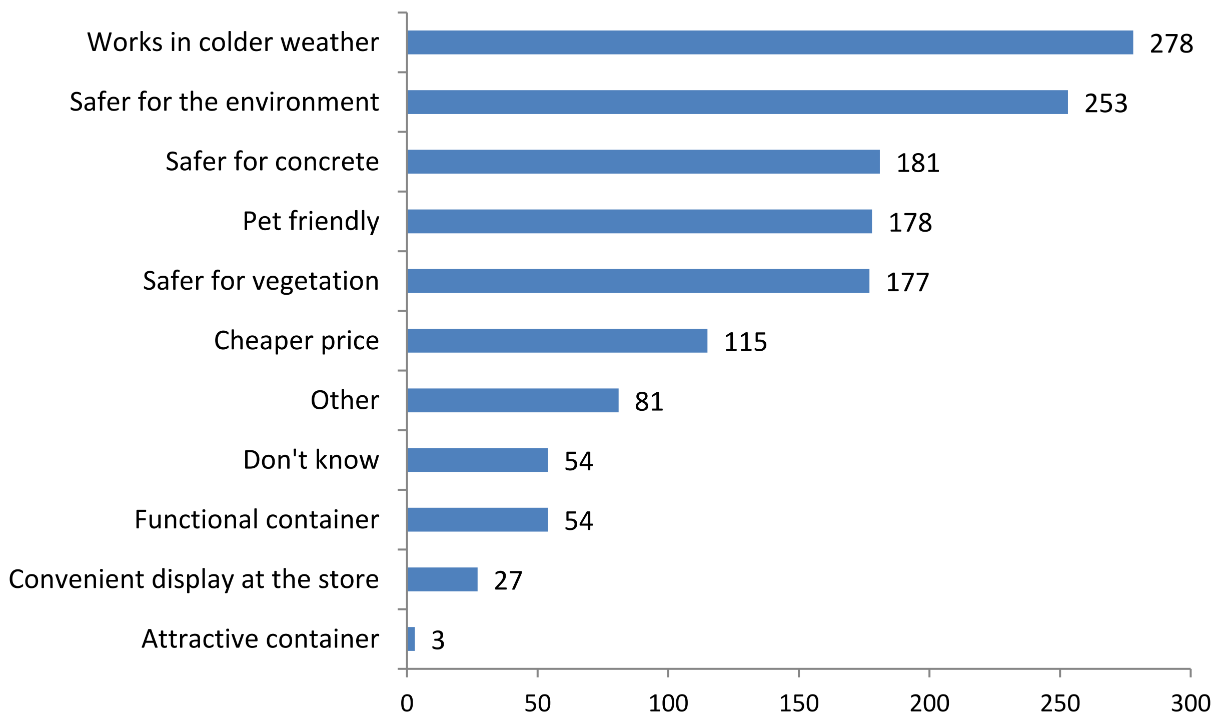
Appendix B – Sidewalk Survey Results

Below is a summary of results of the Sidewalk Survey that was completed by 754 residents in the TCMA from November 2011 through March 2012.

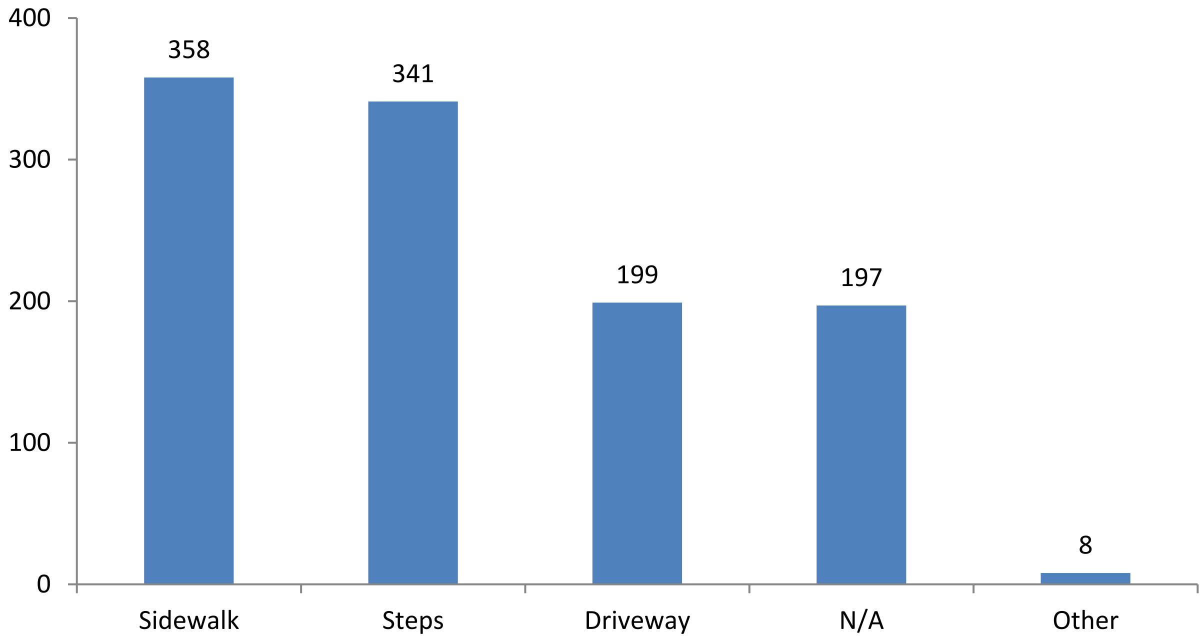
Question 1. What product do you most commonly apply to your icy areas?



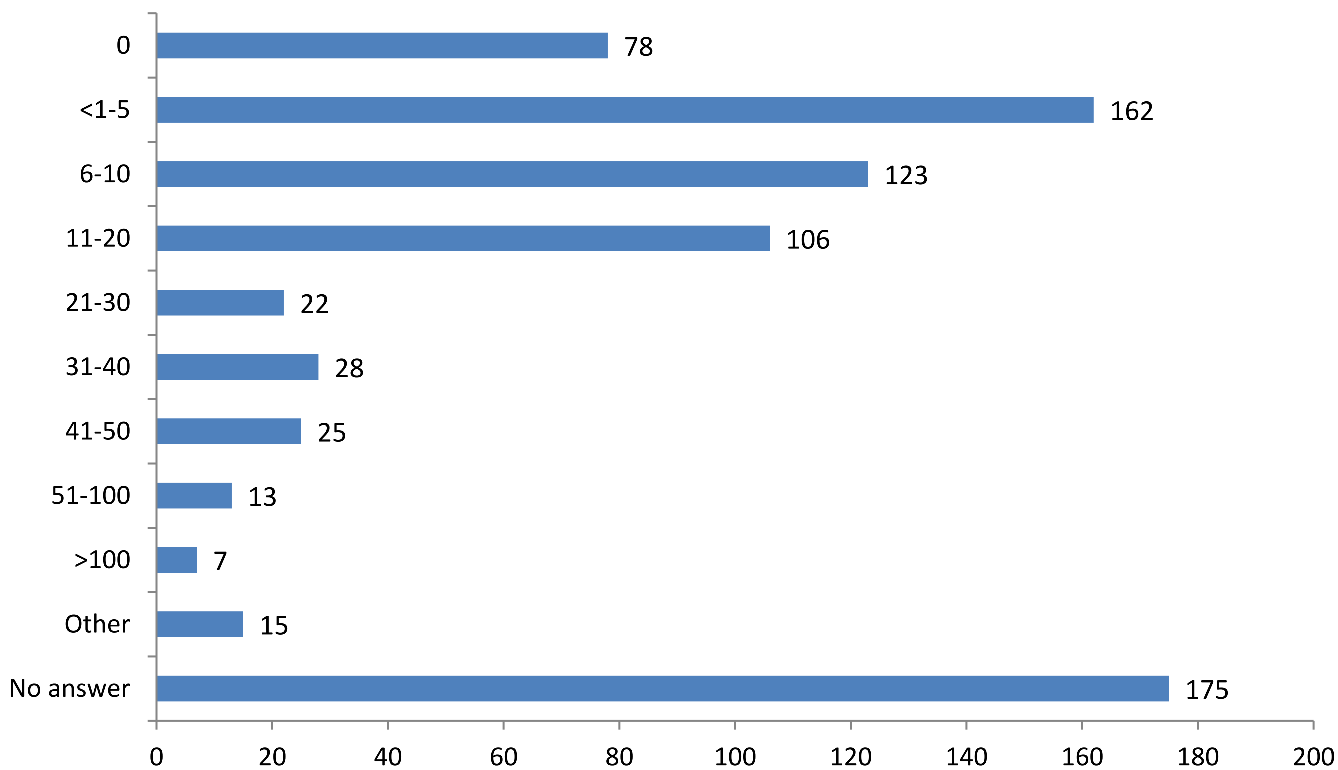
Question 2. Why did you choose that product?



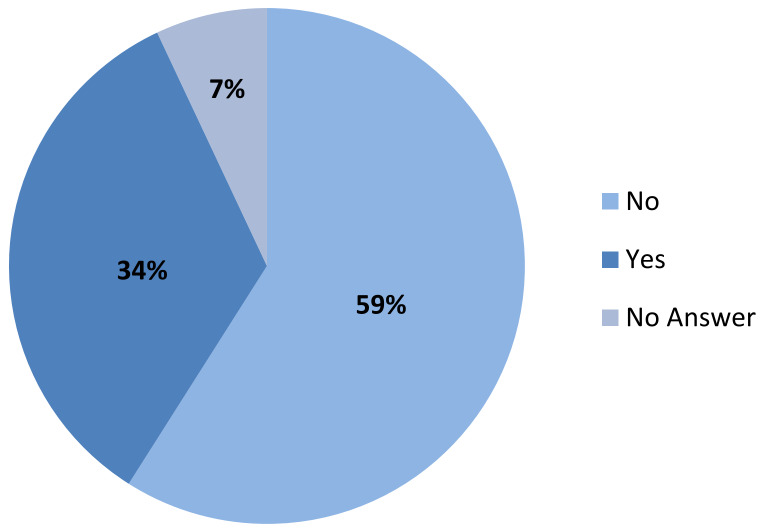
Question 3. Where do you most often apply sidewalk salt?



