Capitol Region Watershed District Chloride Pollution Prevention Plan

June 17th, 2026

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Saint Paul, Minnesota

Cover image: Road salt on sidewalk and parking lot area in business park within CRWD, Photo courtesy of Barb Thoman, CRWD MN Water Steward

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Key Terms

Anti-icing

Applying products (most commonly brine) before a storm to prevent or weaken the bond between pavement and snow/ice.

Baseflow

The sustained non-storm event flow in a channel or pipe dominated by subsurface flows (i.e. groundwater or surface water connection) that is usually at a relatively constant, slow velocity.

Brine

The combination of mixing a type of deicing agent (most commonly road salt) and water to create a liquid which can be used in place of solid (granular) road salt, or in addition to solid (granular) road salt to improve efficacy (Minnesota Department of Transportation [MnDOT], 2019).

Chloride

A negatively charged ionic compound of chlorine (Cl) that is bonded with another element, such as sodium (Na). Chloride is the most common compound in road salt and is a major pollutant of concern when it enters a water resource.

Chloride pollution

The introduction of chloride to the environment that causes contamination, degradation, or harm to natural resources, including surface waters, groundwater, vegetation, soil, and wildlife.

Chloride reduction strategies

Methods for winter maintenance that are aimed at reducing the amount of chloride used for managing snow and ice on all levels of paved surfaces.

CRWD

Referring to the physical land that makes up the area of the Capitol Region Watershed District.

De-icing

Applying products during or after a storm to melt residual snow/ice or to weaken the bond under snow/ice.

District

Referring to the Capitol Region Watershed District organization, staff, projects, and programs.

Impairment or Impaired water

A water that does not meet water quality standards or designated use; assessed and designated by the MPCA as defined by the federal Clean Water Act.

Level of Service

A qualitative measure describing operational conditions of a transportation system; defining what types of maintenance strategies will be used to clear a road to a certain pavement exposure, in a certain amount of time after a winter precipitation event. Road salt is used to maintain road conditions at a high level of service.

MS4 (Municipal separate storm sewer system)

MS4 stands for Municipal Separate Storm Sewer System and is defined by the MPCA as “a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains, etc) that is also: owned or operated by a public entity (which can include cities, townships, counties, military bases, hospitals, prison complexes, highway departments, universities, sewer districts, etc), designed or used for collecting or conveying stormwater, not a combined sewer, and not part of a publicly owned treatment works” (Minnesota Pollution Control Agency [MPCA], 2026).

Paved surfaces

Surfaces such as roads, sidewalks, parking lots, alleys, and driveways that may require winter maintenance practices like road salt application to help ensure safety during winter weather.

Permanent pollutant

A pollutant that cannot be feasibly removed from a water resource or the natural environment once it is introduced. Permanent pollutants can accumulate and increase over time, causing further contamination.

Road salt

Common term referring to sodium chloride (NaCl) or, the most common form of salt used on hard, paved surfaces (i.e. roads, sidewalks, parking lots, alleys, and driveways) to melt snow and ice, prevent ice formation, reduce slipperiness, and increase the safety of those surfaces.

Snowmelt

Water flowing through a pipe from a snow or ice melting event. Snowmelt can occur from snowpack when air temperatures stay above freezing and/or solar radiation causes melting, thereby generating liquid water that becomes runoff and flows into storm sewers.

Stormflow

Water flowing through a pipe during storm events resulting from precipitation. Stormflow usually occurs for a shorter amount of time in a pipe and has a high velocity.

Total Maximum Daily Load (TMDL)

The calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant (United States Environmental Protection Agency [USEPA], 2026).

Winter maintenance practices

Referring to all of the techniques, practices, and technology (e.g. plowing, sweeping, salting) that help various groups and entities (e.g. homeowners, school maintenance staff, large roadway public works departments) efficiently and effectively remove snow and ice from paved surfaces during the winter months to keep these surfaces safe and accessible for use.

1 Introduction

1.1 Overview

Capitol Region Watershed District (CRWD) in Ramsey County, MN is a 41-square mile urban watershed nestled in the Upper Mississippi River basin that includes portions of Saint Paul, Roseville, Lauderdale, Falcon Heights, and Maplewood. CRWD is the most densely populated watershed district in the state with 1 in 24 Minnesotans living within the boundaries (total population = ~245,000). The mission of the District is to protect, manage, and improve the water resources within CRWD boundaries, which includes 5 lakes (Como Lake, Crosby Lake, Little Crosby Lake, Loeb Lake, and Lake McCarrons), a 13-mile reach of the Mississippi River, and numerous ponds and wetlands. The District also manages stormwater that is generated from runoff from a 50%+ impervious surface coverage which eventually discharges to the Mississippi River through a complex network of storm sewer pipes and tunnels.

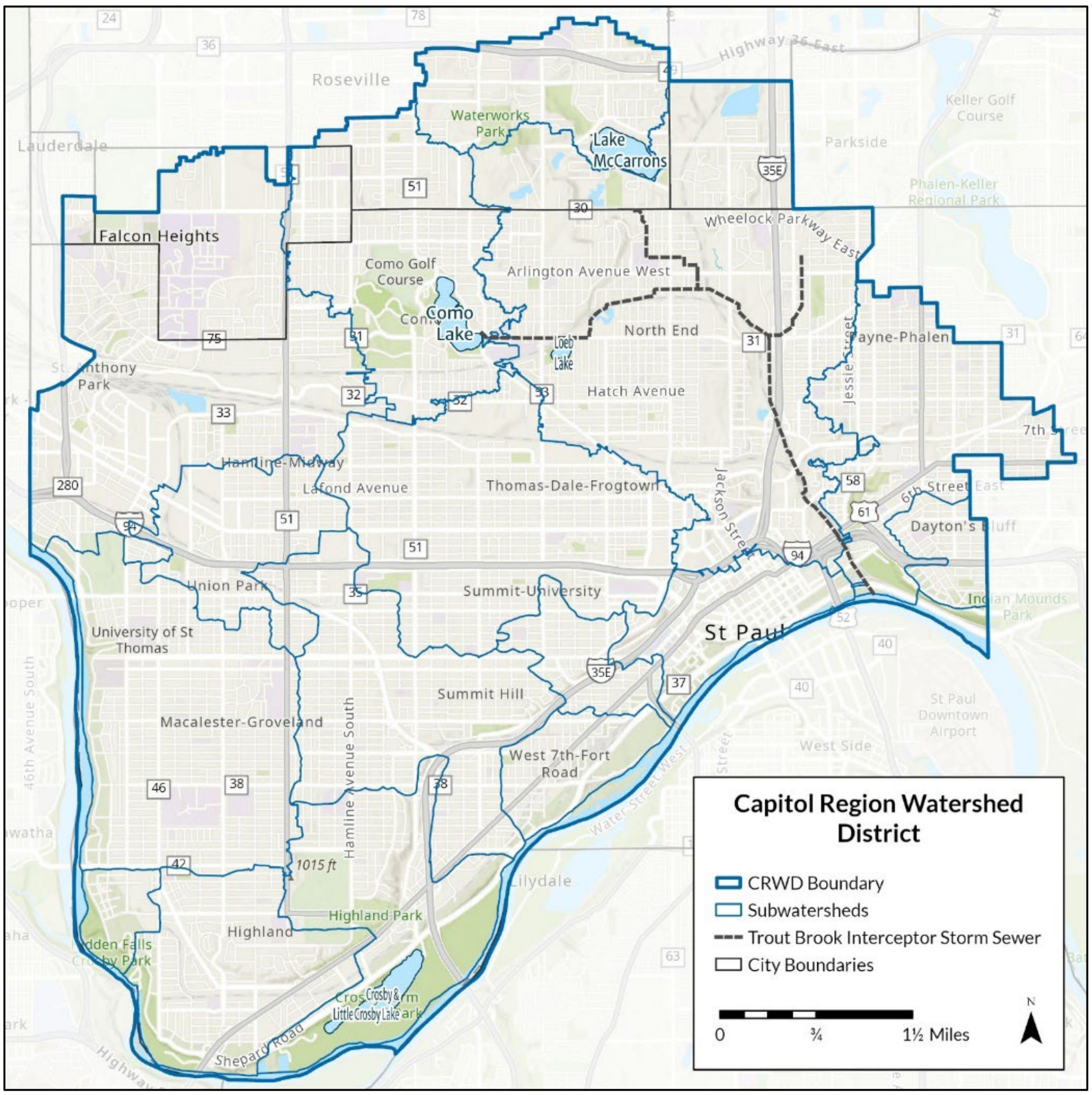

Figure 1: Map of Capitol Region Watershed District

In this fully developed, densely populated, and highly connected urban watershed, all activities that occur on the landscape have direct and immediate impacts to CRWD water resources— anything that ends up on impervious surfaces is subject to washing into the storm sewer system and becoming a pollutant. Common pollutants in CRWD's urban watershed include nutrients (e.g. phosphorus, nitrogen), solids (e.g. sediment), chloride, heavy metals (e.g. lead, copper, zinc), bacteria (e.g. *E. coli*), trash, vehicle fluids (e.g. oil, transmission fluid), and emerging contaminants (e.g. PFAS, microplastics). Preventing pollution from reaching water resources is both challenging and complicated because of the myriad sources of those pollutants as well as their sheer volume, scale, and widespread distribution. In addition, these pollutants have societal and economic implications which introduce other management complexities.

Chloride is a particularly complex pollutant to manage. It has emerged as a significant contaminant to CRWD's water resources over the past decades, and road salt application is known to be the primary source of chloride in CRWD (MPCA, 2016a; MPCA, 2020). Road salt is applied to paved surfaces (roads, sidewalks, parking lots, alleys, and driveways) to prevent the buildup of snow and ice during cold weather months to improve safety. When the weather warms or precipitation occurs, chloride on paved surfaces washes into storm sewers and discharges into lakes, wetlands, ponds, and groundwater. Once road salt is dissolved, chloride cannot be easily removed from a water body and is therefore considered a permanent pollutant. This results in detrimental effects to water quality and freshwater ecosystems. Chloride concentrations have been steadily increasing in CRWD water resources over time: Mississippi River chloride concentrations are increasing (Metropolitan Council Environmental Services [MCES], 2018), Como Lake has been listed as impaired for chloride since 2014 (CRWD, 2019; MPCA, 2016b), and Crosby, Little Crosby Lake, and Lake McCarrons are all listed as high risk of impairment (MPCA, 2025b).

Reducing the use of road salt and preventing chloride pollution in CRWD water resources is a top priority for the District. However, achieving this goal is complicated since road salt is relied upon as a public safety tool during cold weather months. CRWD's climate typically produces cold weather conditions that require ice and snow management from as early as October to as late as April. Additionally, Minnesotans have come to expect a high level of service for paved surfaces during cold weather months, and one of the primary methods for maintaining safe, non-icy surfaces is to apply road salt.

In addition, different types of paved surfaces are being maintained in the winter by varying groups and individuals who each use differing amounts of road salt and application methods. This makes reducing the use extra challenging because there is no singular source to target solutions. Instead, each "Applicator"— municipal, county, state, private, commercial, industrial, institutional, and residential— requires a customized approach to reducing road salt that is specific to their purposes and the paved surfaces they are responsible for managing. There are also many audiences in addition to applicators that are involved with or impacted by road salt issues, including: community members, policymakers, regulatory partners, researchers and scientists, developers, and partner groups. Each of these audiences has a role to play when addressing a challenge of this magnitude. Since the District is not a large-scale applicator of road salt, defining the District's role in addressing chloride pollution issues is critically important for guiding how the District can make meaningful contributions and impacts towards protecting water resources.

1.2 Purpose of the CRWD Chloride Pollution Prevention Plan (CPPP)

The CRWD Chloride Pollution Prevention Plan (CPPP or Plan) was developed in response to evidence of chloride pollution in CRWD lakes and is specific to road salt use and pollution issues occurring within CRWD's boundaries. The CPPP provides a comprehensive approach to addressing this multi-faceted and complex water quality issue in consideration of the District's role as well as the key audiences involved in the issues. The overall goal of the CPPP is:

> ***To reduce the use of road salt for winter maintenance in CRWD to prevent further degradation to CRWD's water resources, natural resources, and infrastructure from chloride pollution.***

The District has been working to reduce chloride pollution for many years by following the guidance of two essential plans created by the Minnesota Pollution Control Agency (MPCA):

1) Twin Cities Metropolitan Area Chloride Management Plan (MPCA, 2016a)
2) Minnesota Statewide Chloride Management Plan (MPCA, 2020)

The initiation of the CPPP came under the guidance of other recently adopted District Plans that identified chloride pollution as a critical water quality issue in CRWD, including the *CRWD 2021-2030 Watershed Management Plan* (CRWD, 2020b), the *Como Lake Management Plan* (CRWD, 2019), and the *Lake McCarrons Management Plan* (CRWD, 2020a). Additionally, the designation of multiple CRWD lakes as either impaired or at high risk for a chloride impairment (CRWD, 2020a; MPCA, 2016b; MPCA, 2025b) has further elevated the need for a coordinated approach for addressing chloride pollution in the watershed.

Other organizations across the Twin Cities Metro Area, including other watershed districts and watershed management organizations, have also pioneered innovative approaches to address chloride issues that the District has looked to for direction. While these plans and strategies provide excellent guidance for reducing the use of road salt at metro- and state-wide scales, the District recognized that a CRWD-specific plan was needed to:

- Provide a comprehensive and coordinated approach to road salt reduction in CRWD that is specific to the conditions within this highly urban watershed, i.e. local hydrology and hydraulics, current state of chloride in CRWD water resources, road salt application surfaces (types and total area), rates, and practices;
- Identify and implement effective District-led strategies that can reduce the amount of road salt used in CRWD to prevent further pollution of CRWD water resources; and
- Expand the District's work to fulfill additional roles and responsibilities in chloride pollution prevention.

The CPPP seeks to address chloride issues in CRWD by identifying and understanding the root causes of the problem and recommending feasible prevention strategies that aim to reduce the initial application of road salt. The CPPP is intended for use by District staff in partnership with all key audiences identified in the planning process. The CPPP is not intended to replace previously written plans, discontinue any current chloride-related work being done by the District, or provide detailed specifics on how the Plan actions might be implemented. The CPPP is meant to be a comprehensive summary of all the actions that can be done in CRWD to reduce road salt use, offer a way to prioritize identified actions, improve winter maintenance practices, and ultimately protect and improve our water resources without impacting safety.

The CPPP takes an adaptive approach to road salt reduction by adjusting the strategies through time in response to changes in existing conditions. The CPPP is a 10-year plan that should be reevaluated every 2 years to confirm the upcoming year's priorities and implementation strategy, and then fully revised at the end of the plan term to match future conditions. The chloride issue is dynamic with rapidly evolving science and solutions, so making the CPPP flexible and adaptable is necessary for its success.

2 CPPP Development Process

The CPPP was developed through a comprehensive, multi-step, collaborative process to:

- Analyze data to determine the extent of the chloride pollution problem in CRWD;
- Compile and understand all current work being done to reduce the use of road salt;
- Understand issues and barriers to reducing road salt use by engaging with key groups;
- Identify the District's role(s) and the key audiences that the District should work with to reduce road salt application;
- Develop the goals, objectives, and actions to guide future work; and
- Develop an implementation approach that includes key audiences and makes meaningful impacts toward reducing road salt use in CRWD.

Sections 2.1 through 2.5 summarize the key stages and outputs from the CPPP development process.

2.1 Data Analysis

While the District has been collecting chloride data since the monitoring program began in 2005, a complete analysis to-date has not occurred to give a big picture overview of the present state of chloride pollution in CRWD. As part of the CPPP development, a detailed assessment of chloride conditions in CRWD water resources was conducted, which established a foundation for advancing CPPP goals, objectives, and actions, and consisted of:

- Evaluations of District stormwater data to identify trends in different flow regimes and seasons;
- Comparisons of water quality datasets to the MPCA state standards;
- Determination of how increasing road salt inputs to CRWD lakes impacts lake chloride concentration, function, and long-term health; and
- An examination of data analyses completed by partners for CRWD water resources.

Section 4 describes the state of chloride and chloride impacts in CRWD water resources including stormwater systems, ponds, wetlands, lakes, groundwater, and the Mississippi River. Appendix A contains the complete results and analysis of the District's stormwater and lakes datasets.

Additionally, a GIS-based spatial analysis was completed to identify and quantify the paved surfaces within the District boundaries where road salt has the potential to be applied (Section 7). The identified paved surfaces were categorized by land use and ownership to further identify where and who is applying the majority of the road salt in CRWD. The results of this analysis were essential for developing actions in the CPPP, ensuring that the District's top road salt applicators are prioritized for outreach and funding to maximize reductions. Appendix B contains the spatial analysis methods and outlines how total area and percentage of paved surfaces by land use and surface type were calculated. Appendix C contains a table of the overall results of the spatial analysis for CRWD as a whole and all major CRWD subwatersheds.

2.2 Literature Review and Compilation of District Work-to-Date

A comprehensive literature review at local, regional, national, and international levels was completed to gain a broad perspective of chloride pollution issues, sources of chloride pollution, and road salt reduction strategies and best practices (Appendix D). Within the literature review summary, each study or report was given a rank of high, medium, low, or unknown with respect to its relevance to the District.

Alongside this larger literature review, all chloride-related work completed to-date by the District was compiled and examined to: understand current roles the District has focused on prior to the creation of the CPPP; summarize the current approach and identify gaps and strengths in the work we currently do; and better understand what parts of our current work should be expanded upon through the development of the CPPP.

This information was used to better understand what solutions are being identified and implemented in and around CRWD as well as what larger solutions could be implemented in the future. Appendix D contains the full summary of both the literature review and Section 5.2 describes current District work. Appendix E highlights current solutions in road salt reduction.

2.3 Engagement with Key Groups

The District conducted engagement on chloride issues with key groups to ensure that the CPPP was guided by the groups that would be most impacted by Plan Actions and/or who had a stake in carrying out Plan Actions. Engagement with four key groups consisted of in-person workshops to brainstorm answers to questions about chloride pollution and reduction. These key groups included: CRWD Board of Managers (Board), CRWD Community Advisory Committee (CAC), CRWD Staff (Staff), and a Technical Advisory Group (TAG) that consisted of partners from municipal, county, and state agencies. Each workshop prompted group discussion to generate answers to the following questions:

1) What emerging trends in chloride use, perception, behavior, or technology are you observing?
2) What are the main issues, constraints, and challenges to reducing chloride use in CRWD?
3) What is your organization's role in chloride management?
4) What should the District's role be in chloride reduction?
5) If there were no limitations, what would you do to reduce chloride pollution?

To engage the general public, a survey was conducted at three community events via direct conversation with attendees. This survey was also converted to an online format and disseminated through various District communication channels (i.e. website, social media, District newsletter, and partner organization's newsletters). This survey asked participants the following questions:

1) Tell us your level of concern (high, medium, or low) about the following issues related to de-icing salt use: Water Quality, Animals, Plants and Soil, Personal Property, and Public Infrastructure
2) What do you think should be done to use less salt or solve the chloride pollution problems in our watershed?

To understand the perspectives of private applicator groups (businesses, commercial property owners, and private winter maintenance companies that contract services to manage small public/private impervious surfaces throughout CRWD), the District utilized the engagement summary results reported in the Hennepin County Chloride Initiative (HCCI) instead of engaging with them directly (HCCI, 2020). This study conducted both qualitative interviews, as well as a quantitative survey, of private winter maintenance companies working in the Twin Cities Metro Area to gain a better understanding of the knowledge and behaviors of this key group to improve outreach and programming. The findings from this thorough report were considered when developing CPPP goals, objectives, and actions.

2.4 Issues and Roles Identification

Following all engagement activities, a complete write-up of the results was created to summarize the major issues identified by all groups, outline the primary role(s) the District should serve in this work, and generate a list of themes to be used as the building blocks for the creation of the CPPP. The five themes identified were: 1) Knowledge, 2) Education and Awareness, 3) Programs and Funding, 4) Policy, and 5) Collaboration and Partnerships.

Appendix F contains the complete results of all engagement sessions with the key groups (Board, CAC, Staff, TAG), and results of the public survey. The engagement efforts and the summary document were critical for developing the Plan goals, objectives, and actions.

2.5 Development of Goals, Objectives, Actions, and Implementation Plan

Using all of the findings generated from the engagement sessions, goals, objectives, and actions were developed which serve as the framework for the CPPP (Sections 8 and 9). The definitions for goals, objectives, and actions are:

- **Goals:** Represent the desired outcome over the life of the plan. They are intended to be broad and overarching and cover the five major themes of Knowledge, Education and Awareness, Programs and Funding, Policy, and Collaboration and Partnerships.
- **Objectives:** The components or sub-categories of each goal that need to be achieved in order to meet the goal.
  Actions: Listed underneath each objective, actions represent the recommended tasks, projects, and programs to be implemented through the CPPP.

Goals and objectives were reviewed by the Staff, Board, and CAC to ensure they were in alignment with District priorities and the overall goal of the plan. Actions were then developed underneath each objective. An implementation plan was created to show the estimated costs of each recommended action and to layout a schedule for implementation within the lifetime of the Plan (Section 10). A full review of all actions and the implementation plan occurred during the Plan review process by the Staff, Board, CAC, and TAG.

3 Chloride Issues in CRWD

3.1 Sources of Chloride in CRWD

Chloride (or sodium chloride (NaCl)) is an ion that is found naturally in the environment. Commonly known as rock salt, it can be mined and made available for a number of anthropogenic purposes, including fertilizers, dust control, water softening, and road salt for snow and ice control (MPCA, 2020). In northern climates, road salt (most commonly in the form of sodium chloride) is frequently used as a winter maintenance tool on paved surfaces because it lowers the freezing point of water. This makes it difficult for ice to form or for snow to freeze and turn to ice. This generally increases the safety and usability of these surfaces during the winter months. In Minnesota, the application of road salt is one of the primary winter maintenance approaches used statewide to reduce icy conditions on paved surfaces.

Road salt use for winter road maintenance has been a standard practice in the United States since the late 1930s, with road salt sales data indicating a steep increase in the 1960s (MPCA, 2020). Because road salt is relatively inexpensive to buy, effective at melting snow and ice, and is easily attainable, it has become widely used by road managers, property managers, and individual households. Road salt can be used for both anti-icing (preventing the buildup of ice on a surface in advance of winter precipitation), de-icing (working to reduce and remove ice after winter precipitation has occurred), and to make brine (created when combining granular road salt with water, forming a liquid that can be more efficiently applied to surfaces and reduces the amount of salt needed). This makes it a versatile tool for winter maintenance.

The application of road salt for winter maintenance is known to be the primary source of chloride in CRWD (MPCA, 2016a; MPCA, 2020). Approximately 33% of the total area in CRWD consists of paved surfaces where road salt has the potential to be applied for winter maintenance (Figure 2) which results in a significant amount of application in the watershed annually.

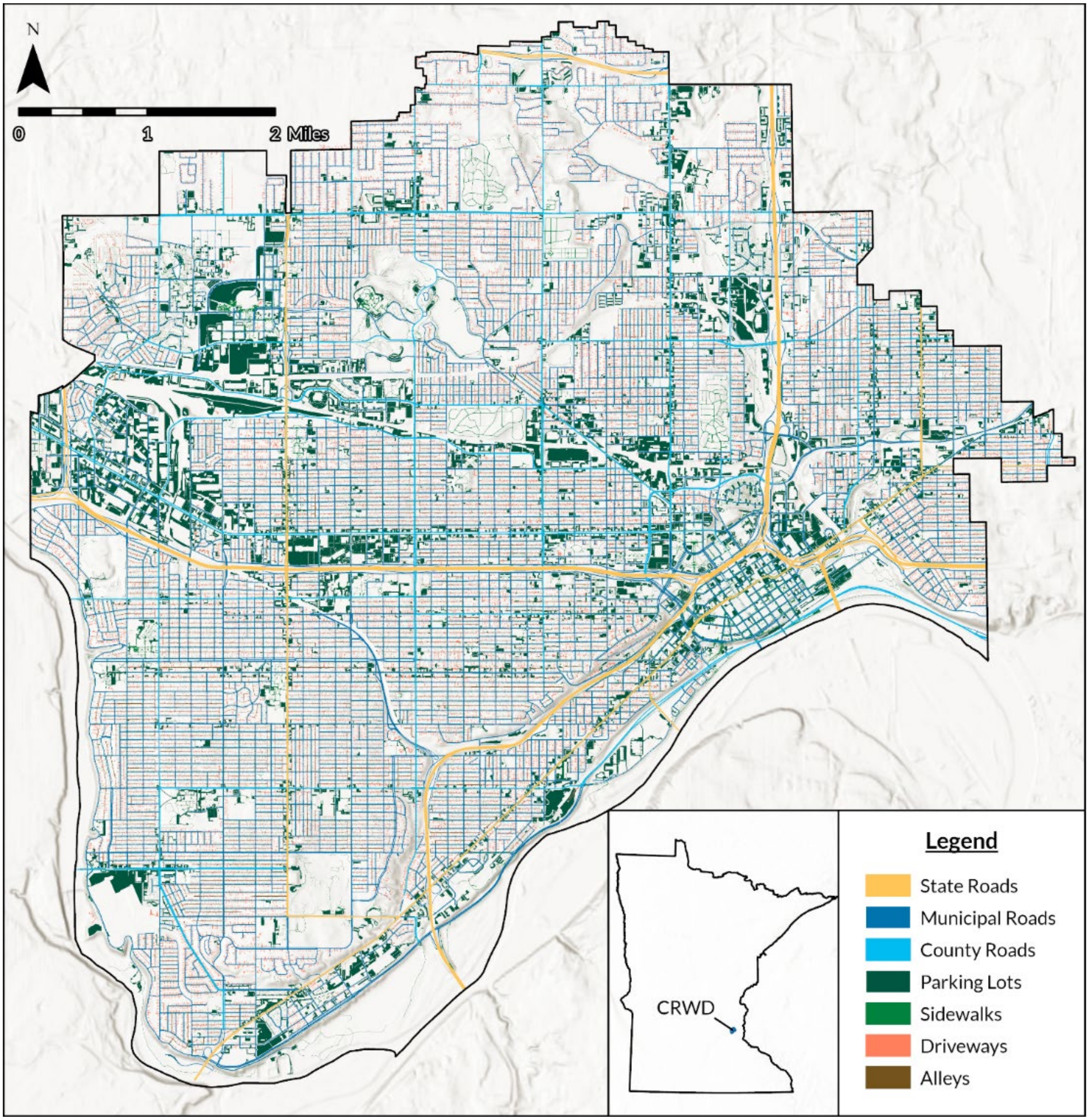

Figure 2: Map of paved surfaces with potential for road salt application in CRWD

3.2 Negative Impacts from Road Salt Use

Once road salt is applied to paved surfaces for winter maintenance, it eventually washes into storm sewers through runoff and then discharges into receiving waters or basins, like lakes, wetlands, rivers, stormwater best management practices (BMPs), or groundwater. Once chloride enters a receiving water or basin in dissolved form, it accumulates and cannot be removed in a cost-effective way.

While using road salt for winter maintenance can make paved surfaces safer for humans to use, its direct introduction to the environment via these surfaces results in chloride pollution, and has the following impacts:

- **Degradation of water quality:** Once road salt is applied to impervious surfaces, runoff from precipitation or snowmelt flushes it into storm drains where it is then transported to surface water bodies (ponds, wetlands, lakes, and rivers) and groundwater. Chloride-laden runoff can also flow onto land or dry basins which transports it to groundwater via the soil. Impacts of this are:
    - Chloride is a permanent pollutant: there is no cost-effective way to remove it from water once it enters a water resource, and a single teaspoon of salt can permanently pollute five gallons of water (MPCA, 2025a).
    - Even water bodies with minimal road salt application in their watershed can still sometimes face exceedances of water quality standards due to historic accumulation (MPCA, 2020).
    - Chloride can inhibit lake turnover and stormwater pond function by creating a saline water layer that sinks and stays on the bottom of the water body, as chloride-laden water is more dense than freshwater (MPCA, 2023).
- **Risks to wildlife**: Chloride can be toxic to birds, fish, and aquatic bugs that live in or rely on water resources like ponds, wetlands, lakes, and rivers. It can also sicken pets that lick salt off their paws or consume salty runoff.
- **Risks to human health:** Chloride can permanently pollute groundwater used for drinking water supplies. In Minnesota, 75% of residents rely on groundwater for drinking water (MPCA, 2025a).
- **Harm to plants:** Chloride can harm and kill both terrestrial and aquatic vegetation. It can also allow for conditions in which invasive plants can thrive over native species, causing major changes to plant community structures.
- **Harm to soil:** Chloride can contaminate soils, which also further degrades groundwater resources where salt infiltrates. Soil that has been saturated with salt is also less able to retain water and nutrients, which can lead to compaction or erosion (Weisenhorn et. al., 2026).
- **Damage to public and private property and infrastructure:** Chloride can cause rusting on vehicles and can also severely decrease the lifespan and safety of concrete/asphalt pavements and bridges.

3.3 Water Quality Degradation from Chloride Pollution in CRWD

The degradation of water quality from chloride pollution is the impact of most concern to the District. The District's mission is to protect, manage, and improve the water resources of CRWD and the Mississippi River, so addressing chloride pollution in water resources strongly aligns with current priorities.

The severity of chloride pollution in CRWD has been confirmed by monitoring data collected over multiple decades that show increasing chloride levels in all water resources. Of highest concern to the District is the impairment status of CRWD lakes. To protect aquatic life from chloride pollution, the US Environmental Protection Agency (USEPA) established state standards for chloride in classified surface waters: a chronic standard of 230 mg/L and a maximum standard of 860 mg/L (USEPA, 1988). The MPCA evaluates exceedances of these standards and an impairment is considered where there are two or more exceedances of the chronic standard, or one exceedance of the maximum standard, over consecutive three-year periods (MPCA, 2024a). Lakes that do not meet the state standards are considered impaired. Lakes considered high risk are identified by the MPCA as having had one or more samples with a value equal to or greater than 120 mg/L. Como Lake was listed as impaired for chloride in 2014 and included in the 2016 Twin Cities Metropolitan Area Chloride Total Maximum Daily Load Study (MPCA, 2016b; CRWD, 2019), and Crosby Lake, Little Crosby Lake, and Lake McCarrons are all considered high risk for impairment based on current trends and threshold exceedances (CRWD, 2020a; MPCA, 2025b).

Additionally, CRWD borders 13 miles of the Mississippi River to which all stormwater runoff from CRWD eventually discharges. The Mississippi River has also exhibited extremely large increases in chloride concentrations over the last three decades (MCES, 2018). Unfortunately, these trends will not change unless the use of road salt for winter maintenance is reduced.

3.4 Challenges to Road Salt Reduction in CRWD

While chloride pollution is widely confirmed by the District, partners, scientists, and the literature to be a significant problem, finding an effective solution to road salt use is complicated. Chloride pollution is costly—both environmentally (Section 3.2 and 3.3) and economically (Dindorf & Fortin, 2014)—but those costs do not yet outweigh the public safety benefits that road salt provides. Reducing road salt use, therefore, is highly complicated and has many challenges and barriers that prevent meaningful change.

An overarching issue that drives the chloride problem in CRWD is that snow and ice management in northern climates is absolutely necessary during the winter months to keep paved surfaces safe and useable and road salt is currently one of the most effective tools available for that purpose. CRWD contains the most densely populated area in Minnesota and serves as a vital economic core, so having continued functionality of transportation infrastructure during the winter is essential. This includes maintaining snow and ice on paved surfaces for driving, parking, biking, walking, and ADA compliance.

As the population has grown and development has expanded, the pressures on paved surfaces have increased through time, causing an increased reliance on fast and effective winter maintenance practices that currently demand the use of road salt. In addition, the infrastructure within CRWD was not specifically designed to accommodate winter weather to prevent the need for road salt application and instead were built in a way that requires active maintenance during snow and ice conditions. The population is also not always prepared to operate in winter conditions (e.g. footwear, snow tires, restricted street parking) yet at the same time demands a high level of service (i.e. clear pavement within a short time after winter events occur) from their paved surfaces. This public demand can result in a reliance upon road salt for functioning in winter.

Identifying and understanding key challenges and barriers for reducing the use of road salt was a focus of the literature review (Appendix D) and the engagement workshops (Appendix F). The results from both efforts are listed in Table 1 and reinforce that there is no one solution that will reduce road salt use and prevent chloride pollution in CRWD water resources. It is going to take a multi-faceted approach by the District and all impacted audiences, with solutions that encourage both voluntary changes as well as mandatory requirements to see measurable change.

Table 1: Challenges and barriers to road salt reduction with descriptions

Challenge/Barrier	Description
Scale	Road salt is applied by numerous applicators ranging from large public works crews managing roadways of varying sizes, to individual homeowners managing their sidewalks, so it's hard to target reduction efforts to so many different scales of applicators and surfaces.
Normalization	Because it is "nontoxic" to humans (i.e. we use salt on a daily basis for food consumption), society has become accustomed to its ubiquitous use and even overuse. Therefore, road salt is not viewed with a high enough level of concern that will be required to reduce or stop the use of this permanent pollutant.
Awareness	There is a lack of awareness of chloride pollution and its impacts among all individuals in our society ranging from community member to community leader that can result in increased chloride use by all different types of applicators.
Collaboration	Challenges exist to collaboration and communication across agencies and sectors. There is great chloride pollution reduction work happening at different levels, but it lacks a central voice to bring all of this work together to elevate and see larger scale change and reductions.
Expectations	Overall public expectation of level of service for various public and private surfaces in the winter/spring (i.e. bare pavement following winter weather) is unsustainable and can lead to overuse of road salt.
Funding	While many applicators may have the knowledge or experience to enact best management practices, lack of money and time can be a barrier to implementation. There is also inadequate funding at the state level to match the need for solutions in both improved practices as well as more research for alternatives and technology.
Policies	There are a lack of policies, regulations, and/or mandates to require training and tools for reduction, limit liability of private applicators, etc.
Alternatives	While there are other deicing alternatives for different scales of impervious surfaces available (such as sand, grit, organic brines, beet molasses, calcium magnesium, and potassium acetate), none of them are currently as effective as road salt for the cost of use. Additionally, all deicing alternatives also have negative environmental impacts of use.
Costs	Total cost estimates of road salt application don't take into account the environmental and infrastructure damage costs of use, resulting in a drastic underrepresentation of the total overall cost of road salt use. A 2014 MPCA report produced by Fortin Consulting, Inc estimated the financial impacts of road salt use to be $800-3,300/ton of salt applied (Dindorf & Fortin, 2014).
Climate	Climate change is changing winter precipitation and temperature. While this could result in an increase in freeze-thaw cycles, which could drive more frequent and intensive applications of de-icing salts, it could also result in decreased precipitation that could affect stormwater runoff and the flushing of chloride into/out of various water resources (MPCA, 2020). The 2025 CRWD Climate Resiliency Framework highlights additional trends and their impacts, and also includes activities for chloride reduction (CRWD, 2025).

4 Chloride Pollution in CRWD Water Resources

The District works in partnership with other organizations to monitor and manage numerous water resources within CRWD. Monitoring data has shown very concerning chloride concentrations with increasing trends in CRWD water resources. The water quality impacts and trends are summarized below. See Appendix A for the full data analysis of the District's stormwater and lakes datasets.

4.1 Stormwater

Storm sewer pipes define the hydrology and water quality in CRWD since there are no natural or above-ground streams present. All storm sewers in CRWD discharge stormwater directly to CRWD lakes and the Mississippi River. Stormwater is not classified as a surface water by the MPCA and therefore does not have state water quality standards to comply with or compare to, though it is typically highly concentrated with pollutants from runoff.

The District installs and maintains monitoring stations at key storm sewer locations in CRWD to evaluate the contribution of stormwater to water resources. State chloride standards apply to CRWD lakes and the Mississippi River, so stormwater data is essential to show how much chloride enters these water resources from stormwater. Additionally, high values of chloride in stormwater also cause degradation to stormwater infrastructure over time, requiring pipes and underground stormwater systems to be repaired or replaced more frequently, or in severe cases, can cause infrastructure failure.