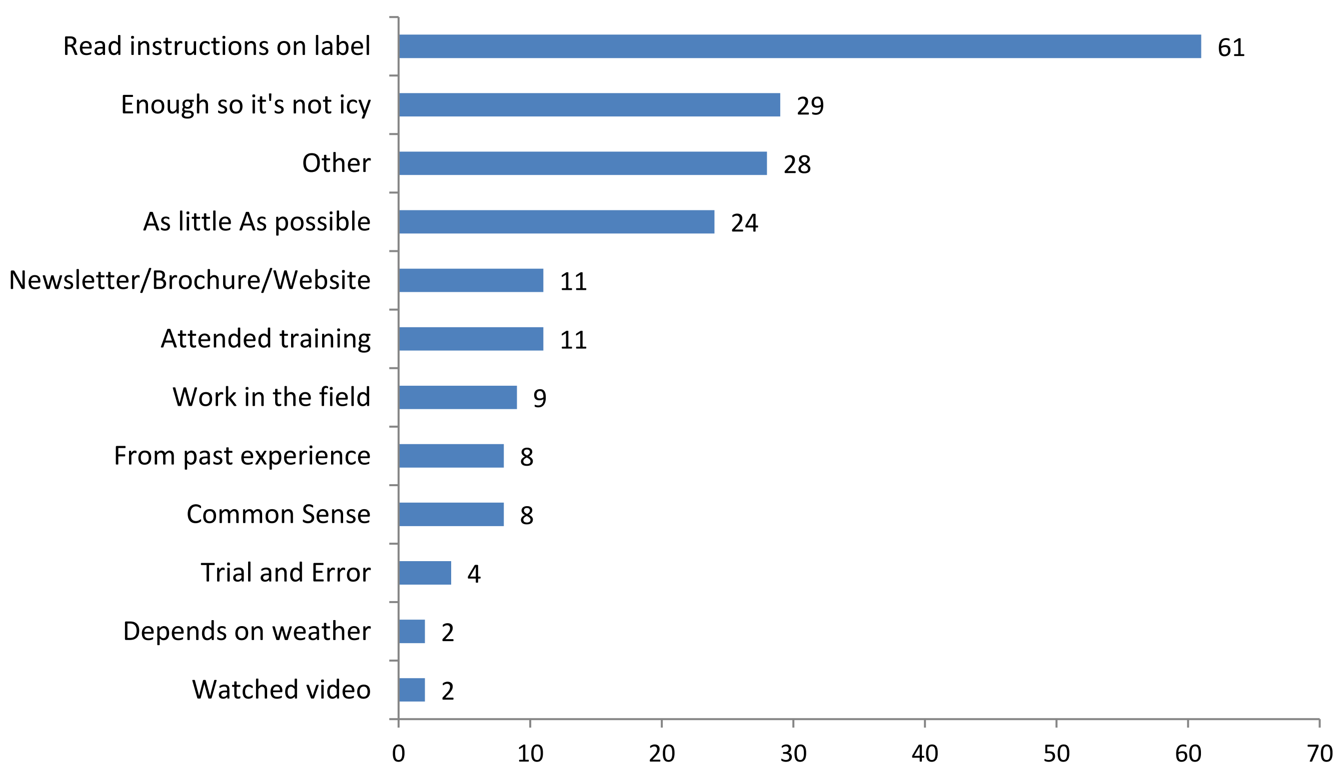
Question 4. How much sidewalk salt (lb.) do you use in an average winter?



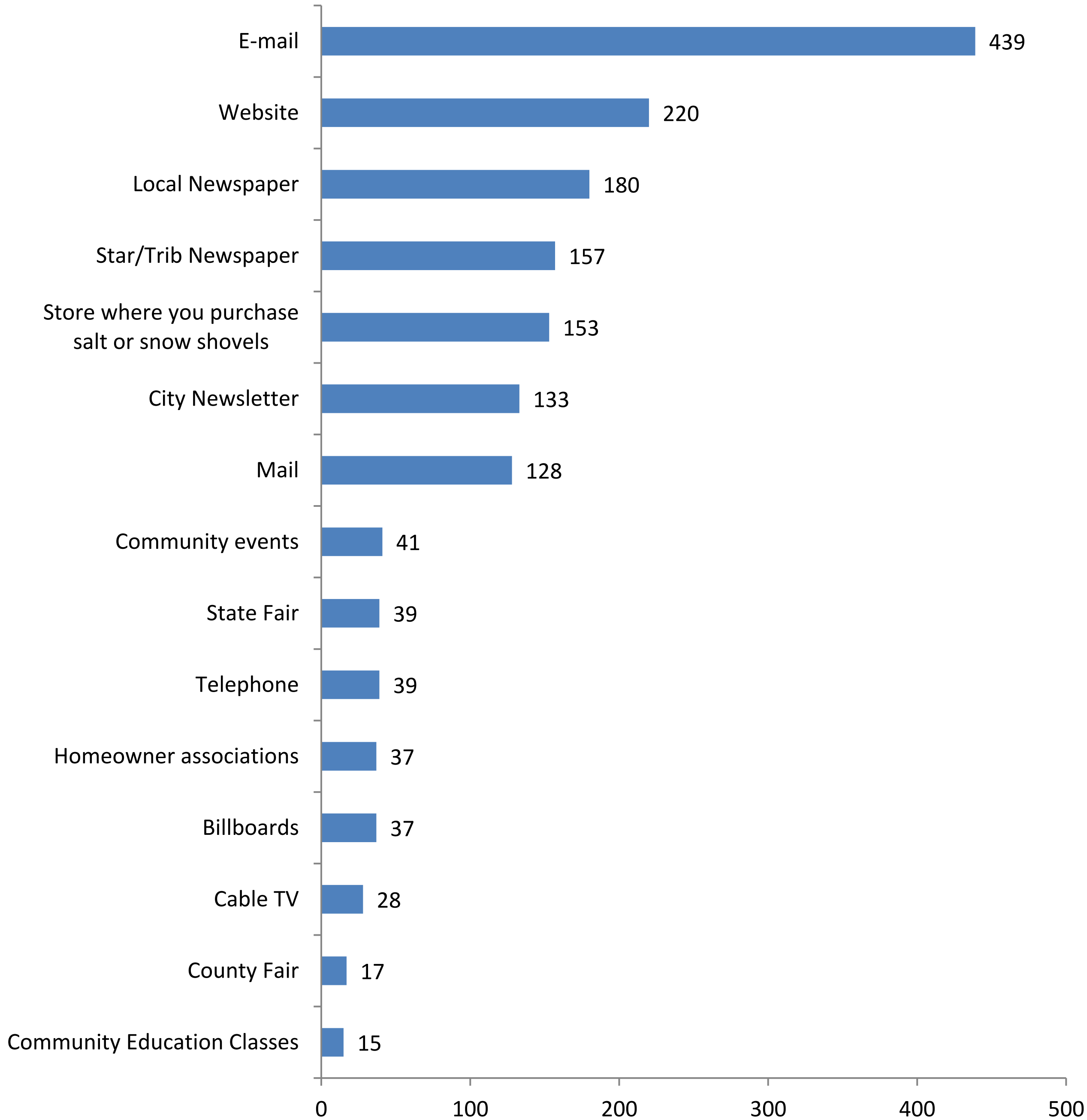
Question 5. Do you know how much sidewalk salt you should apply? (n = 754)



If yes, how do you know? (n=197)



Question 6. What are the best ways to get information to you?



Appendix C - Chloride Relationships to Ecoregion

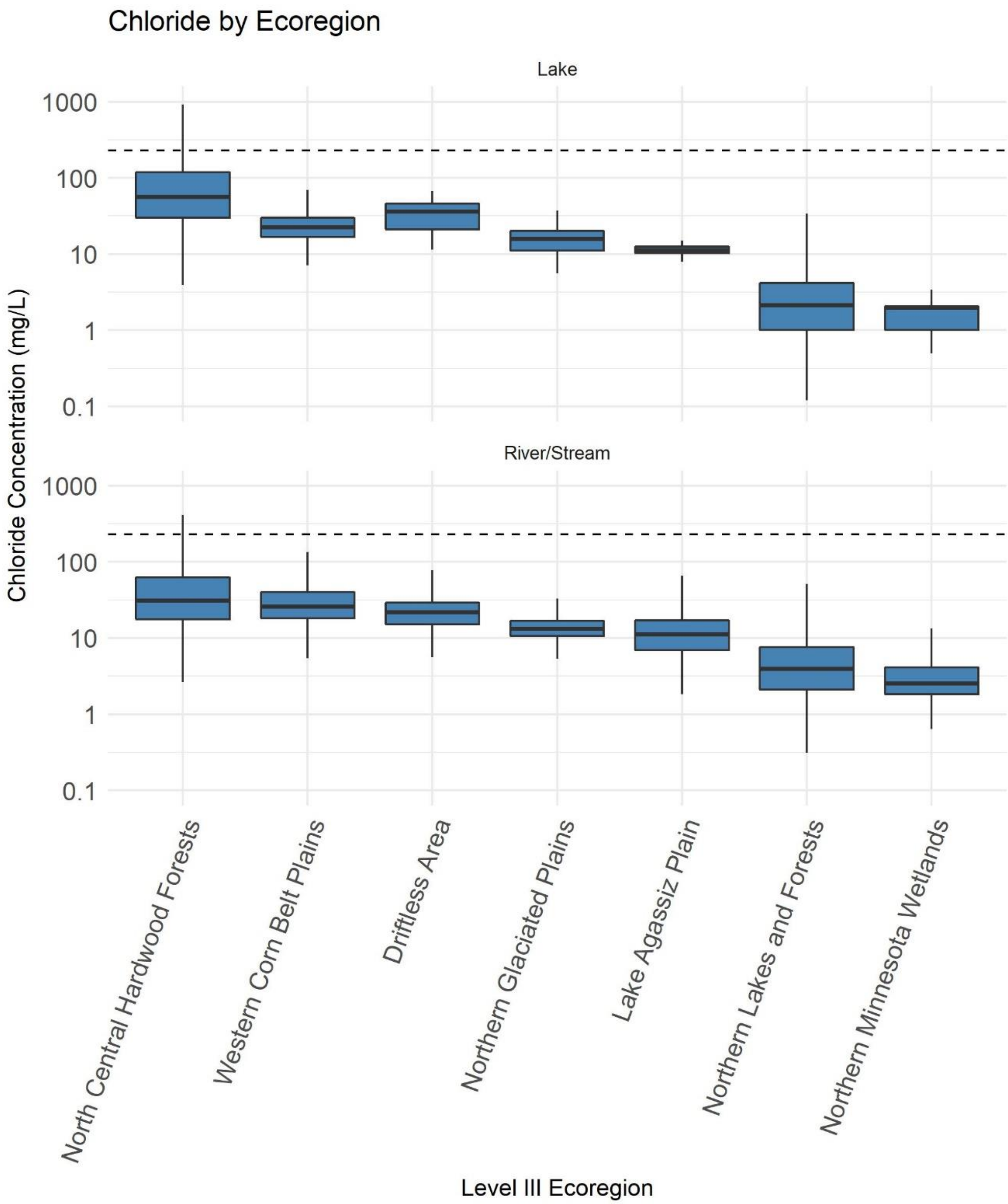


Figure 79: Chloride concentrations for all surface water samples taken in each level III Ecoregion since 2007.
The boxes are shaded blue over the inner-quartile region (IQR; 25 percentile – 75 percentile concentrations). The median is drawn as the heavy black line within the IQR, and each line extends 1.5*IQR +/- Quartiles Concentration. Outliers are not shown. The dashed line indicates the chloride water quality standard of 230 mg/L.

The influence of the TCMA, which is the most developed region of the state, is clear when comparing the ecoregions. Similarly, concentrations are relatively high in the agriculturally developed Driftless and Western Corn Belt ecoregions. The measured concentrations in the less developed ecoregions of the state were dramatically smaller. In order to assess whether there is a natural variance in chloride concentrations across the ecoregions (i.e. variation not due to development or agricultural influence), each sampling location was binned into a land use category based on the National Land Cover Database coverage in its surrounding HUC 12 watershed (Table 18).