The analysis of the District's stormwater data corroborates previous analyses (MPCA, 2016a; MPCA 2020) which indicate that urban stormwater can have very high chloride concentrations with high seasonal variability. Snowmelt samples collected at key CRWD storm sewers had the highest values of all three monitored sample types (base, storm, and snowmelt) and 13 of the 15 monitored stations had snowmelt median values above the chronic state standard of 230 mg/L (Figure 3). Additionally, winter samples from all three sample types also had the highest values from all four seasons. These data indicate that chloride from road salt used in winter maintenance is the main driver of high and increasing chloride concentrations observed in CRWD water resources.

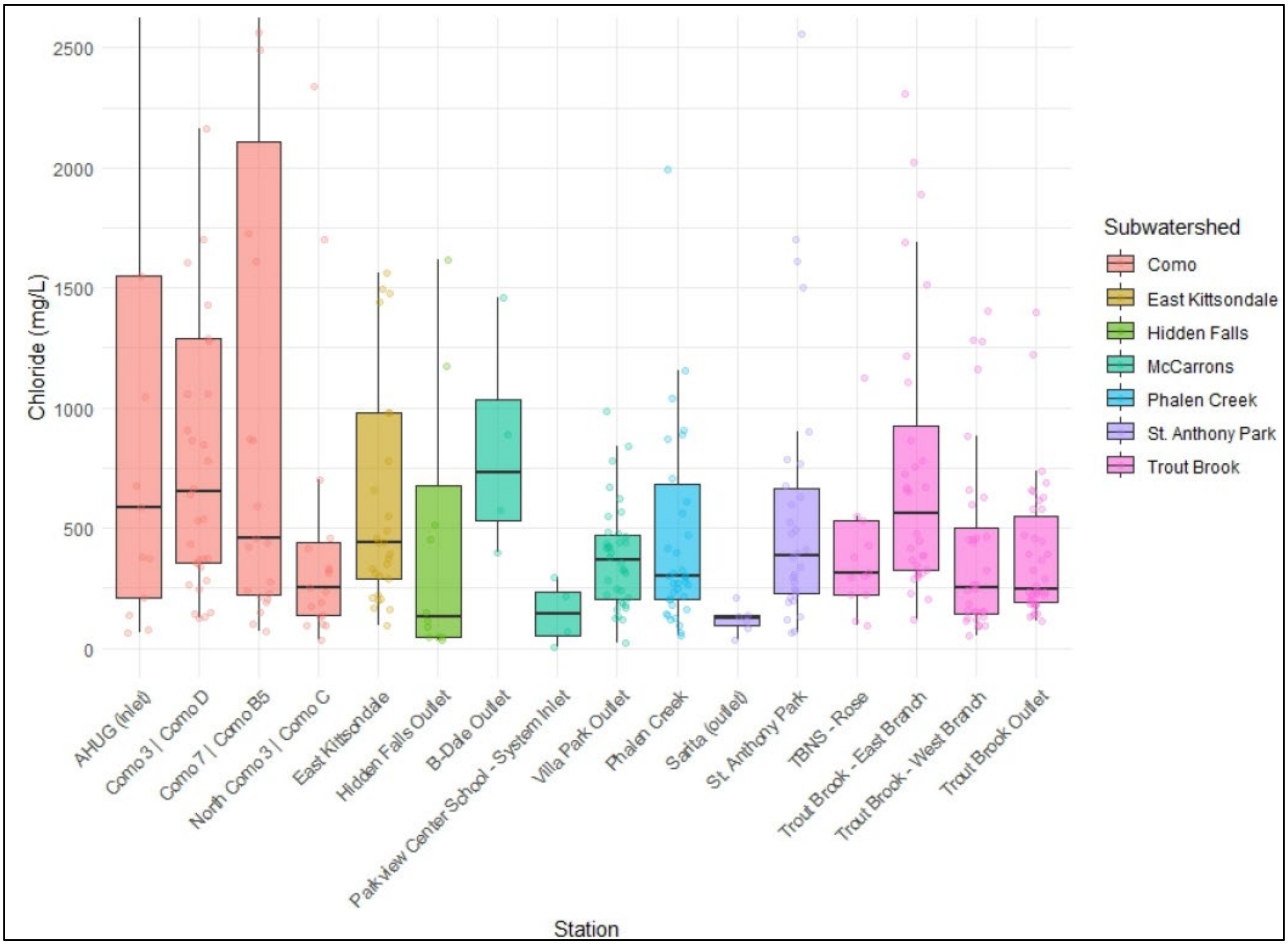

Figure 3: Boxplots of snowmelt chloride concentrations at each District stormwater monitoring location (Appendix A)

4.2 Ponds and Wetlands

Research has shown that road salt inputs have detrimental impacts to urban ponds and wetlands. Recent findings by University of Minnesota researchers offer evidence that chloride can negatively impact turnover of stormwater ponds by creating a dense, salty layer at the bottom of the pond, which in turn exacerbates anoxic conditions and can lead to phosphorus release (McDivitt, 2019). High levels of chloride on the bottom of stormwater ponds can also cause the release of heavy metals bound to sediment (McDivitt, 2019). Data from a study conducted by researchers at the St. Anthony Falls Laboratory examining chloride concentrations into and through three ponds in CRWD showed that these urban detention ponds have a high chloride residence time and slowly export chloride during the entire open water season after building up chloride during the winter and spring runoff period (Herb, 2017). These findings are important in CRWD given how valuable stormwater ponds are for retaining stormwater in our highly developed area and for storing phosphorus and heavy metals in pond sediments. In addition, many of CRWD's ponds and wetlands eventually discharge to lakes and the Mississippi River, resulting in additional downstream impacts.

Data collected by the District also demonstrates the severity of this problem. The District collects base, storm, and snowmelt samples from the Villa Park Wetland outlet, a large wetland system in Roseville that discharges to Lake McCarrons. This monitoring location has the highest median storm sample concentration (81 mg/L) of all monitored stormwater sites (Figure 4), confirming the above understanding that stormwater ponds and wetlands can become sinks for chloride during periods of runoff in the winter and spring, and then flush into downstream water bodies during rain events throughout the year.

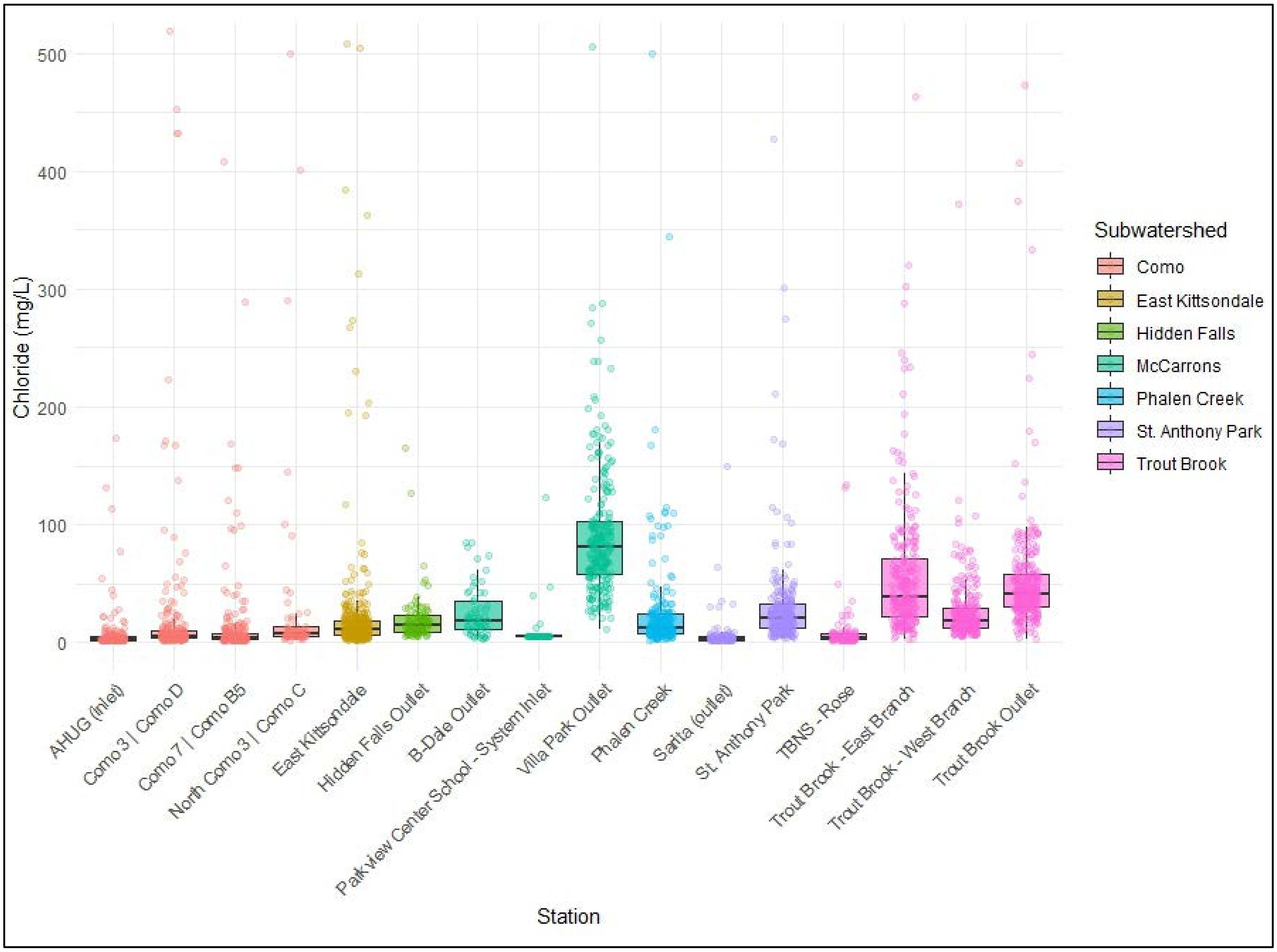

Figure 4: Boxplots of stormflow chloride concentrations at each District stormwater monitoring location (Appendix A)

Therefore, increasing levels of chloride in stormwater ponds and wetlands will continue to be a concern for management not only for how ponds and wetlands function as a stormwater resource, but for the further impact to downstream water resources long after road salt has been applied.

4.3 Lakes

There is immediate cause for concern when examining trends in chloride concentrations in all five CRWD lakes (Figure 5), which show either increasing annual trends (Como, Loeb, and McCarrons), or have a somewhat static trend but high annual concentrations (Crosby, Little Crosby) (see Appendix A for individual lake analyses and figures). High levels of chloride in a lake can be toxic to aquatic organisms that require freshwater to survive (MPCA, 2025a). Lakes that experience increasing chloride concentrations can also experience changes in stratification patterns, changes in phytoplankton and zooplankton community structures, and increased sediment anoxia conditions leading to increased internal phosphorus loading (MPCA, 2020). All of these negative impacts will affect CRWD lakes in different ways and at different levels of impact.

While Loeb Lake receives a much lower input of stormwater runoff than any of the other lakes and therefore has the lowest overall concentrations of all lakes, it is nevertheless experiencing an increase in average annual chloride concentration. Loeb Lake is also a good example of how a lake with a relatively small subwatershed and lower road salt input can still see impacts over time from chloride pollution and demonstrate how the problem doesn't just get diluted or washed away; it can build up over years until it's much more expensive and difficult to fix.

Crosby and Little Crosby Lakes are both considered high risk for impairment (MPCA, 2025b), but do not exhibit any current annual trends in chloride concentrations (Appendix A). Both are greatly impacted by river flooding due to their location in the floodplain of the confluence of the Mississippi and Minnesota Rivers. This may contribute to frequent flushing and low residence time in the lakes, but it also contributes to an influx of chloride-laden river water into these lakes during periods of flooding. Chloride inputs to the lakes via flooding will continue to be an issue as long as increasing concentrations of chloride in the Mississippi and Minnesota Rivers are observed (MCES, 2018).

Como Lake has been listed as impaired for chloride since 2014 (MPCA, 2024b) and was included in the Twin Cities Metropolitan Area Chloride Total Maximum Daily Load Study (MPCA, 2016b). Monitoring data in Como Lake not only shows the highest annual average chloride concentrations of all lakes, but has also shown an increasing trend in annual average chloride concentration since 1984 when monitoring began. Since Como Lake is a shallow lake and has a short water residence time, chlorides are flushed out of the lake at a higher rate, resulting in a high level of annual variability (annual averages range from 47 mg/L to 253 mg/L) (Janke & Finlay, 2025; Small et al, 2025) (Appendix A). Como Lake has the highest watershed-to-lake area ratio of any CRWD lake, so it experiences the highest levels of snowmelt inputs of chloride from the surrounding watershed. In recent years, this has resulted in winter hypolimnetic chloride concentrations of 1300 mg/L in March 2022 and 1650 mg/L in March 2023 from samples collected below the ice. These concentrations exceed not only the chronic standard of 230 mg/L but also the maximum standard of 860 mg/L, and are extremely high chloride levels for a lake to experience.

While Lake McCarrons has lower annual average concentrations than Como Lake (ranging from 62 mg/L to 155 mg/L), it has a similar increasing trend and has been identified as high risk for chloride impairment (CRWD, 2020a; Janke &Finlay, 2025; MPCA, 2025b). Lake McCarrons also exhibits a statistically significant increasing trend in chloride concentration at all measured depths (Appendix A). The 2020 Lake McCarrons Management Plan calculated that if the increasing trend in chloride concentrations continues, it was likely the lake would become impaired by 2030 (CRWD, 2020a). Recent research has evaluated the longer-term impacts of chloride pollution on deep lakes using Lake McCarrons monitoring data (Small et al, 2025). These results highlight a more worrisome concern of increasing chloride trends in deep lakes: due to their higher residence time, once impaired it will take much longer to reverse the effects of chloride pollution since it will take much longer to flush chloride from the lake system (Small et al, 2025). Longer-term, therefore, Lake McCarrons will be more impacted by changes to lake stratification patterns from chloride due to its depth. The threat of increasing chloride pollution on a deep lake of high value in CRWD requires immediate action to prevent further pollution.

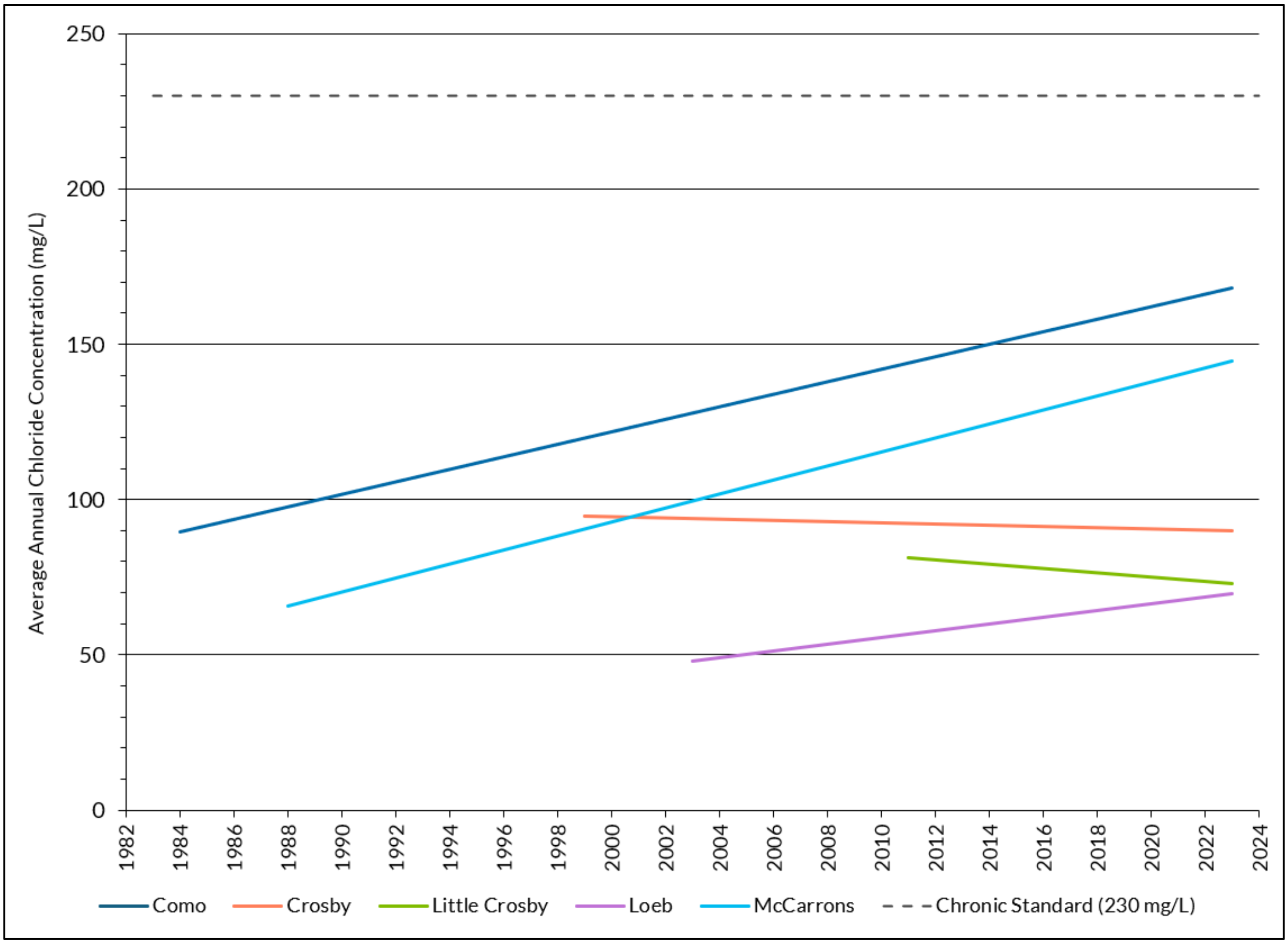

Figure 5: Trends in average annual chloride concentration for CRWD lakes (data collected from April – October from all monitoring depth points; data points for annual averages not included in figure for clarity)

4.4 Groundwater

The MPCA has outlined the high and concerning trend in increasing concentrations of groundwater throughout the metro and state over the past 30+ years of monitoring (MPCA, 2016a, MPCA, 2020). The District does not currently monitor chloride concentrations in groundwater directly, but monitors baseflow in select storm sewers. Baseflow is largely driven by groundwater flow and surface water discharges during dry weather periods and not the result of active stormflow from rain and periods of snowmelt. Two District stormwater monitoring stations, East Kittsondale and Trout Brook – East Branch, have baseflow that is heavily groundwater-influenced. These two datasets can be viewed as representative of groundwater concentrations of chloride, exhibiting persistently high chloride concentrations, frequently exceeding the chronic state standard (Figure 6). Other metro area watershed districts have observed a similar trend in their groundwater datasets (Coon Creek Watershed District [CCWD], 2024). This is evidence of the long-term accumulation of chloride in urban soils and surface waters that continues to make its way to shallow groundwater long after snowmelt runoff and spring rainfall has occurred, contributing heavily to shallow groundwater pollution (Janke & Finlay, 2025). Groundwater in turn is also an input to a lake's water budget (to varying degrees depending on the lake), so increasing groundwater chloride levels will continue to impact chloride levels in all CRWD lakes.

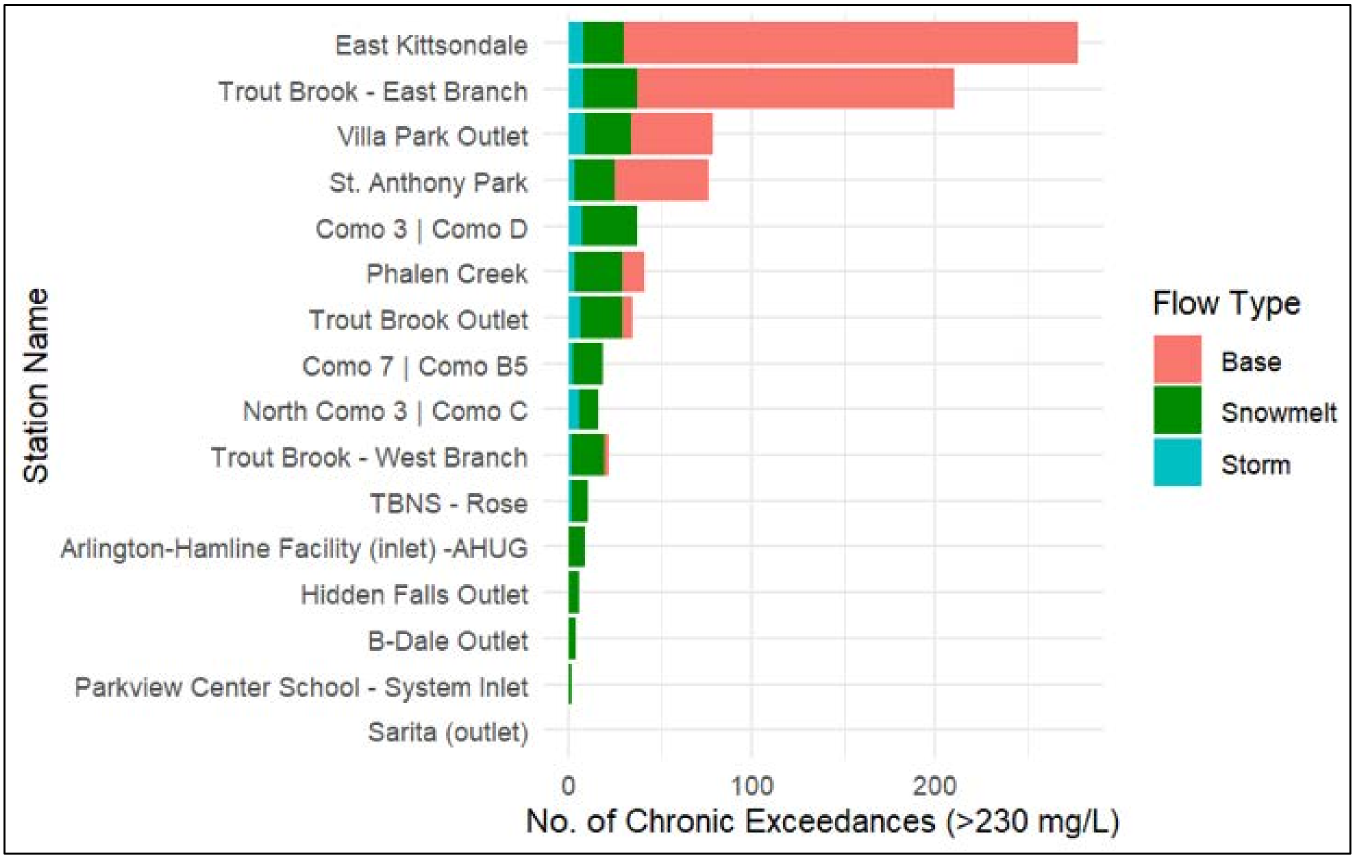

Figure 6: Chronic chloride standard exceedances for base, snowmelt, and storm samples at active and inactive District monitoring stations (Appendix A)

4.5 Mississippi River

All stormwater runoff from CRWD (which is monitored at the various locations listed in Sections 4.1 – 4.4) ultimately flows into the Mississippi River, which has had substantial increases in chloride concentrations in the last few decades. The District does not monitor river water quality directly since other organizations are conducting this monitoring to understand changes over time. The most recent assessment of river water quality in the Twin Cities Metro Area highlights the increases observed regionally in the Minnesota, Mississippi, and St. Croix Rivers from 1985 – 2015 (MCES, 2018). This report shows flow-adjusted chloride concentration increases of 86% at Lock and Dam 1 (located near the southwestern border of CRWD), and 50% at both the downtown St. Paul Mississippi River monitoring station (located along the south central border of CRWD) and the Grey Cloud Island monitoring station (located south of CRWD, but upstream of the confluence with the St. Croix River) (Figure 7). These trends show consistent increases over time, indicating that if larger steps are not taken to reduce chloride use by all upstream contributors, including within CRWD, concentrations will continue to increase.

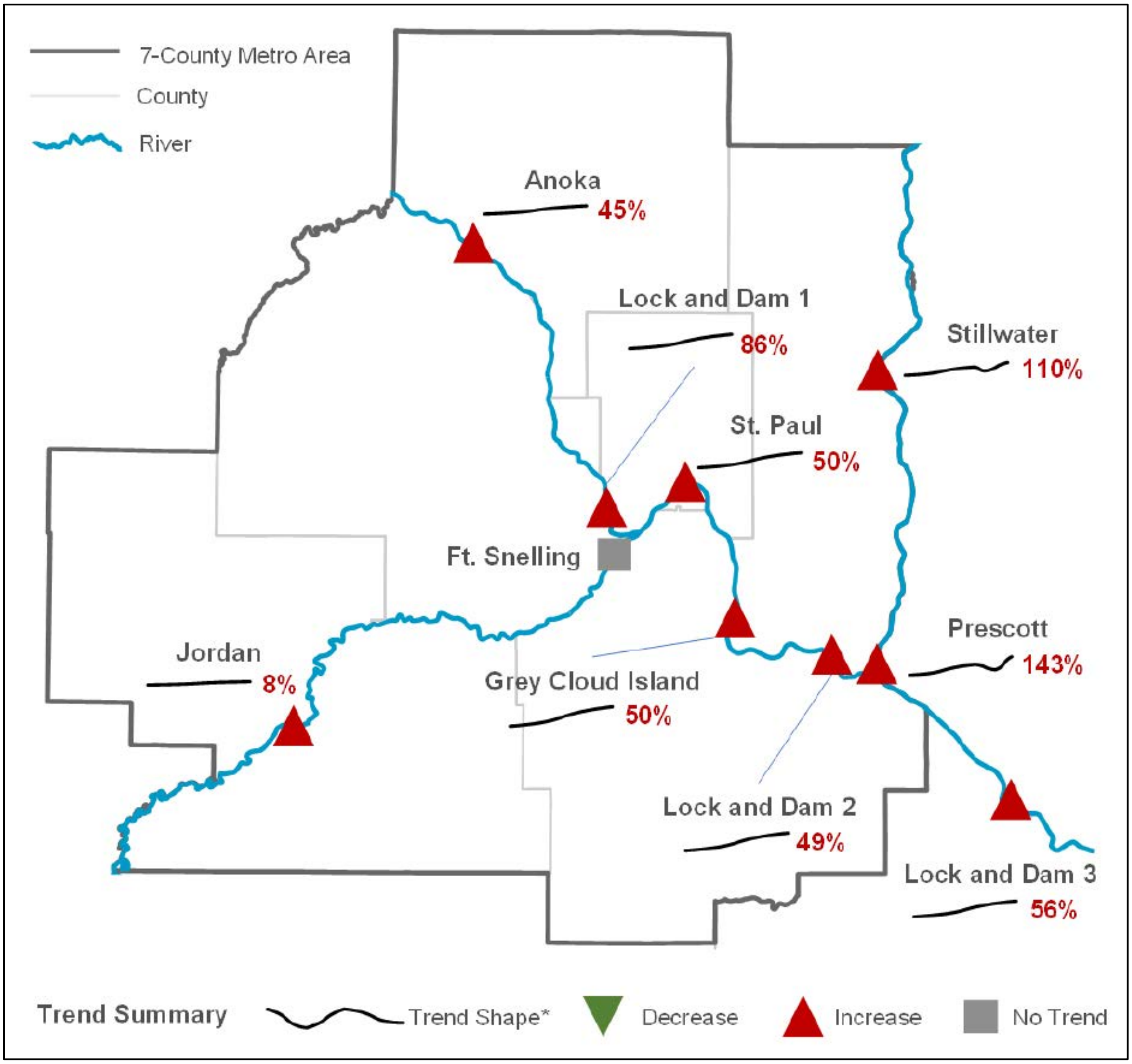

Figure 7: Flow-adjusted chloride concentration trends in the Mississippi, Minnesota, and St. Croix Rivers, 1985-2015 (MCES, 2018)

5 Overview of Road Salt Reduction Solutions

5.1 Current Road Salt Reduction Solutions

Individuals and organizations in both the public and private sectors within CRWD, as well as in the larger Twin Cities metropolitan area, have been working for years to curb road salt use and protect natural resources. During the CPPP development and literature review, numerous reports, websites, plans, and presentations developed by partners were reviewed that highlight road salt reduction solutions. An audit of the current work of metro area watershed districts and water management organizations in road salt reduction initiatives was also completed. Appendix E offers a summary of this extensive review of current solutions by grouping them by major themes. Brief examples of work that fall under each theme are described to show the types of solutions that are currently being utilized.

5.2 Road Salt Reduction Work by the District

Road salt reduction work to date by the District has occurred annually through the following established District program areas: education and outreach, training, monitoring, and facilities management. Examples of work-to-date in these program areas include:

- **Education and outreach**
  - Utilizing the Low Salt, No Salt Minnesota campaign resources to create a District-specific version of the educational powerpoint presentation to inform faith-based leadership teams, as well as District Staff.
  - Incorporating best practices in winter maintenance and smart salting in District educational messaging (including flyers, digital communications like newsletters and social media, and materials distributed at District and partner-led events) to target individual and general household behavior change.
  - Reaching out to entities in CRWD following community complaints or observations of excess salting practices and including this work in the District's Illicit Discharge Detection and Elimination (IDDE) program.
- **Training**
  - Sponsoring the 5-year MPCA Smart Salting Training for Roadways for Public Works employees in CRWD, the MPCA Smart Salting for Property Management Training for the head engineers at Saint Paul Public Schools, and the MPCA Smart Salting Training for Parking Lots & Sidewalks for employees in the Saint Paul Parks and Recreation Department.
  - Sponsoring annual refresher courses for the above organizations for applicable Smart Salting Trainings to continue to keep this issue front of mind.
- **Monitoring**
  - Collecting stormwater samples in different flow regimes at various storm sewer pipes, BMPs, and stormwater ponds across CRWD and analyzing these samples for chloride.
  - Partnering with Ramsey County Public Works to collect lake samples at different depth points throughout the growing season (~April – October), as well as pre-ice out samples on all lakes, and analyzing these samples for chloride.
  - Collecting winter hypolimnetic samples on Como Lake to understand the chloride problem for a CRWD Lake on the impaired waters list for chloride.

    - Sharing data publicly for use by other organizations and researchers to better understand chloride issues in urban water resources.
- **Facilities management**
    - Following all requirements of CRWD's municipal separate storm sewer (MS4) permit.
    - Creating a winter maintenance plan to guide management of the District campus.
    - Maintaining safe paved areas on the District campus without the use of road salt.
    - Training District staff through the MPCA Smart Salting for Property Management Training to understand how to best manage our own District campus.
    - Hiring a Smart Salting certified contractor to maintain surfaces of the District campus in the winter.

6 District Roles and CPPP Key Audiences

6.1 District Roles in Road Salt Reduction

Solutions for road salt reduction will need to come from a variety of individuals and organizations to satisfy all the roles needed for change, and no one organization or entity can take on all roles and responsibilities. While the District understands the need to expand our work outside of the areas listed in Section 5.2, the District will also not attempt to take on all roles related to road salt reduction, as this is neither efficient nor feasible. A core part of the initial CPPP engagement process involved having all groups discuss what the District's role should be in reducing road salt use (Section 2.3, Appendix F). These key groups identified five primary roles for the District: 1) Education, communications, and training; 2) Policy and collaboration; 3) District programs and funding; 4) Research; and 5) Regulations (Figure 8). These roles formed the basis for the five overarching CPPP goals (Section 8).

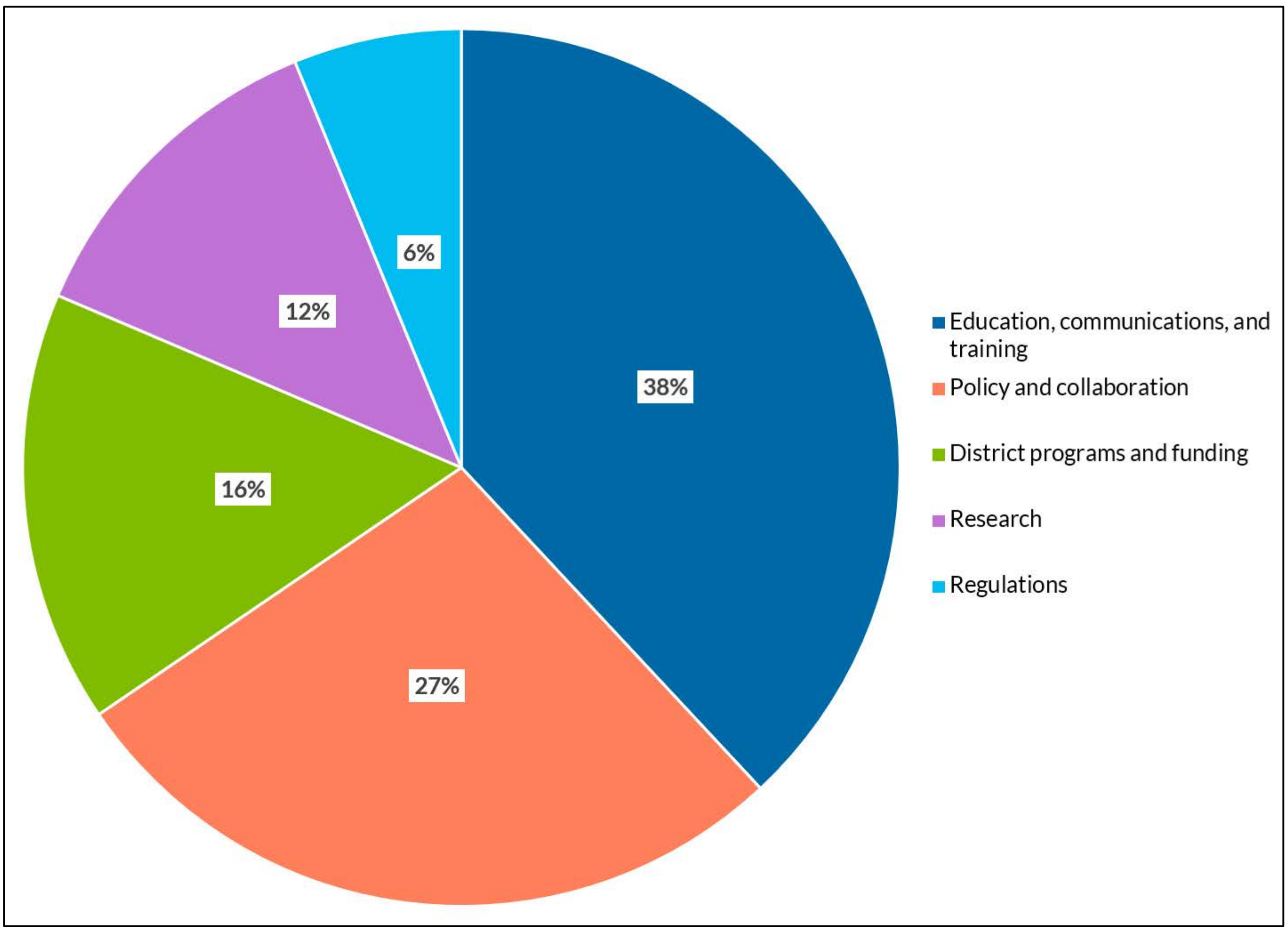

Figure 8: District roles for road salt reduction (identified by key groups of the 2024 CPPP engagement process)

6.2 CPPP Key Audiences

Fulfilling the District roles identified in Section 6.1 will require staff to work in partnership with a multitude of groups to achieve the actions in this Plan. A list of "Key Audiences" consisting of external groups was developed to identify which individuals and organizations the District could partner with to carry out the actions of the CPPP as well as those that could be impacted by CPPP actions. The results of the spatial analysis (Section 7, Appendix C) were also used when evaluating Key Audiences to understand the wide variety of applicators in CRWD. The Key Audiences and descriptions listed below will allow District staff to better understand what roles these groups may have in road salt reduction, who to target or collaborate with on the implementation of CPPP actions (Section 10, Table 5), and the scale of their involvement or partnership.

<u>Key Audiences</u>

1. **Applicators**

This group includes all potential road salt Applicators responsible for winter maintenance of paved surfaces in CRWD (Section 7, Appendix B), including:

- Municipal departments of the five cities within CRWD (Saint Paul, Lauderdale, Falcon Heights, Roseville, and Maplewood)
- Ramsey County
- Minnesota Department of Transportation (MnDOT)
- Private winter maintenance companies
- Commercial maintenance departments, including office and mix-ed use commercial
- Industrial maintenance departments, including utility and mixed-use industrial
- Institutional maintenance departments, including religious, governmental, educational, social, cultural, and major health-care facilities
- Single-family home residents, including owners or renters of a single-family home

2. **Community Members**

This audience includes the general public, organized community groups, and planning councils. These are individuals or groups who help drive larger municipal, county or state policies, and who are impacted by any policies (local, county, or state) that are implemented. This group includes groups like City of Saint Paul District Councils.

3. **Policymakers**

This audience includes elected officials of municipal, county, and state government that develop policies and regulations, guide funding, and listen to views of their constituents to make changes that can drive road salt use on multiple levels. This audience includes lobbyists (e.g. MN Watersheds) pursuing clean water initiatives at the State and Federal level.

4. **Regulatory Partners**

This audience includes all parties within municipal, county, and state governing bodies that are responsible for enforcing any new or existing policies or regulations surrounding road salt use or reduction. This audience includes the MPCA.

5. **Researchers and Scientists**

This audience includes researchers and scientists that collect and analyze chloride data, disseminate data, and use this data to make advancements in the way road salt is used and managed. This audience includes consultants that work in the field and support organizations with their policies and plans.

6. **Developers**

This audience includes all companies, including their design and engineering departments, completing new development or re-development of properties within CRWD that are required to follow watershed rules or city ordinances, including road salt use or management of surfaces where road salt could be applied. This includes business associations that make larger and collective decisions on development within CRWD.

7. **Partner Groups**

This audience includes partner groups, both inside and outside CRWD, that are working on road salt reduction efforts, including the member groups of the Low Salt No Salt campaign, members of the Hennepin County Chloride Initiative (HCCI), and other watershed districts and water management organizations in the Twin Cities metropolitan area.

7 Spatial Analysis of Paved Surfaces Requiring Winter Maintenance in CRWD

CRWD is a fully developed urban watershed with ~50% impervious surface coverage. The majority of the total impervious areas in CRWD are paved surfaces like roads, driveways, parking lots, and sidewalks, that have the potential for road salt to be applied to them for winter maintenance. Identifying and quantifying the total area of paved surfaces in the District where road salt may be applied is an essential step for determining how to reduce the amount of road salt being applied to them. To explore this further, a spatial analysis of the paved surfaces in CRWD was completed to:

- Quantify the total paved area within CRWD's boundaries where road salt has the potential to be applied;
- Categorize paved areas by land use type and surface type;
- Quantify and categorize the paved areas of all major CRWD subwatersheds;
- Identify the Applicators of road salt based on ownership/winter maintenance responsibility of all categorized paved surface areas; and
- Assist in the prioritization and implementation of CPPP actions in Section 9 based on the scale of road salt reduction potential.

7.1 Methods for Spatial Analysis

The spatial analysis was completed using Geographic Information Systems (GIS) software and categorized paved surface areas based on land use types and surface types using the following designations:

- **Land Use Type:** residential, agricultural, commercial, institutional, parks, industrial, transit, and undeveloped.
- **Surface Type:** sidewalks, parking lots, driveways, alleys, municipal roads, county roads, and state roads.

Appendix B provides a detailed description of the methods used for this analysis, including data sources, data preprocessing, and model development. Because every surface type could be found in every land use type, further grouping of these areas was required to better understand the major areas where road salt has the potential to be applied. This was completed by examining the primary entities responsible for winter maintenance of each land use and surface type combination, referred to as "Applicators". Areas with the same Applicators were grouped together.

While the spatial analysis was an essential first step to determining where road salt is applied in CRWD, it did not attempt to estimate chloride loading from these surfaces. This was due to the difficulty in accurately estimating the rates or amounts of road salt being applied in CRWD using values from the literature. The District understands that all of the identified surface types require differing winter maintenance practices and application rates or amounts, if any at all. Road salt application method and amount is dependent upon many factors, including (MPCA, 2020):

- Surface type;
- Designated level of service;
- The speed at which cars are traveling on different road types;
- Previous surface conditions;

- Current surface and air temperatures;
- The type, duration, and severity of the winter storm;
- Knowledge and implementation of best application practices by Applicators; and
- Forecasted conditions before and after a winter event.

7.2 Summary of Spatial Analysis Results

The results of the spatial analysis (Appendix C) show that ~33% of CRWD's total area are paved surfaces requiring winter maintenance, and these paved surfaces span all land uses and surface types. When grouped by Applicator, however, there are eight major groups of paved surfaces and corresponding Applicators. Figure 9 shows the percent of each grouped land use and surface type. Table 2 details the grouped major land uses and surface types, along with the Applicators, descriptions, areas of each specific land use and surface type, combined area, and percent of each grouped paved surface area.

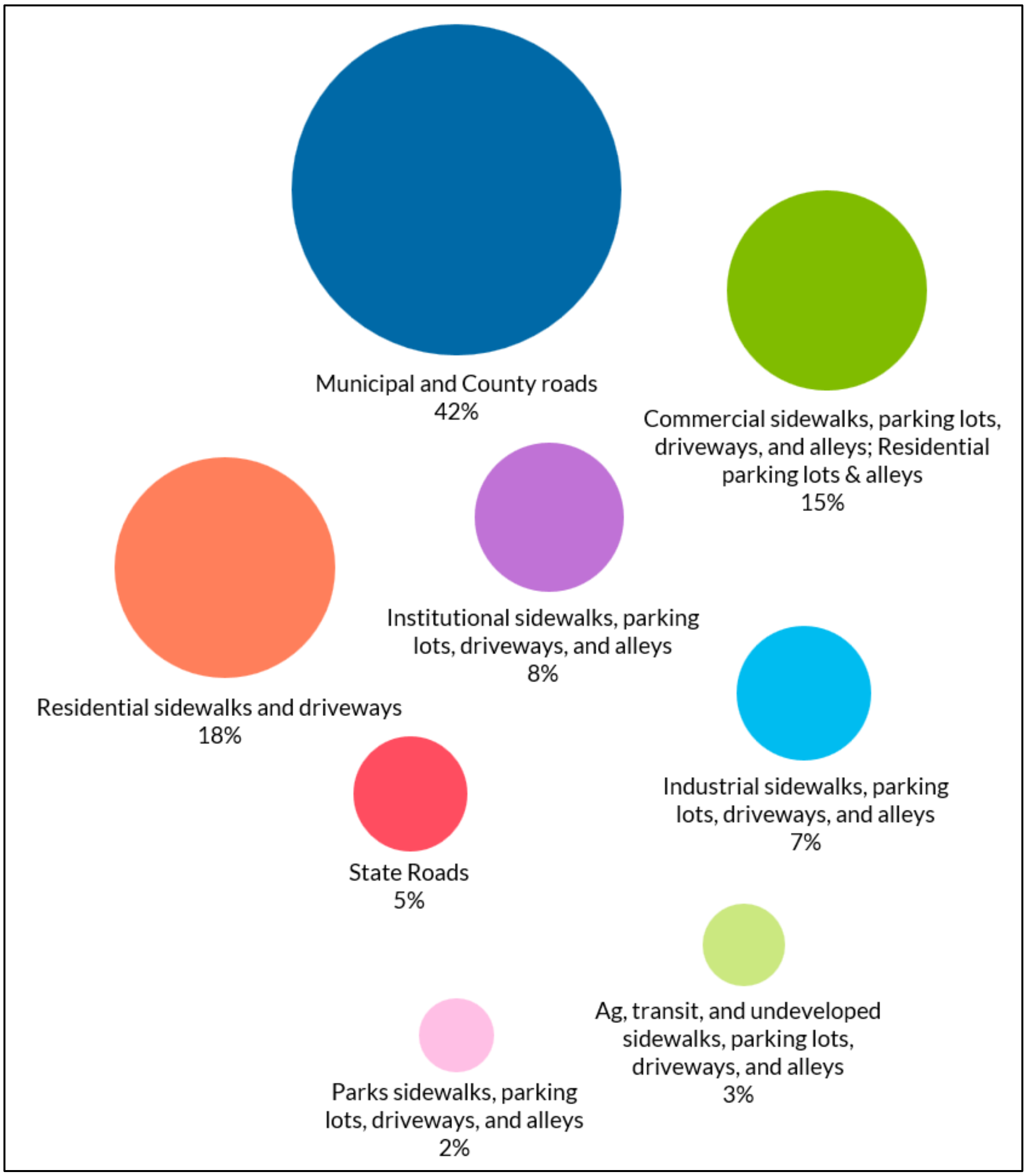

Figure 9: Percent of CRWD paved surface areas grouped by major land use and surface type

Table 2: Grouped major land uses and surface types in CRWD, including the Applicators, description, specific land uses and surface types, area, combined areas, and the percent of each grouped paved surface area

Major land uses and surface types	Applicators	Description	Specific land uses and surface types	Area (acres)	Combined areas (acres)	CRWD paved surface area (%)
Municipal and County roads	Municipal public works departments	All municipal and county roadways including bridges and ramps	Municipal roads	3,180	3,615	42%
			County roads	435		
Residential sidewalks and driveways	Individual household residents	Sidewalks and driveways located within residential areas	Residential sidewalks	784	1,603	18%
			Residential driveways	819		
Commercial sidewalks, parking lots, driveways, and alleys; Residential parking lots & alleys	Private winter maintenance companies	Sidewalks/parking lots/driveways/alleys for commercial properties such as retail stores or office complexes; parking lots (i.e. apartment complexes) and alleys in residential areas	Commercial sidewalks	98	1,318	15%
			Commercial parking lots	637		
			Commercial driveways	9		
			Commercial alleys	12		
			Residential parking lots	275		
			Residential alleys	288		
Institutional sidewalks, parking lots, driveways, and alleys	Individual institutional maintenance departments; private winter maintenance companies	Sidewalks through school grounds and along streets; parking lots for schools and universities	Institutional sidewalks	215	726	8%
			Institutional parking lots	494		
			Institutional driveways	11		
			Institutional alleys	7		
Industrial sidewalks, parking lots, driveways, and alleys	Individual industrial company maintenance departments; private winter maintenance companies	All sidewalks, parking lots, driveways, and alleys associated with industrial areas	Industrial sidewalks	29	597	7%
			Industrial parking lots	561		
			Industrial driveways	5		
			Industrial alleys	2		
State Roads	Minnesota Department of Transportation (MnDOT)	All state roadways including bridges and ramps	MnDOT roads	433	433	5%
Ag, transit, and undeveloped sidewalks, parking lots, driveways, and alleys	Organizations responsible for the maintenance of all ag, transit, and undeveloped areas in CRWD	All sidewalks, parking lots, driveways, and alleys associated with ag, transit, and undeveloped District areas	Ag, transit, and undeveloped sidewalks	56	227	3%
			Ag, transit, and undeveloped parking lots	158		
			Ag, transit, and undeveloped driveways	8		
			Ag, transit, and undeveloped alleys	5		
Parks sidewalks, parking lots, driveways, and alleys	Municipal and county parks and recreation departments	All parking lots, sidewalks, driveways, and alleys located on park property	Parks sidewalks	120	182	2%
			Parks parking lots	59		
			Parks driveways	2		
			Parks alleys	1		
				TOTAL	**8,701**	**100%**

As shown in Table 2, there are three groupings of paved surfaces that have private winter maintenance companies as an Applicator: commercial areas and residential parking lots & alleys; institutional areas; and industrial areas. When combined, these three areas represent 30% of CRWD paved surface area, which becomes the second highest total paved surface area in CRWD. Table 3 shows the top three major land use and surface type areas that represent the majority (90%) of CRWD paved surfaces alongside their corresponding Applicators. This more clearly shows which Applicators are responsible for managing the majority of the total paved surface area in CRWD.

Table 3: Applicators and percent of CRWD paved surface area for the top three major land uses and surface type groups.

Major land uses and surface types	Applicator	CRWD paved surface area (%)
Municipal and County roads	Municipal public works departments	42%
Commercial sidewalks, parking lots, driveways, and alleys Residential parking lots & alleys Institutional sidewalks, parking lots, driveways, and alleys Industrial sidewalks, parking lots, driveways, and alleys	Private winter maintenance companies Institutional maintenance departments Industrial maintenance departments	30%
Residential sidewalks and driveways	Individual household residents	18%
	TOTAL	**90%**

7.3 Recommendations from the Spatial Analysis Results

The results from the spatial analysis demonstrate that while the paved surfaces in CRWD are highly variable, 90% of the surfaces are being managed by three main Applicator groups, making it easier to understand who is applying road salt in CRWD. These results point to three overall recommendations for future road salt reduction action.

Recommendation 1: Actions should be prioritized based on the Applicators identified in the spatial analysis.

The District should prioritize efforts and resources towards Applicators that manage the highest percentages of paved surfaces in CRWD to yield the greatest benefit in road salt reduction. Table 4 ranks the top three Applicator groups in CRWD by highest percent of paved surface area, then evaluates them as low, medium, or high based on the following two categories:

- **Potential for road salt use:** how likely the Applicator is to use road salt as a tool for winter maintenance.
- **Current District level of engagement effort**: how much money and staff time is currently being used to engage with the Applicator (examples of District work-to-date are described in Section 5.2).

Table 4: Current District level of engagement effort and potential for road salt use for the top three Applicator groups in CRWD based on percent of CRWD paved surface area.

Applicator	CRWD paved surface area (%)	Potential for road salt use (low, medium, high)	Current District level of engagement effort (low, medium, high)
Municipal public works departments	42%	High	Medium
Private winter maintenance companies Institutional maintenance departments Industrial maintenance departments	30%	High	Low
Individual household residents	18%	Low	High

Current road salt reduction efforts by the District have focused a high level of outreach work towards individual household residents, but the spatial analysis shows that this is only 18% of paved surfaces in CRWD—a smaller total area in comparison to the other top two Applicator groups. In addition, individual households are inconsistent applicators of road salt and don't necessarily always use it for winter maintenance, so the total area within the 18% of paved surfaces where road salt is actually applied is likely less. Thus, continuing to focus a high level of effort towards individual households will yield lower road salt reductions.

Municipal and county roads make up a large majority of CRWD paved surface area (42%), so continuing District work towards this applicator group will be essential. Municipal departments have made, and continue to make, strides towards road salt reduction using best management practices while at the same time balancing essential public safety needs. Currently, the District helps provide Smart Salting training to help municipal partners in CRWD meet their MS4 permit requirements and implement best management practices for road salt reduction. Since municipal departments are large-scale Applicators that manage the largest total area of paved surfaces of CRWD, funding and resources to support improved training, equipment, and technology, as well as municipal outreach efforts, will continue to be a high priority in the CPPP.

Finally, the spatial analysis revealed the Applicators that manage a high percentage of the paved surfaces in CRWD (30%) but have been underserved by current District road salt reduction efforts: private winter maintenance companies, institutional maintenance departments, and industrial maintenance departments. These Applicators consistently utilize road salt for winter maintenance, yet have not been a focus for road salt reduction efforts by the District, offering the highest potential for large reductions in road salt use.

Therefore, the following Primary Applicators should be targeted in CPPP Actions to achieve the highest reductions in road salt use in CRWD:

Primary Applicators:

- **Private Winter Maintenance Companies**
- **Institutional Maintenance Departments**
- **Industrial Maintenance Departments**
- **Municipal Public Works Departments**

The District should continue to work with the other Applicators identified in Figure 9 if beneficial opportunities arise or to support partner efforts but at a lower level of priority due to their lesser level of road salt reduction potential.

Recommendation 2: Results of the major subwatershed analyses should be used to focus actions (if and where possible) on subwatersheds with higher priority water bodies.

Next, the spatial analysis results allow the District to understand the paved surface areas and Applicators within each major CRWD subwatershed (Appendix C), giving the District the ability to focus road salt reduction efforts on Applicators within subwatersheds containing high risk or impaired water bodies, like Como Lake or Lake McCarrons (see Section 4.3). While any large-scale efforts to reduce road salt use in CRWD will ultimately reduce road salt use in these lake's subwatersheds, there may be efforts which can target reductions for direct benefit to these individual lakes. Since the ultimate goal of all CPPP actions is to reduce chloride pollution in District water resources, targeted actions could achieve higher benefits.

Recommendation 3: Application rates by Primary Applicators in CRWD should be determined and utilized to calculate chloride loading for the major paved areas of CRWD.

Finally, while chloride loading values were unable to be accurately estimated for the CPPP, the spatial analysis provides the framework to complete this in the future. As more information becomes known about road salt use by the Primary Applicators in CRWD following the implementation of the CPPP, this spatial analysis could be expanded to include road salt application rates and loading estimates for CRWD as a whole, for major CRWD subwatersheds, and for estimating chloride loading to CRWD lakes. This will allow the District to better measure reductions in chloride pollution as a result of CPPP actions that reduce road salt use.

8 Goals and Objectives

8.1 Overview of Goals and Objectives

The overall goal of the CPPP is to reduce the use of road salt for winter maintenance in CRWD to prevent further degradation to CRWD's water resources, natural resources, and infrastructure from chloride pollution. The CPPP contains five goals to meet this overarching goal, which are intended to provide the framework for the CPPP. They are broad in scope and describe an overall desired outcome. The objectives underneath each goal are the primary components that must be achieved to fulfill each goal. Each objective contains a series of recommended actions that were identified as necessary steps for fulfilling each objective. This management framework provides the basis of the CPPP and is essential for Plan implementation and prioritization.

Similar to role identification, the results of the engagement process were used as the primary guidance for developing goals and objectives (Appendix F). The summary in Appendix F qualitatively analyzed all responses from all participants of the workshops with key groups, effectively representing the core values of the entities that the CPPP will impact. As discussed in Section 2.3, the CPPP planning process did not include the engagement of private winter maintenance companies, but the results from the HCCI study of this group were considered during the development of the CPPP goals and objectives to ensure the viewpoints of this key group were considered (HCCI, 2020).

8.2 CPPP Goals and Objectives

This section lists all goals and corresponding objectives as well as descriptions of each. Goals and corresponding objectives are not listed in order of priority. Goals and objectives are also listed in Table 5 of Section 9.

Goal 1: Serve as a knowledgeable resource on chloride issues in CRWD.

The District recognizes the foundational role of high-quality data and knowledge in understanding chloride issues in CRWD. Through targeted monitoring, data transparency, continuous learning, and research, the District aims to deepen its understanding of chloride dynamics in the watershed and position itself as a dependable knowledge resource for its partners. The District also recognizes that road salt application is widespread and varied, and an understanding of the use within CRWD, as well as up-to-date strategies for reduction will be essential to make an impact. This goal supports adaptive decision-making, data dissemination, and research advances.

Objective 1a: Monitor chloride levels in CRWD water resources.

The District will maintain and expand its year-round monitoring network to track chloride levels across lakes, stormwater infrastructure, and other water resources. Monitoring data will support long-term trend analysis, the work and research of partners, and adaptive management of chloride-related impacts in CRWD. These efforts will also help fill data gaps and provide a more complete understanding of chloride pathways in CRWD, as well as impacts of chloride to other water resources not yet consistently monitored. This action ensures the District is comprehensive in its monitoring efforts and is responsive and adaptable to new developments.

Objective 1b: Make chloride pollution data from CRWD water resources available and accessible.

The District is committed to analyzing and sharing its chloride monitoring data to support decision-making, help inform reduction strategies, increase public understanding of the issue, detect trends, and aid in determining impairment of lakes. This will also guide internal and public-facing reports, identify data gaps, and ensure chloride information is used to inform both the CPPP and contribute to partner research and analysis.

Objective 1c: Understand changes in road salt use in CRWD.

The amount of road salt used in CRWD in any given year is directly related to the severity of winter weather conditions (i.e. a winter with a lot of snow/winter precipitation or freeze/thaw events will require more winter maintenance which currently includes the use of road salt). The practices, technology, and human behavior of any given applicator, however, are also greatly impacting how much road salt is being applied to all impervious surfaces in CRWD. Understanding how road salt is used (i.e. application practices, amount, rate, and frequency) by the Primary Applicators (as defined by the spatial analysis from Section 7) will be key to understanding how road salt use is changing in CRWD. It will also help track: the effectiveness of changes to application methods by Applicators; the amount of road salt entering CRWD conveyance systems and water resources; and the barriers or challenges for reducing road salt use.

Objective 1d: Stay informed on advances in chloride science.

The District recognizes that chloride science and best practices in winter maintenance are constantly progressing. Any improvements in the understanding of chloride pollution (e.g. emerging research on lakes) and winter maintenance practices (e.g. understanding how to advise the general public on product use) will aid in the reduction of road salt use and therefore needs to be a high priority for the District to stay current on. Additionally, by supporting research and collaborating with industry leaders, the District helps advance the field of chloride science to: ensure that decisions are rooted in evidence, improve road salt alternatives, and promote innovation in tools and technology.

Goal 2: Increase knowledge and awareness of chloride pollution and reduction strategies in CPPP key audiences.

The District recognizes that widespread knowledge and awareness are essential to achieving lasting reductions in chloride pollution. Goal 2 focuses on building an understanding of chloride's environmental impacts among identified key audiences of the CPPP and supporting improved education and training.

Objective 2a: Conduct outreach to key audiences through education and trainings to increase the acceptance, implementation, and effectiveness of road salt reduction strategies.

To maximize the impact of road salt reduction efforts, the District must identify, tailor, and utilize outreach strategies (both education and trainings) to reach the key audiences defined in the CPPP. Through outreach, the District will increase knowledge in key audiences of best winter maintenance practices and road salt reduction strategies to ultimately reduce application.

Goal 3: Utilize road salt reduction solutions in CRWD.

The District understands that reducing chloride pollution to CRWD water resources requires not only monitoring and outreach but also the implementation of solutions that directly reduce road salt use or directly mitigate chloride pollution, thereby improving water quality. Goal 3 focuses on implementing more of these solutions, which will require additional resources to Primary Applicators.

Objective 3a: Support the implementation of road salt reduction solutions.

The District will work to support road salt reduction solutions (including projects, tools, and technologies) throughout the watershed. This objective includes both externally funded efforts through a dedicated grant program and internally led initiatives that showcase innovation and impact.

Goal 4: Support policies that reduce road salt use in CRWD.

The District understands that lasting change in road salt reduction requires the support of effective policy and regulatory frameworks. Through proactive engagement in local- and state-level policy development, the District will advocate for reforms that reduce the use of road salt throughout CRWD and ensure chloride pollution reduction remains a regulatory priority. In parallel, the District will explore updates to its own rules and permit processes to model best practices and support other organizations already committing to rule and permit updates to help set a regional standard.

Objective 4a: Include road salt reduction strategies in the District's rules and permitting program.

The District will incorporate road salt reduction considerations into its regulatory toolbox. By evaluating and potentially revising its rules and permitting framework, the District can better align its internal policies with its chloride pollution reduction goals and support the work of other metro-area watershed districts.

Objective 4b: Advocate for laws and regulations that aim to reduce road salt use.

The District will serve as a visible and proactive voice in advancing policies that support road salt reduction at both local and state levels. The District will work in partnership with other agencies that have already initiated work in this area, and other organizations that support the work of watersheds to bridge the gap between watershed districts and state government/associations.

Goal 5: Leverage partnerships and resources to successfully implement the CPPP.

The District recognizes that chloride pollution is a regional challenge that requires broad-based collaboration. Through the CPPP, the District aims to engage and support its partners through shared planning, coordination, and resource development. The District recognizes that other partner organizations have also been working hard to reduce and prevent chloride pollution across the metro area and the state. Through collaboration, all CPPP actions have a much higher likelihood of success. This goal focuses on strengthening relationships and securing the funding needed to fully implement the CPPP.

Objective 5a: Collaborate with partners to implement the CPPP.

The District will cultivate partnerships with public agencies, nonprofits, community groups, academic institutions, and private entities. Many of the CPPP actions outline the need for District staff to gain more knowledge through partnership with other organizations or require the commitment of external partners for implementation.

Objective 5b: Continually identify sources of funding for implementing Plan actions.

To fully implement the CPPP, the District must secure dedicated sources of funding. This objective ensures District Staff are committed to exploring external grant opportunities to support plan implementation. This action will supplement District budget funding for the Plan, allowing for more Plan actions to be realized.

9 Actions

9.1 Overview of Actions

Management actions were developed to achieve CPPP goals and objectives by defining the specific activities, projects, and programs associated with each objective (Table 5). Like the roles, goals, and objectives, these actions were also developed using the results of the CPPP engagement process (Appendix F), alongside the literature review (Appendix D). Additional research examining what other watershed districts and water management organizations in the metro area are doing to address road salt reduction and chloride pollution, as well as various conferences, meetings, and discussions with partners throughout the Plan development process also helped identify realistic solutions for reducing road salt use (Appendix E).

Alongside these actions, several other metrics were created to aid in categorizing, organizing, and prioritizing actions, including: status, audience, outcome, implementation frequency, and prioritization level. The descriptions of these metrics are described below in Sections 9.1.1 - 9.1.5.

9.1.1 Status

This metric describes the status of the action to understand what progress has been made to-date, and includes:

- *Ongoing:* the action has started and will likely continue as is
- *Some progress:* the action has been partially completed but will be adjusted as a result of the Plan
- *New:* the action has not been started

9.1.2 Audience(s)

This metric was included to help determine the scale of the impact of each action, and what types of individuals and groups each action would involve or impact. See Section 6.2 for the descriptions of all key audiences.

9.1.3 Outcome

This metric describes what the action will produce, giving an idea of what can be expected if the action is achieved. This includes:

- *Behavior Change:* the action promotes a behavior change in the identified group, which could then lead to other outcomes (e.g. application reduction as outlined below).
- *Data/Information*: the action generates data or information that can be used by the identified groups to help identify road salt issues or chloride pollution, promote behavior change, further research, etc.
- *Policy Change:* the action results in a change of policy at the watershed, local, or state level that results in a restriction or reduction in the use of road salt for winter maintenance.
- *Application Reduction:* the action results in an immediate reduction in the use of road salt (i.e. it involves substituting a different tool in place of road salt or improves a current tool for winter maintenance that reduces how much road salt is used).
- *CPPP Implementation:* the action assists in implementing other actions of the CPPP.

9.1.4 Implementation Frequency

This metric describes how frequently the action will occur.

- *One-time:* the action requires a single effort and will not occur regularly
- *Continuous:* the action requires regular effort over a defined timescale, i.e. monthly, annually, etc

9.1.5 Prioritization Level

The District recognizes that there is limited time and money available to confront the many challenges facing CRWD water resources, and therefore aims to maximize effectiveness with all activities, projects, and programs. Prioritizing actions is key to understanding which can have the biggest impact given available time and money. Prioritization levels of "critical, important, and beneficial" were developed and assigned to each action. Considerations in assigning a prioritization level to each action in the CPPP included: the scale of total paved surface area affected (Section 7), potential implementation costs (time and money), ease of implementation, likelihood of success, and partner participation and/or collaboration. The CPPP prioritization levels are defined as:

- *Critical:* necessary and vital actions that will make a significant impact toward road salt reduction in CRWD and/or is foundational for the implementation of other CPPP actions
- *Important:* actions that will work toward road salt reduction in CRWD and/or support the implementation of other CPPP actions
- *Beneficial:* actions that may work toward some road salt reduction and/or the successful implementation of CPPP is not contingent upon completion of the action

9.2 CPPP Actions

This section lists all actions as well as descriptions of each. They are not listed in order of priority. This list of actions represents the full suite of solutions that are feasible for the District to engage in to reduce road salt use in CRWD.

Goal 1: Serve as a knowledgeable resource on chloride issues in CRWD.

Objective 1a: Monitor chloride levels in CRWD water resources.

Action 1a.1: Develop a comprehensive chloride monitoring plan for CRWD water resources.

The District currently monitors chloride as part of its larger monitoring program that includes lakes and stormwater infrastructure. To better capture chloride levels across all CRWD water resources, including those locations already being monitored, the District will develop a chloride monitoring plan that outlines station locations, purpose, frequency of sampling, sample types, duration of data collection, and data analysis and reporting needs. This plan will include stations already being monitored for chloride, as well as identifying new stations for future monitoring.

Action 1a.2: Conduct year-round chloride monitoring at all five CRWD lakes.

The District currently partners with Ramsey County to collect routine water quality monitoring of all five CRWD lakes during the growing season (April through October). Chloride is one parameter that is selected for sample analysis. The District will continue analyzing lake samples during the growing season for chloride at all lakes (locations identified in Action 1a.1). For winter sampling

(November through March), the District currently collects samples on Como Lake only. The District will evaluate increasing winter chloride sampling for the other four lakes as directed by the chloride monitoring plan.

Action 1a.3: Conduct year-round chloride monitoring at District stormwater monitoring stations.

The District has collected water quality samples at various stormwater monitoring locations since 2005 and has analyzed all samples for chloride. These include stations that are direct outfalls to the Mississippi River. The District will continue analyzing sample data for chloride concentrations at active stormwater sites during baseflow, snowmelt, and storm events. Changes to sample collection locations and frequency will be directed by the chloride monitoring plan (developed under Action 1a.1).

Action 1a.4: Conduct year-round chloride monitoring at additional monitoring locations within CRWD, including wetlands, stormwater ponds, and groundwater wells.

The District will expand its monitoring network to include additional chloride sampling in wetlands, stormwater ponds, and groundwater wells—key systems that may act as both sinks and sources for chloride. The chloride monitoring plan (Action 1a.1) will define site selection, as well as sample types, purpose, and frequency. The District will also maintain flexibility to complete targeted site investigations in response to community concerns, observed overapplication, or emerging chloride hotspots.

Objective 1b: Make chloride pollution data from CRWD water resources available and accessible.

Action 1b.1: Regularly analyze and report upon collected chloride data.

The District will develop an approach for compiling, analyzing, reporting, and disseminating collected chloride data. This approach will outline collected datasets, the reporting frequency (e.g. an annual summary), and communication formats (e.g. using the District website for reporting upon data) and will be defined within the Chloride Monitoring Plan created in Action 1a.1.

Objective 1c: Understand changes in road salt use in CRWD.

Action 1c.1: Obtain a baseline understanding of application rates and practices by Primary Applicators.

The District will initiate conversations with Primary Applicators (as defined by the spatial analysis in Section 7) to gather information on road salt application rates, equipment, calibration, and decision-making processes used to guide application. These conversations could occur through e-mail exchanges and/or meetings and will result in documented baseline application rates.

Action 1c.2: Track changes in application rates and practices by Primary Applicators.

Building from the baseline understanding established in Action 1c.1, the District will engage with Primary Applicators (as defined by the spatial analysis in Section 7) on a regular basis and document changes in application rates and practices (e.g., equipment upgrades or improvements to training). These conversations could also occur through both e-mail and meetings, and will result in a record of annual usage by Primary Applicators.

Objective 1d: Stay informed on advances in chloride science.

Action 1d.1: Participate in trainings, meetings, and events to regularly review emerging research on chloride issues.

District staff will remain active in chloride-focused learning opportunities and collaborative conversations, such as seminars, trainings (e.g. the Salt Symposium or Winter Salt Week), and partner meetings. Participation ensures staff stay informed and capable of applying the most up-to-date science in all Plan actions. The outcomes of Objectives 1a – 1c will also contribute to staff knowledge.

Action 1d.2: Provide funding to external research groups that seek to advance chloride science and future management strategies.

The District will support chloride-focused research through partnerships or funding contributions to organizations such as the Minnesota Stormwater Research Council. Topics may include low-salt design technologies, deicing alternatives, salt-tolerant vegetation, and chloride impacts on groundwater and biota. The District will also support chloride-focused events and conferences to further knowledge dissemination.

Action 1d.3: Implement chloride research.

The District will lead or participate in chloride-related research within the District's overall role in conducting research as an organization. This could include collecting or analyzing specific datasets, investigating a specific CRWD water resource, or supporting research that partner organizations are initiating that involve monitoring and data analysis.

Goal 2: Increase knowledge and awareness of chloride pollution and road salt reduction strategies in CPPP key audiences.

Objective 2a: Conduct outreach to key audiences through education and trainings to increase the acceptance, implementation, and effectiveness of road salt reduction strategies.

Action 2a.1: Develop an outreach plan that identifies the education and/or training needs and strategies for priority audiences.

The District will develop an outreach plan that can be provided to priority audiences to increase knowledge and improve winter maintenance practices to ultimately reduce road salt application. The outreach plan will identify needs, opportunities, strategies, methods, and schedule for:

- Education: the dissemination of information through multiple modes of communication
- Training: the participation in organized hands-on skill building and learning sessions

The outreach plan may also include direction on: what materials are needed to support outreach efforts, where information gaps exist, what education and/or training methods would best address those information gaps, and how to prioritize implementation of all outreach efforts.

The District recognizes that it is not feasible to conduct intensive outreach to all key audiences defined in Section 6.2. While key audiences represent all audiences that the District could partner with to carry out CPPP actions or those that could be impacted by CPPP actions, priority audiences are defined as those that will have the most significant impact on reducing overall road salt application. Therefore, the priority audience of focus for the outreach plan will be Applicators. Prioritizing this audience and creating an outreach plan specific to their education and training needs will be more efficient and yield higher road salt reduction results since they are responsible for road salt application in the District.

The Primary Applicators to be targeted for education and training in the outreach plan are: private winter maintenance companies, institutional maintenance departments, industrial maintenance departments, as well as municipal public works departments (defined in Section 7).

Action 2a.2: Provide education to priority audiences on chloride issues and best practices for winter maintenance using various communication tools and materials.

The District will provide education according to the outreach plan created in Action 2a.1 using communication tools and materials such as videos, flyers, or signage to the identified priority audience: Applicators. Education methods and materials will be strategically determined in the outreach plan to improve their effectiveness and increase the likelihood of road salt reduction behaviors.

The District has previously provided extensive chloride pollution education and information sharing to several key audiences and Applicators, including residents, municipal departments, and other partners. Education and information sharing has been delivered through a variety of methods such as: public events and presentations; digital communications via the District's website, e-newsletters, and social media channels; and flyers or handout materials distributed at events or through the mail. These education efforts will continue to be available to key audiences of the District by request. The District will also continue to support educational strategies being conducted by partner organizations where applicable.

Action 2a.3: Provide training to priority audiences on best practices for winter maintenance and road salt reduction strategies.

The District will provide training according to the outreach plan created in Action 2a.1 on best practices for winter maintenance and road salt reduction strategies to the identified priority audience: Applicators. Trainings will include the MPCA Smart Salting Trainings as well as annual refresher trainings, both of which have previously been provided by the District to both municipal and school district employees. Additional training opportunities and strategies will be identified in the outreach plan and targeted towards the Primary Applicators.

Goal 3: Utilize road salt reduction solutions in CRWD.

Objective 3a: Support the implementation of road salt reduction solutions.

Action 3a.1: Develop and implement a grant program that provides financial support for partners to pursue road salt reduction projects, tools, and technologies.

The District will create a grant program to fund projects, tools, and technologies that demonstrate or support road salt reduction. Grant funds could go toward supporting strategies such as improving brine operations, supporting better snow removal through the purchase of brushes and better plow blades, or increasing frequency of equipment calibration. Eligible applicants may include local governments, nonprofits, businesses, and property owners with preference given to Primary Applicators (identified in Section 7). Grants will be distributed based on road salt reduction potential. Application processes, evaluation criteria, and grant cycles will be aligned with other District grant programs and will be based on the amount of funding the District can contribute annually. See Appendix E for solutions that could be implemented by partners through this grant program.

Action 3a.2: Identify, prioritize, and implement road salt reduction practices and projects led by the District.

CRWD will lead and fund the implementation of road salt reduction practices and projects that are in scope with the District's role. Road salt reduction practices and project opportunities will be identified, prioritized, and budgeted for annually. Potential practices and projects to consider include:

- Continue improving winter maintenance practices on the paved surfaces of the District's office site to demonstrate and promote new technologies that reduce dependence on road salt for de-icing and to work toward a salt-free campus.
    - Examples include: heated pavement, increased infiltration to reduce direct runoff from impervious surfaces where salt is applied, or use of de-icing alternatives .
- Developing an approach for addressing reports of road salt overapplication from community members and groups.
- Expanding existing CRWD illicit discharge detection and elimination (IDDE) program strategies to address road salt overapplication.