Table 18: Land Use Classifications based on Percentages of NLCD Cover

Land Use Category	Definition
Agricultural	>75% Hay/pasture + Cultivated crops
Predominately Agriculture	50-75% Hay/pasture + Cultivated crops
Developed	>75% Developed (low density + medium density + high density + open space)
Predominately Developed	50-75% Developed (low density + medium density + high density + open space)
Natural	>75% Barren land + Forests (Deciduous + Evergreen + Mixed) + Shrub + Herbaceous + Wetlands (Woody + Emergent/herbaceous)
Predominately Natural	50-75% Barren land + Forests (Deciduous + Evergreen + Mixed) + Shrub + Herbaceous + Wetlands (Woody + Emergent/herbaceous)
Mixed	All other breakdown

Samples collected from locations that were in “natural” (>75% undeveloped and nonagricultural land cover) or predominately “natural” (50% to 75% undeveloped and nonagricultural land cover) conditions were compared, and a different trend emerged. Concentrations in the Driftless ecoregion were the highest observed, by a considerable margin, and the median Northern Central Hardwood Forests ecoregion were much lower. There were no samples collected in “natural” conditions in the Western Corn Belt, Northern Glacial Plains, and Lake Agassiz ecoregions, thus these were excluded from the analysis.

A deeper look into the land use characteristics, beyond the influence of ecoregions, suggests that development and agriculture have a greater influence on the magnitude of chloride concentrations.

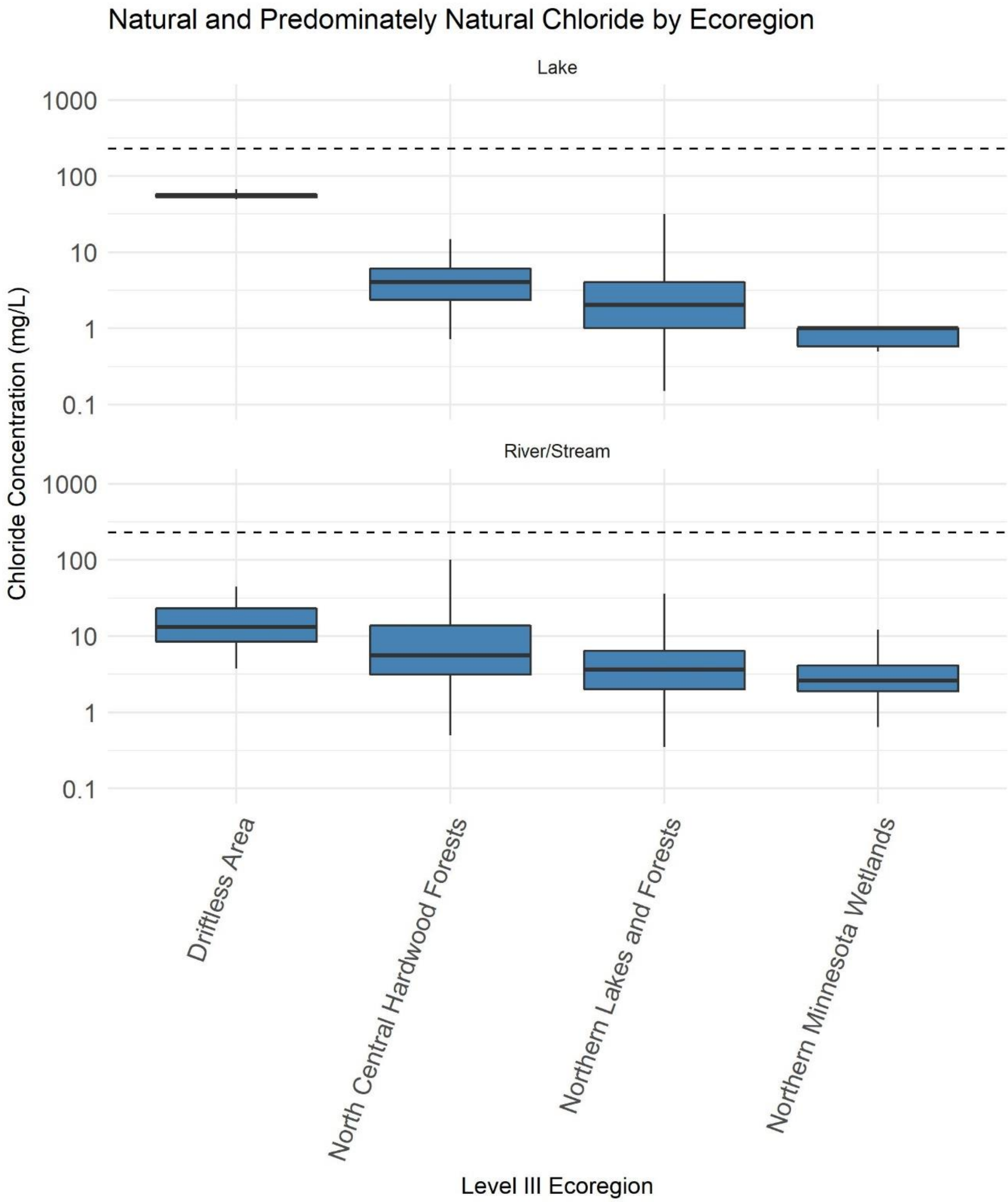


Figure 80: Chloride concentrations for lake samples taken from waterbodies in HUC 12 watersheds that have natural or predominately natural land use since 2007.

The boxes are shaded blue over the inner-quartile region (IQR; 25 percentile – 75 percentile concentrations). The median is drawn as the heavy black line within the IQR, and each line extends 1.5*IQR +/- Quartiles Concentration. Outliers are not shown. The dashed line indicates the chloride water quality standard of 230 mg/L.

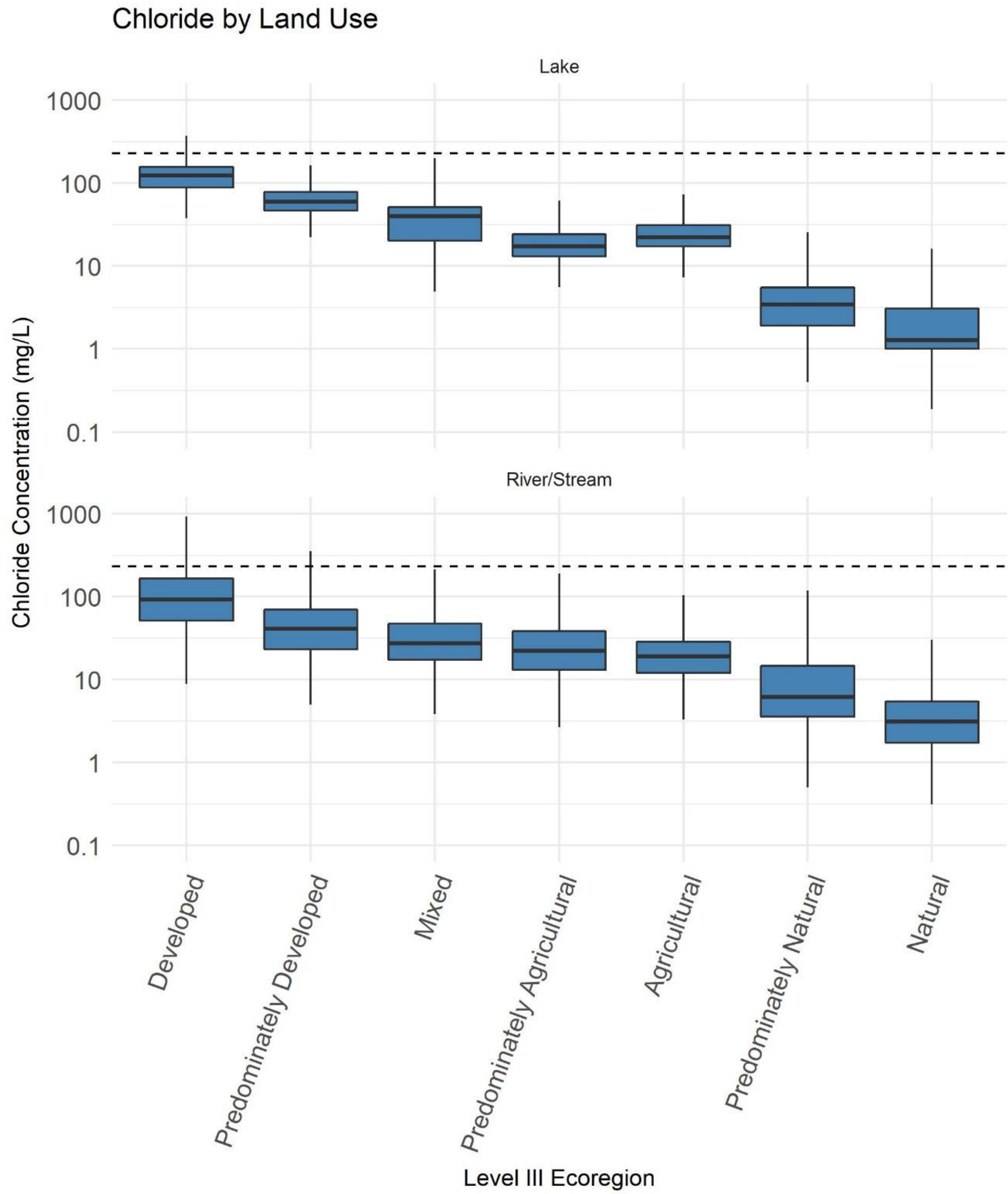


Figure 81: Chloride concentrations in all lake samples, broken out by land use category, since 2007.
The boxes are shaded blue over the inner-quartile region (IQR; 25 percentile – 75 percentile concentrations). The median is drawn as the heavy black line within the IQR, and each line extends 1.5*IQR +/- Quartiles Concentration. Outliers are not shown. The dashed line indicates the chloride water quality standard of 230 mg/L.

Given that detailed chloride source assessments are tied to land use and that natural background chloride concentrations are well below at-risk levels, ecoregions may be better suited as a surrogate for land use characteristics than a direct predictor of impairment likelihood. For example, the Western Corn Belt is dominated by agricultural lands, thus an investigation into the source of an at-risk waterbody may begin with an assessment of possible agricultural sources of chloride (Table 19). A description of each ecoregion and their characteristics is presented in the following section.

Table 19: Level III Ecoregion Land Use Characteristics (summarized from NLCD)

Level III Ecoregion	% Developed	% Agricultural	% Natural
Driftless Area	7	55	36
Lake Agassiz Plain	6	79	14
North Central Hardwood Forests	12	53	30
Northern Glaciated Plains	5	78	13
Northern Lakes and Forests	3	6	81
Northern Minnesota Wetlands	2	9	79
Western Corn Belt Plains	7	84	8

Ecoregion

Below, each level III ecoregion is described in brief, with specific attention given to land use and development characteristics. Mean monthly surface concentrations are displayed for two lakes in each ecoregion. Lakes were selected first, based on quality (total number of samples and number of months sampled) and second, to demonstrate the varying seasonal trends that exist within an ecoregion. Additional ecoregion details related to water quality can be found at:

https://www.pca.state.mn.us/quick-links/eda-guide-typical-minnesota-water-quality-conditions

Driftless Area

The Driftless Ecoregion is located in the southeastern corner of Minnesota and is characterized by the lack of glacial drift deposits. This area is hilly with thin soils. There are few lakes in this area, of which only two have a measured chloride concentration in the last 10 years. Both of these lakes are part of flowing waterways (Lake Zumbro – Zumbro River; Lake Pepin – Mississippi River).