Goal 4: Support policies that reduce road salt use in CRWD.

Objective 4a: Include road salt reduction strategies in the District's rules and permitting program.

Action 4a.1: Evaluate and incorporate revisions to District Rules that target road salt reduction practices.

The District will assess its existing rules to determine where road salt reduction can be more explicitly addressed, drawing on work already in place at other watershed districts, as well as emerging research. This evaluation will consider: site salt management plans (including the designation of MPCA smart salting certified applicators in winter maintenance contracts), site plan review that considers design standards that reduce the need for salt, and snow storage requirement plans. This review will occur during the rules revision process that occurs every two years in conjunction with partners but can also be completed during non-revision years. Once rule revisions are adopted, the District will update its permitting procedures, and ensure staff have the knowledge to enforce all new rules.

Objective 4b: Advocate for laws and regulations that aim to reduce road salt use.

Action 4b.1: Identify and advocate for local-level ordinances and regulations that reduce road salt use.

The District will work with municipal partners to identify opportunities for enhancing chloride-related local regulations, such as: applicator training and certification; deicer bulk storage facility regulations; low salt design requirements, road salt use information, or Smart Salting Certification requirements for new or re-development sites; or parking lot, sidewalk, and road sweeping requirements (MPCA, 2019). This action could also include restrictions and reductions of the use of road salt on specific surfaces or in defined areas that are directly connected to vulnerable CRWD water resources; for example, limiting road salt application on sidewalks within immediate proximity to a high-risk water resource like Como Lake or Lake McCarrons.

Action 4b.2: Identify and advocate for state laws and regulations that reduce road salt use.

The District will work with partners to identify laws and regulations that can reduce road salt application. Some examples of these types of policies include: limited liability laws, a state salt fee, labeling requirements to prohibit false claims, occupational licensing requiring that all salt applicators obtain a license to apply salt (similar to plumbers and electricians), and requiring that state contractors model best practices. District staff will work in partnership with other watershed organizations to amplify their shared priorities and increase the potential for success.

Goal 5: Leverage partnerships and resources to successfully implement the CPPP.

Objective 5a: Collaborate with partners to implement the CPPP.

Action 5a.1: Communicate and participate with partners to further the implementation of the CPPP.

The District will build working relationships with partners identified in the CPPP and continue to identify and connect with new partners not currently outlined in the CPPP to stay current with all key audiences. These partnerships will be reinforced by consistent communication and will include regular meetings as needed. The District will also participate in other partners' ongoing road salt reduction efforts to maximize efficiency and build on the momentum already generated by partner efforts.

Action 5a.2: Provide a biannual update to partners to review Plan progress, upcoming implementation activities, and funding opportunities.

The District will provide an update every other year to Plan partners to review CPPP progress, identify new opportunities, and share new tools and funding resources.

Objective 5b: Continually identify sources of funding for implementing Plan actions.

Action 5b.1: Regularly identify and pursue outside funding opportunities to assist in implementation of the prioritized actions in the CPPP.

The District will regularly identify and apply for state, federal, and philanthropic grants that align with CPPP goals.

Table 5: CPPP Actions, status, audience(s), outcome, implementation frequency, and prioritization level

Goal	Final Objective and Action	Status	Audience(s)	Outcome	Implementation Frequency	Prioritization Level
Goal 1: Serve as a knowledgeable resource on chloride issues in CRWD.	**Objective 1a: Monitor chloride levels in CRWD water resources.**					
	Action 1a.1: Develop a comprehensive chloride monitoring plan for CRWD water resources.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	One-time/ Continuous	Critical
	Action 1a.2: Conduct year-round chloride monitoring at all five CRWD lakes.	Some Progress	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	Continuous	Critical
	Action 1a.3: Conduct year-round chloride monitoring at District stormwater monitoring stations.	Ongoing	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	Continuous	Important
	Action 1a.4: Conduct year-round chloride monitoring at additional monitoring locations within CRWD, including wetlands, stormwater ponds, and groundwater wells.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	Continuous	Important
	Objective 1b: Make chloride pollution data from CRWD water resources available and accessible.					
	Action 1b.1: Regularly analyze and report upon collected chloride data.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	One-time/ Continuous	Critical
	Objective 1c: Understand changes in road salt use in CRWD.					
	Action 1c.1: Obtain a baseline understanding of application rates and practices by Primary Applicators.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	One-time/ Continuous	Important
	Action 1c.2: Track changes in application rates and practices by Primary Applicators.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	Continuous	Beneficial
	Objective 1d: Stay informed on advances in chloride science.					
	Action 1d.1: Participate in trainings, meetings, and events to regularly review emerging research on chloride issues.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	Data/Information	Continuous	Important
	Action 1d.2: Provide funding to external research groups that seek to advance chloride science and future management strategies.	New	Researchers/Scientists	Data/Information	Continuous	Important
	Action 1d.3: Implement chloride research.	New	Researchers/Scientists	Data/Information	Continuous	Beneficial
Goal 2: Increase knowledge and awareness of chloride pollution and road salt reduction strategies in CPPP key audiences.	**Objective 2a: Conduct outreach to key audiences through education and trainings to increase the acceptance, implementation, and effectiveness of road salt reduction strategies**					
	Action 2a.1: Develop an outreach plan that identifies the education and/or training needs and strategies for priority audiences.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Developers	Behavior Change	One-time/ Continuous	Critical
	Action 2a.2: Provide education to priority audiences on chloride issues and best practices for winter maintenance using various communication tools and materials.	Some Progress	Applicators, Community Members, Policymakers, Regulatory Partners	Behavior Change	Continuous	Critical
	Action 2a.3: Provide training to priority audiences on best practices for winter maintenance and road salt reduction strategies.	Some Progress	Applicators, Community Members, Policymakers, Regulatory Partners, Developers	Behavior Change	Continuous	Critical

Goal	Final Objective and Action	Status of Action	Audience(s)	Outcome of Action	Frequency of Implementation	Prioritization Level
Goal 3: Utilize road salt reduction solutions in CRWD.	**Objective 3a: Support the implementation of road salt reduction solutions.**					
	Action 3a.1: Develop and implement a grant program that provides financial support for partners to pursue road salt reduction projects, tools, and technologies.	New	Applicators, Developers, Community Members	Application Reduction	One-time/ Continuous	Critical
	Action 3a.2: Identify, prioritize, and implement road salt reduction projects led by the District.	New	Applicators, Community Members	Application Reduction	Continuous	Important
Goal 4: Support policies that reduce road salt use in CRWD.	**Objective 4a: Include road salt reduction strategies in the District's Rules and permitting program.**					
	Action 4a.1: Evaluate and incorporate revisions to District Rules that target road salt reduction practices.	New	Developers, Regulatory Partners, Partner Groups	Policy Change	One-time/ Continuous	Important
	Objective 4b: Advocate for laws and regulations that aim to reduce road salt use.					
	Action 4b.1: Identify and advocate for local-level ordinances and regulations that reduce road salt use.	New	Community Members, Policymakers, Regulatory Partners, Partner Groups	Policy Change	One-time/ Continuous	Critical
	Action 4b.2: Identify and advocate for state laws and regulations that reduce road salt use.	New	Policymakers, Regulatory Partners, Partner Groups	Policy Change	One-time/ Continuous	Important
Goal 5: Leverage partnerships and resources to successfully implement the CPPP.	**Objective 5a: Collaborate with partners to implement the CPPP.**					
	Action 5a.1: Communicate and participate with partners to further the implementation of the CPPP.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	CPPP Implementation	Continuous	Critical
	Action 5a.2: Provide a biannual update to partners to review Plan progress, upcoming implementation activities, and funding opportunities.	New	Applicators, Community Members, Policymakers, Regulatory Partners, Researchers/Scientists, Partner Groups	CPPP Implementation	Continuous	Beneficial
	Objective 5b: Continually identify sources of funding for implementing Plan actions.					
	Action 5b.1: Regularly identify and pursue outside funding opportunities to assist in implementation of the prioritized actions in the CPPP.	New	Internal only	CPPP Implementation	Continuous	Beneficial

10 Implementation

10.1 Plan Duration and Adaptive Management

The CPPP is intended to guide the District's road salt reduction work for the next ten years. This duration allows for enough time to accomplish priority actions, while being flexible to work on solutions in an ever-changing environment. The CPPP was designed to be an adaptive plan to be reviewed and updated regularly to maintain an effective and responsive plan. The CPPP should be reevaluated every 2 years to confirm the upcoming year's priorities and implementation strategy, and then fully revised at the end of the plan term to match future conditions. This will include adjustments to uncompleted actions, or modifications to ongoing actions. Two major factors require the need for adaptive management in CPPP implementation: 1) climate change impacts, and 2) changes in technology, research, and policy.

10.1.1 Climate Change Impacts on Winter Maintenance Practices and Chloride Pollution

Multiple recent planning efforts outline the ways that climate change is impacting winter weather in Minnesota and the influence it has on how we manage our impervious surfaces, including road salt application (CRWD, 2025; MPCA 2016a; MPCA, 2020). One of these plans is the 2025 CRWD Climate Resiliency Framework, which outlines how Minnesota can expect warming winters, producing heavier snowstorms and increased freeze/thaw events in future climate scenarios. This will be the main climate change challenge to winter maintenance practices in CRWD. As discussed in the CPPP, taking a proactive approach to managing snow and ice during winter months is not only more effective, but also reduces the need for salt. When winter weather is more variable as a result of climate change, it becomes much harder to be proactive, and entities responsible for public safety often rely more heavily on salt when reacting to impacts of winter weather. Therefore, creating more tools and strategies that are adaptable to changing conditions allows for more proactive approaches to variabilities in future winter weather.

10.1.2 Changes in Chloride Science, Winter Maintenance Practices, Research, Regulation, and Policy

Use of road salt as a winter maintenance practice is evolving with new research, technology, regulation, and policy. These changes are happening at all levels of paved surface management, and the District needs to be ready to adjust any CPPP actions to meet these changes. One example of a recent change to regulation and policy is the inclusion of chloride-specific requirements that were added to the MPCA MS4 permit in 2020 (MPCA, 2023) (Appendix E). The MPCA updates the MS4 permit every five years, so it will be important to be adaptable to future changes in these requirements.

Additionally, during the creation of this Plan, a new partnership between the University of New Hampshire and the University of Minnesota was created called the Cold Climate Stormwater Center of Excellence (CCSCoE), which was founded on the principle that cold climates present unique challenges in managing stormwater, including the use of road salt. One of their current research projects is called "Source Control of Road Salts", which aims to measure the success of current education and certification programs for smart salting. This partnership highlights the growing need to find solutions to the challenges we face in CRWD, and as a state, to manage stormwater runoff in winter. This also demonstrates the continued need to stay abreast of these research and collaboration results.

Finally, the MPCA Smart Salting for Roads manual states “Winter maintenance is becoming a precision industry” (MPCA, 2023). This statement is indicative of the frequency of technology updates and why it will be important to be adaptable in programming and planning. The District recognizes the actions in the CPPP need to be carried out with this in mind. In the ten-year life of the Plan, District staff can adapt priority or scope of any action as technology, research, regulation, or policy needs inevitably shift.

10.2 Estimated Implementation Costs and Financing

Estimated individual costs for all CPPP actions are detailed in Table 6 and have an estimated summed total cost of $1.816M. These costs are based on estimates of current work, discussions with other organizations that have already began implementing similar actions, as well as initial cost estimates in the 2021-2030 WMP to create a District Chloride Plan (i.e. initiate a Deicing Practices Rule, and fund five annual Chloride Reduction Grants for eight years (CRWD, 2020b)). Inflation is not included in the estimates. The estimates are important to give District Board, Staff, and CAC a shared expectation of the level of investment to fully fund all listed actions for the ten-year plan life.

Table 6: CPPP Implementation Plan

			Cost (in thousands)										
Goal 1 Actions	**Priority**	**Potential Partners**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Estimated Total Cost**
Action 1a.1: Develop a comprehensive chloride monitoring plan for CRWD water resources.	Critical	CRWD-led	$ 5	--	--	--	--	--	--	--	--	--	$ 5
Action 1a.2: Conduct year-round chloride monitoring at all five CRWD lakes.	Critical	Ramsey County	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 100
Action 1a.3: Conduct year-round chloride monitoring at District stormwater monitoring stations.	Important	CRWD-led	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 50
Action 1a.4: Conduct year-round chloride monitoring at additional monitoring locations within the CRWD, including wetlands, stormwater ponds, and groundwater wells.	Important	MN DNR	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 10
Action 1b.1: Regularly analyze and report upon collected chloride data.	Critical	CRWD-led	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1
Action 1c.1: Obtain a baseline understanding of application rates and practices by Primary Applicators.	Important	Primary Applicators	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 10
Action 1c.2: Track changes in application rates and practices by Primary Applicators.	Beneficial	Primary Applicators	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 10
Action 1d.1: Participate in trainings, meetings, and events to regularly review emerging research on chloride issues.	Important	CRWD-led	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 10
Action 1d.2: Provide funding to external research groups that seek to advance chloride science and future management strategies.	Important	Researchers/Scientists	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 100
Action 1d.3: Implement chloride research.	Beneficial	CRWD-led	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 10
												Subtotal of Goal 1 Actions	**$ 306**
Goal 2 Actions	**Priority**	**Potential Partners**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Estimated Total Cost**
Action 2a.1: Develop an outreach plan that identifies the education and/or training needs and strategies for priority audiences.	Critical	CRWD-led	--	$ 15	--	--	--	--	--	--	--	--	$ 15
Action 2a.2: Provide education to priority audiences on chloride issues and best practices for winter maintenance using various communication tools and materials.	Critical	CRWD-led	--	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 135
Action 2a.3: Provide training to priority audiences on best practices for winter maintenance and road salt reduction strategies.	Critical	CRWD-led	--	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 135
												Subtotal of Goal 2 Actions	**$ 285**
Goal 3 Actions	**Priority**	**Potential Partners**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Estimated Total Cost**
Action 3a.1: Develop and implement a grant program that provides financial support for partners to pursue road salt reduction projects, tools, and technologies.	Critical	CRWD-led	$ 25	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 925
Action 3a.2: Identify, prioritize, and implement road salt reduction practices and projects led by the District.	Important	CRWD-led	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 100
												Subtotal of Goal 3 Actions	**$ 1,025**
Goal 4 Actions	**Priority**	**Potential Partners**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Estimated Total Cost**
Action 4a.1: Evaluate and incorporate revisions to District Rules that target road salt reduction practices.	Important	Ramsey Washington Metro Watershed District	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 50
Action 4b.1: Identify and advocate for local-level ordinances and regulations that reduce road salt use.	Critical	CRWD Municipalities	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	$ 100
Action 4b.2: Identify and advocate for state laws and regulations that reduce road salt use.	Important	MN Watersheds, Twin Cities Metro Area watershed districts & management organizations	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 50
												Subtotal of Goal 4 Actions	**$ 200**
Goal 5 Actions	**Priority**	**Potential Partners**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Estimated Total Cost**
Action 5a.1: Communicate and participate with partners to further the implementation of the CPPP.	Critical	CRWD-led	--	--	--	--	--	--	--	--	--	--	Included in other costs
Action 5a.2: Provide a biannual update to partners to review Plan progress, upcoming implementation activities, and funding opportunities.	Beneficial	CRWD-led	--	--	--	--	--	--	--	--	--	--	Included in other costs
Action 5b.1: Regularly identify and pursue outside funding opportunities to assist in implementation of the prioritized actions in the CPPP.	Beneficial	State and Federal Agencies	--	--	--	--	--	--	--	--	--	--	Included in other costs
												Subtotal of Goal 5 Actions	**$ -**
												Total Cost of all Plan Actions	**$ 1,816**

11 Summary and Recommendations

The evidence of chloride pollution from road salt use in CRWD is well-documented and greatly concerning. The CPPP offers feasible and effective actions to increase the District's capacity to address this high priority issue and to work toward the overall Plan goal to:

> ***Reduce the use of road salt for winter maintenance in CRWD to prevent further degradation to CRWD's water resources, natural resources, and infrastructure from chloride pollution.***

Based upon current District and partner work, capacity and resources, and the prioritization levels of Table 5, it is recommended that the following "new" actions be prioritized over the course of the next two years of CPPP implementation:

- Action 1d.1: Participate in trainings, meetings, and events to regularly review emerging research on chloride issues.
- Action 2a.1: Develop an outreach plan that identifies the education and/or training needs and strategies for priority audiences.
- Action 3a.1: Develop and implement a grant program that provides financial support for partners to pursue road salt reduction projects, tools, and technologies.
- Action 4a.1: Evaluate and incorporate revisions to District Rules that target road salt reduction practices.
- Action 4b.1: Identify and advocate for local-level ordinances and regulations that reduce road salt use.
- Action 4b.2: Identify and advocate for state laws and regulations that reduce road salt use.

It is recommended that the following actions categorized as "ongoing" and "some progress" in Table 5 will continue over the next two years of CPPP implementation:

- Action 1a.2: Conduct year-round chloride monitoring at all five CRWD lakes.
- Action 1a.3: Conduct year-round monitoring at District stormwater monitoring stations.
- Action 2a.2: Provide education to priority audiences on chloride issues and best practices for winter maintenance using various communication tools and materials.
- Action 2a.3: Provide training to priority audiences on best practices for winter maintenance and road salt reduction strategies.

After the first two years of implementation, a progress review will be completed and utilized to inform the next two years of CPPP action implementation.

The District is committed to working towards all actions of the CPPP. The District will continue to work with partners to reduce the use of road salt for winter maintenance in CRWD, the Twin Cities metro area, and the state. This work is imperative to reduce the current impacts of chloride pollution and prevent future chloride pollution to CRWD's water resources, natural resources, and infrastructure.

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13 Appendices

Appendix A: Chloride Management Plan Project – Task 2.1 Review of Applicable CRWD Data

Technical Memorandum

To: Britta Belden, Division Manager
Sarah Wein, Water Resource Project Manager
Capitol Region Watershed District (CRWD)

From: Lan Tornes, Natural Resources Scientist
Emily O'Donnell, Water Resources Scientist I
Della Schall Young, CPESC, PMP, CTF, Principal Scientist

Date: January 8, 2025 (Revised October 21, 2025)

Re: Chloride Management Plan Project – Task 2.1 Review of Available CRWD Data

1 INTRODUCTION

The Capitol Region Watershed District (CRWD) is developing a Chloride Pollution Prevention Plan (CPPP) to help guide District efforts to reduce chloride pollution in CRWD to better protect District water resources. This memorandum provides a comprehensive review of CRWD's stormwater and lake chloride monitoring datasets, fulfilling Task 2.1 of the CPPP Project. It evaluates chloride conditions across the watershed, compares data to MPCA state standards, examines trends in samples from different flow regimes and different seasons, discusses impacts of stormwater chloride concentrations on District lake water quality, and offers strategic monitoring recommendations to support CPPP actions and future work. Overall, the findings in this memo provide a detailed assessment of chloride conditions within the watershed and establish a foundation for advancing CRWD's chloride reduction goals.

This memo incorporates findings from an additional April 2025 supplementary technical analyses: Attachment A: *Supplementary Data Analysis for Chloride Pollution Prevention Plan Project—Task 2.1 Review of Available CRWD Data (April 18, 2025)*. This addition enhances the robustness of seasonal trend analysis, spatial prioritization, and the technical basis for chloride management strategies.

2 WATERSHED OVERVIEW

The CRWD spans 41 square miles and consists of 16 delineated subwatersheds (Figure 1), eight of which have both inactive and active monitoring locations that have been included in this study (Table 1). Each subwatershed is made up of varying land use characteristics, including residential, industrial, park/golf course, retail/office, institutional, and undeveloped. CRWD has over 50% impervious surface cover that can accelerate runoff and contribute to elevated chloride concentrations in District water bodies.

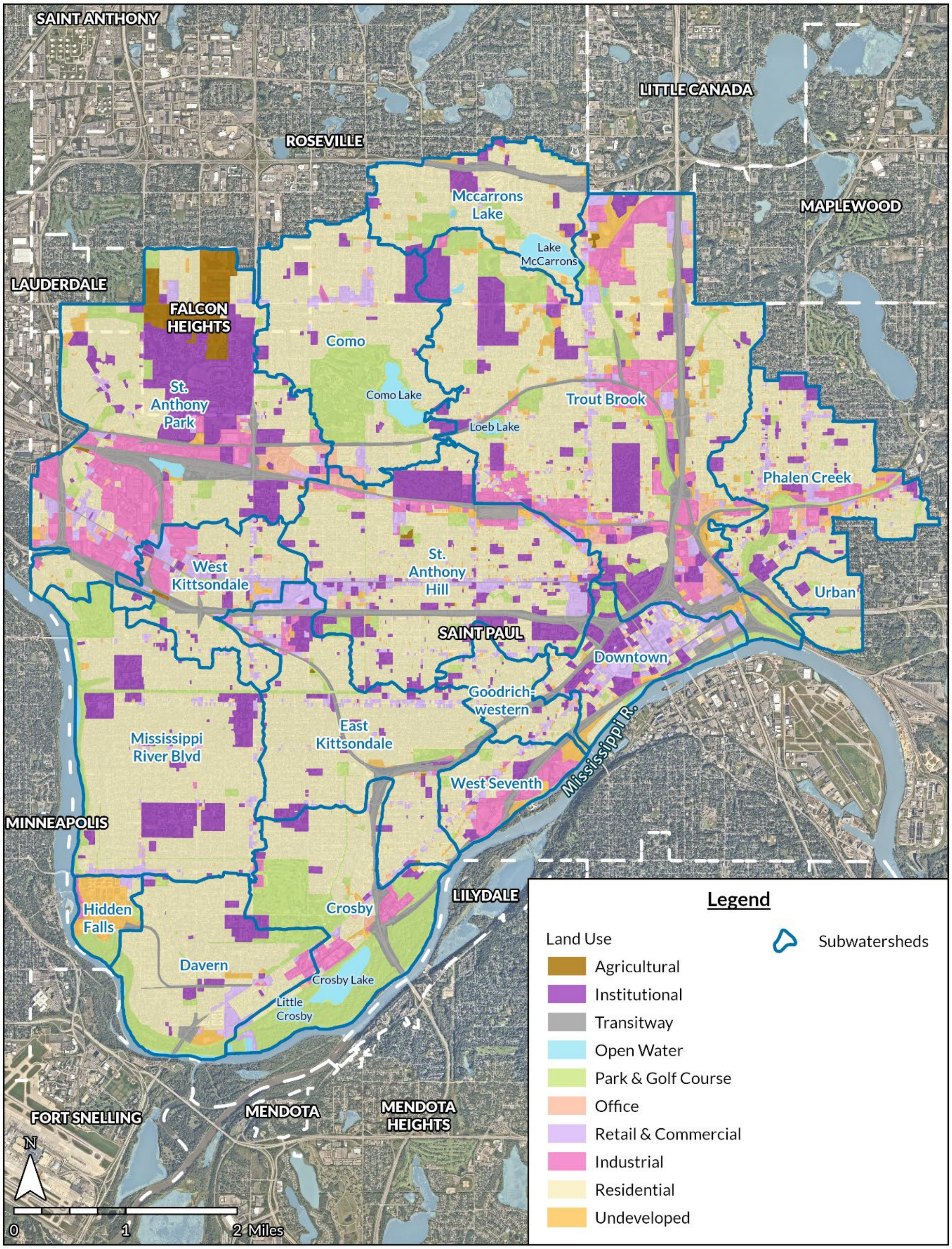

Figure 1. Map of land use data in the CRWD

Table 1. Land use breakdown for each subwatershed of the CRWD. Sites highlighted in yellow have active and inactive monitoring locations that were incorporated into this study.

Subwatershed	Total Acreage	Residential %	Park/Golf Course %	Undeveloped %	Retail %	Office %	Institutional %	Transitway %	Industrial %
Crosby	1,520.5	29.1	44.7	1.2	2.0	0.5	3.5	6.9	5.9
Davern	1,311.5	66.0	14.8	2.6	3.9	0.2	5.8	3.4	2.1
Downtown	741.5	21.4	9.4	4.2	21.0	3.6	20.2	17.1	0.7
East Kittsondale	1,856	71.3	3.8	0.9	7.7	0.8	6.9	7.2	1.6
Goodrich-Western	452.5	75.2	3.1	2.4	5.5	0.9	6.9	6.0	0.0
Hidden Falls	239.5	7.1	23.0	60.5	3.3	0.0	0.0	1.7	4.4
McCarrons Lake	1,076.5	63.4	10.5	3.0	0.8	0.5	7.3	7.4	0.0
Mississippi River Blvd	2,330	71.1	9.9	0.4	3.0	0.4	14.3	0.0	0.2
Phalen Creek	1,427	58.4	6.7	6.5	6.2	1.5	10.3	3.6	6.7
St. Anthony Hill	2,530	58.2	4.3	2.6	7.7	1.4	15.3	7.1	3.3
St. Anthony Park	3,412	34.6	4.9	1.4	4.0	2.6	20.4	9.4	14.8
Trout Brook	4,980	45.1	9.5	6.2	4.3	1.8	12.4	8.5	11.7
West Kittsondale	899	54.5	2.7	1.7	14.7	2.8	5.6	8.3	9.5
West Seventh	490	40.8	4.9	7.8	4.7	0.4	6.9	10.2	24.1
Urban	310.5	82.4	5.8	2.1	1.3	0.0	3.5	4.8	0.0
Como	1,809	61.6	21.3	0.3	3.6	1.8	6.2	1.1	0.3

3 MONITORING NETWORK AND DATA COLLECTION

This section provides an overview of CRWD's monitoring locations, including active and inactive sites, and key parameters measured. The datasets evaluated in this memo include sample data collected from in-lake monitoring sites and active/inactive stormwater monitoring sites. Sample data from baseflow, stormflow, and snowmelt conditions are collected from stormwater monitoring sites (Figure 2). Below is a summary of the monitoring locations, including operational status and sampling dates of the data provided by the CRWD.

3.1 Active In-Lake Monitoring Locations

- **Como Lake:** This lake has been monitored for chloride since 1984. This lake lies within the Como subwatershed which is primarily composed of residential land use (61.6%) followed by park/golf course land use (21.3%).

- **Crosby Lake:** This lake has been monitored for chloride since 1999. The lake lies within the Crosby subwatershed which is primarily composed of park/golf course land use (44.7%) followed by residential land use (29.1%).

- **Little Crosby Lake:** This lake has been monitored for chloride since 2011. The lake lies within the Crosby subwatershed which is primarily composed of park/golf course land use (44.7%) followed by residential land use (29.1%).

- **Loeb Lake:** This lake has been monitored for chloride since 2003. The lake lies within the Trout Brook subwatershed which is primarily composed of residential land use (45.1%) followed by institutional land use (12.4%).

- **Lake McCarrons:** This lake has been monitored for chloride since 1988. The lake lies within the MCCarrons subwatershed which is primarily composed of residential land use (63.4%) followed by park/golf course land use (10.5%).

3.2 Active Stormwater Monitoring Locations

- **Como 3**: This site has been monitored for stormflow since 2009 and snowmelt since 2011. It is located in a predominantly residential drainage area which accounts for 43.4% of the area. This site is the outlet of one of the thirteen subwatersheds that empty into Como Lake (Como D subwatershed).

- **East Kittsondale**: This site has been monitored for baseflow, stormflow, and snowmelt since 2005. It is dominated by residential land use (71.3%) with a notable transitway presence (7.2%). This site is the outlet of the majority of the drainage of the East Kittsondale subwatershed. Other pipes connect between the monitoring station location and the actual outfall on the river.

- **Villa Park Outlet**: This site has been monitored for baseflow, stormflow, and snowmelt since 2006. The subwatershed is primarily residential (63.4%), and the site is located at the outlet of the entire Villa Park wetland treatment system. This pipe is the direct inlet to Lake McCarrons from this wetland treatment system.

- **Trout Brook Outlet**: This site has been monitored for baseflow, stormflow, and snowmelt since 2007. The subwatershed is a mixed-use drainage area influenced by residential, transitway, and industrial contributions. This site is the outlet of the majority of the drainage of the Trout Brook subwatershed, the largest subwatershed in the CRWD. Located upstream from the actual outfall on the river, however, other pipes connect between the monitoring station location and the actual outfall.

- **Parkview System Inlet**: This site has been monitored for stormflow and snowmelt since 2021 and stormwater since 2020. The drainage area is predominantly residential. This site is located at the inlet to the Parkview Center School BMP project.

3.3 Inactive Stormwater Monitoring Locations

- **Arlington-Hamline Facility (inlet) – AHUG:** This site was monitored for stormflow from 2007 to 2016 and snowmelt from 2009 to 2017. This is the inlet pipe to the large underground infiltration pipe gallery called "the Arlington-Hamline Underground".

- **B-Dale Outlet:** This site was monitored for stormflow from 2013 to 2015 and for snowmelt from 2014-2015. This station was monitored prior to the 2016 construction of the Upper Villa Water Reuse project located upstream of this station. This site is located at one of the inlets to the Villa Park wetland treatment system.

- **Hidden Falls Outlet:** This site was monitored for baseflow and stormflow from 2014 to 2021, and for snowmelt from 2015 to 2021. This location no longer exists due to the construction of Highland Bridge but was the previous location of the main outlet of the Hidden Falls subwatershed.

- **North Como 3 | Como C:** This site was monitored for stormflow from 2018 to 2024 and for snowmelt from 2019 to 2024. This site is the outlet of one of the thirteen subwatersheds that empty into Como Lake (Como C subwatershed).

- **Como 7 | Como B5:** This site was monitored for stormflow from 2007 to 2021 and for snowmelt from 2008 to 2020. This site is located just upstream of the outlet of one of the thirteen subwatersheds that empty into Como Lake (Como B5 subwatershed).

- **Sarita (outlet):** This site was monitored for stormflow from 2006-2014 and snowmelt in 2007, 2008, 2011, and 2013. This site is located at the outlet of a wetland/stormwater pond with a drainage area that encompasses large parts of the state fairgrounds and UMN St. Paul campus.

- **St. Anthony Park:** This site was monitored for baseflow, stormflow, and snowmelt from 2005 to 2021. This site is the outfall of the entire St. Anthony Park subwatershed which consists of residential (34.6%), institutional (20.4%), and industrial (14.8%) land uses.

- **Phalen Creek**: This site was monitored for baseflow, stormflow, and snowmelt from 2005 to 2023 (excluding 2017 to 2019 due to tunnel reconstruction). It has a residential-dominated drainage area (75.2%) with minor retail and undeveloped land. This site is the main outlet of the majority of the Phalen Creek subwatershed. Other pipes connect between the monitoring station location and the actual outfall on the river.

- **Trout Brook – East Branch:** This site was monitored for baseflow and stormflow from 2006-2021 and snowmelt from 2007-2021. This site is the branch of Trout Brook receiving drainage from the easternmost (and smaller) portion of the larger Trout Brook subwatershed. This site is located just upstream of where the east and west branches of the TBI connect.
- **Trout Brook –West Branch**: This site was monitored for baseflow and stormflow from 2005 to 2021 and snowmelt from 2008 to 2021. The site receives drainage from the western (and larger) portion of the Trout Brook subwatershed, and is located just upstream where the east and west branches of the TBI connect. Contains the drainage from the Como and McCarrons subwatersheds.
- **TBNS – Rose:** This site was monitored for stormflow from 2015 to 2021 and snowmelt from 2016 - 2021. This is the outfall pipe representing the drainage from a residential area located NW of the Trout Brook Nature Sanctuary (TBNS). The pipe was created during the construction of the TBNS.

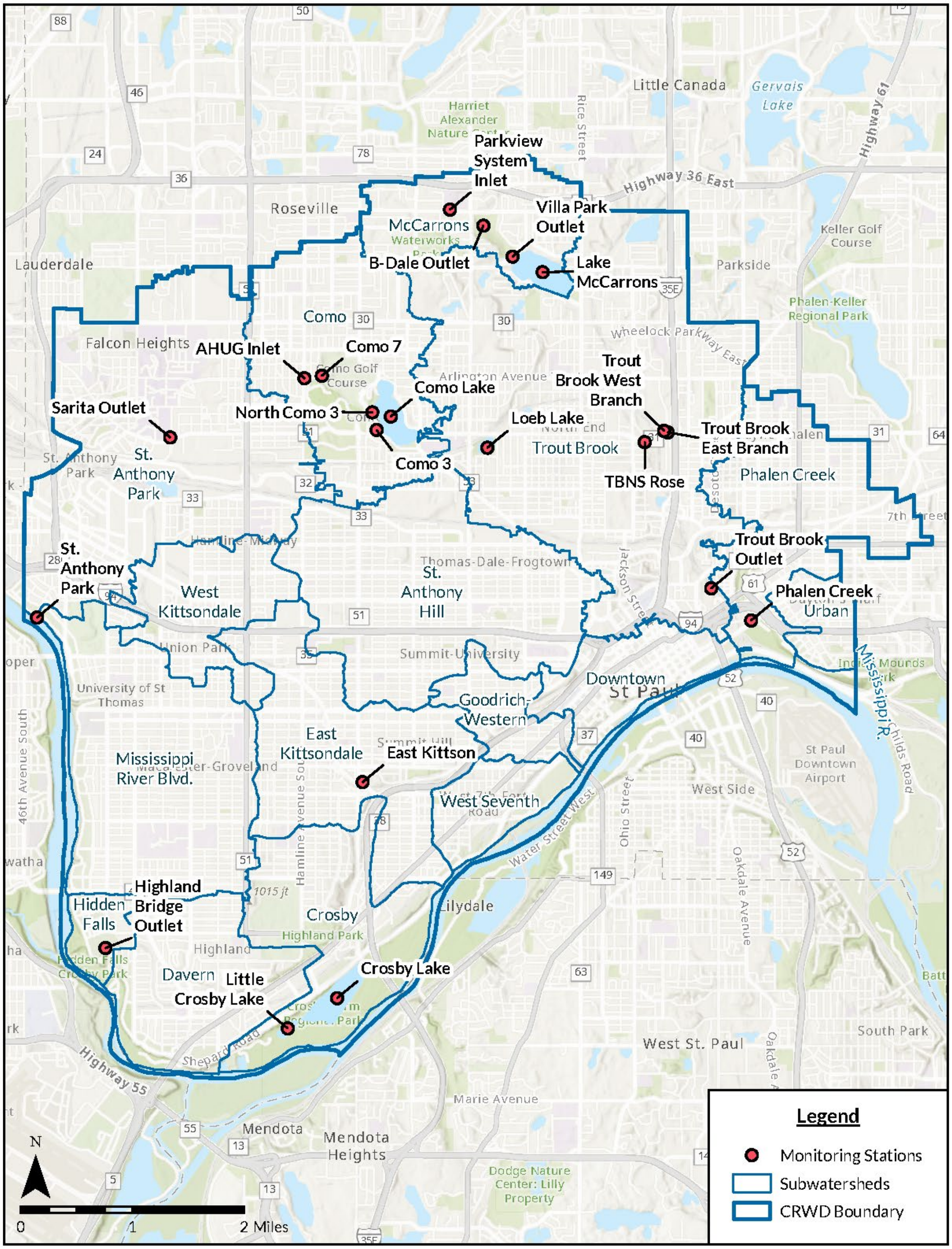

Figure 2. Map of CRWD subwatershed boundaries and monitoring station locations.

4 METHODS

4.1 Data Collection Methods

Stormwater samples are collected by CRWD year-round using both grab samples and automated composite sampling techniques during baseflow, stormflow, and snowmelt. Not all stormwater monitoring locations had data available for each flow condition or season. All CRWD stormwater samples are analyzed for chloride alongside a suite of other parameters.

In all five CRWD lakes, routine grab samples are collected from the surface and the bottom (and middle depths where lake depth allowed for additional sampling) ~10 times from ~April – October, and analyzed for chloride alongside a suite of other parameters. Targeted lake monitoring has resulted in additional sampling outside of this timeframe both historically and in more recent monitoring years.

All field sampling procedures for both stormwater and lakes are documented in CRWD's annual monitoring reports available on their website (https://www.capitolregionwd.org/monitoring-research/monitoring-program/).

4.2 Data Analysis Methods

Data used in the analysis were provided in the form of MS Excel workbooks (sample data for both stormwater and lake data), digital copies of related reports (lake data), and GIS files. GIS data included watershed boundaries, land use, and impervious surface information. To assess land use influence, CRWD-provided GIS data were used to calculate the percentage of land use types within each monitored drainage area. Categories were simplified to support analysis: residential, parks/golf courses, institutional, industrial, transitways, retail, and undeveloped.

Stormwater site chloride data were grouped by flow regime (baseflow, snowmelt, and stormflow) and season [spring (March–May), summer (June–August), fall (September–November), and winter (December–February)]. Samples from lake monitoring sites were grouped by depth (surface, middle, and bottom), and season [spring (March–May), summer (June–August), fall (September–November), and winter (December–February)].

To protect aquatic life, the Minnesota Pollution Control Agency (MPCA) and US Environmental Protection Agency (EPA) has established state standards for chloride in classified surface waters: a chronic standard of 230 milligrams per liter (mg/L) and a maximum standard of 860 mg/L (MPCA, 2025; USEPA, 1988; L. Charles, personal communication, June 3, 2025). District Lakes are compared to these standards to determine impairment status. While not directly applicable to District stormwater pipe and conveyance systems flow, these standards can provide critical context for evaluating observed chloride concentrations in stormwater pipes, and assessing potential impacts to District lakes, wetlands, and the Mississippi River.

Statistical summaries of chloride data were developed using R (via RStudio), including means, medians, and percentiles, which were visualized using boxplots and time series plots. The temporal analysis applied linear regression to assess changes in chloride concentration over time. Mann–

Kendall trend tests were used to evaluate the significance of observed trends in seasonal chloride concentrations. Supplementary figures, tables, and statistical code outputs are provided in Attachment A.

4.3 Predictive Analysis Methods

To estimate potential future trends in chloride concentrations, linear regression models were produced. For each monitoring site, chloride (dependent variable) was regressed against time (independent variable). These models provide slopes which represent the rate of change in chloride concentrations over the observed period of time. If chloride trends continue at the same rate for each monitoring location, future chloride concentrations could be extrapolated based on historical trends. However, it is important to remember that the linear regression is a simple model that does not take into account external variables such as changes in land use, climate, or road salt application practices.

The strengths of these models are supported by R^2 values, which indicate the strength of the correlation between chloride and time, as well as p-values, which represent the statistical significance of these models. P-values < 0.05 have been used as a common threshold in the scientific literature for determining statistical significance.

5 STORMWATER SITE RESULTS

5.1 Stormwater Chloride Concentrations by Flow Condition

5.1.1 Baseflow

Baseflow is characterized as flow where no storm or event flow contributes to the monitoring location's discharge. Baseflow in urban stormsewer pipes is supplemented by groundwater flow and, in urban environments, can receive flow from leaky sewer infrastructure, stormwater infrastructure, residential irrigation runoff, and other urban sources. Many baseflow data points at all stations fall above the boxplots, indicating high variability of baseflow concentration data and seasonal variability.

East Kittsondale exhibits the highest chloride baseflow concentrations of all sites, followed by Trout Brook East Branch (Figure 3). Consistently high chloride levels in CRWD baseflow samples indicate the long-term accumulation of salts in urban soils, shallow groundwater, and surface stormwater systems (e.g. stormwater ponds). Persistently high concentrations during baseflow conditions highlight the cumulative impacts of salt application over time and the challenge of reversing these trends.

5.1.2 Stormflow

Stormflow is defined as event flow where precipitation events cause increased discharge from runoff of impervious surfaces and stormwater infrastructure in urban areas. Storm events can produce a "first flush" effect, where pollutants accumulated during dry conditions (normal baseflow) are quickly mobilized from urban impervious surfaces and introduced to the sampling location, resulting in an initial spike in pollutant concentration at the early stages of a storm. Typically, high flow events lead to diluted concentrations, particularly in chloride, after the first flush has passed.

Villa Park Outlet has the highest median chloride stormflow concentration of all sites (Figure 4). This could be due to the accumulation of chloride in the upstream wetland ponds during winter and early spring that are then being flushed out during storm events (see Appendix A for further detail). Many stormflow data points at all stations fall above the boxplots, indicating high variability of stormflow concentration data and seasonal variability. Stormflow exhibits lower chloride concentrations overall (Figure 4) when compared to baseflow (Figure 3) and snowmelt (Figure 5).

5.1.3 Snowmelt

Snowmelt is defined as runoff resulting from melting snow during periods of warmer temperatures in the winter and spring, and may also include rain-on-snow events during this time period. The highest overall chloride concentrations are found in the snowmelt data across all three flow conditions (Figure 5). This is evidence of the widespread application of road salt during winter/early spring when snowmelt samples are collected.

The site with the highest median concentration is B-Dale Outlet followed by Como 3. Fewer snowmelt events are available as compared to baseflow and stormflow data. Many of the sites have greater variation in the upper 50% of their data (right-skewed boxplots) which demonstrates the variability in high chloride application rates as a result of highly variable winter weather.

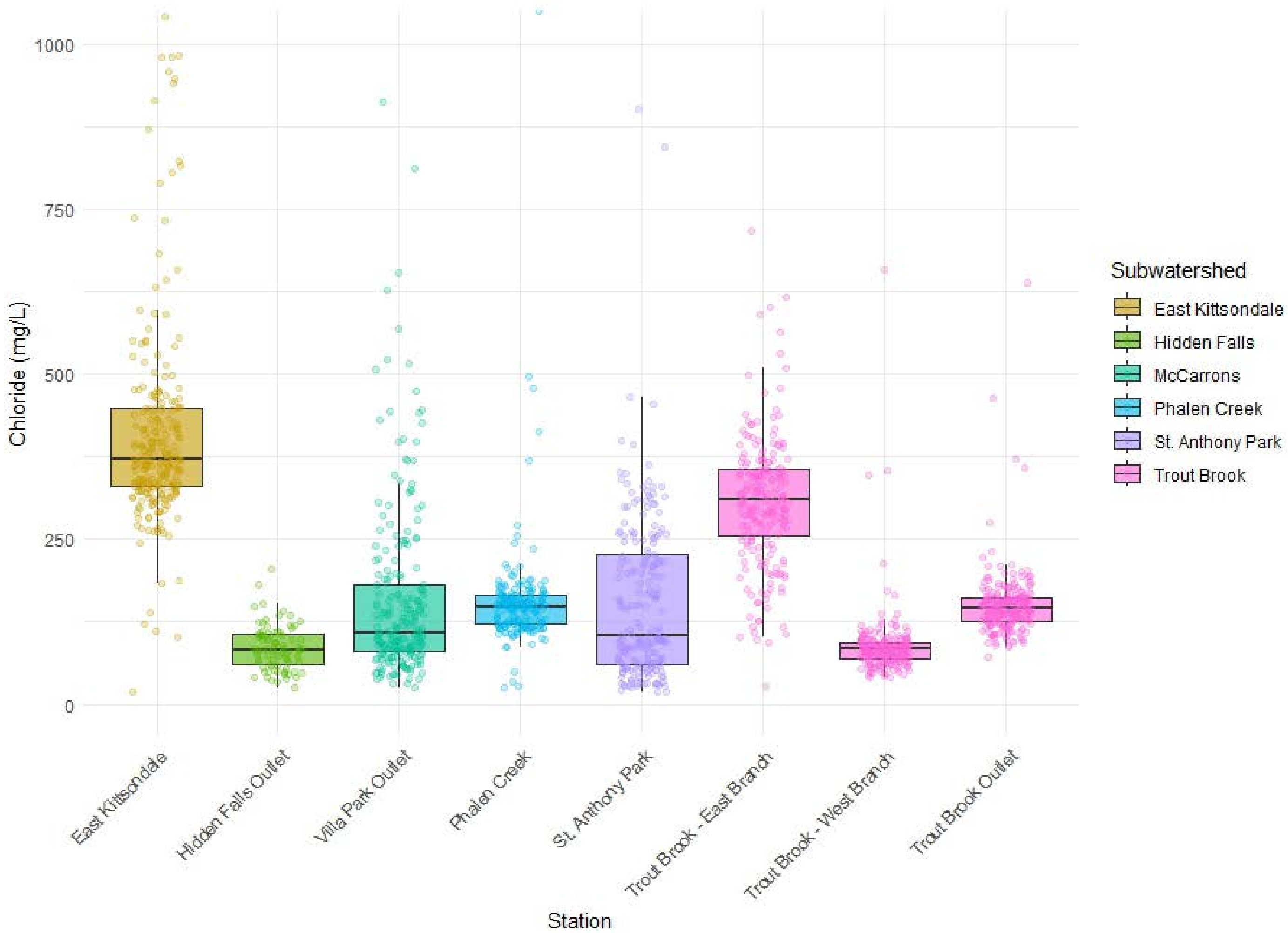

Figure 3. Boxplots of baseflow chloride concentrations at each stormwater monitoring location. Sites are color coordinated by subwatershed and data points are plotted over top of the boxplot. The axis was limited to 1000 mg/L to enhance visual clarity. As a result, 17 total outlier data points exceeding this threshold are not displayed in the figure but are retained in the dataset and included in all analyses. These outliers occurred at East Kittsondale, Phalen Creek, and Trout Brook – East Branch andrange from 1040 – 3309 mg/L. Sites excluded from the figure did not have baseflow data available.

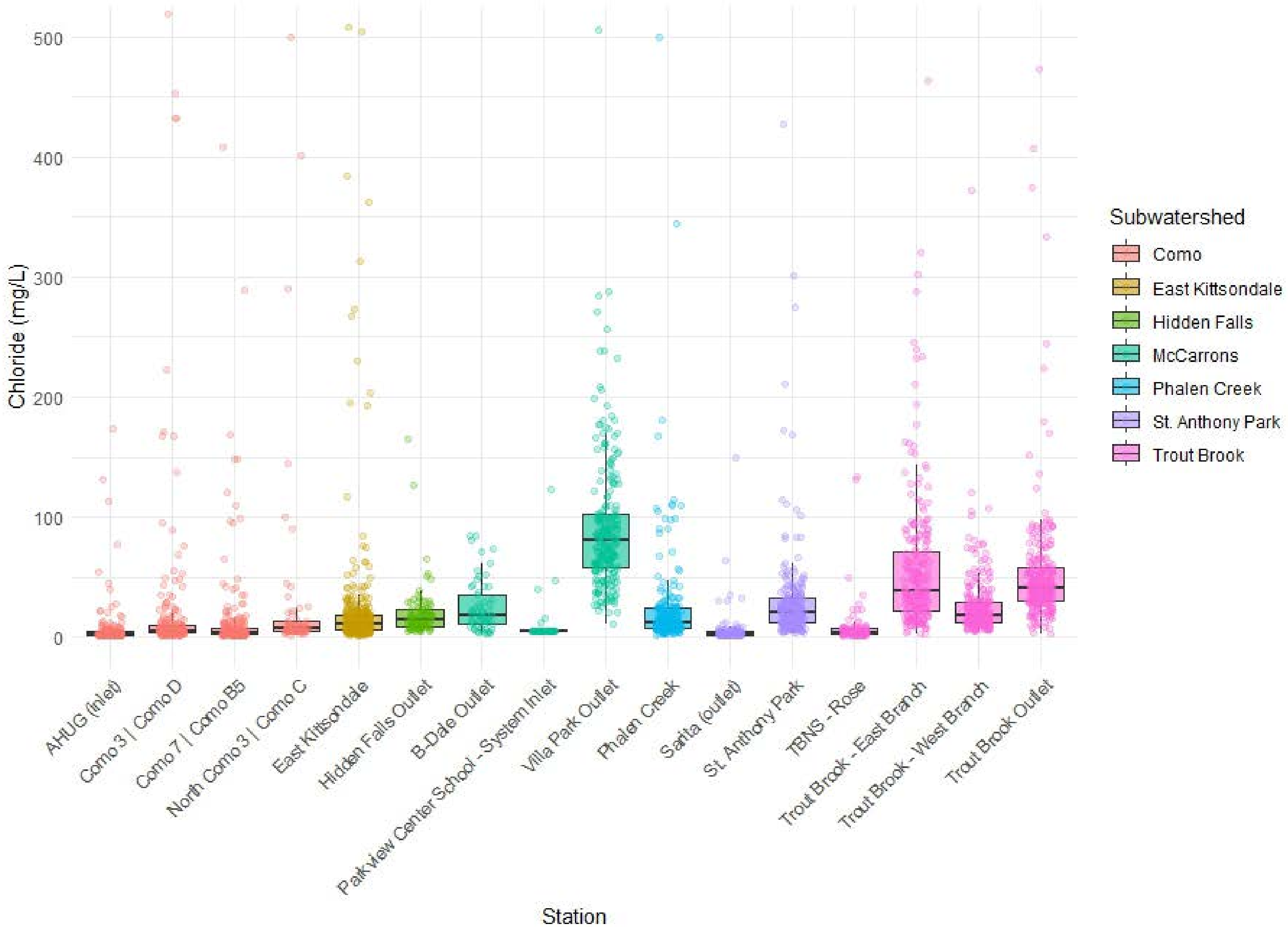

Figure 4. Boxplots of stormflow chloride concentrations at each stormwater monitoring location. Sites are color coordinated by subwatershed and data points are plotted over top of the boxplot. The axis was limited to 500 mg/L to enhance visual clarity. As a result, 14 total outlier data points exceeding this threshold are not displayed in the figure but are retained in the dataset and included in all analyses. These outliers occurred at Como 3, East Kittsondale, North Como 3, Phalen Creek, and Trout Brook Outlet, TBNS – Rose, and Villa Park Outlet andrange from 504 – 3570 mg/L.

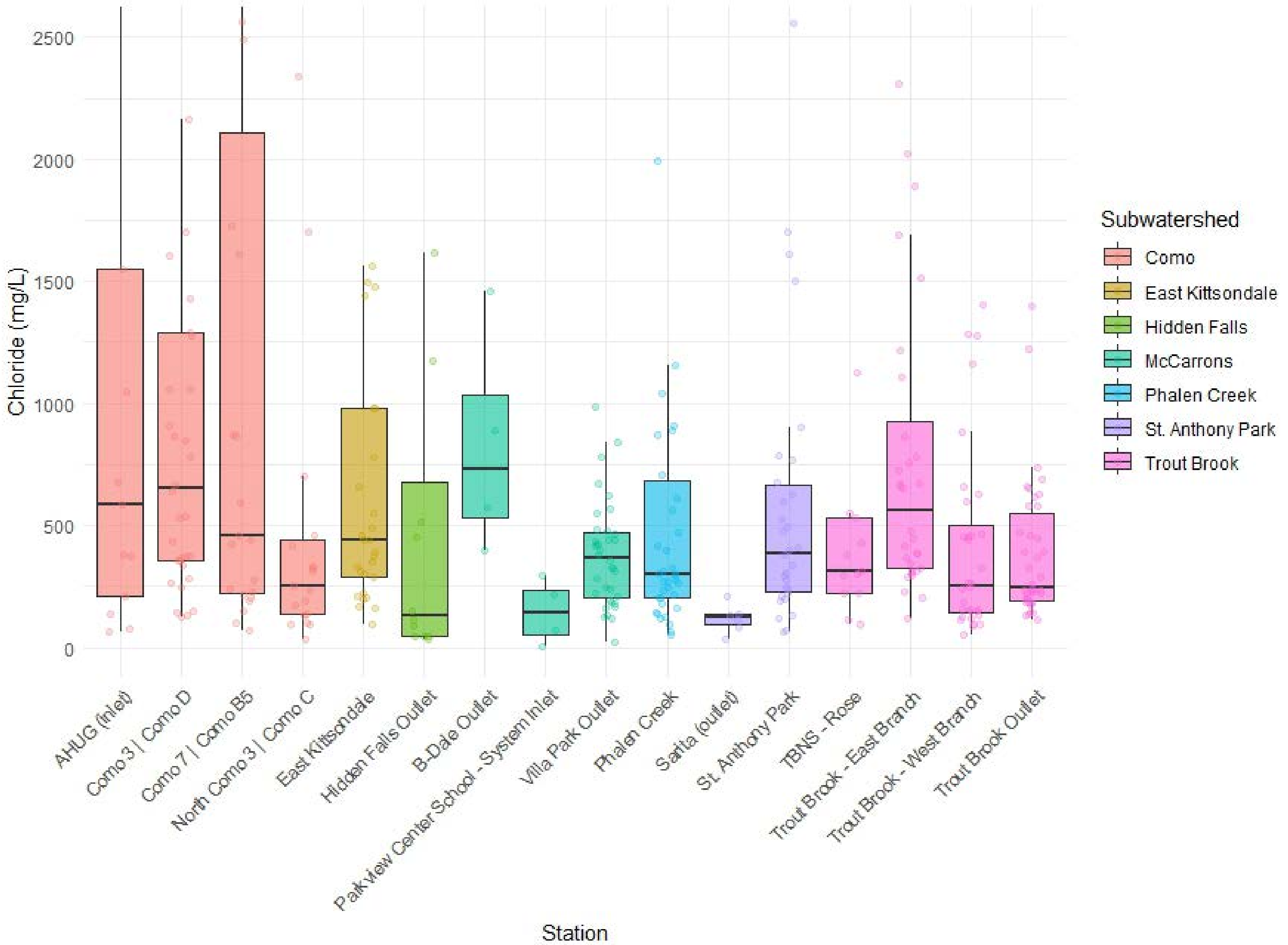

Figure 5. Boxplots of snowmelt chloride concentrations at each stormwater monitoring location. Sites are color coordinated by subwatershed and data points are plotted over top of the boxplot. The axis was limited to 2500 mg/L to enhance visual clarity. As a result, 22 total outlier data points exceeding this threshold are not displayed in the figure but are retained in the dataset and included in all analyses. These outliers occurred at AHUG, Como 3, Como 7, East Kittsondale, Hidden Falls Outlet, North Como 3, Phalen Creek, St. Anthony Park, Trout Brook – East Branch, and TBNS – Rose and range from 2554 – 18,622 mg/L.

5.2 Stormwater Chloride Concentrations by Season

Stormwater chloride concentrations exhibit pronounced seasonal variability at nearly all monitoring locations, with winter snowmelt sample data exhibiting the highest concentrations of all seasons, followed by spring snowmelt sample data (Figures 6-9). This seasonal peak offers further evidence that the widespread use of deicing salts during winter months for roadway, sidewalk, and parking lot maintenance is the primary contributor to the high levels of chloride observed in District stormsewer pipes.

Using Mann-Kendall trend tests, however, no statistically significant seasonal trends were found for active monitoring sites in the winter season (Attachment A) which could be due to the fact that chloride application is highly dependent upon winter weather, which is highly variable between winters and over time. In the spring, summer, and fall seasons, Trout Brook Outlet exhibits statistically significant increasing chloride concentrations during baseflow conditions. In the spring season, Villa Park Outlet exhibits statistically significant increasing chloride during stormflow only, whereas in the summer season, Villa Park Outlet exhibits statistically significant increases in chloride across both baseflow and stormflow. Increasing chloride in the nonwinter season when road salt is not being applied may be due to legacy chloride in soil and stormwater infrastructure from previous winter salt applications.

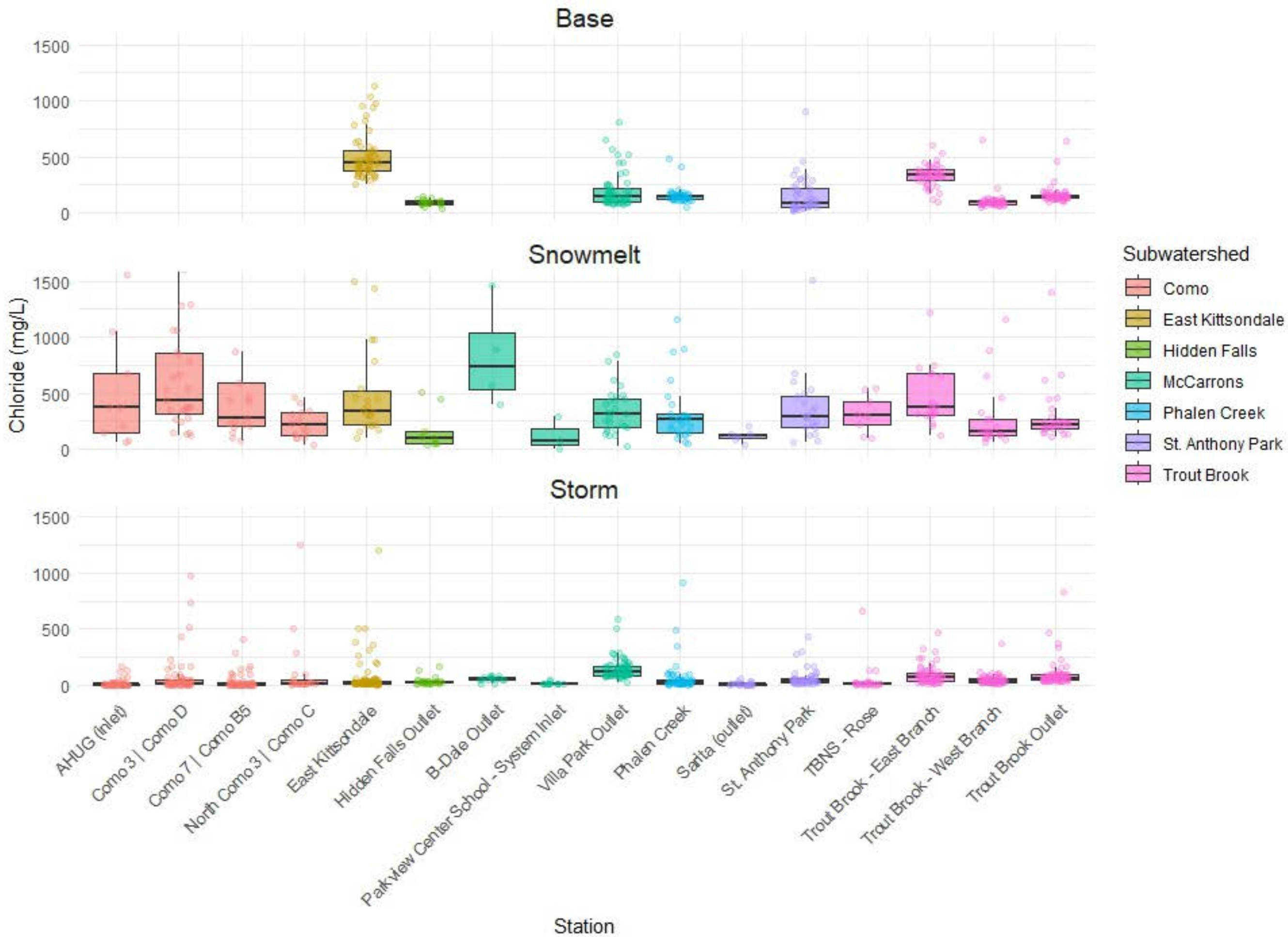

Figure 6. Boxplots of spring chloride concentrations at each stormwater monitoring location. Sites are color coordinated by subwatershed and data points are plotted over top of the boxplot. The axis was limited to 1500 mg/L to enhance visual clarity. As a result, 14 total outlier data points exceeding this threshold are not displayed in the figure but are retained in the dataset and included in all analyses. These outliers occurred at AHUG, Como 3, Como 7, East Kittsondale, North Como 3, Phalen Creek, St. Anthony Park, and Trout Brook – East Branch andrange from 1501.4-3570 mg/L.

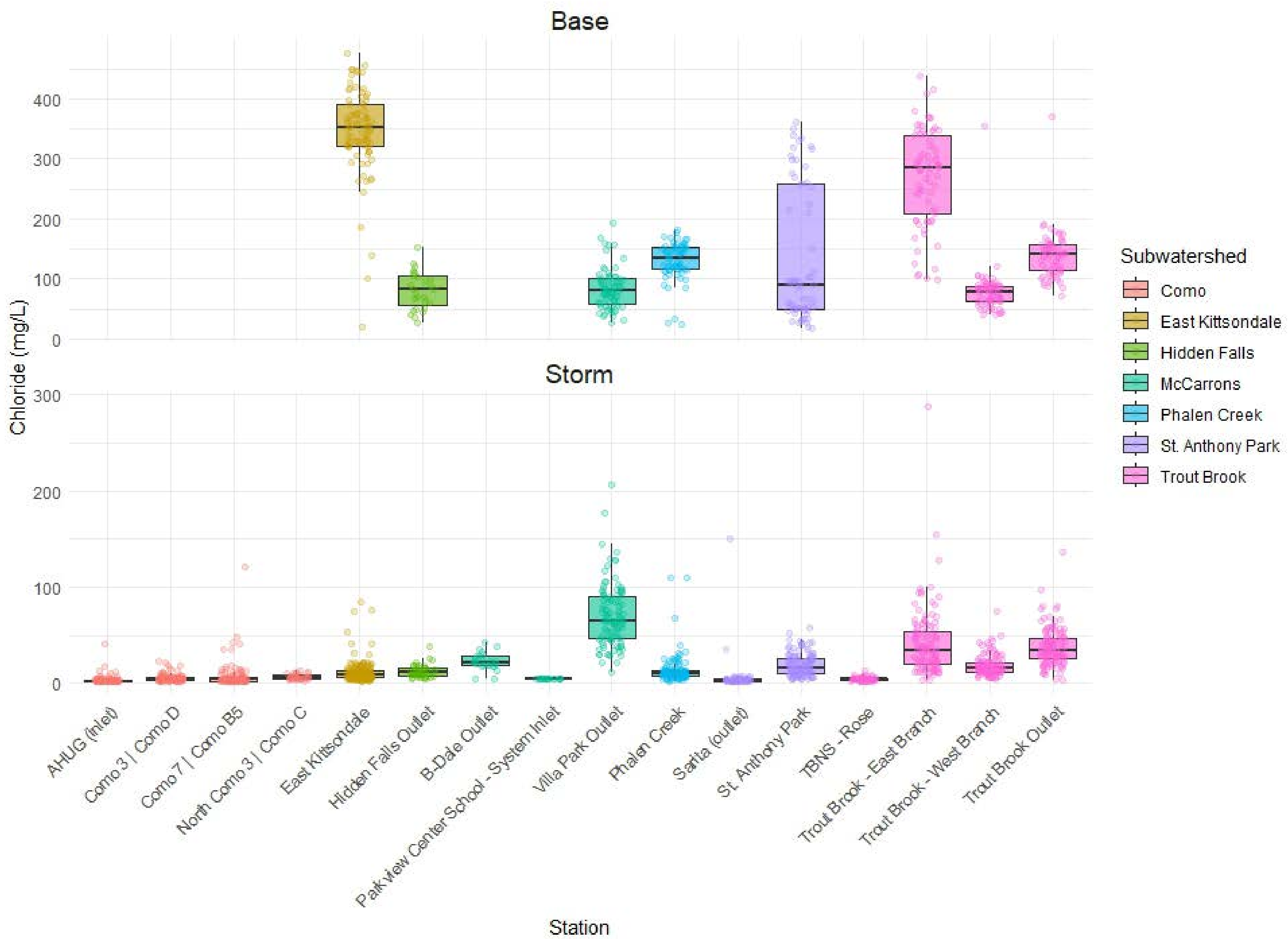

Figure 7. Boxplots of summer chloride concentrations at each stormwater monitoring location. Sites are color coordinated by subwatershed and data points are plotted over top of the boxplot. Note the differences in y-scales.

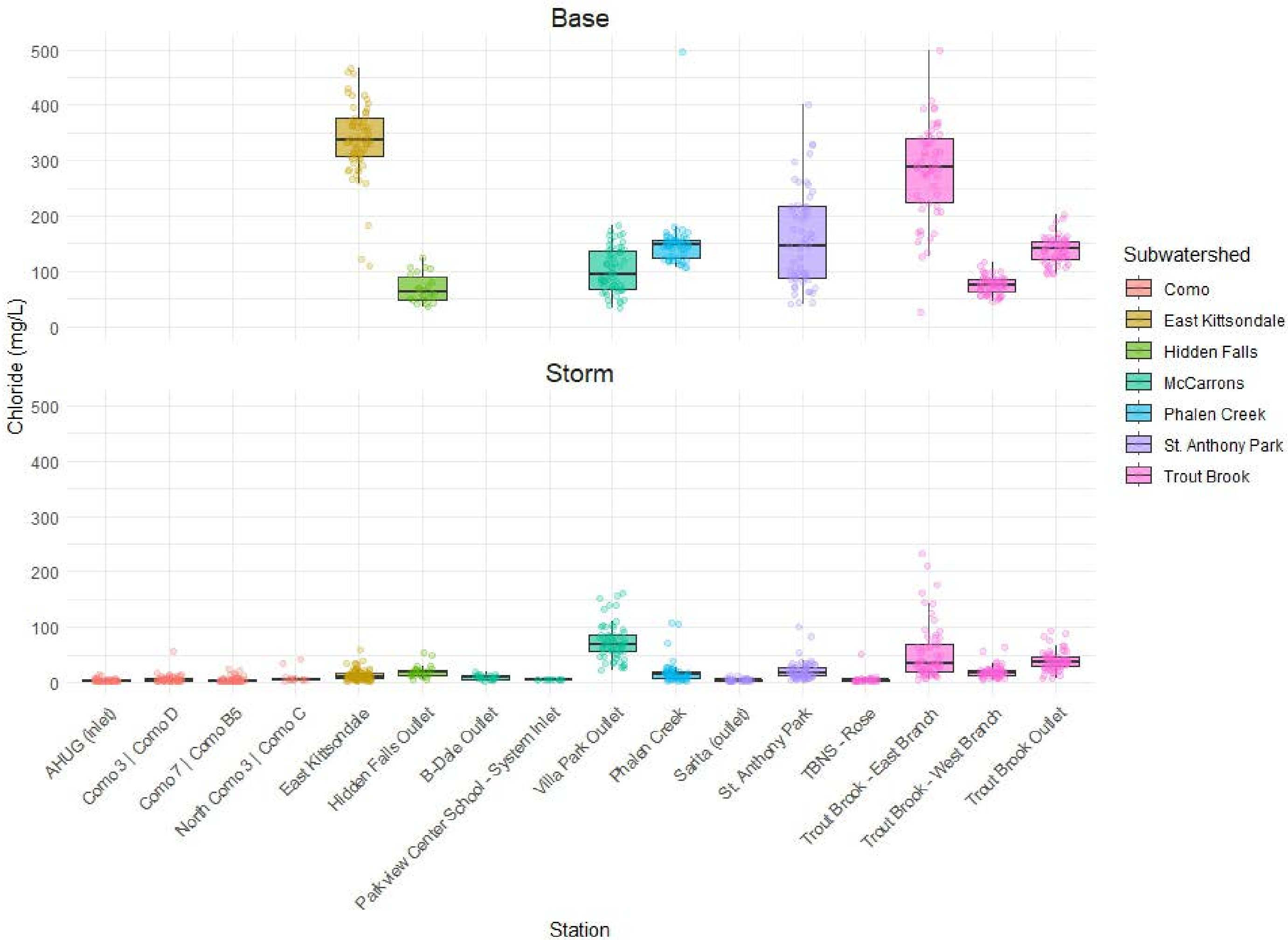

Figure 8. Boxplots of fall chloride concentrations at each stormwater monitoring location. Sites are color coordinated by subwatershed and data points are plotted over top of the boxplot. The axis was limited to 500 mg/L to enhance visual clarity. As a result, 3 total outlier data points exceeding this threshold are not displayed in the figure but are retained in the dataset and included in all analyses. These outliers occurred at East Kittsondale and range from 549-1461 mg/L.

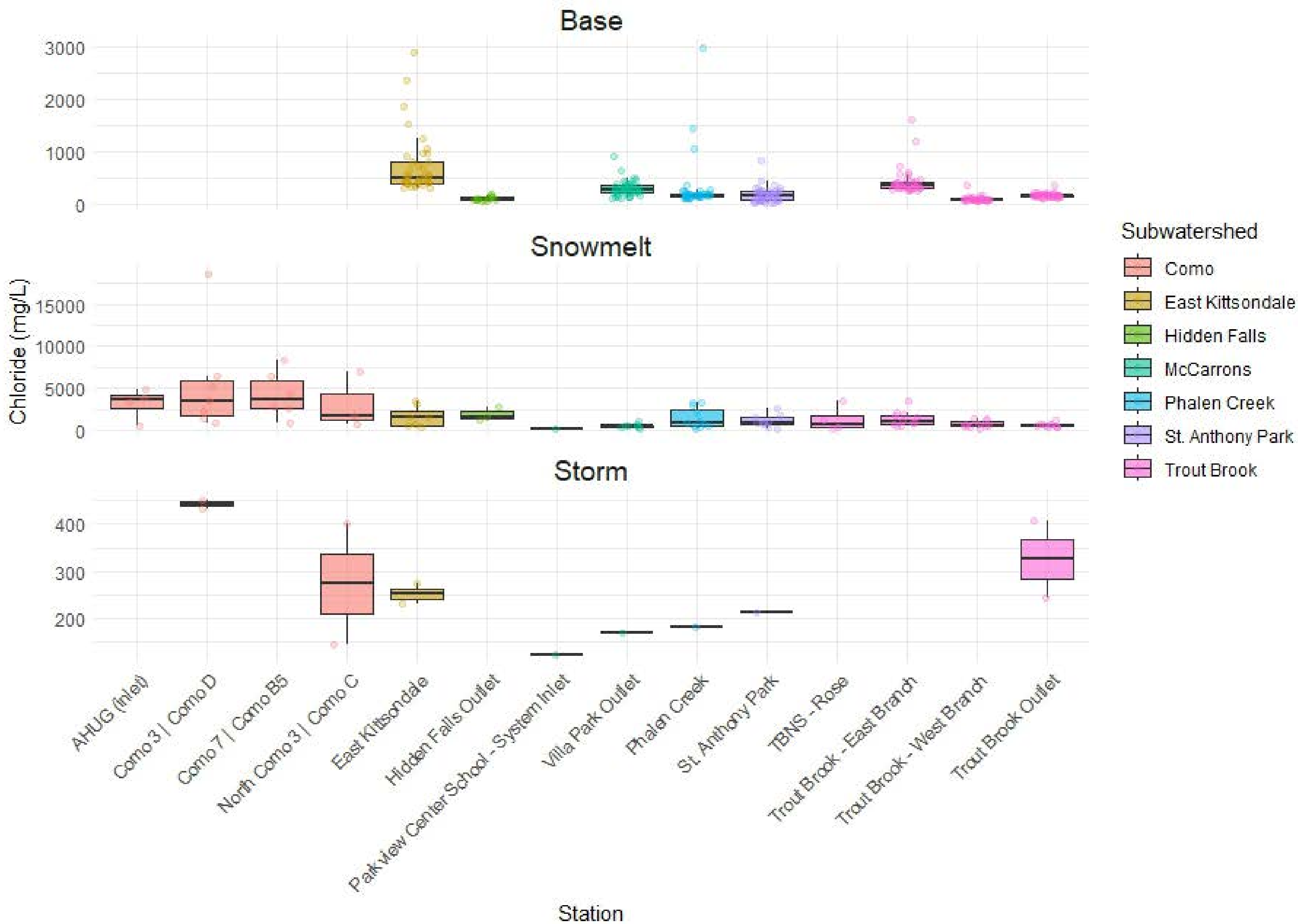

Figure 9. Boxplots of winter chloride concentrations at each stormwater monitoring location. Sites are color coordinated by subwatershed and data points are plotted over top of the boxplot. Note the variation in y-scale axes for each flow type.

5.3 Stormwater Chloride Concentrations – Comparison to State Standards

While the MPCA state standards are not directly applicable to stormwater pipes or conveyances, the comparison of CRWD stormwater site data to the chronic standard (230mg/L) and maximum standard (860 mg/L) can be used as context to interpret the magnitude of chloride concentrations across all monitored stormwater stations and to assess potential impacts on downstream receiving waters (see Attachment A for more details).