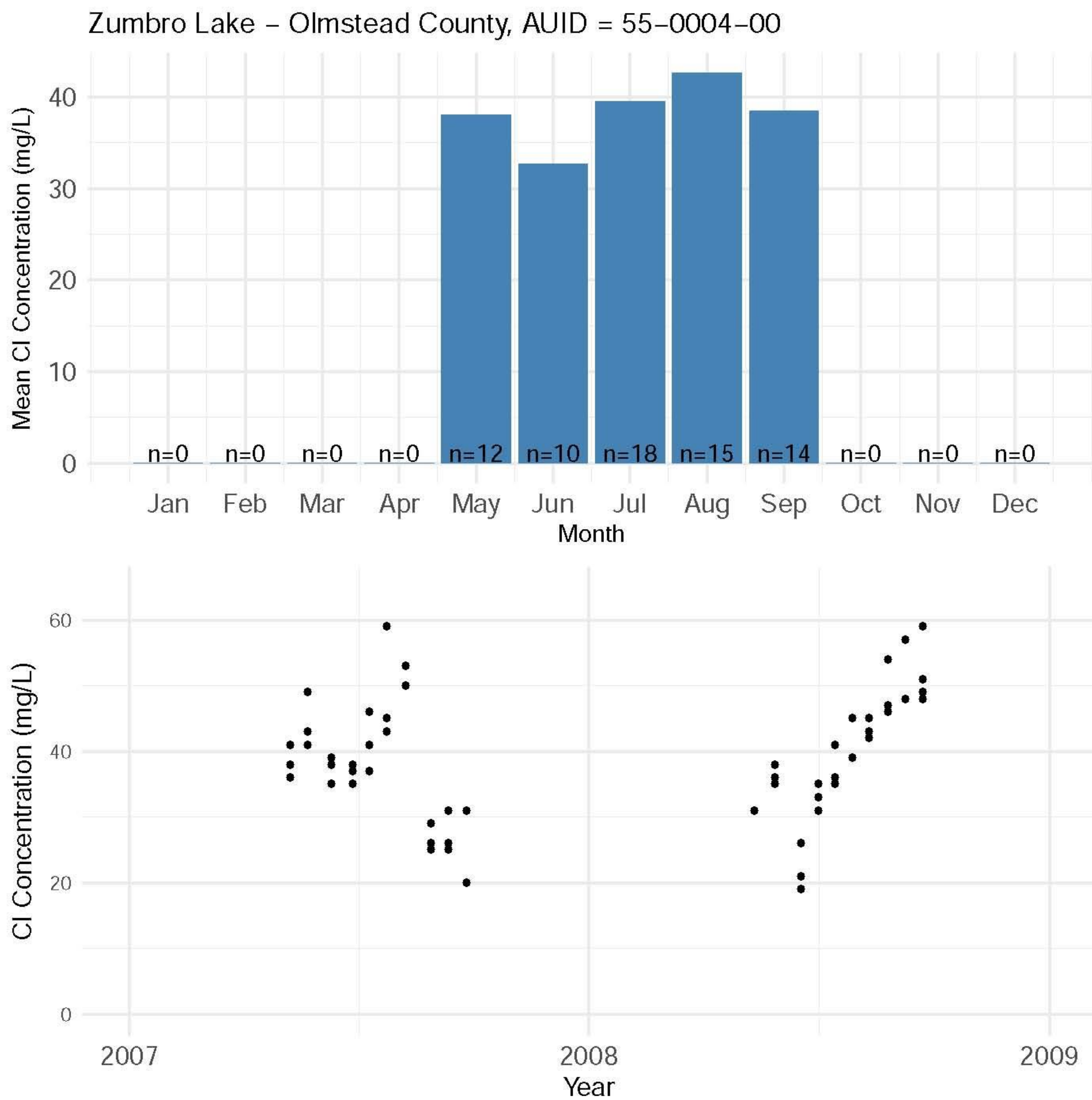


Figure 82: Chloride concentration trends in Zumbro Lake.
Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

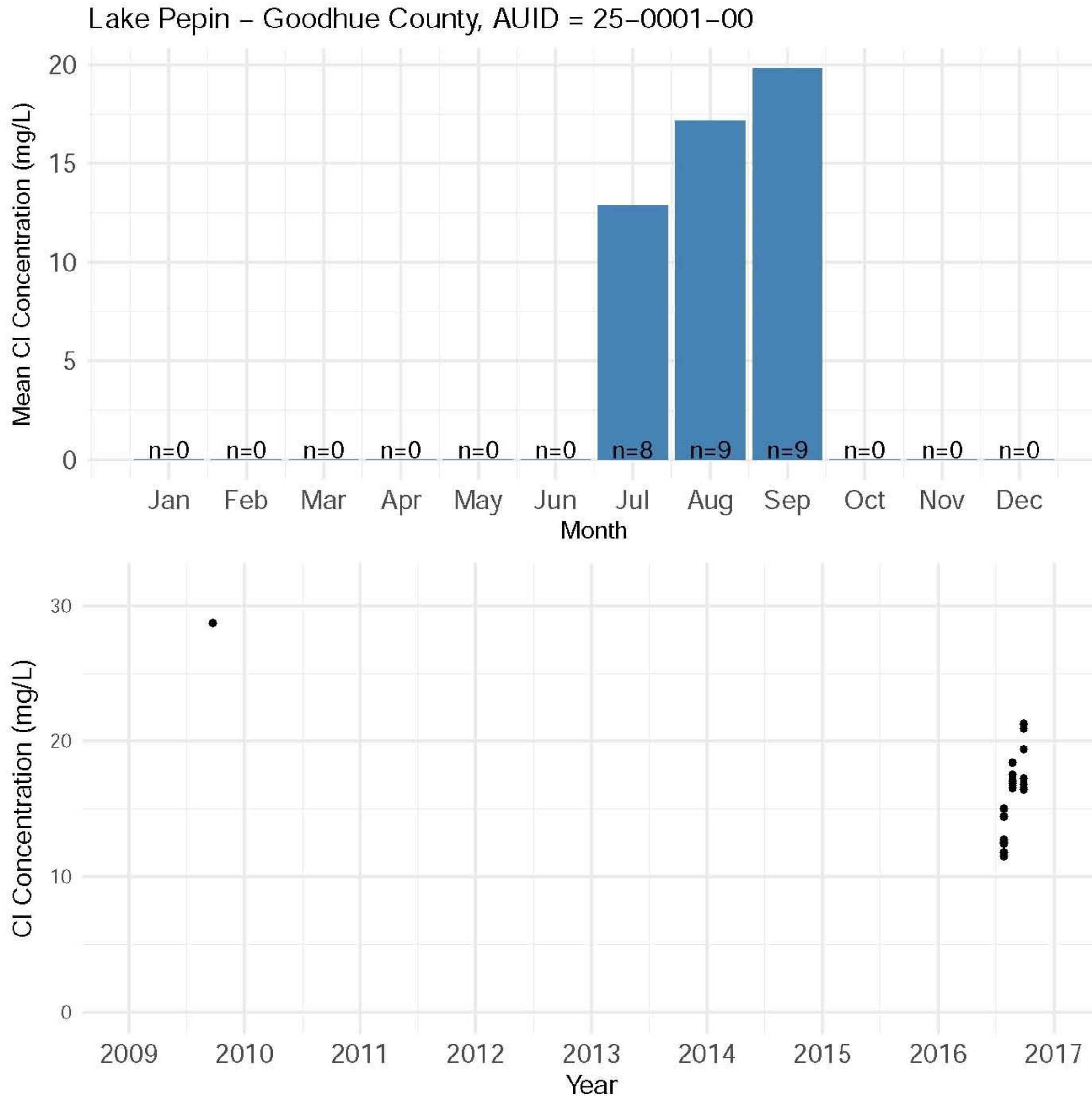


Figure 83: Chloride concentration trends in Lake Pepin.
Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

Lake Agassiz Plain

Lake Agassiz Plain, also referred to as the Red River Valley is located in the northwestern corner of Minnesota, bordering with Canada and North Dakota. This ecoregion is heavy with agricultural lands and drains to the Hudson Bay.

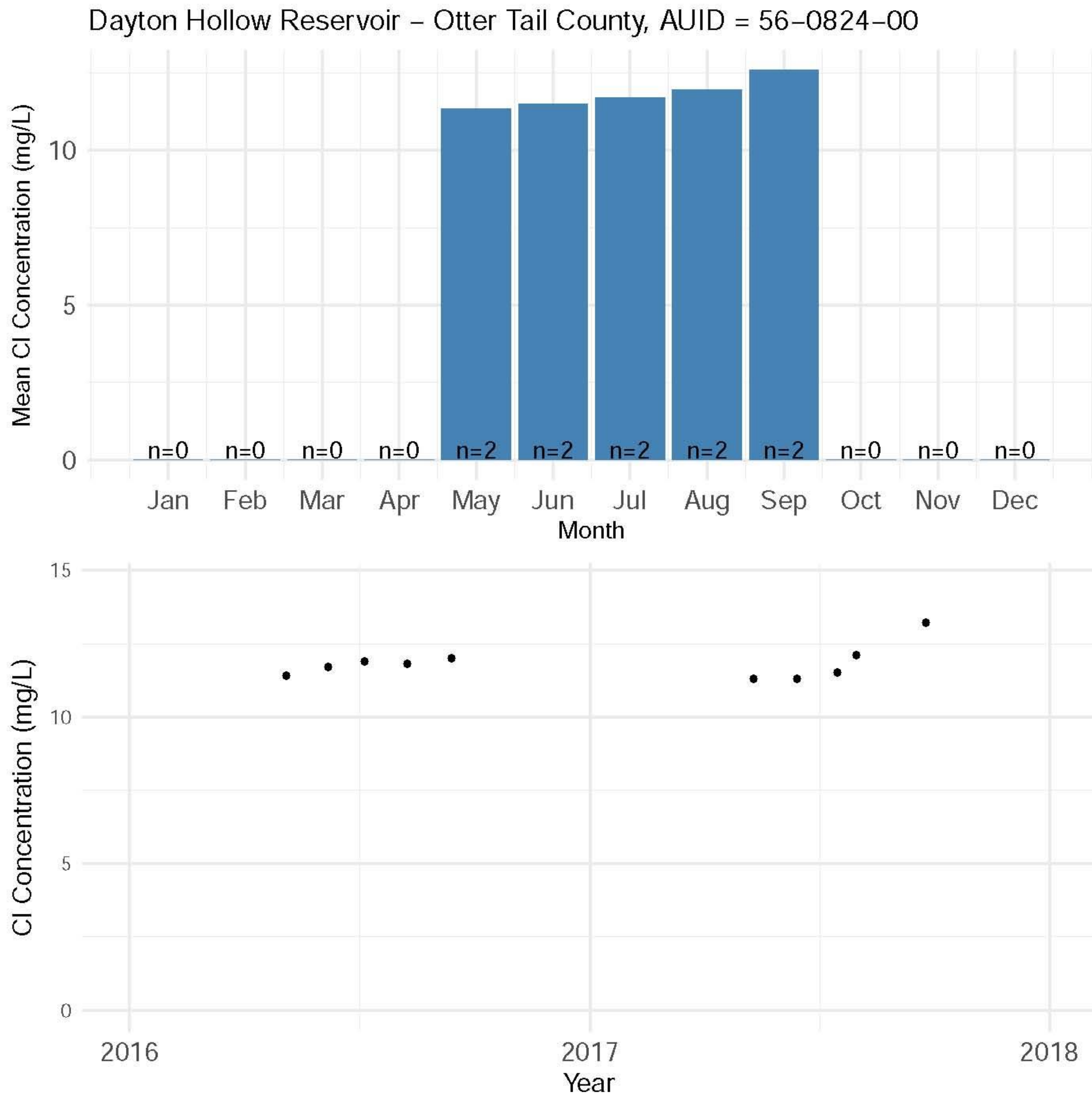


Figure 84: Chloride concentration trends in Dayton Hollow Reservoir.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

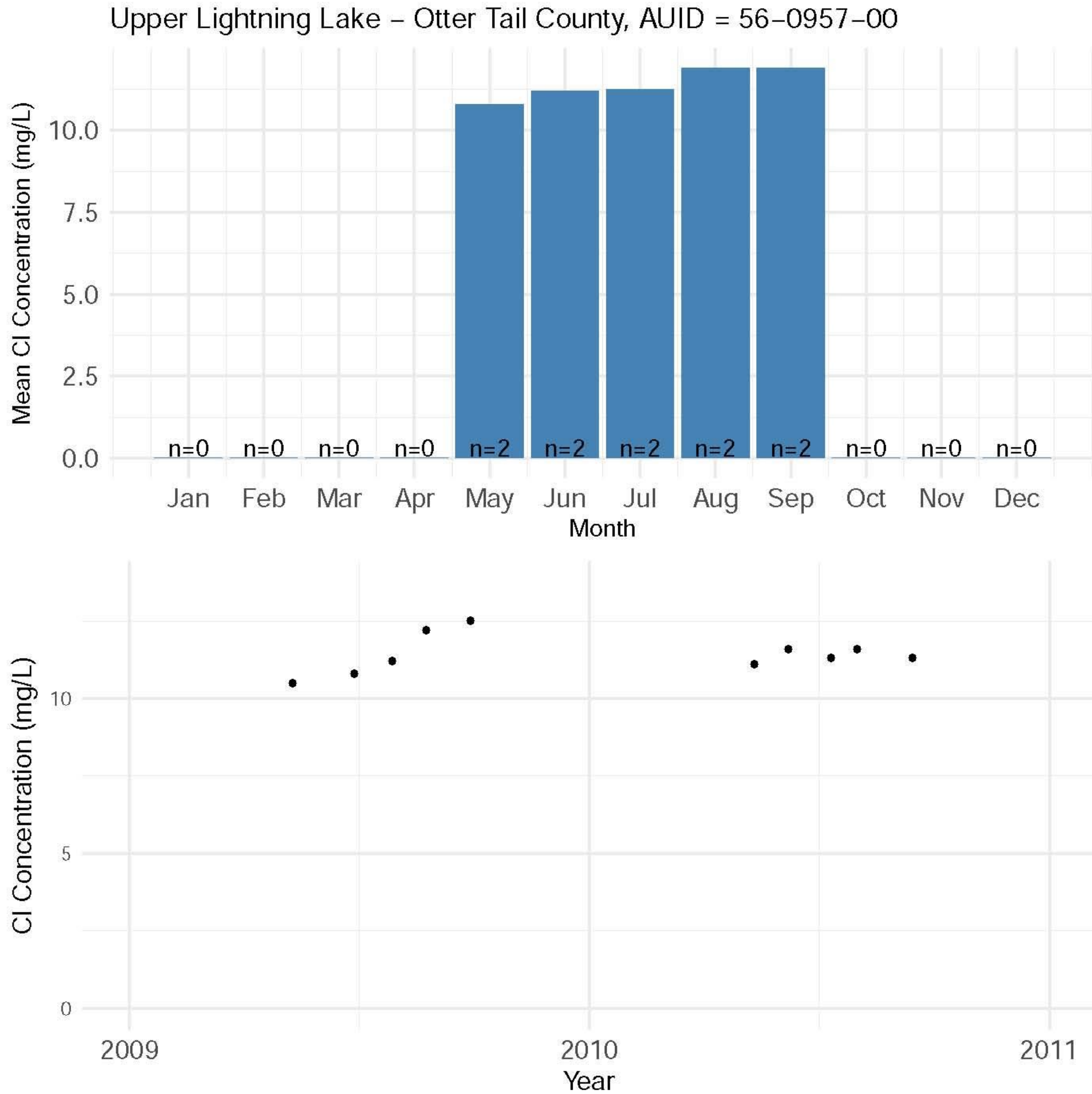


Figure 85: Chloride concentration trends in Upper Lightning Lake

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

North Central Hardwood Forests

This ecoregion covers a large portion of central Minnesota, including the TCMA. This area is described as a transitional area between the agricultural ecoregions to the south and west and forested areas to the east and north. There is not one dominate land use type throughout this ecoregion, as this region includes plains, croplands, pastures, and forests, as well as urban and suburban development. Therefore, chloride concentration patterns will vary greatly (Figure 86 and Figure 87).

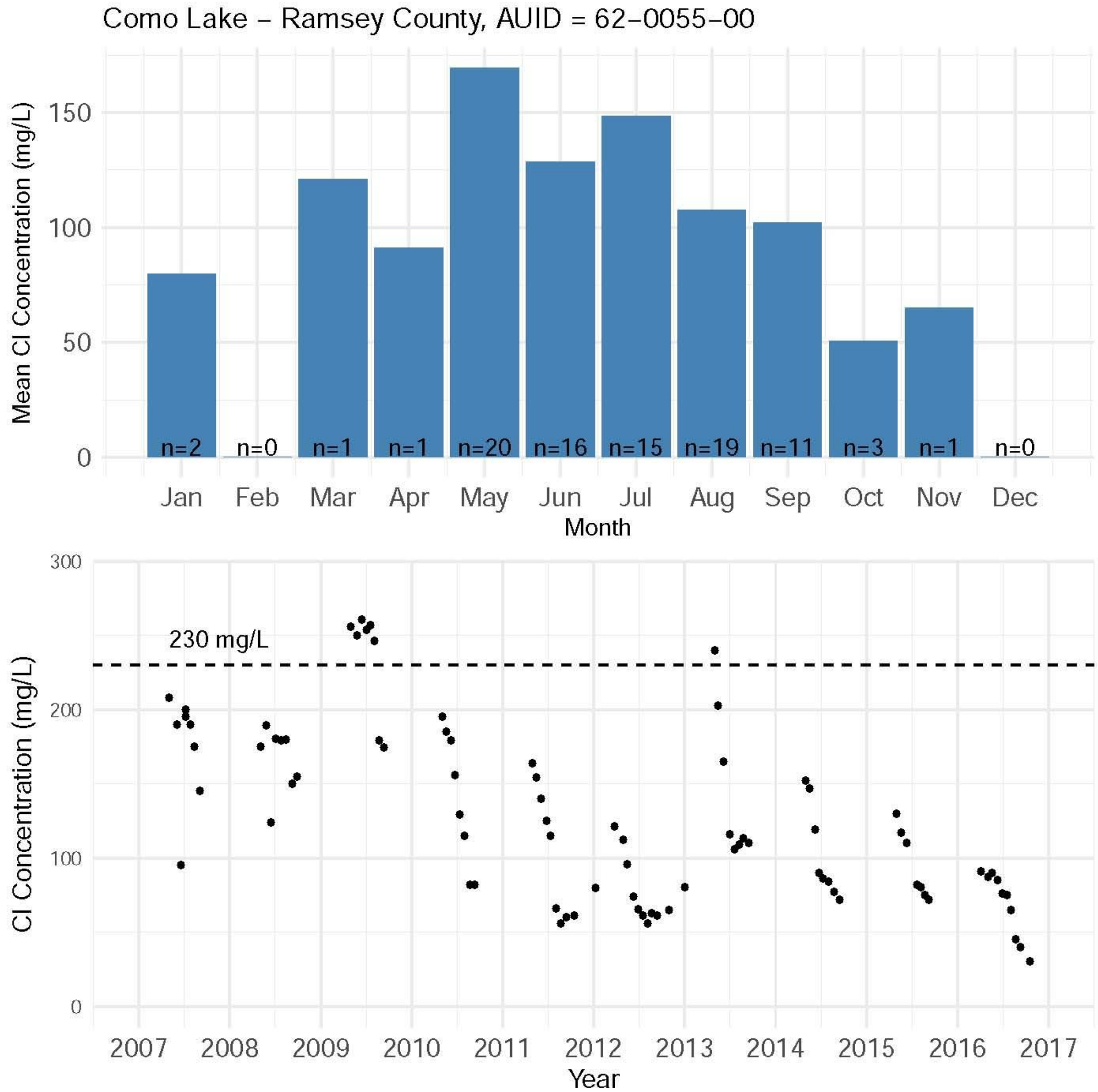


Figure 86: Chloride concentration trends in Como Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