Figure 10 shows that there are chronic exceedances in all flow regimes, and the majority occur in baseflow samples. This demonstrates how high the concentrations of chloride are in groundwater in the District, and indicates that chloride is being conveyed to receiving water bodies via baseflow in addition to snowmelt and periods of active chloride application.

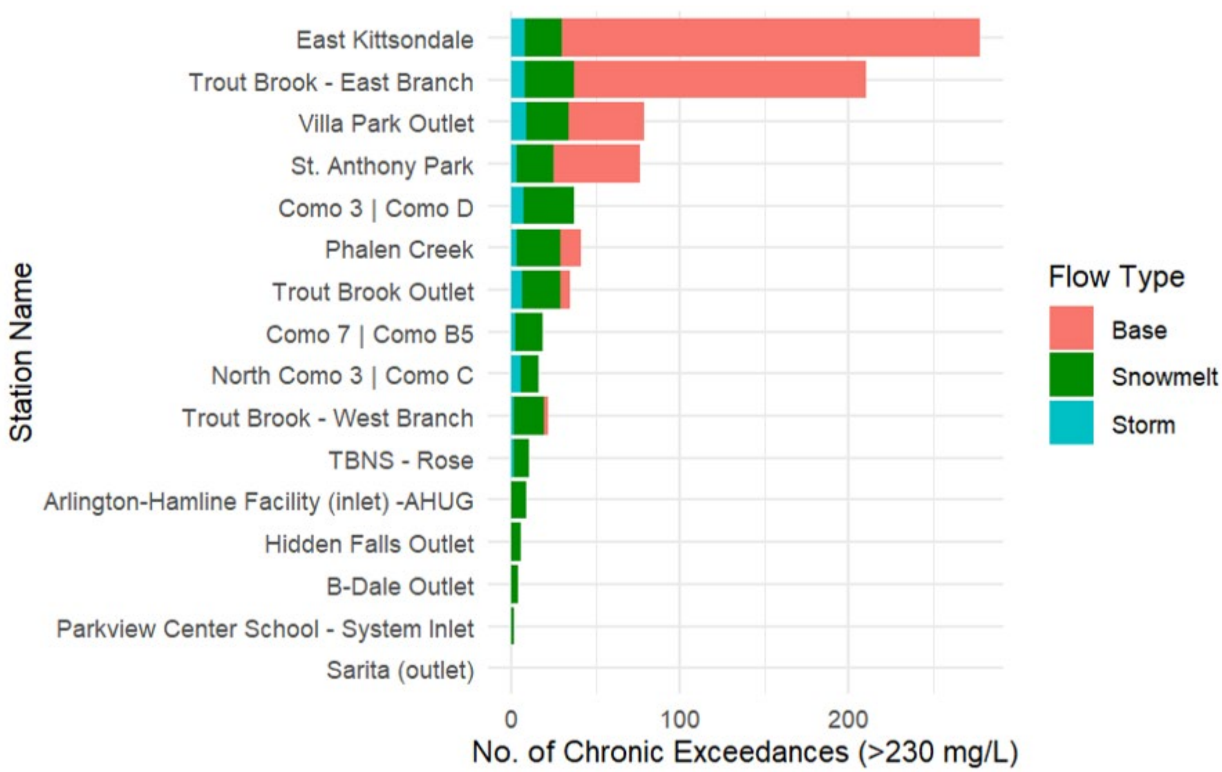

Figure 10. *All inactive and active sites with the highest number of occurrences where discrete sample concentrations exceeded the chronic aquatic life criterion (230 mg/L). These exceedances are shown for context only; the criteria apply to classified lakes and streams, not to stormwater conveyances. Data are color coded by sample flow type: red = baseflow and blue = snowmelt. R packages used for this figure include ggplot2, dplyr, and tidyverse. Como 3, Como 7, North Como 3, TBNS – Rose, AHUG, B-Dale Outlet, Parkview Center School – System Inlet, and Sarita (outlet) do not have any base samples collected on record and therefore will not show any chronic exceedances.*

6 IMPACT OF STORMWATER CHLORIDE ON DISTRICT LAKE WATER QUALITY

6.1 Lake Chloride Concentrations by Depth

All five lakes in CRWD receive stormwater runoff to varying degrees. Chloride-laden runoff (as indicated in Figures 6 – 9 above) has been having an impact over time on lake water quality, especially at Como Lake and Lake McCarrons. Lake data analysis was broken down by lake depth: surface, middle, and bottom (Appendix A, Table 2, and Figure 11) and annual median chloride concentrations across both the entire period of record and the past 12 years of chloride data for all depth ranges were examined.

Como, Loeb, and McCarrons surface chloride concentrations are all increasing over time. However, Como Lake surface concentration shows greater rates of increase and correlation to increased concentration over the past 12 years as compared to the entire period of record in comparison to the other two lakes. This indicates that the impact of higher salt use in more recent history has had a larger short-term impact on Como Lake than Loeb or McCarrons. Como Lake also exhibits some of the highest variability in surface chloride concentration among all five lakes.

Crosby and Little Crosby Lakes have fewer statistically significant trends at any of the three depth ranges. This could be due in part to the fact that the lakes have smaller watershed-to-lake area ratios and therefore less stormwater input. Additionally, Crosby and Little Crosby Lakes are located in the floodplain of the confluence of the Mississippi and Minnesota Rivers, and water quality in both lakes is significantly impacted by periods of river flooding.

Loeb Lake receives less stormwater input than Como Lake, and generally has some of the lowest chloride concentrations of all five lakes at all depths. Even so, the chloride data from the period of record as well as the past 12 years show that there are statistically significant increasing trends in all depth ranges for this lake.

Lake McCarrons also has a higher rate of increase in chloride concentrations over the past 12 years than in the entire period of record, indicating that the more recent years have had a higher impact on chloride concentration than in the earlier part of the period of record. While the rate of increase is lower than Como Lake, the fact that Lake McCarrons is a deep lake presents a potentially bigger threat, since once chloride enters the lake, it will take much longer to flush from the system than a shallow lake like Como. This could also impact lake turnover.

Table 2. *Annual median chloride linear regression statistically significant results between 2011 and 2023 (the overlapping years for all lakes). Green-shaded boxes indicate higher correlation at these depths with chloride concentrations over time.*

Lake	Depth	Slope	*p*-value	R^2	n
McCarrons	Surface	2.893	2.20×10^{-4}	0.725	13
Como	Surface	8.897	3.90×10^{-4}	0.696	13
Loeb	Surface	1.635	0.008	0.484	13
Como	Bottom	11.584	0.042	0.325	13

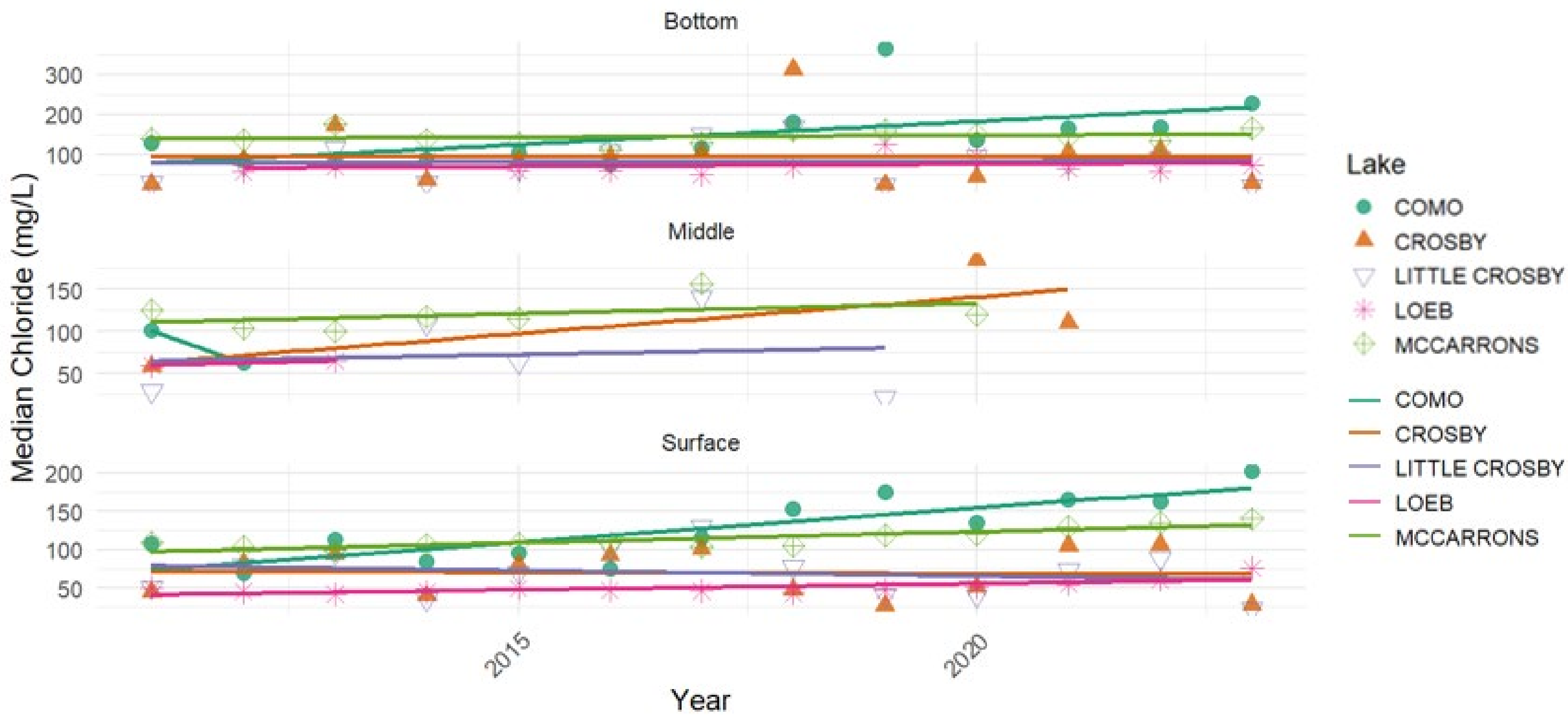

Figure 11. Annual median chloride concentrations (mg/L) by sample depth (bottom, middle, and surface) between 2011 and 2023 (the overlapping years for all lakes). Annual medians are color coded and shape coded by lake, with a corresponding linear regression line overlaid using the same color scheme as the median points. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.

6.2 Lake Chloride Concentrations by Season

Seasonal variation in lake data reveals that all lakes, except for Little Crosby, exhibit increasing chloride trends (Attachment A). The majority of the datapoints collected at all lakes come from nonwinter (March – November) data and it is therefore harder to determine trends in the winter data for any lake.

In Como Lake, all seasons at all depths exhibit statistically significant increasing chloride trends, with the highest trends occurring during the fall and winter seasons (Como is the only lake to have enough winter data to examine trends for this season). Loeb Lake data shows that all seasons have statistically significant increasing surface depth concentrations and increasing bottom depth concentrations during the summer season. Lastly, in Lake McCarrons, all seasons and all depths exhibit increasing chloride concentrations, with the exception of the winter season, which had too few datapoints to interpret a valid trend.

All of the above analyses indicate that the impact of road salt, even though it is applied/used during the winter and early spring, is impacting District lakes throughout other seasons.

6.3 Lake Chloride Concentrations – Comparison to State Standards and Implications for Impairment

District lake concentration data was compared to the state standards to determine impairment status. Figures 12 – 16 show the average annual chloride concentration for each lake, along with annual minimums/maximums, comparison to the chronic standard, and overall trend of the annual averages for each lake. Maximum values that fall above the chronic standard line on each figure indicate an exceedance.

Como Lake has been formally listed as impaired for chloride since 2014, with an MPCA-approved Total Maximum Daily Load (TMDL) study completed in 2016 (CRWD, 2019). Since the lake was listed, there have been multiple exceedances of both the chronic and maximum standards, indicating that chloride continues to be an issue over ten years after being placed on the impaired waters list. If nothing is done to curb chloride use and runoff in the Como Lake subwatershed, these exceedances will continue with no prospect for removal of the impairment status.

As noted in Sections 6.1 and 6.2, Crosby, Little Crosby, and Loeb Lakes are not being impacted by chloride pollution to the same extent as Como Lake and Lake McCarrons. Crosby has had multiple exceedances of the chronic standard mainly occurring during 2018 sample collection, with one instance in 2013 and another in 2023. Little Crosby and Loeb have not had any exceedances of either standard.

Lake McCarrons has only had two exceedances of the 230 mg/L chronic standard in the last 20 years (occurring in 2009 and 2013). Lake McCarrons, however, was identified as high risk of chloride impairment in the most recent lake management plan (CRWD, 2020) due to the documented increasing trend in chloride concentration. If this increasing trend continues, more exceedances will occur, and it is likely that the lake could become impaired before 2030. As discussed in section 6.1 above, this has much greater implications for lake health in the long-term.

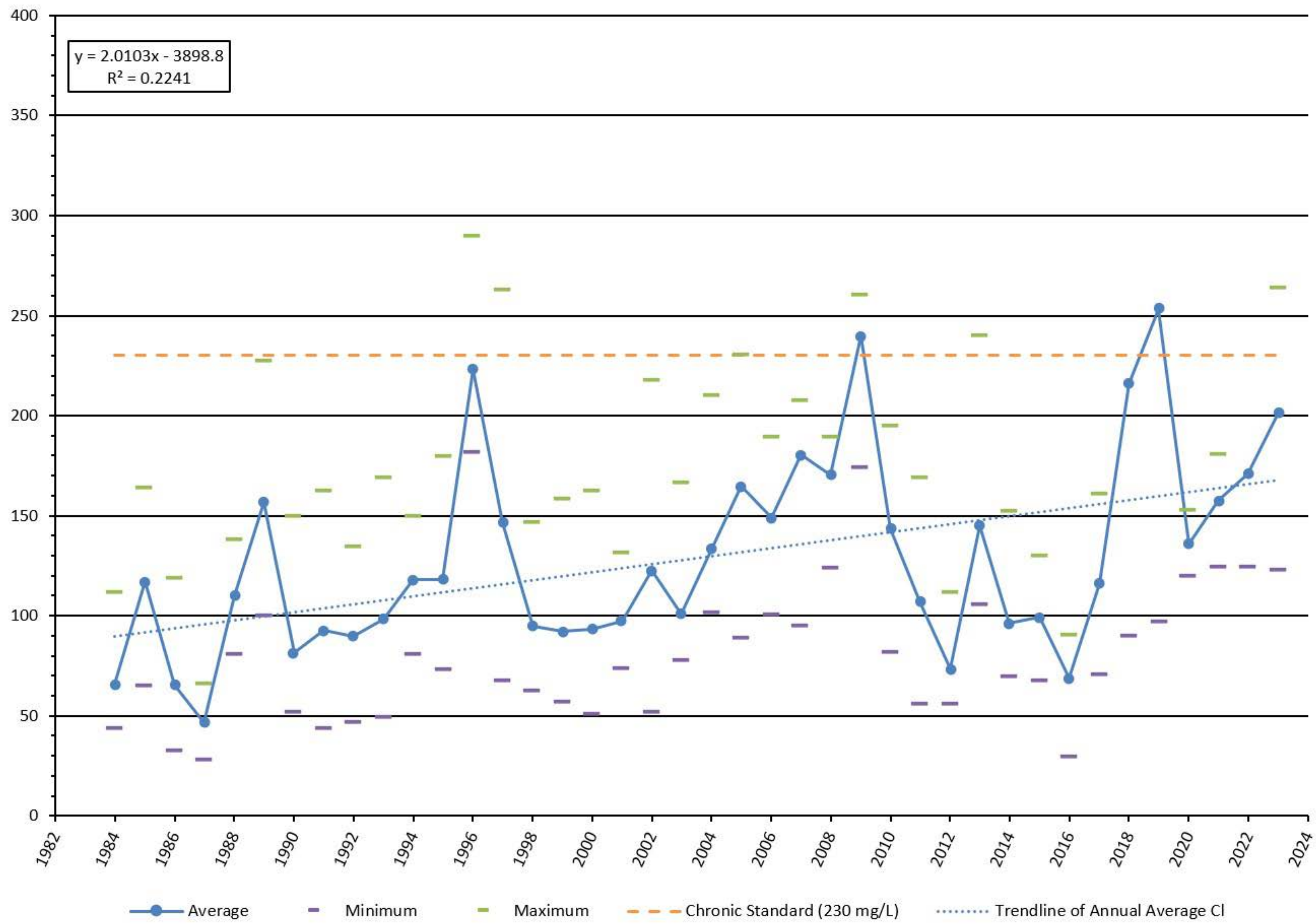

Figure 12. *Como Lake average, minimum, and maximum recorded chloride concentration data from all measured depths for April – October by year. Note: maximum values for 2018 (1475 mg/L) and 2019 (1250 mg/L) are not shown.*

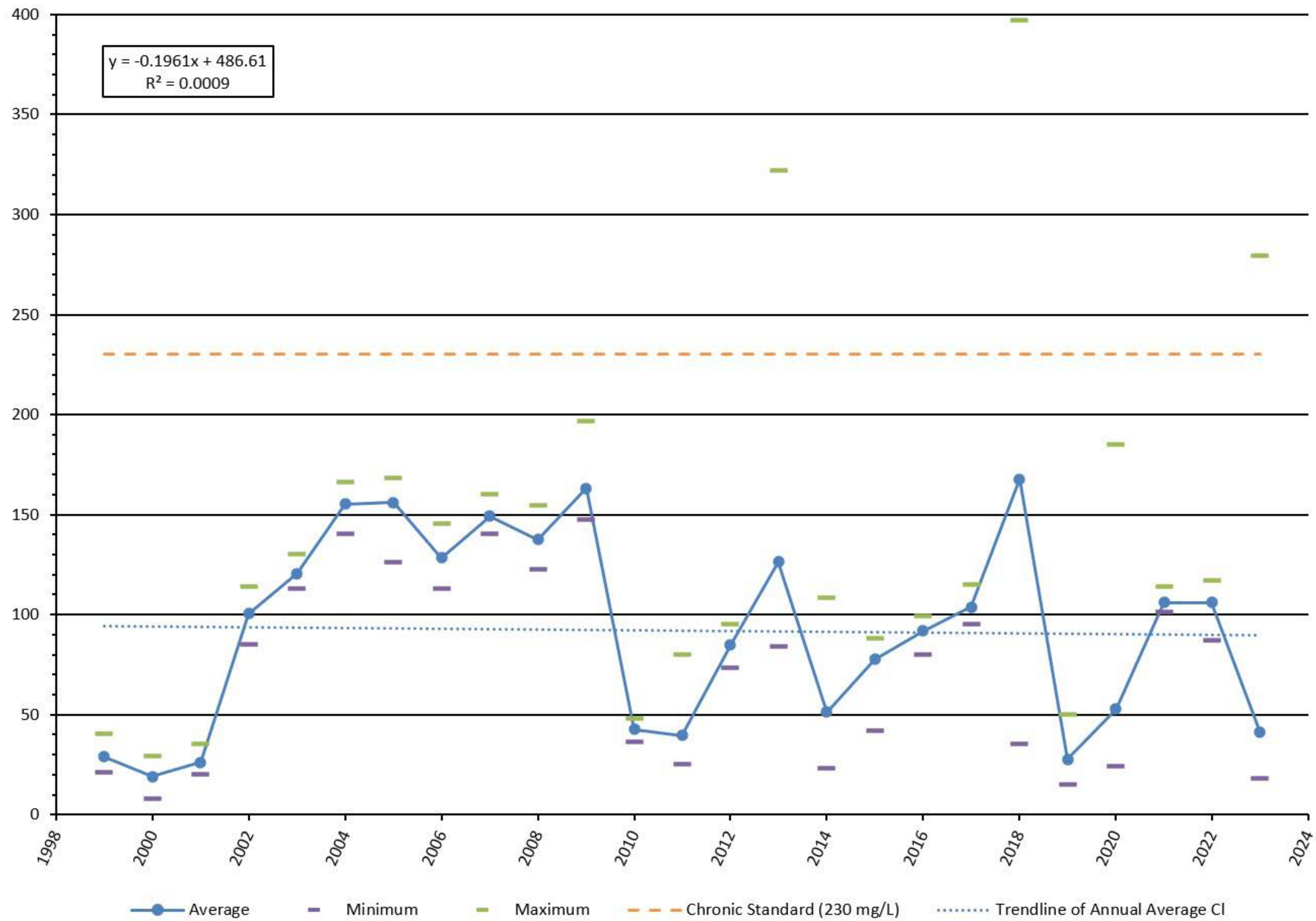

Figure 13. *Crosby Lake average, minimum, and maximum recorded chloride concentration data from all measured depths for April – October by year.*

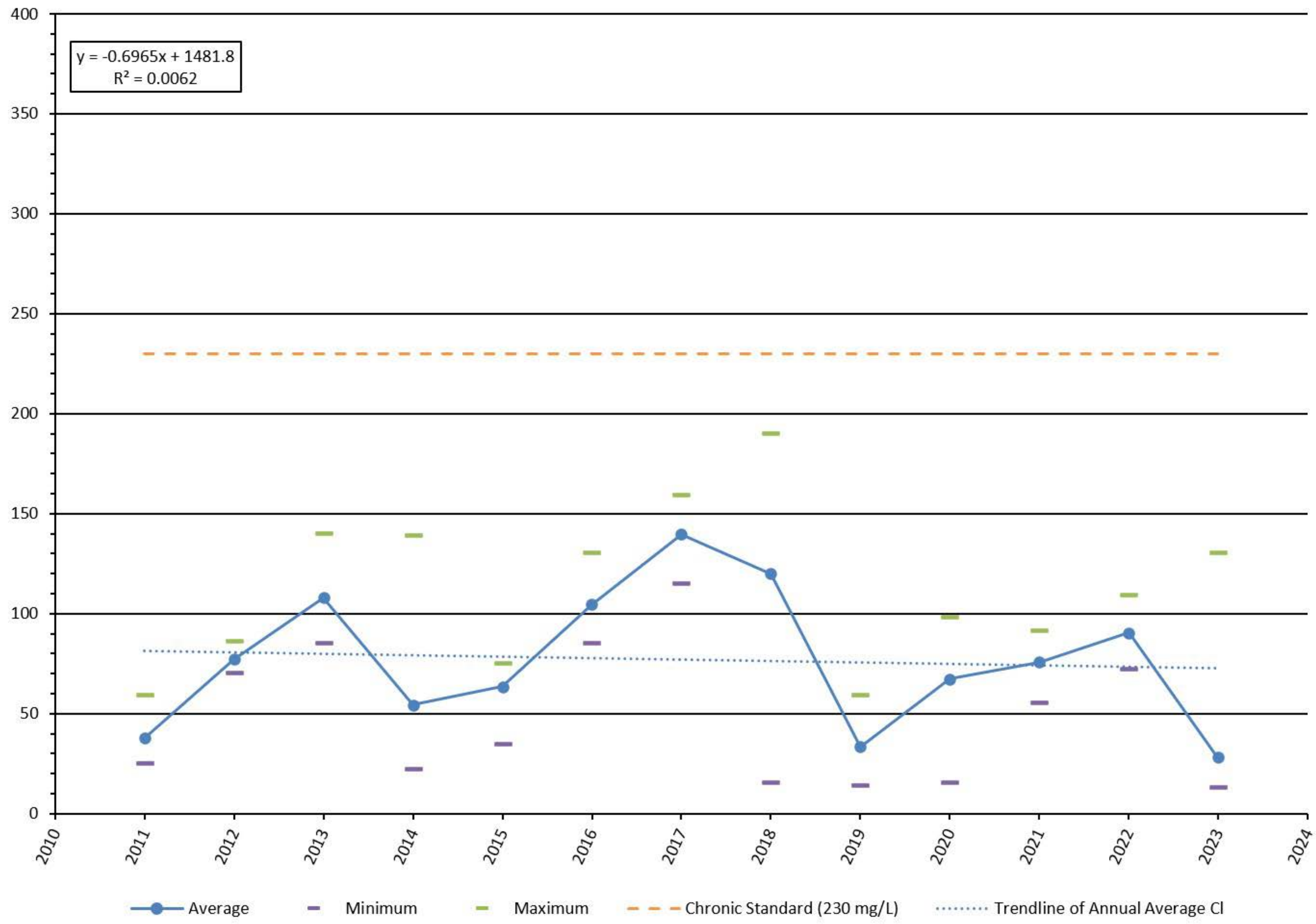

Figure 14. *Little Crosby Lake average, minimum, and maximum recorded chloride concentration data from all measured depths for April – October by year.*

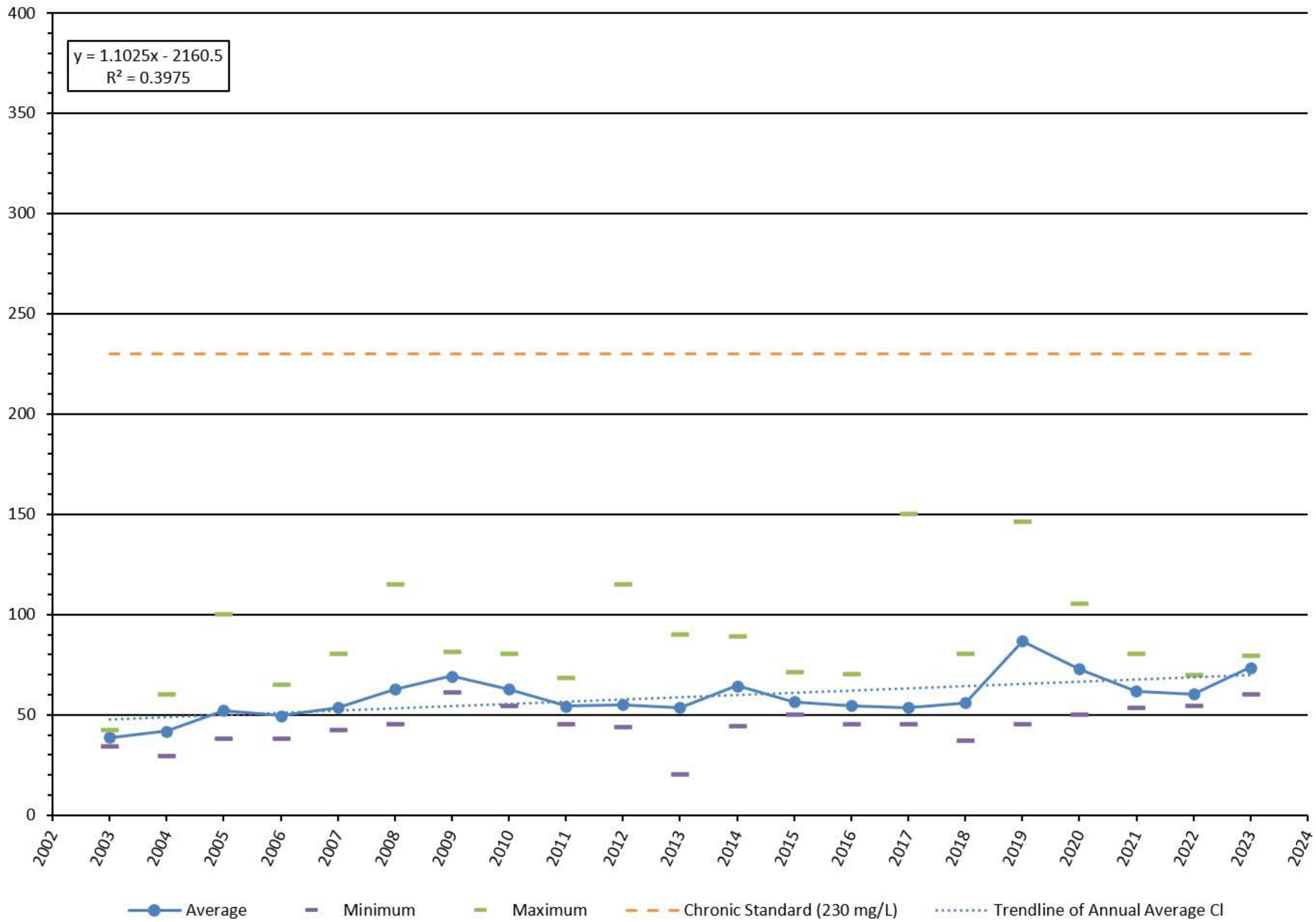

Figure 15. Loeb Lake average, minimum, and maximum recorded chloride concentration data from all measured depths for April – October by year.

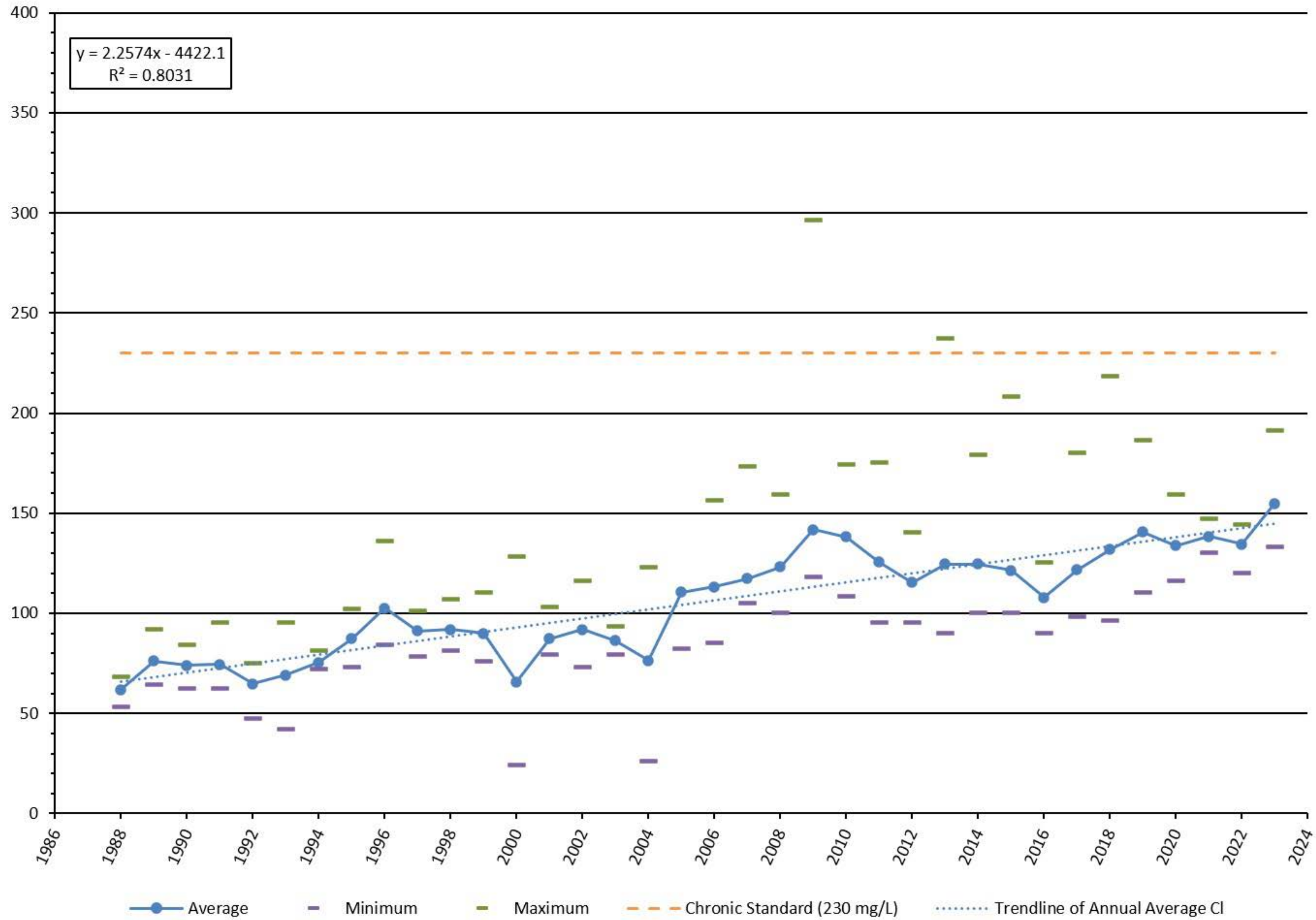

Figure 16. *Lake McCarrons average, minimum, and maximum recorded chloride concentration data from all measured depths for April – October by year.*

7 CONCLUSION

The increasing trends in chloride concentrations across CRWD monitoring sites underscores the urgent need for comprehensive management interventions. The correlation between urban expansion, impervious surfaces, and chloride levels in District water resources necessitates targeted strategies to reduce salt application and improve water quality. These strategies, coupled with continued monitoring, are essential to safeguarding our aquatic ecosystems from further degradation and ensuring sustainable urban development.

8 REFERENCES

Capitol Region Watershed District (CRWD), 2019. Como Lake Management Plan. St. Paul, MN.

Capitol Region Watershed District (CRWD), 2020. Lake McCarrons Management Plan. St. Paul, MN.

Minnesota Pollution Control Agency (MPCA). "Chloride Standards." Minnesota Pollution Control Agency. Accessed April 18, 2025. https://www.pca.state.mn.us/business-with-us/water-quality-standards/chloride-standards.

U.S. Environmental Protection Agency (USEPA). "National recommended water quality criteria – Aquatic life criteria table. EPA Office of Water. 1988. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table.

ATTACHMENTS

Attachment A: Supplementary Data Analysis for Chloride Pollution Prevention Plan Project—Task 2.1 Review of Available CRWD Data (April 18, 2025)

Attachment A

Technical Memorandum

To: Britta Belden, Division Manager
Sarah Wein, Water Resource Project Manager
Capitol Region Watershed District (CRWD)

From: Emily O'Donnell, Water Resources Scientist I
Della Schall Young, CPESC, PMP, CTF, Principal Scientist

Date: April 18, 2025 (Revised October 22, 2025)

Re: Supplementary Data Analysis for Chloride Pollution Prevention Plan Project—Task 2.1 Review of Available CRWD Data

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INTRODUCTION

This document serves as a supplementary document to the Task 2.1 Review of Available CRWD Data Technical Memorandum of the Chloride Pollution Prevention Plan (CPPP) Project. Young Environmental ran additional statistic and visual analyses (including temporal and linear trend tests) to determine whether any significant correlation or patterns emerged across lake and stormwater chloride concentrations at active and inactive sites within the CRWD.

METHODS

Actively and inactively monitored chloride data from CRWD stations were analyzed for temporal trends across CRWD. To support this effort, the programming language R, used within the RStudio environment, was employed to compile, wrangle, and visualize the data. R is a powerful, open-source statistical programming language widely used in environmental science for its robust data processing capabilities, advanced statistical tools, and high-quality graphical outputs. Its flexibility makes it particularly well-suited for handling large, complex, and nonuniform environmental datasets, such as those collected from CRWD lake and stormwater monitoring sites over different seasons and time periods.

R packages utilized in this analysis include the following:

- **trend and Kendall** for conducting nonparametric trend testing
- **dplyr, tidyverse, and purrr** for efficient data cleaning, manipulation, and automation across datasets
- **lubridate** for managing date and time formats
- **ggplot2 and RColorBrewer** for creating compelling, customizable static and interactive visualizations
- **broom** for organizing model outputs into standardized formats
- **sf** for handling of spatial data and mapmaking

Statistical analyses used include linear regression models and Mann–Kendall trend tests. The linear regression models provide regression equations of chloride concentrations over time in addition to

R^2 (indicates correlation strength) and *p*-values (assesses statistical significance) to evaluate if there was any association of chloride concentration over time. If the model produces a p-value of <0.05, then it is considered statistically significant. R^2 value between 0.5 and 0.7 was considered moderately correlated, whereas values > 0.75 had a strong correlation. The resulting slope of the linear equation model provides the rate at which chloride concentrations are increasing or decreasing over the time interval.

Mann–Kendall trend tests were conducted across four seasons—spring, summer, fall, and winter—to determine whether increasing, decreasing, or no trends were occurring at the various depth intervals over the period of record. A Mann–Kendall test, a nonparametric test, determines whether a statistically significant trend exists in time series data without assuming a specific distribution (e.g., normal distribution). This makes it suitable for environmental analyses. A positive tau value indicates an increasing trend, whereas a negative tau value indicates a decreasing trend. Tau values range from −1 to 1; values closer to these extremes indicate stronger trends, whereas a value near zero suggests no significant trend.