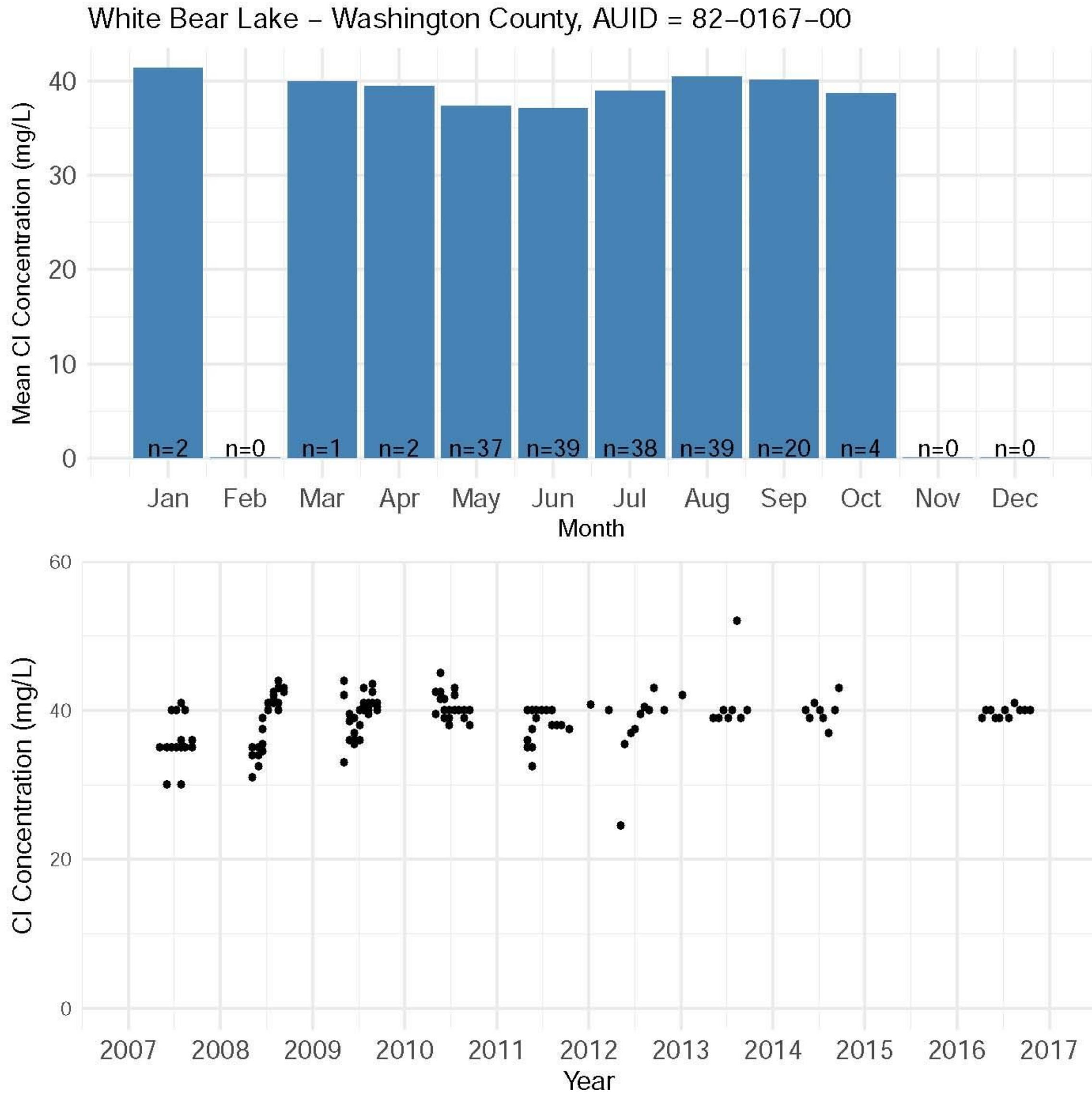


Figure 87: Chloride concentration trends in White Bear Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

Northern Glaciated Plains

The Northern Glaciated Plains is another largely agricultural ecoregion located along the South Dakota Border.

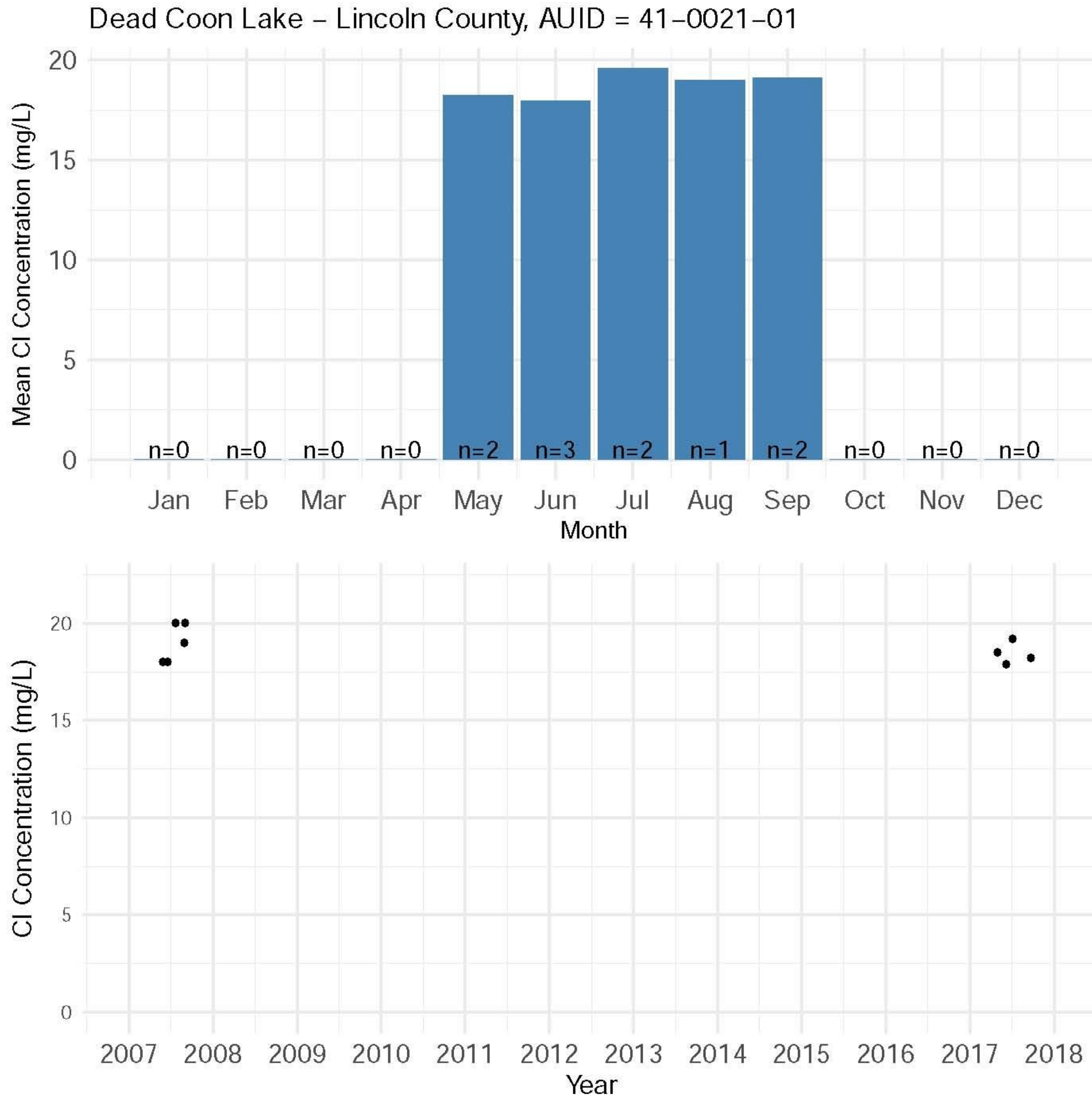


Figure 88: Chloride concentration trends in Dead Coon Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

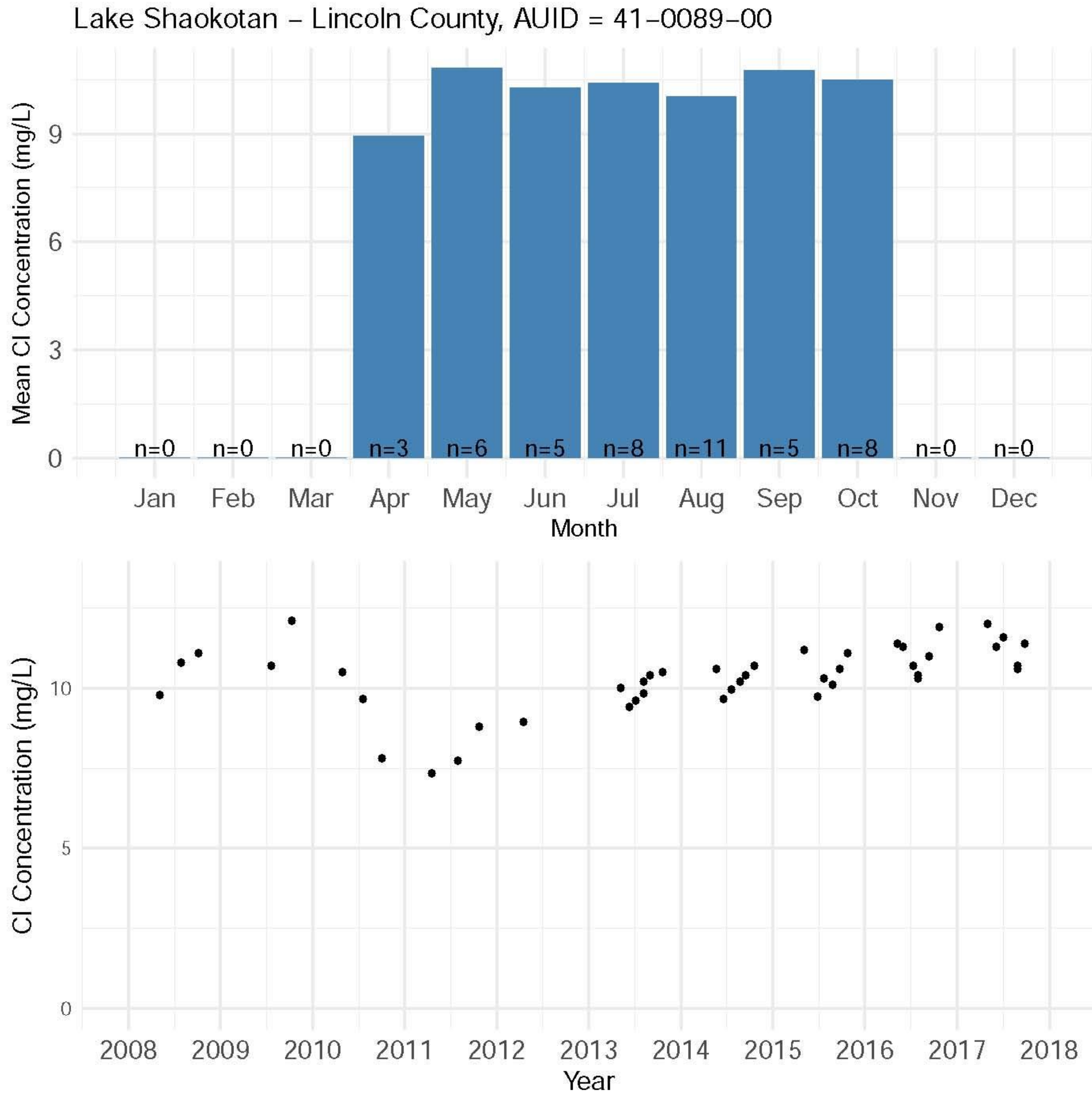


Figure 89: Chloride concentration trends in Lake Shaokotan.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

Northern Lakes and Forests

The Northern Lakes and Forests ecoregion covers the north eastern corner of Minnesota. The region is largely forested and lightly developed, with a large number of lakes.