Lake data were available for five lakes in CRWD: Como, McCarrons, Loeb, Crosby, and Little Crosby. Chloride measurements were collected at varying depths, from surface to bottom and varying depths in-between. Lake data span across varying time intervals for each lake, as seen in the heatmap figures below of data availability. Stormwater data consist of both active and inactive sites, with varying and sometimes limited or inconsistent data availability across seasons and years.

The Minnesota Pollution Control Agency (MPCA) and the United States Environmental Protection Agency (USEPA) have established chloride water quality criteria for aquatic life in classified waterbodies: a chronic standard of 230 mg/L and a maximum standard of 860 mg/L (MPCA, 2025; USEPA, 1988, L. Charles, personal communication, June 3, 2025). While these standards are used to assess potential impairments in District lakes, they are not directly applicable to stormwater pipes or conveyances. However, in this analysis, these criteria are used as context to interpret the magnitude of chloride concentrations across all monitored stormwater stations and to assess potential impacts on downstream receiving waters.

This analytical approach, powered by R, enabled a detailed and scientifically rigorous evaluation of chloride trends to support CRWD's adaptive management goals.

DISCUSSION

1. Lake Data

CRWD has data for five lakes: Como, Crosby, Little Crosby, Loeb, and McCarrons. Chloride samples were collected at varying depths, including surface, bottom, and intermediate depths, referred to as "middle." Data availability varies across depths and over time, with more data points collected at surface and bottom depths across the entire time series for each lake as compared to the middle range of depths.

An overarching glance at all lake data available reveals differing temporal trends for each lake system. Figure 1 shows annual median chloride concentrations versus annual mean chloride to justify why median chloride is being compared. For the most part, mean and median chloride fall closely to the 1:1 line in this figure, except for Como Lake, where mean chloride concentrations are pulled by outliers to higher concentrations. These outliers disproportionately inflate the mean, potentially misrepresenting typical lake conditions. To provide a more representative summary of chloride concentrations, especially with skewed or nonnormally distributed data, median chloride concentrations were used in Figures 2 and 3 for summarizing lake data.

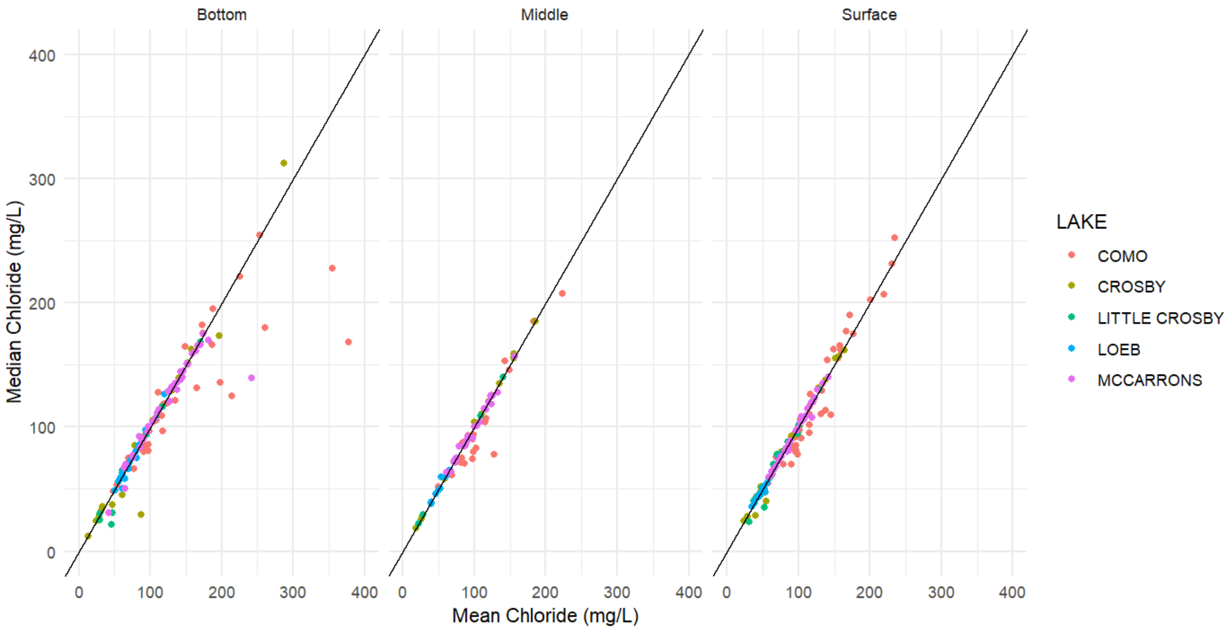


Figure 1. *Annual median chloride versus annual mean chloride for each depth, color-coded by lake station name. A 1:1 line is plotted over the image, indicating that if the mean and median were equal, they would fall along this line. R packages used for this figure include ggplot2, dplyr, and tidyverse.*

In Figure 2, annual median chloride concentrations are shown across all study years for all five lake systems. Each lake site is color coded and shape coded, with a linear regression line fitted to the data. The results of the linear regression on annual median chloride are presented in Table 1. Only three of the five lakes—McCarrons, Loeb, and Como—show a significant relationship between median chloride and time. Como Lake and Loeb Lake surface data show increasing median chloride concentrations, but exhibit low correlation (low R^2). Lake McCarrons exhibits increasing median chloride at both surface and middle depths with a strong correlation (R^2 = 0.836 and 0.762, respectively). Lake McCarrons bottom depth chloride data show a moderate correlation (R^2= 0.547), with a rate of increase in median chloride of 2.523 mg/L per year .

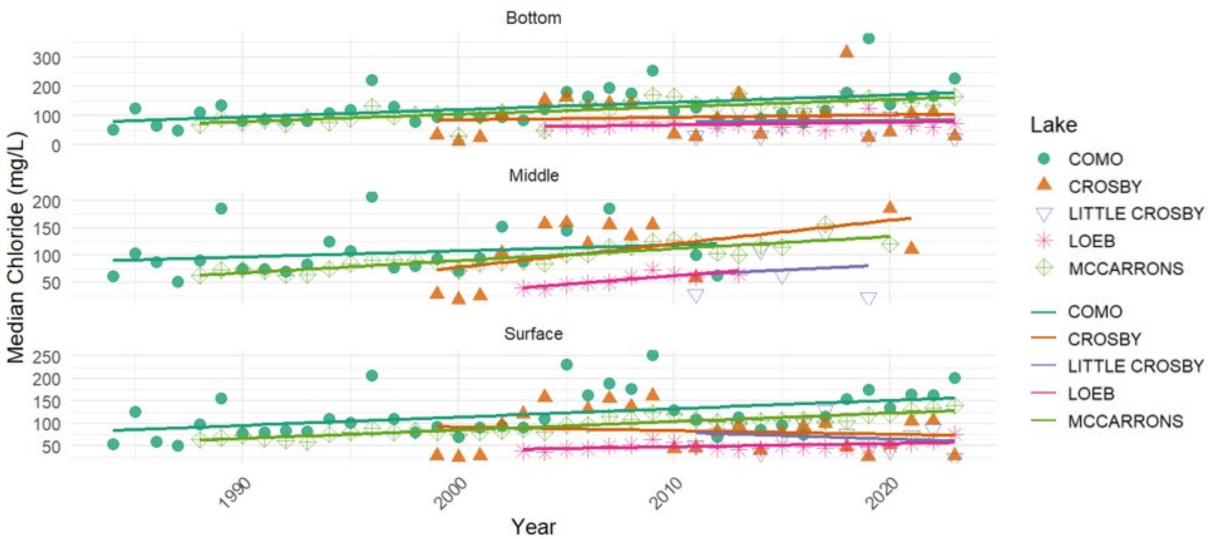


Figure 2. Annual median chloride concentrations (mg/L) over the entire period of record for each lake. Annual medians are color coded and shape coded by lake, with a corresponding linear regression line overlaid using the same color scheme as the median points. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.

Table 1. Annual median chloride linear model results for statistically significant results only ($p < 0.05$). This table includes annual median chloride across the entire period of record for each lake site listed.

Lake	Depth	Slope	p-value	R^2	n
McCarrons	Surface	1.880	6.40×10^{-15}	0.836	36
McCarrons	Middle	2.209	3.18×10^{-10}	0.762	30
McCarrons	Bottom	2.523	3.89×10^{-7}	0.547	35
Loeb	Surface	0.727	2.53×10^{-2}	0.237	21
Loeb	Middle	3.128	1.64×10^{-3}	0.730	10
Como	Surface	1.851	5.19×10^{-3}	0.188	40
Como	Bottom	2.490	2.13×10^{-3}	0.222	40

As shown in Figure 2, each lake has varying years of data availability. However, all five lakes have data between 2011 and 2023. In Figure 3, we condense the data to those common years, and the linear regression model is rerun. The results are presented in Table 2. Using only the common years, the same three lakes exhibit significant correlations with increasing median chloride over time, but at fewer depths. Lake McCarrons shows the strongest linear correlation at surface depths, increasing at a rate of 2.893 mg/L per year for median chloride concentrations. Como Lake exhibits a strong increasing trend at surface depths, at a rate of 8.897 mg/L per year, whereas bottom depths are statistically significant but have a lower correlation ($R^2 = 0.325$). Loeb Lake surface data show a slight increasing correlation at a rate of 1.63 mg/L per year.

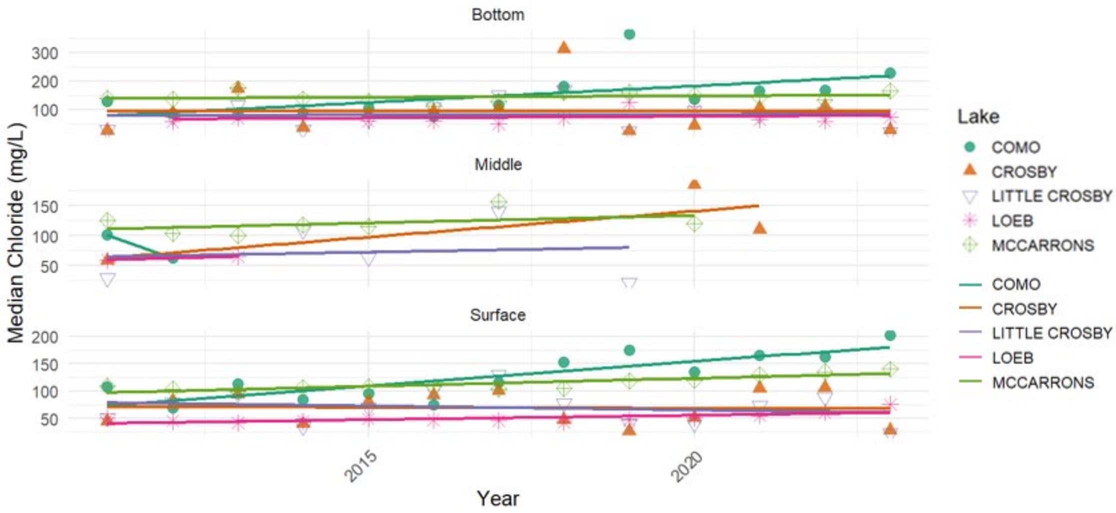


Figure 3. *Annual median chloride concentrations (mg/L) between 2011 and 2023 (the overlapping years for all lakes). Annual medians are color coded and shape coded by lake, with a corresponding linear regression line overlaid using the same color scheme as the median points. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

Table 2. *Annual median chloride linear regression statistically significant results for common years only (2011–2023). Green-shaded boxes indicate higher correlation at these depths with chloride concentrations over time.*

Lake	Depth	Slope	p-value	R^2	n
McCarrons	Surface	2.893	2.20×10^{-4}	0.725	13
Como	Surface	8.897	3.90×10^{-4}	0.696	13
Loeb	Surface	1.635	0.008	0.484	13
Como	Bottom	11.584	0.042	0.325	13

1.1 Como Lake

Como Lake data has been collected since 1984. Data were collected at varying depths, summarized in the heatmap in Figure 4. More data were collected at surface and bottom depths than at middle depths (1–2.9 meters), and in some years, no data were collected at the middle depths.

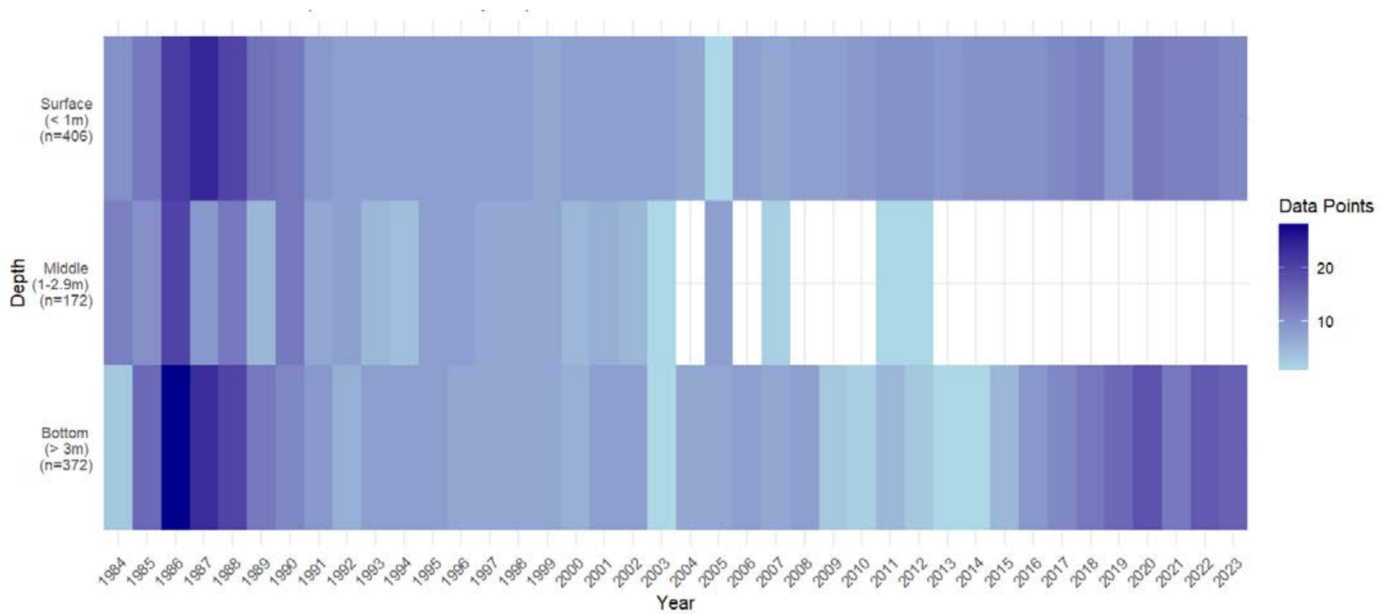


Figure 4. *Heatmap of available data for Como Lake at surface (<1m), middle (1–2.9m), and bottom (>3m) depths. Lighter colors represent fewer data points for each year, whereas darker colors represent more data points available for each year. The number of data points for each lake depth bin is indicated by "n" on the figure. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

In Figure 5, the Mann–Kendall trend test shows that Como Lake has statistically significant increasing trends across all seasons at all depths, though the greatest increasing trends were found at the surface and bottom depths of the fall and winter seasons.

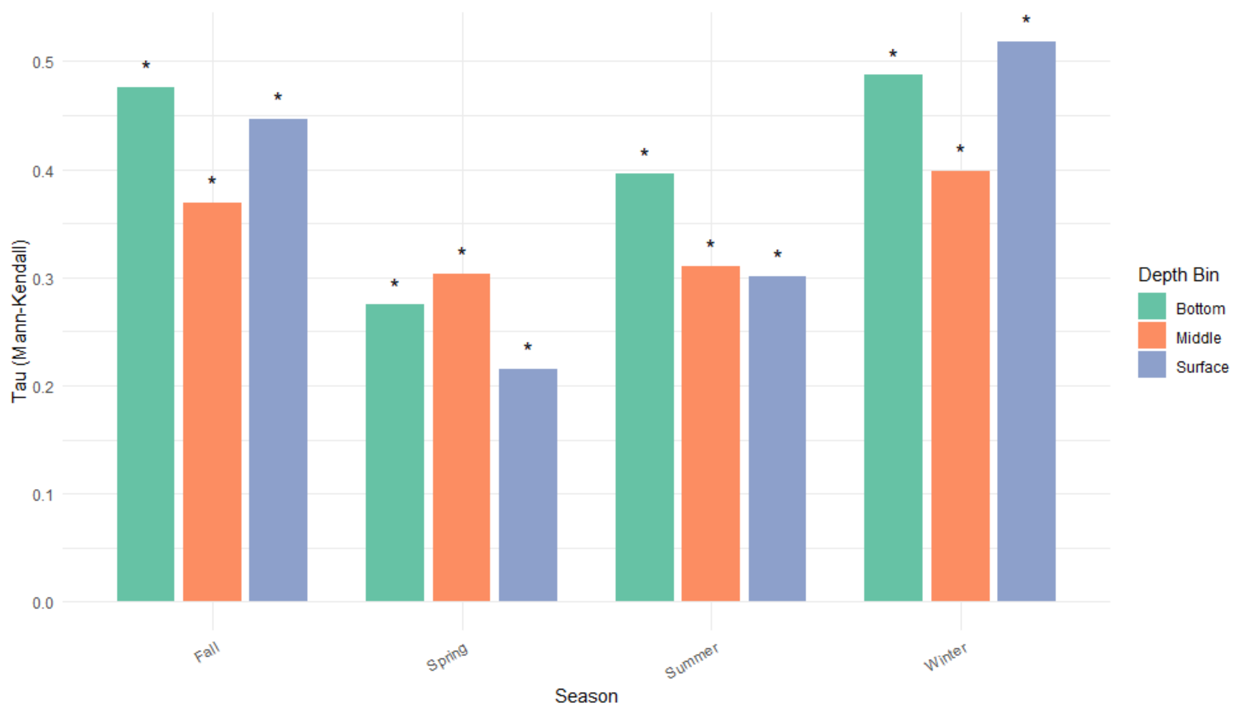


Figure 5. *Mann–Kendall trend test results for Como Lake. Asterisks (*) indicate significant increasing trends in chloride concentrations (p < 0.05). Depth bins are color coded: green = bottom (<1m), orange = middle (1–2.9m), and blue = surface (>3m) depths. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall.*

Linear regression model results (Table 3) and plot (Figure 6) show that although the linear regression models for each depth are statistically significant, overall trends in Como Lake are not very well correlated (indicated by a low R^2 value) and that likely using the Mann–Kendall trend test or splitting data up by season can provide further context for this lake. Data were color coded in these linear model figures for each lake by winter (December–February) and nonwinter (March–November) to visualize if the winter season appeared to be different because of potential road salt pulses in winter weather.

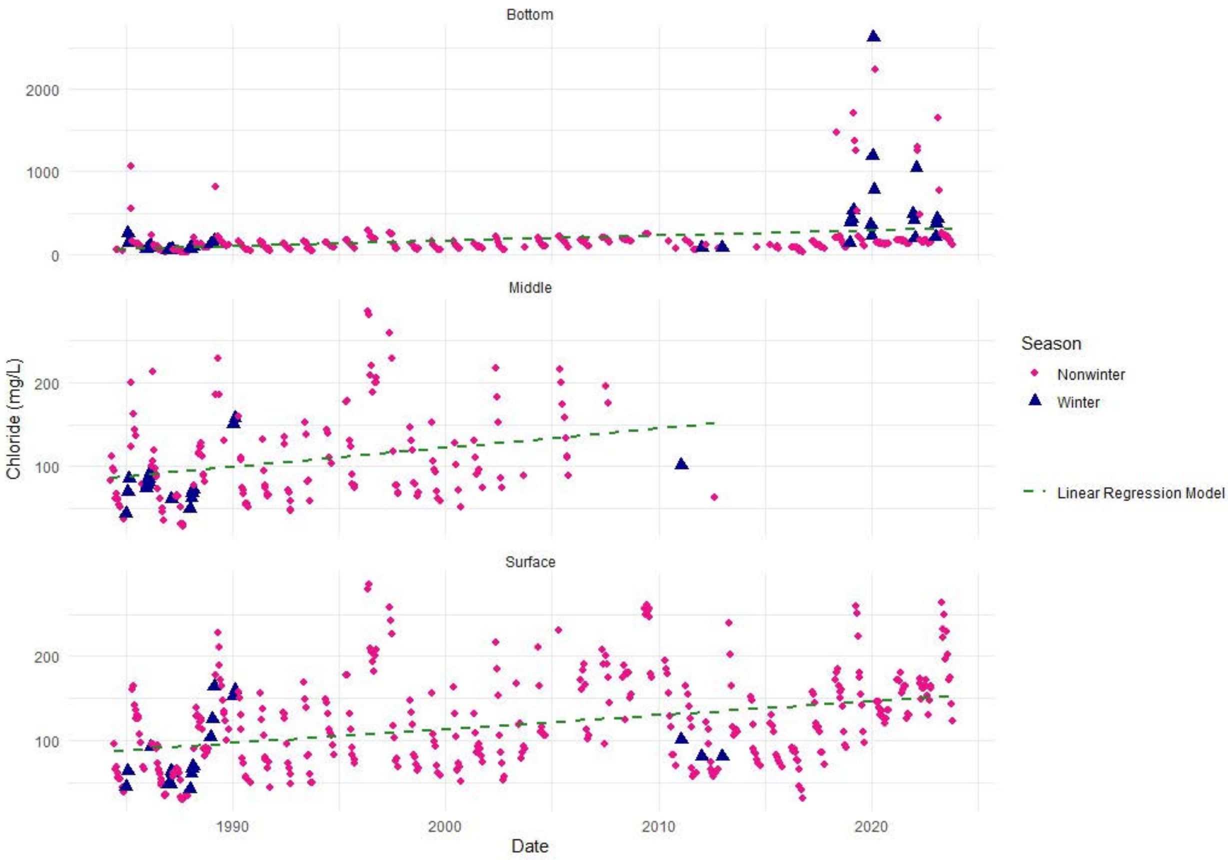


Figure 6. *All chloride data for each depth (bottom, middle, and surface), color coded and shaped by winter (December–February) and nonwinter (March–November) seasons. Note that the y-axis in the bottom depth plot is much larger than in the middle and surface depth plots. The linear regression model dashed line is plotted on top of the data and incorporates both Nonwinter and Winter data. R packages used for this figure include ggplot2, dplyr, tidyverse, and lubridate.*

Table 3. *Como Lake Linear Model Results of Chloride Concentrations over Time. The number of data points for each lake depth bin is indicated by "n" in the table.*

	Slope	Intercept	R^2	p-value	n
Bottom	0.017	-26.680	0.098	6.81×10^{-10}	372
Middle	0.006	53.690	0.082	0.000137	172
Surface	0.005	63.159	0.151	4.93×10^{-16}	406

1.2 Crosby Lake

Crosby Lake data have been collected since 1999. Data were collected at varying depths, and data collection is summarized in the heatmap in Figure 4. More data have been collected at surface and bottom depths than in the middle ranges of 1–3.9 meters depth, and in some years, no data were collected at the middle depth at all.

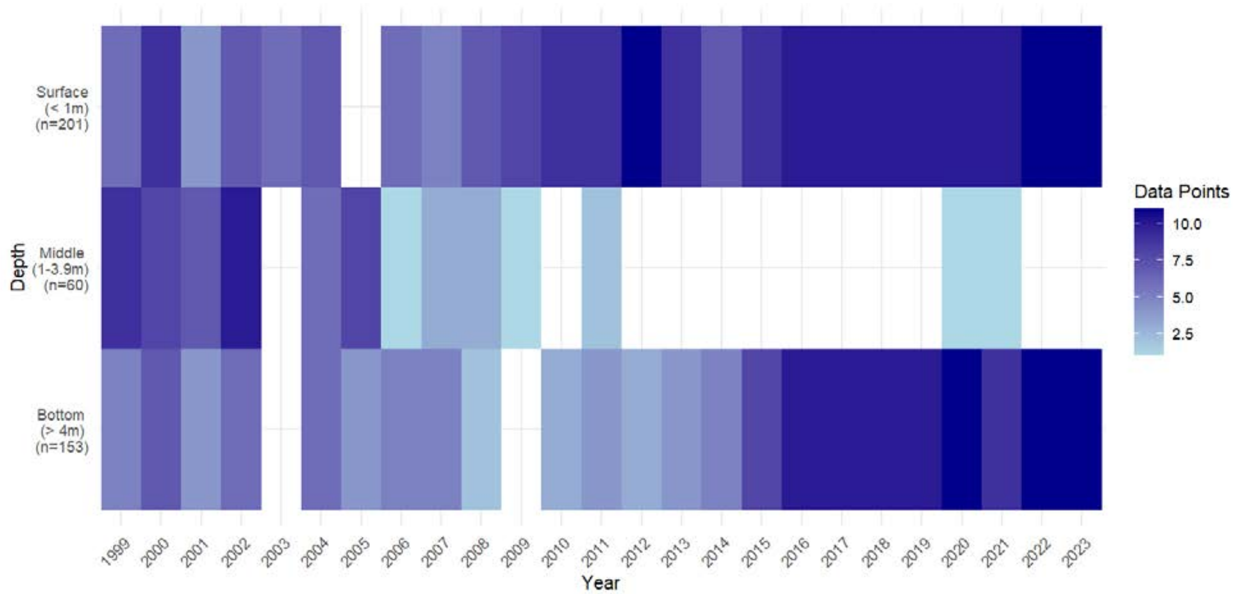


Figure 7. *Heatmap of available data for Crosby Lake at surface (<1m), middle (1–3.9m), and bottom (>4m) depths. Lighter colors represent fewer data points for each year, whereas darker colors represent more data points available for each year. The number of data points for each lake depth bin is indicated by "n" on the figure. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

In Figure 8, the Mann–Kendall trend test shows that Crosby Lake has increasing chloride trends during fall, spring, and summer seasons in the middle depths of the lake. All other flow types and seasonal trends were insignificant.

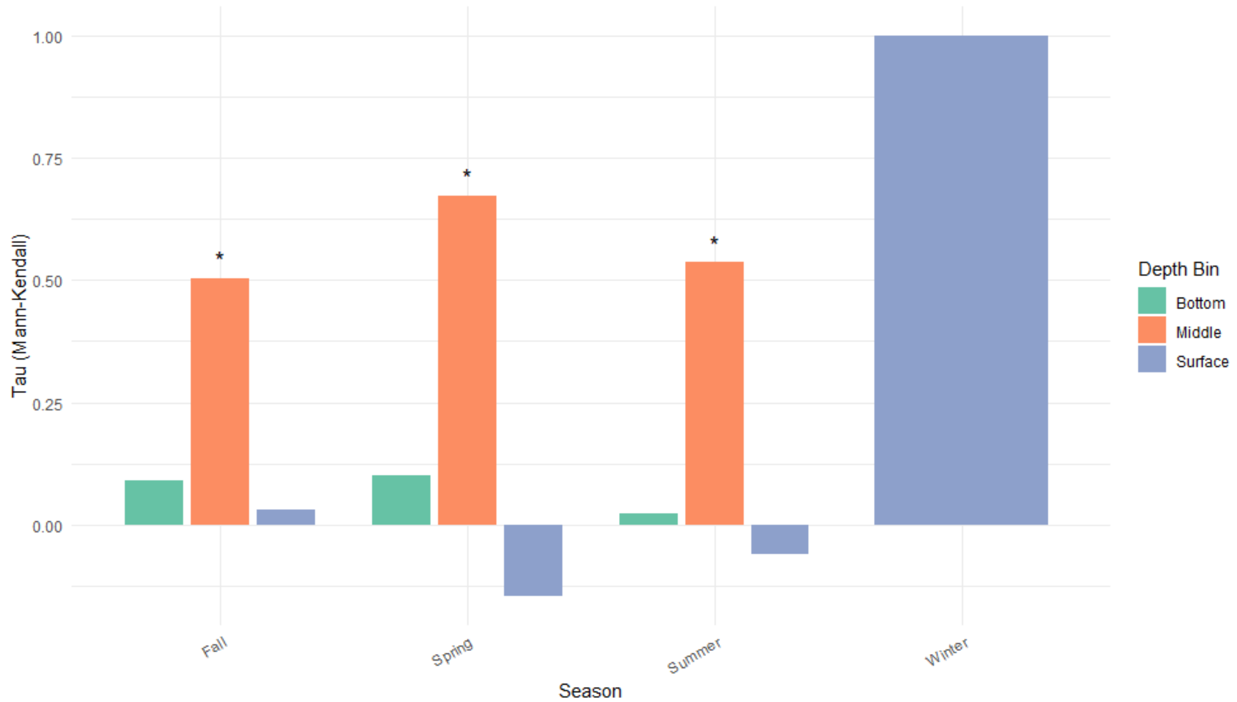


Figure 8. Mann–Kendall trend test results for Crosby Lake. Asterisks (*) indicate significant increasing trends in chloride concentrations ($p < 0.05$). Depth bins are color coded: green = bottom (>4m), orange = middle (1–3.9m), and blue = surface (<1m) depths. Winter data were only available for surface depth. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall. Note: Crosby only had three surface samples collected during the winter season over its period of record, resulting in a tau value of 1.0.

Linear regression model results (Table 4) and plot (Figure 9) show that only the middle and surface depths have statistically significant linear relationships over time. However, both are weakly or only slightly correlated (indicated by low R^2 values); therefore, seasonal relationships may be a better test, as shown above in the Mann–Kendall trend test for in-depth analysis.

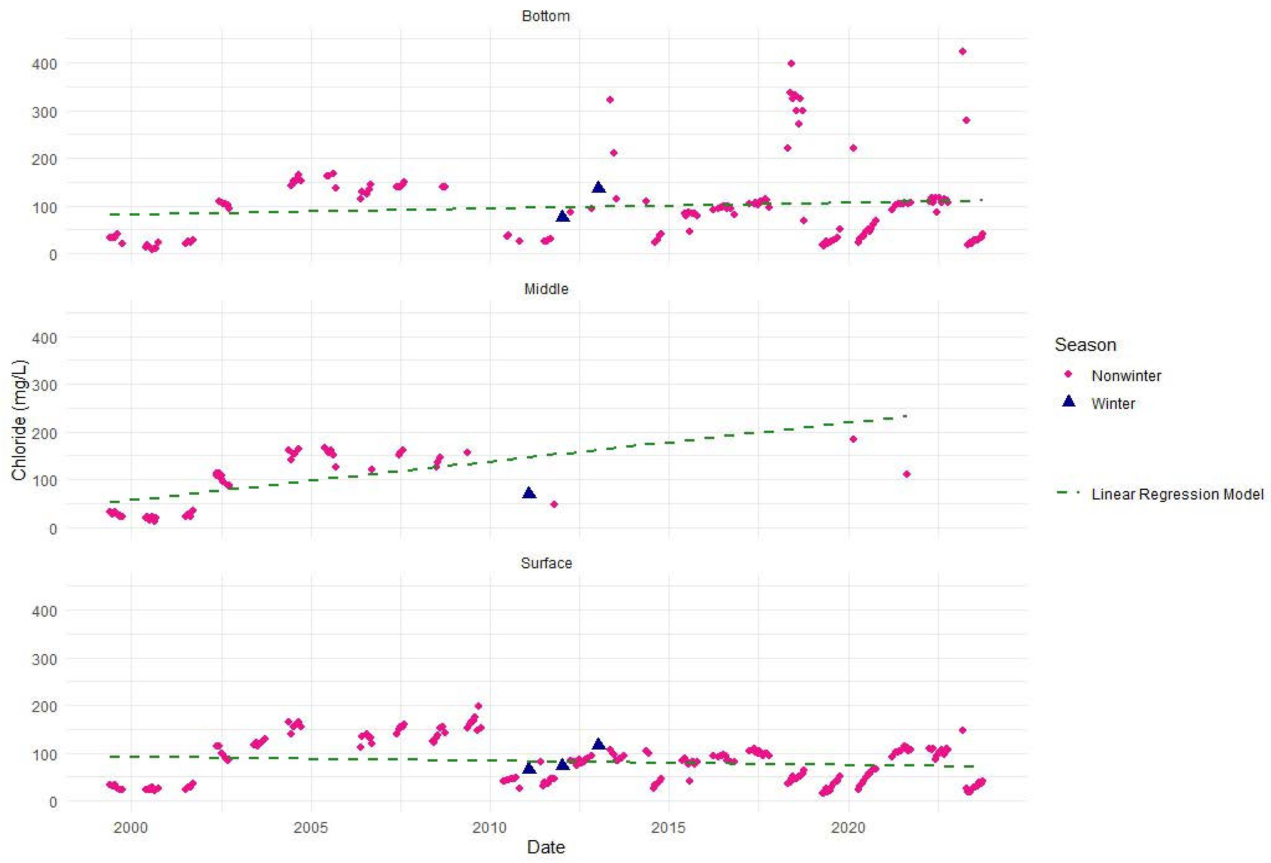


__Figure 9.__ All chloride data for each depth (bottom, middle, and surface), color coded and shaped by winter (December–February) and nonwinter (March–November) seasons. The linear regression model dashed line is plotted on top of the data and incorporates both Nonwinter and Winter data. The number of data points for each lake depth bin is indicated by n on the figure. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.

__Table 4__. Crosby Lake overall linear model results of chloride concentrations over time. Red-shaded boxes indicate the p-value > 0.05; therefore, the result is not statistically significant. The number of data points for each lake depth bin is indicated by n in the table.

	Slope	Intercept	R^2	p-value	n
Bottom	0.003	44.285	0.014	0.152	153
Middle	0.022	-186.608	0.376	1.88×10^{-7}	60
Surface	-0.002	117.937	0.020	0.044	201

1.3 Little Crosby Lake

Little Crosby Lake data have been collected since 2011. Data were collected at varying depths, and data collection is summarized in the heatmap in Figure 10. More data have been collected at surface and bottom depths than in the middle ranges of 1–7.9 meters depth, and in some years, no data were collected at the middle depth at all.

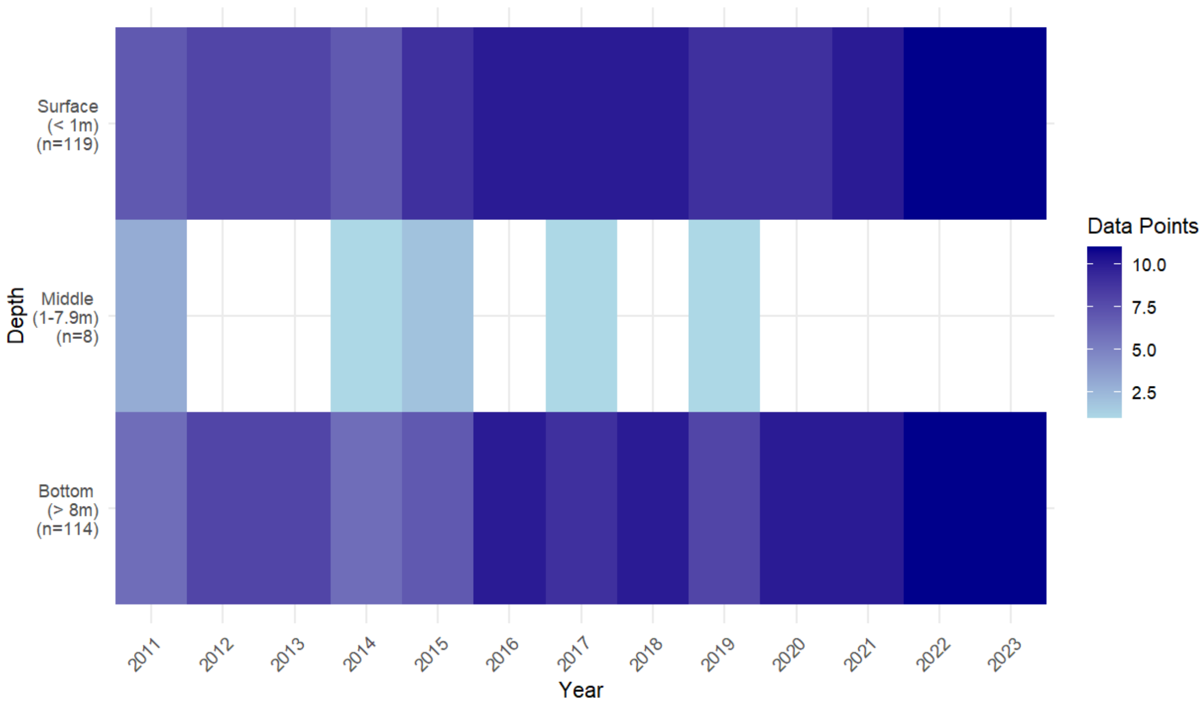


Figure 10. Heatmap of available data for Little Crosby Lake at surface (<1m), middle (1–7.9m), and bottom (>8m) depths. Lighter colors represent fewer data points for each year, while darker colors represent more data points available for each year. The number of data points for each lake depth bin is indicated by "n" on the figure. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.