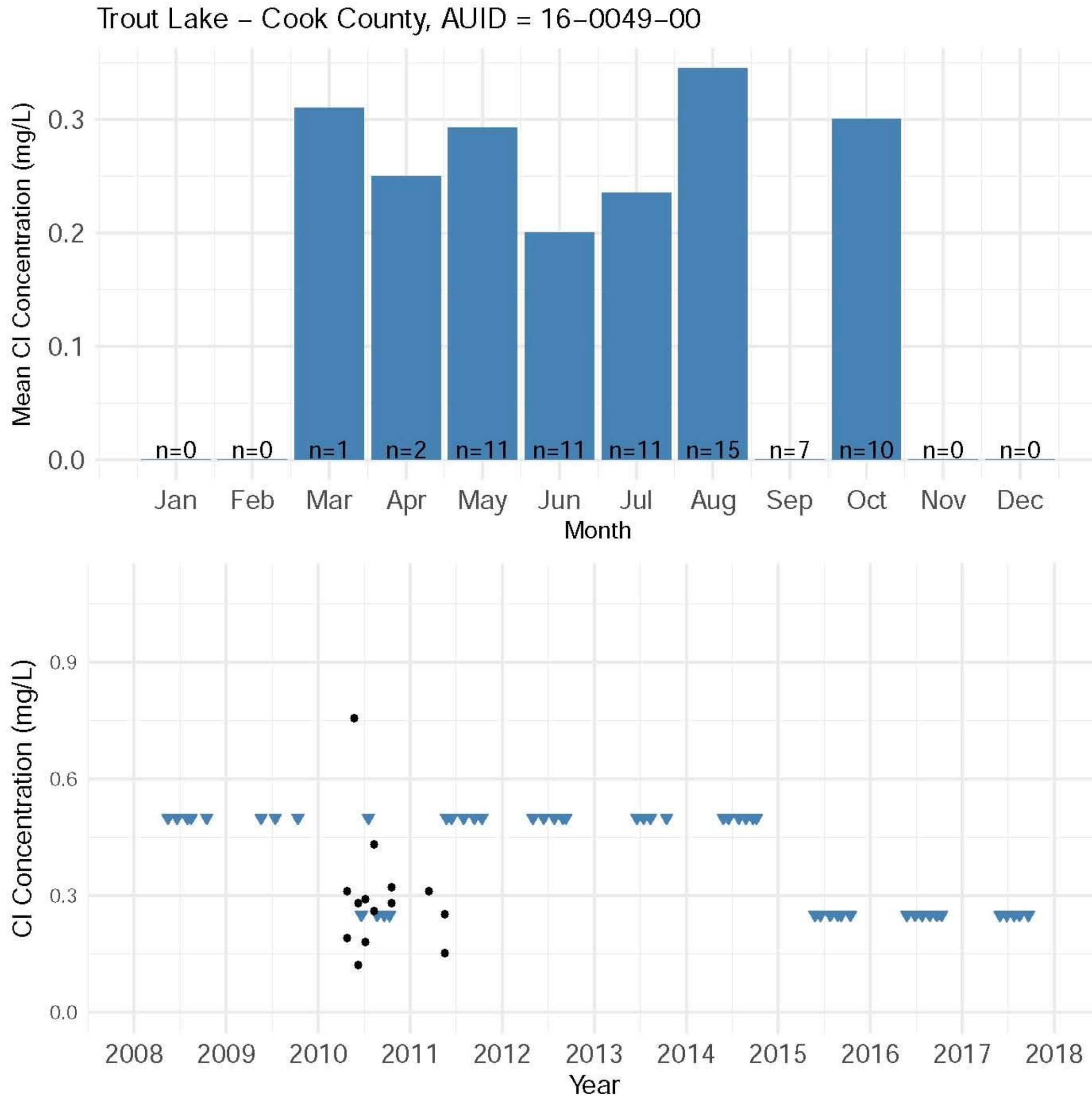


Figure 90: Chloride concentration trends in Trout Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

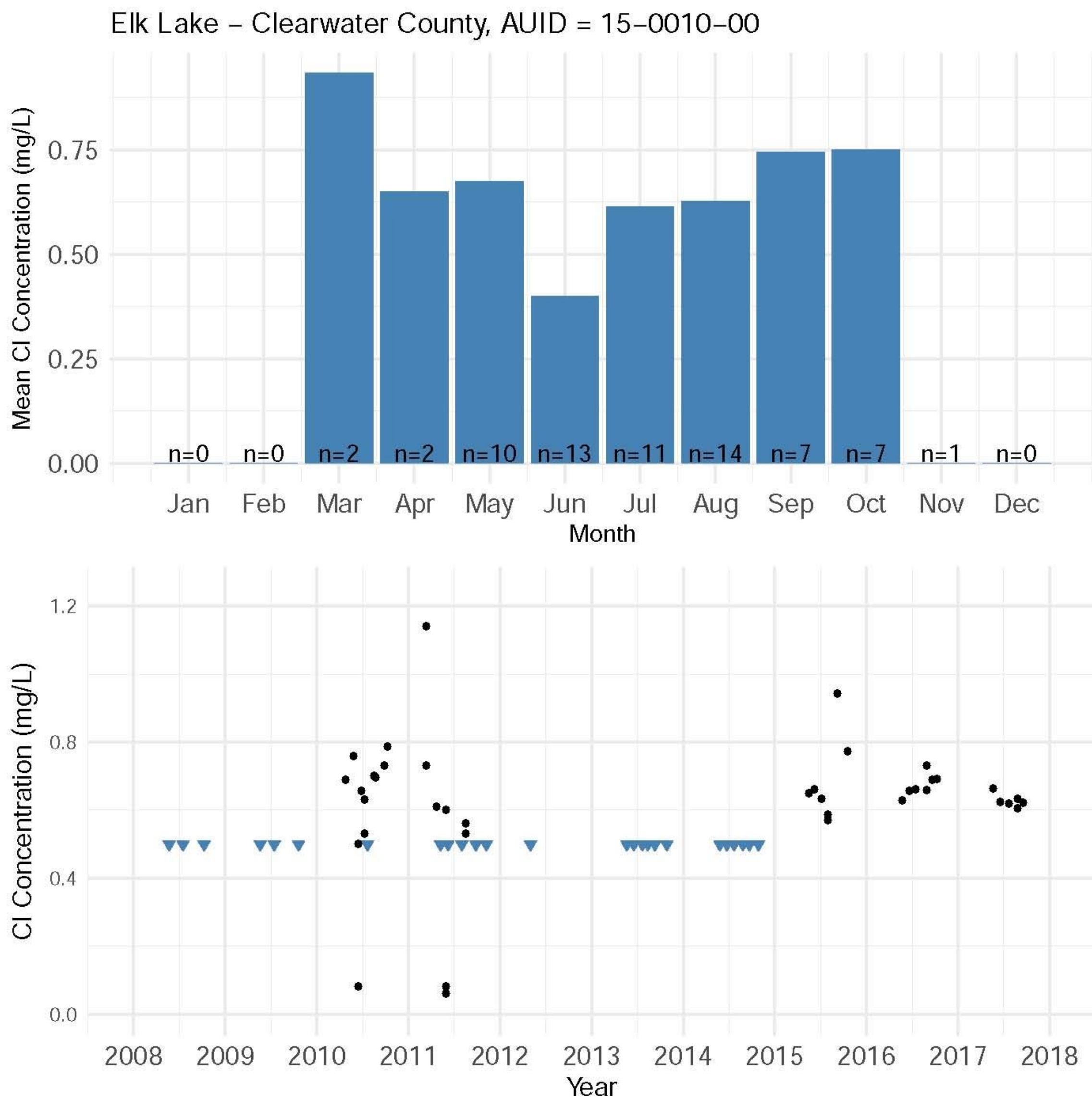


Figure 91: Chloride concentration trends in Elk Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

Northern Minnesota Wetlands

The Northern Minnesota Wetlands ecoregion, which borders with Canada, is known for its flat topography, which is covered in many wetlands, bogs, and marshes. There is little development or agriculture in this ecoregion.

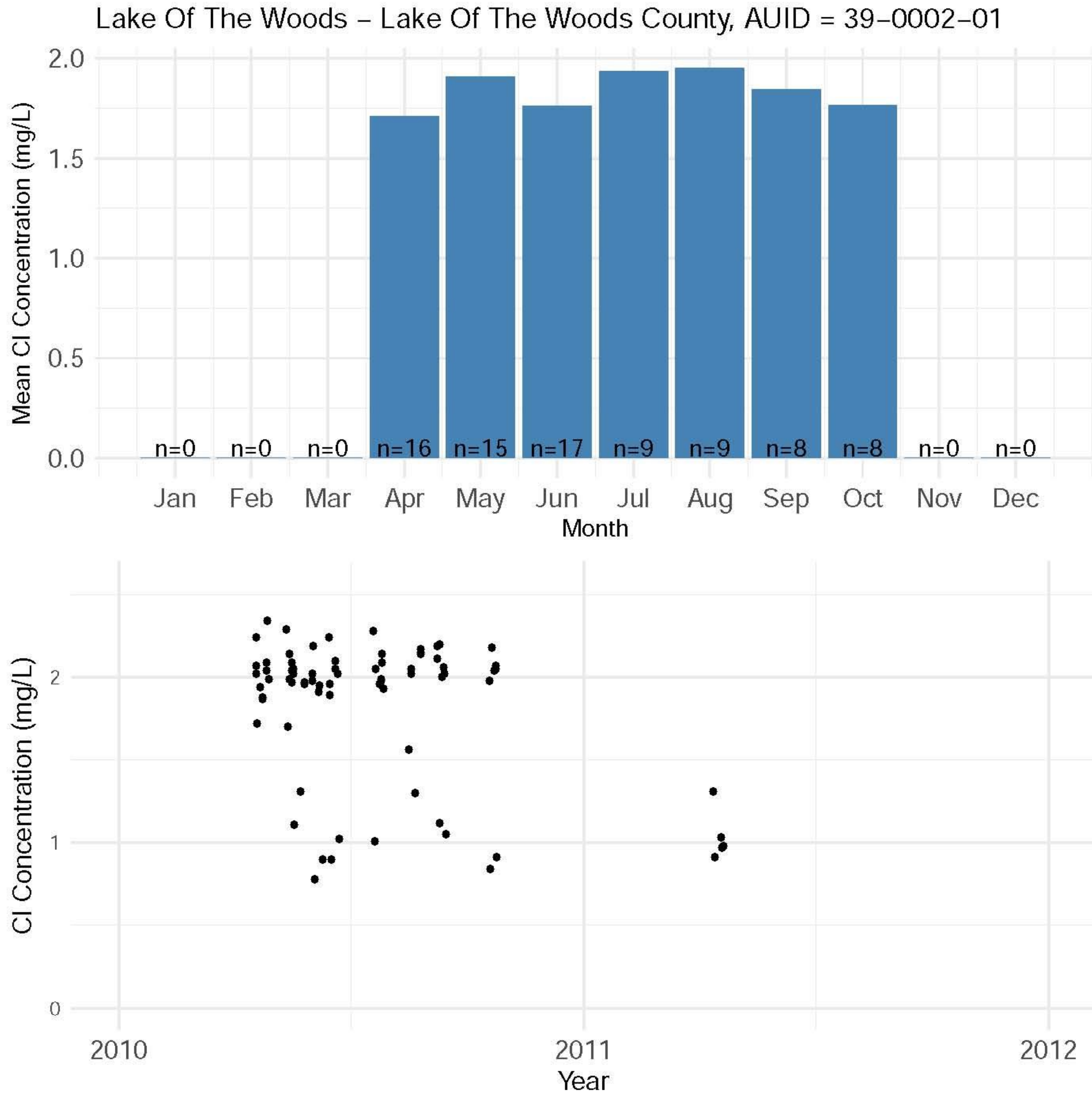


Figure 92: Chloride concentration trends in Lake of the Woods.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

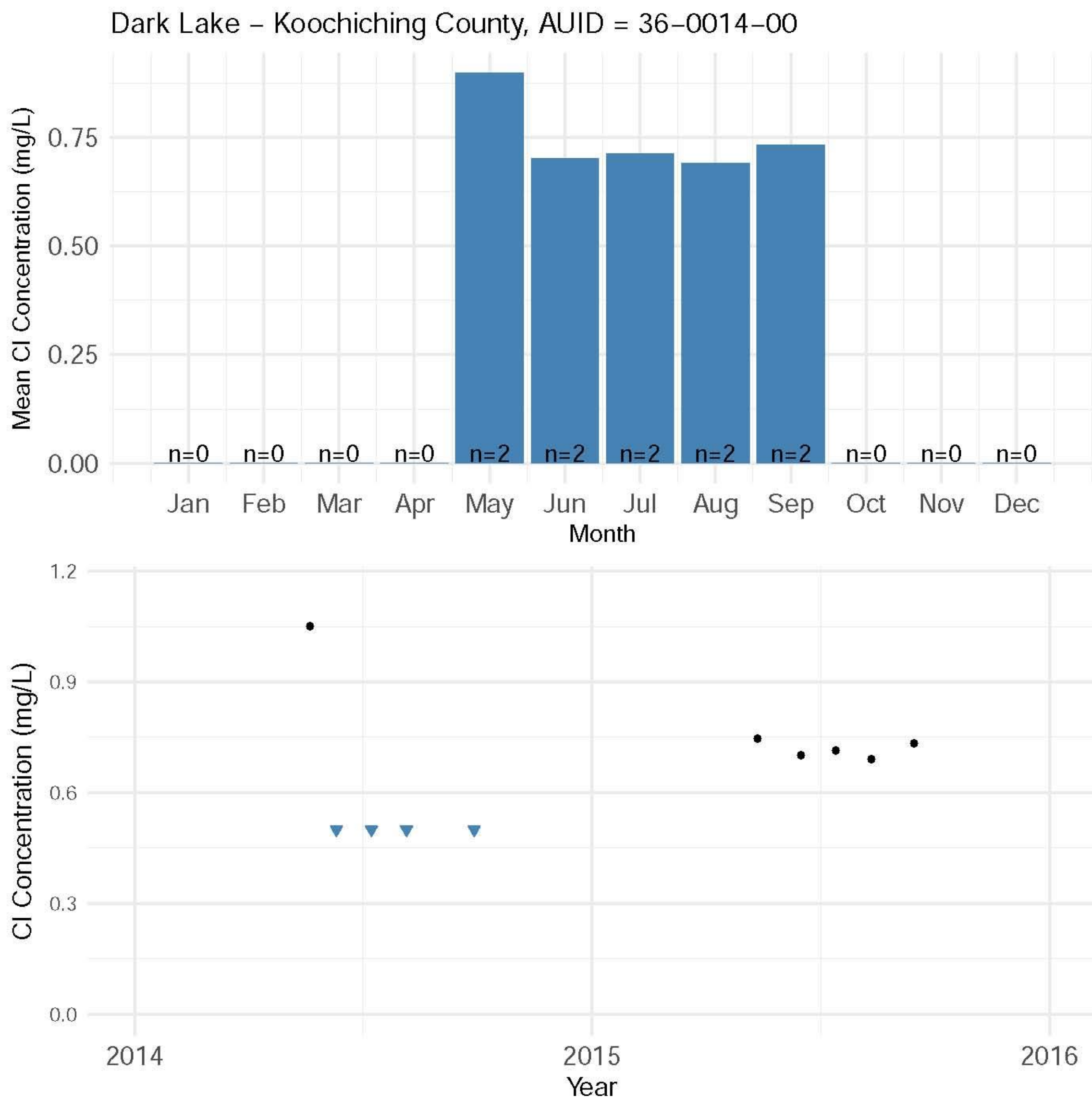


Figure 93: Chloride concentration trends in Dark Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

Western Corn Belt Plains

The Western Corn Belt Plains span much of the southern border of Minnesota. This ecoregion is the most heavily cultivated ecoregion in Minnesota.

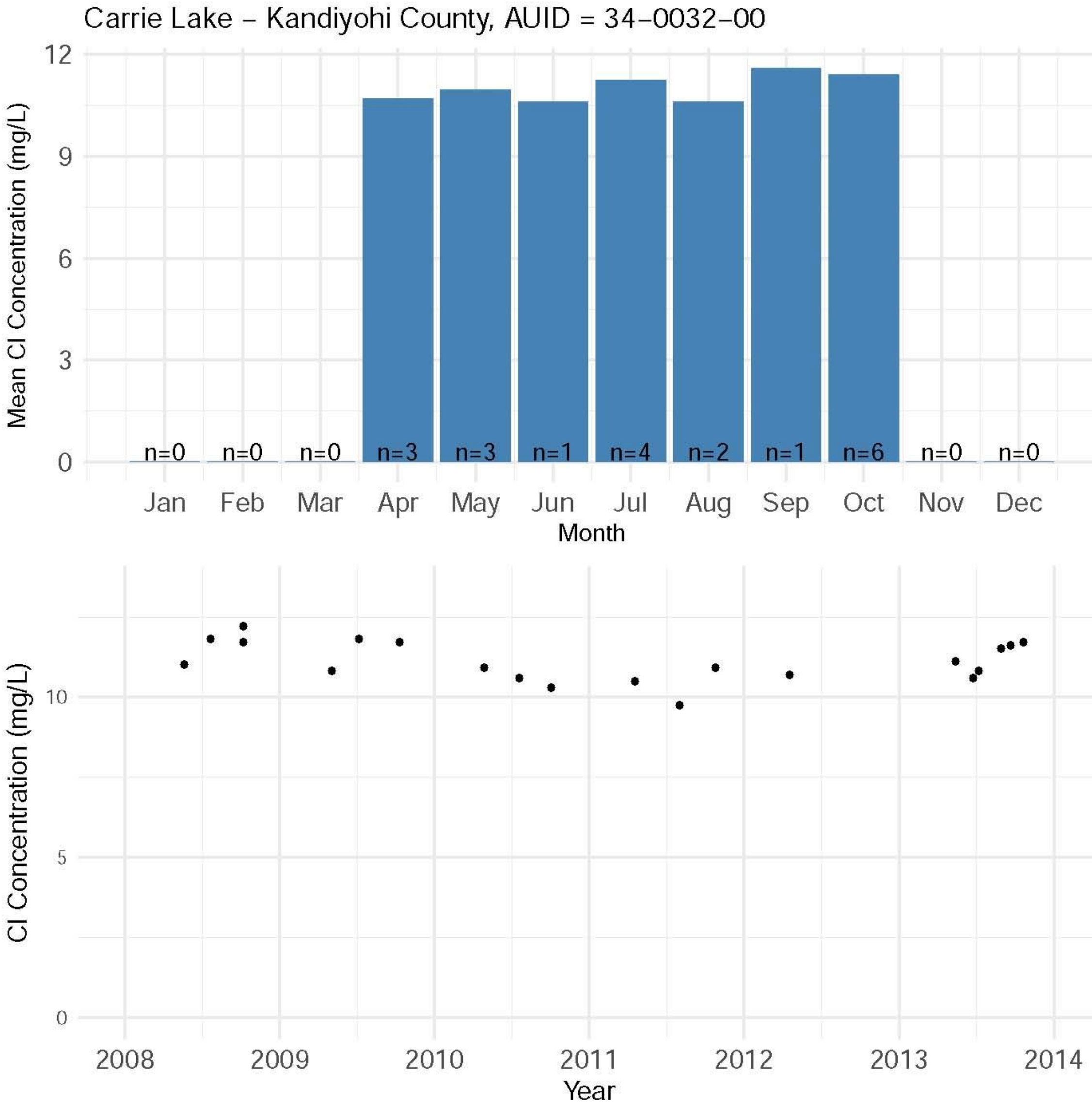


Figure 94: Chloride concentration trends in Carrie Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.

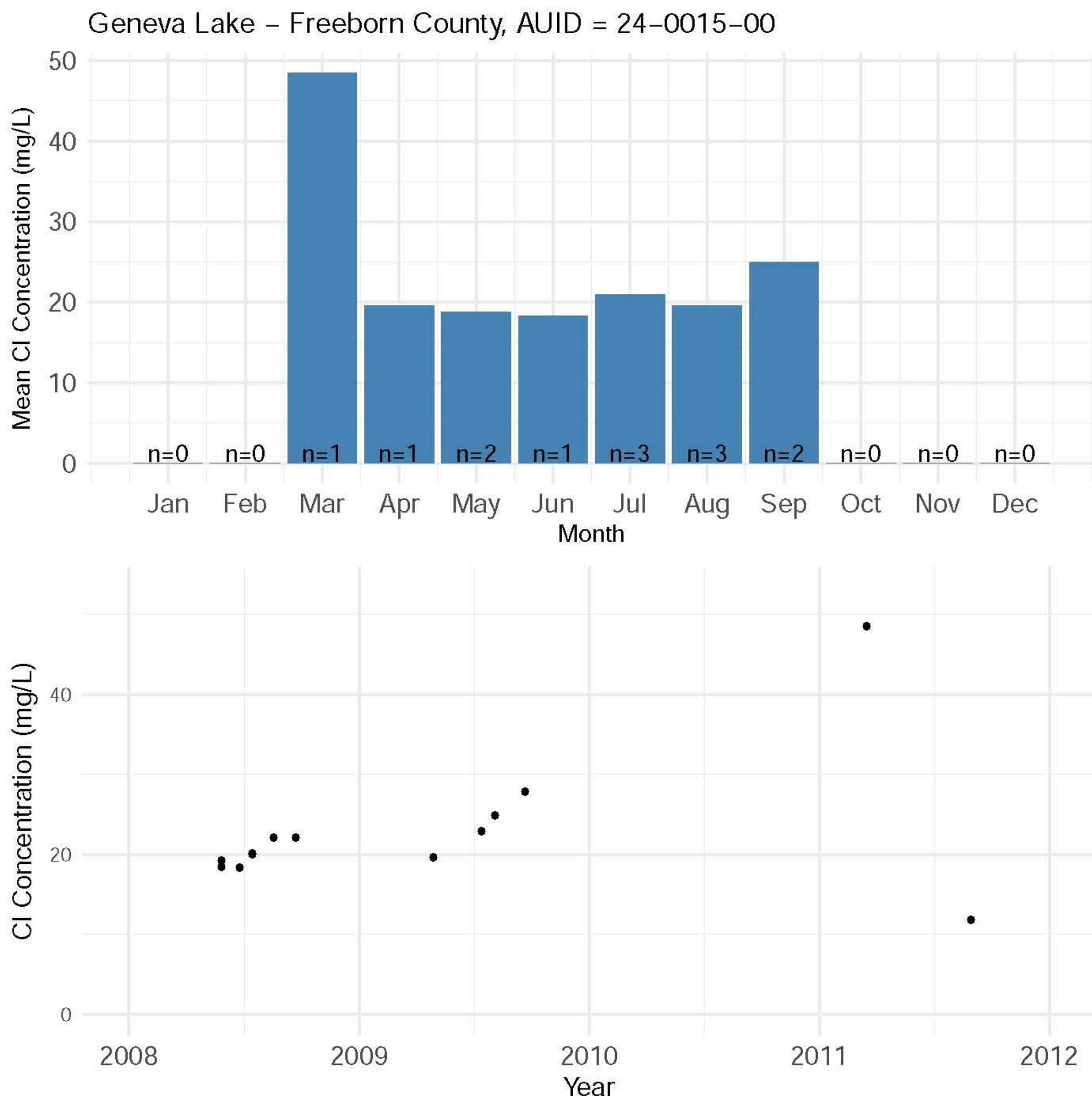


Figure 95: Chloride concentration trends in Geneva Lake.

Mean concentrations are Kaplan-Meier estimates to adjust for nondetects. Nondetects are symbolized by blue downward-pointing triangles and are drawn at half the reported detection limit.