In Figure 11, the Mann–Kendall trend test shows that Little Crosby Lake has no significant trends whatsoever at any depth across any season over the period of record.

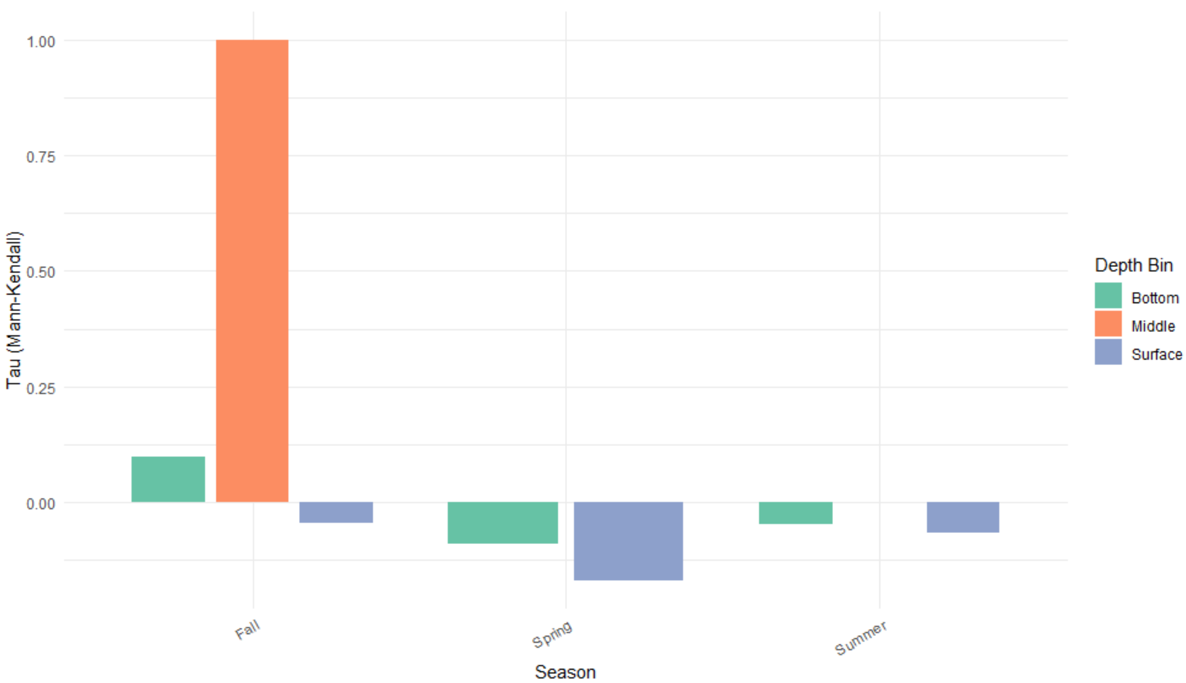


Figure 11. Mann–Kendall trend test results for Little Crosby Lake. Depth bins are color coded: green = bottom (>8m), orange = middle (1–7.9m), and blue = surface (<1m) depths. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall. Note: Little Crosby only had three fall samples collected in the middle depth range, resulting in a tau value of 1.0.

Linear regression model results (Table 5) and plot (Figure 12) reveal that only the surface depth has any significant relationship to chloride concentrations over time; however, the correlation is very weak; thus, no real linear relationship exists for Little Crosby Lake.

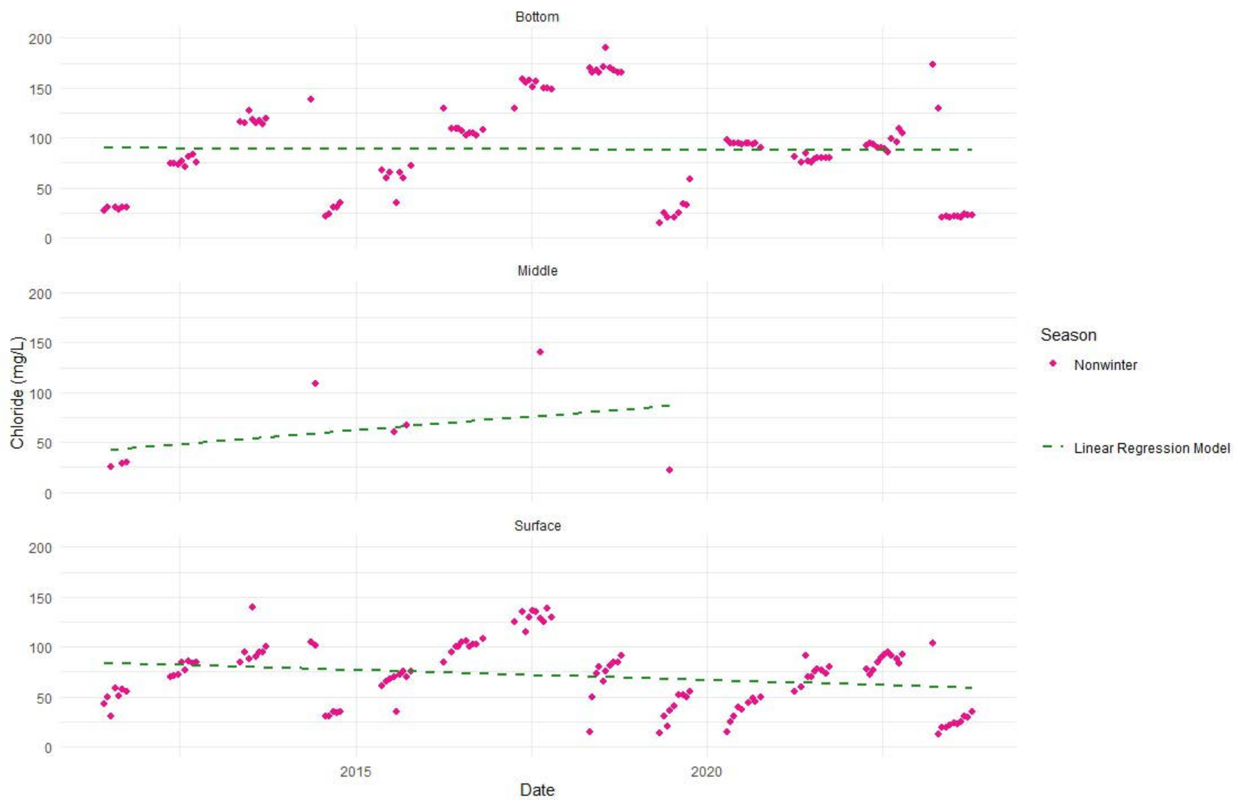


Figure 12. All chloride data for each depth (bottom, middle, and surface). No winter (December–February) data were available, and only nonwinter (March–November) data are shown in the figure. The linear regression model dashed line is plotted on top of the data and only uses Nonwinter data. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.

Table 5. Little Crosby Lake linear model results of chloride concentrations over time. Red-shaded boxes indicate the p-value > 0.05; therefore, the result is not statistically significant. The number of data points for each lake depth bin is indicated by "n" in the table.

	Slope	Intercept	R^2	p-value	n
Bottom	-0.001	97.937	0.000	0.869	114
Middle	0.015	-188.031	0.141	0.359	8
Surface	-0.006	167.572	0.054	0.011	119

1.4 Loeb Lake

Loeb Lake data have been collected since 2003. Data were collected at varying depths, and data collection is summarized in the heatmap in Figure 13. More data have been collected at surface and bottom depths than in the middle ranges of 1–5.9 meters depth, and in some years, no data were collected at the middle depth at all.

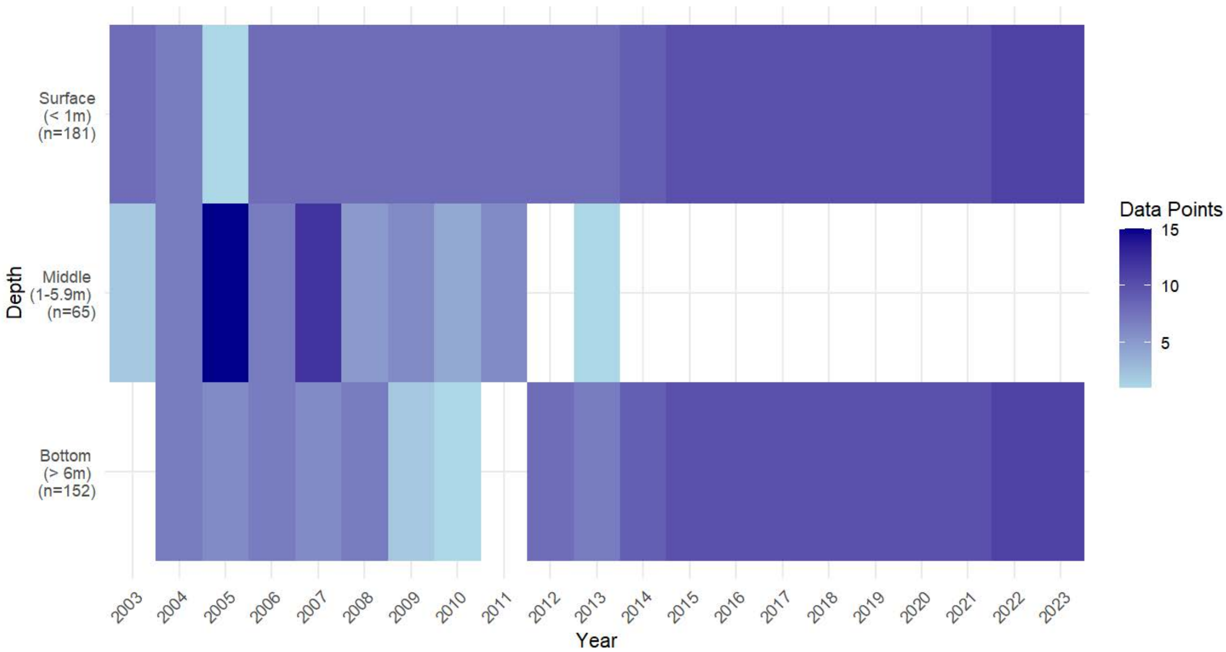


Figure 13. *Heatmap of available data for Loeb Lake at surface (<1m), middle (1–5.9m), and bottom (>6m) depths. Lighter colors represent fewer data points for each year, while darker colors represent more data points available for each year. The number of data points for each lake depth bin is indicated by "n" on the figure. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

Loeb Lake had no winter data available to analyze. In Figure 14, the Mann–Kendall trend test shows that Loeb Lake has statistically significant increasing trends at all depths in the summer season, though the greatest increase in chloride is in the middle depth. In the fall season, both middle and surface depths have statistically significant increasing trends, whereas in the spring, only surface depth chloride concentrations have a significant correlation, increasing over time.

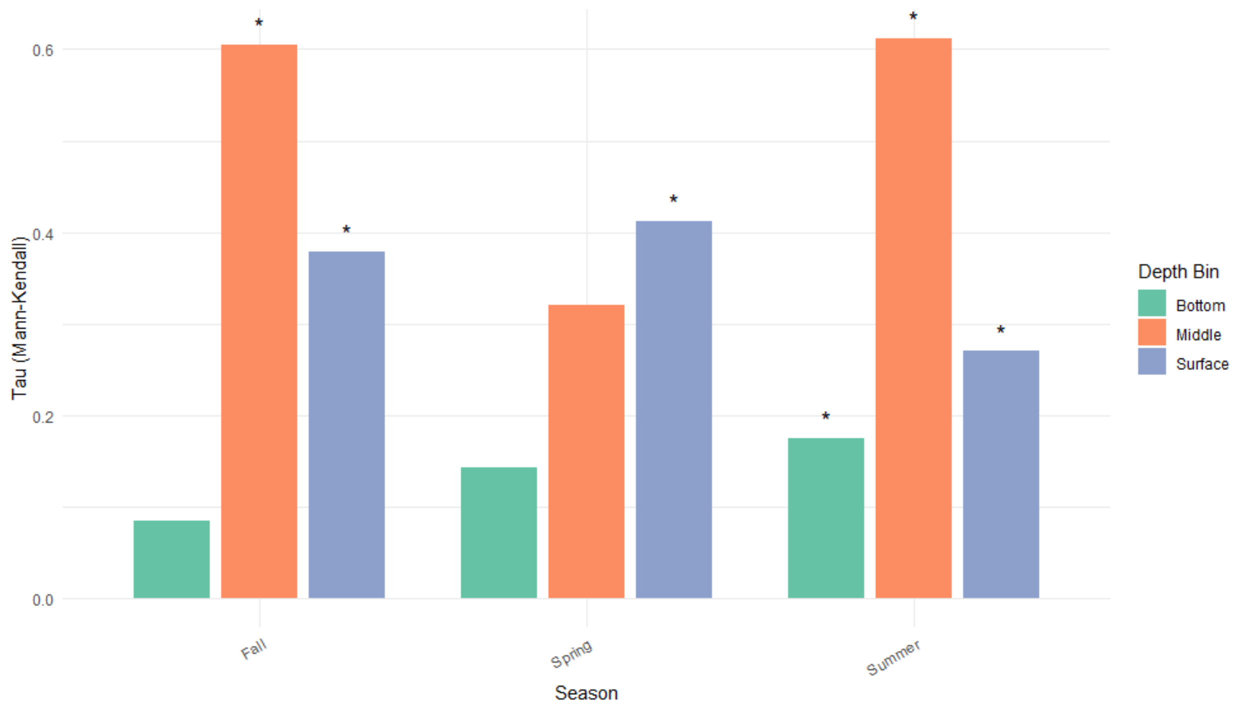


Figure 14. *Mann–Kendall trend test results for Loeb Lake. Asterisks (*) indicate significant increasing trends in chloride concentrations (p < 0.05). No winter data were available for this lake. Depth bins are color-coded: green = bottom (>6m), orange = middle (1–5.9m), and blue = surface (<1m) depths. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, and RcolorBrewer, purrr, trend, and Kendall.*

Linear regression model results (Table 6) and plot (Figure 15) show that all depths have a significant relationship between chloride and time; however, only the middle depth has a moderate correlation, with an R^2 of 0.509 and a slope of 0.010, which indicates that, according to this model, chloride is increasing by 0.01 mg/L per day over the period of record.

Figure 15. All chloride data for each depth (bottom, middle, and surface) of Loeb Lake. No winter (December–February) data were available for Loeb Lake; all points are color-coded as nonwinter (March–November). The linear regression model dashed line is plotted on top of the data and only uses Nonwinter data. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.

Table 6. Loeb Lake linear model results of chloride concentrations over time. Green-shaded boxes indicate higher correlation at these depths with chloride concentrations over time. The number of data points for each lake depth bin is indicated by "n" in the table.

	Slope	Intercept	R^2	p-value	n
Bottom	0.002	32.200	0.055	0.003731	152
Middle	0.010	-79.056	0.509	2.63×10^{-11}	65
Surface	0.002	14.112	0.204	1.79×10^{-10}	181

1.5 Lake McCarrons

Lake McCarrons data have been collected since 1988. Data were collected at varying depths, and data collection is summarized in the heatmap in Figure 16. More data have been collected at surface and bottom depths than in the middle ranges of 1–13.9 meters depth, and in some years, no data were collected at the middle depth at all.

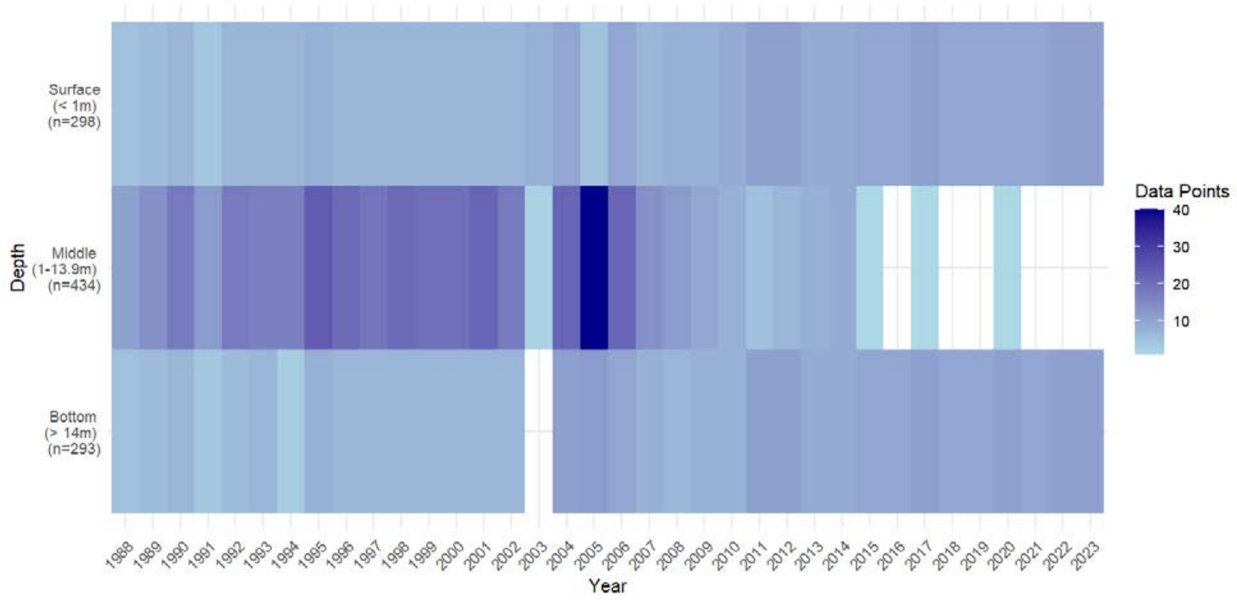


Figure 16. *Heatmap of available data for Lake McCarrons at surface (<1m), middle (1–13.9m), and bottom (>14m) depths. Lighter colors represent fewer data points for each year, while darker colors represent more data points available for each year. The number of data points for each lake depth bin is indicated by "n" on the figure. The number of data points for each lake depth bin is indicated by "n" on the figure. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

In Figure 17, the Mann–Kendall trend test shows that Lake McCarrons has increasing trends across all seasons at all depths except for the winter season, where no significant trend was found. This is most likely due to the fact that there have been very few samples collected during the winter season over the period of record.

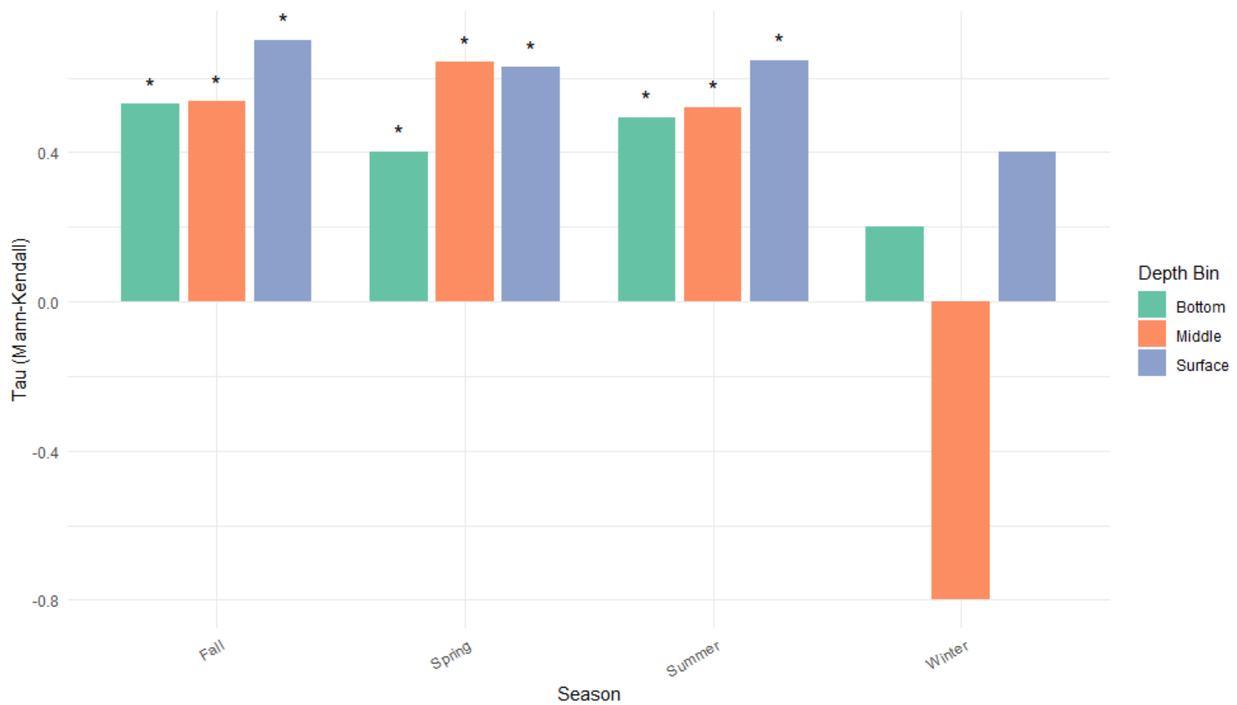


Figure 17. *Mann–Kendall trend test results for Lake McCarrons. Asterisks (*) indicate significant increasing trends in chloride concentrations (p < 0.05). Depth bins are color-coded: green = bottom (>14m), orange = middle (1–13.9 m), and blue = surface (<1m) depths. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RcolorBrewer, purrr, trend, and Kendall.*

Linear regression model results (Table 7) and plot (Figure 18) show that all depths are statistically significant between chloride concentration and time; however, the surface and middle depths are moderately correlated with increasing chloride over time. All depths are increasing at low rates when examining the entire period of record.

Figure 18. *All chloride data for each depth (bottom, middle, and surface), color coded and shaped by winter (December–February) and nonwinter (March–November) seasons. One data point (1365 mg/L from May 5, 2005) was removed to better visualize the data and condense the y-axis. The linear regression model dashed line is plotted on top of the data and incorporates both Nonwinter and Winter data. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

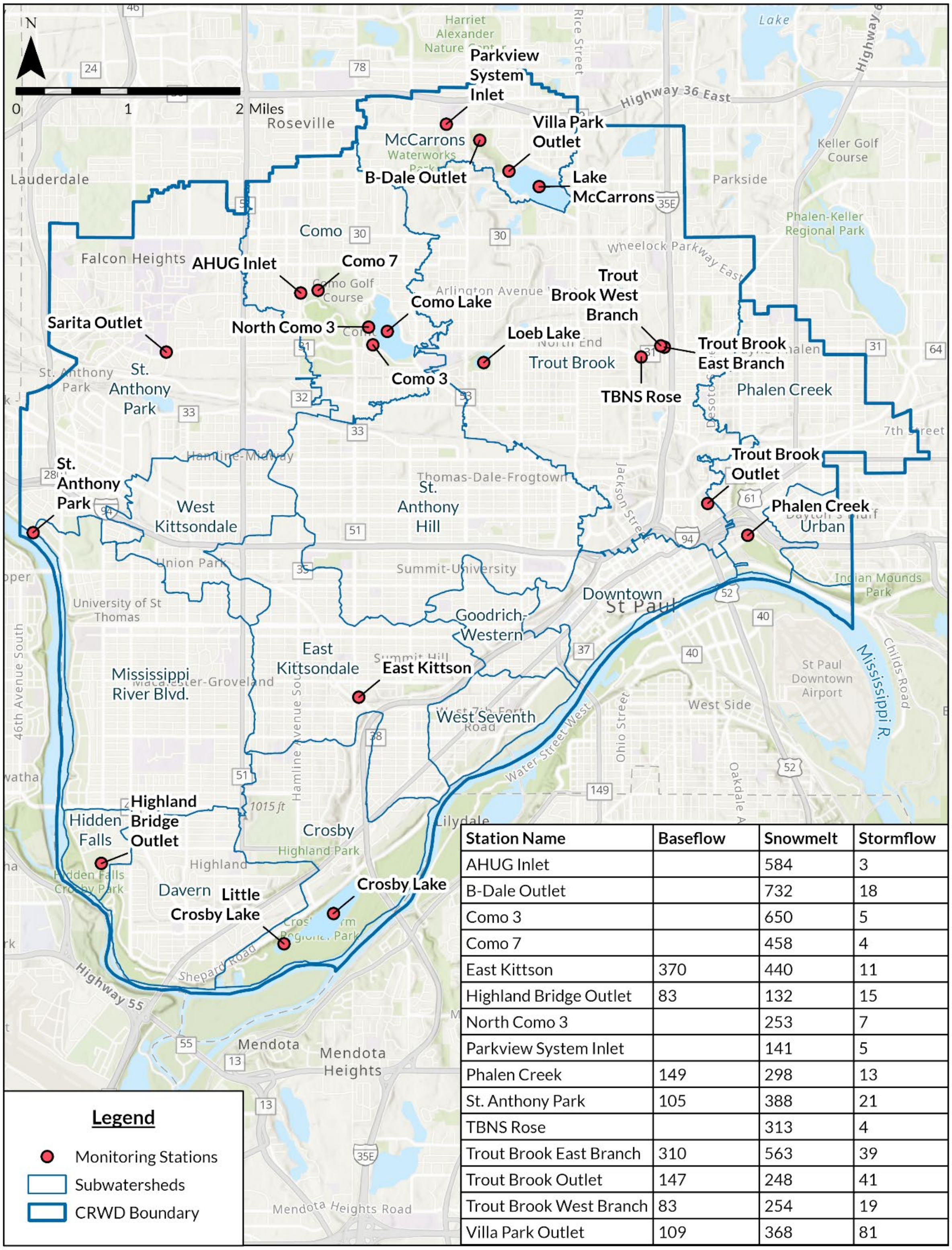
Table 7. *Lake McCarrons linear model results of chloride concentrations over time. Green-shaded boxes indicate higher correlation at these depths with chloride concentrations over time. The number of data points for each lake depth bin is indicated by "n" in the table.*

	Slope	Intercept	R^2	p-value	n
Bottom	0.007	36.979	0.089	1.97×10^{-7}	293
Middle	0.006	25.789	0.505	5.38×10^{-68}	434
Surface	0.005	28.959	0.696	1.80×10^{-78}	298

2. Stormwater Data

Chloride concentrations were measured across three flow conditions at various stormwater locations, including baseflow (base), snowmelt, and storm. Chloride concentration intensity varies across space and flow type in the CRWD, as seen in Figure 19. Data availability varies by flow type and time, as well as active vs. inactive monitoring (Figures 20, 21, and 22). The chloride criteria referenced in this section are intended for natural surface waters (e.g., lakes, rivers) designated for aquatic life protection. While not directly applicable to stormwater infrastructure, the thresholds are included here to provide a consistent framework for comparing chloride concentrations and to identify locations that may pose risks to downstream waters.

In Figure 19, sites with the highest median chloride concentrations in stormflow include Villa Park Outlet, Trout Brook – East Branch, and Trout Brook Outlet. Sites with the highest median chloride concentrations in snowmelt include B-Dale Outlet, Como 3, AHUG Inlet, and Trout Brook – East Branch. The highest median baseflow concentrations include East Kittsondale, and Trout Brook – East Branch.



Station Name	Baseflow	Snowmelt	Stormflow
AHUG Inlet		584	3
B-Dale Outlet		732	18
Como 3		650	5
Como 7		458	4
East Kittson	370	440	11
Highland Bridge Outlet	83	132	15
North Como 3		253	7
Parkview System Inlet		141	5
Phalen Creek	149	298	13
St. Anthony Park	105	388	21
TBNS Rose		313	4
Trout Brook East Branch	310	563	39
Trout Brook Outlet	147	248	41
Trout Brook West Branch	83	254	19
Villa Park Outlet	109	368	81

Figure 19. Map of median chloride concentrations (mg/L) for each stormwater monitoring site across each flow type (baseflow, snowmelt, and stormflow).

2.1 Data Availability by Sample Type

2.1.1 Stormflow Data Availability

The earliest stormflow data are available beginning in 2005, and some sites still have active monitoring through the present time (Figure 20).

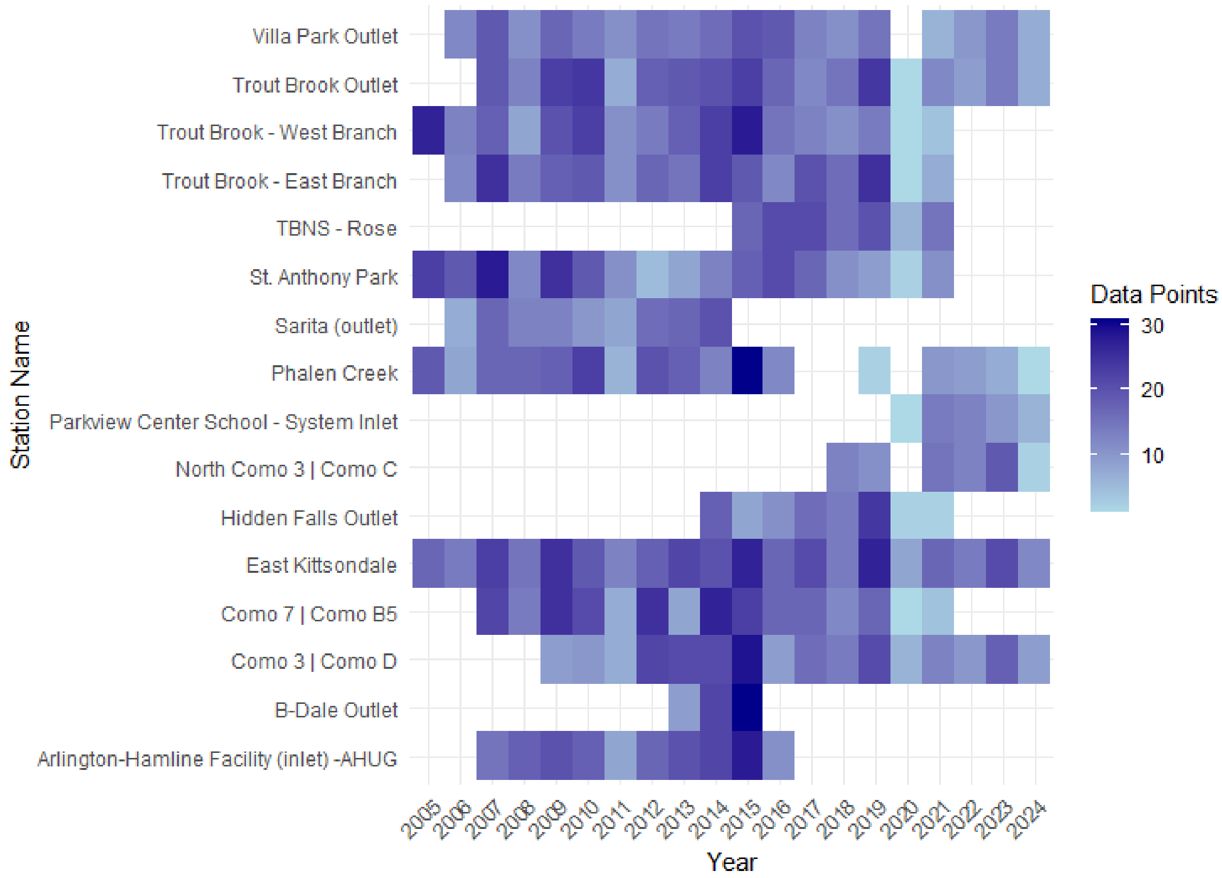


Figure 20. *Data availability of data during storm flow at stormwater sites. Color indicates the amount of data points available for each site across each year, with darker colors indicating more data availability and lighter color, indicating fewer data points collected. No color indicates no sample was collected at that time. The number of data points for each site is indicated by "n" on the figure. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

2.1.2 Snowmelt Data Availability

The earliest snowmelt flow data are available beginning in 2005, and some sites still have active monitoring through the present time (Figure 21). Overall, there are fewer snowmelt data points collected across all sites as compared to stormflow and baseflow.

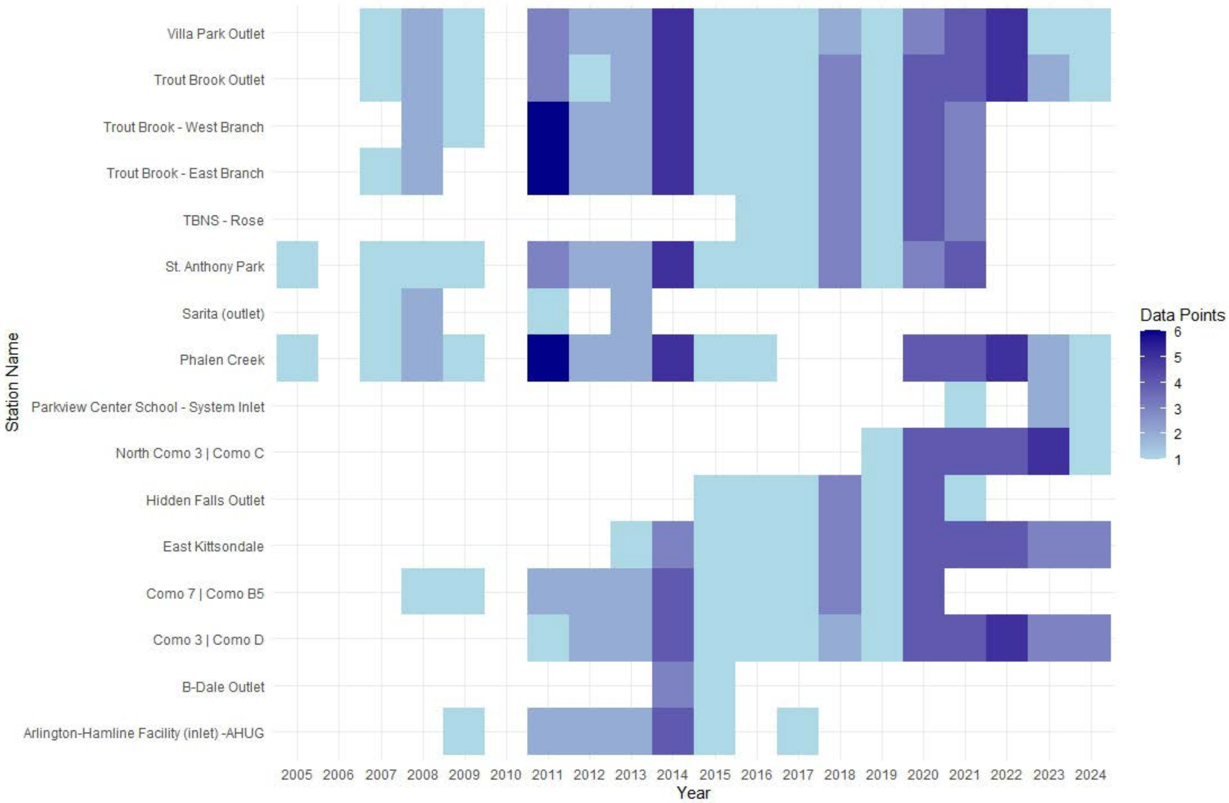


Figure 21. Availability of data during snowmelt flow at stormwater sites. Color indicates the number of data points available for each site across each year, with darker colors indicating more data availability and lighter colors indicating fewer data points collected. No color indicates no sample was collected for that year. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.

2.1.3 Baseflow Data Availability

The earliest baseflow data are available beginning in 2005, and some sites still have active monitoring through the present time (Figure 22).

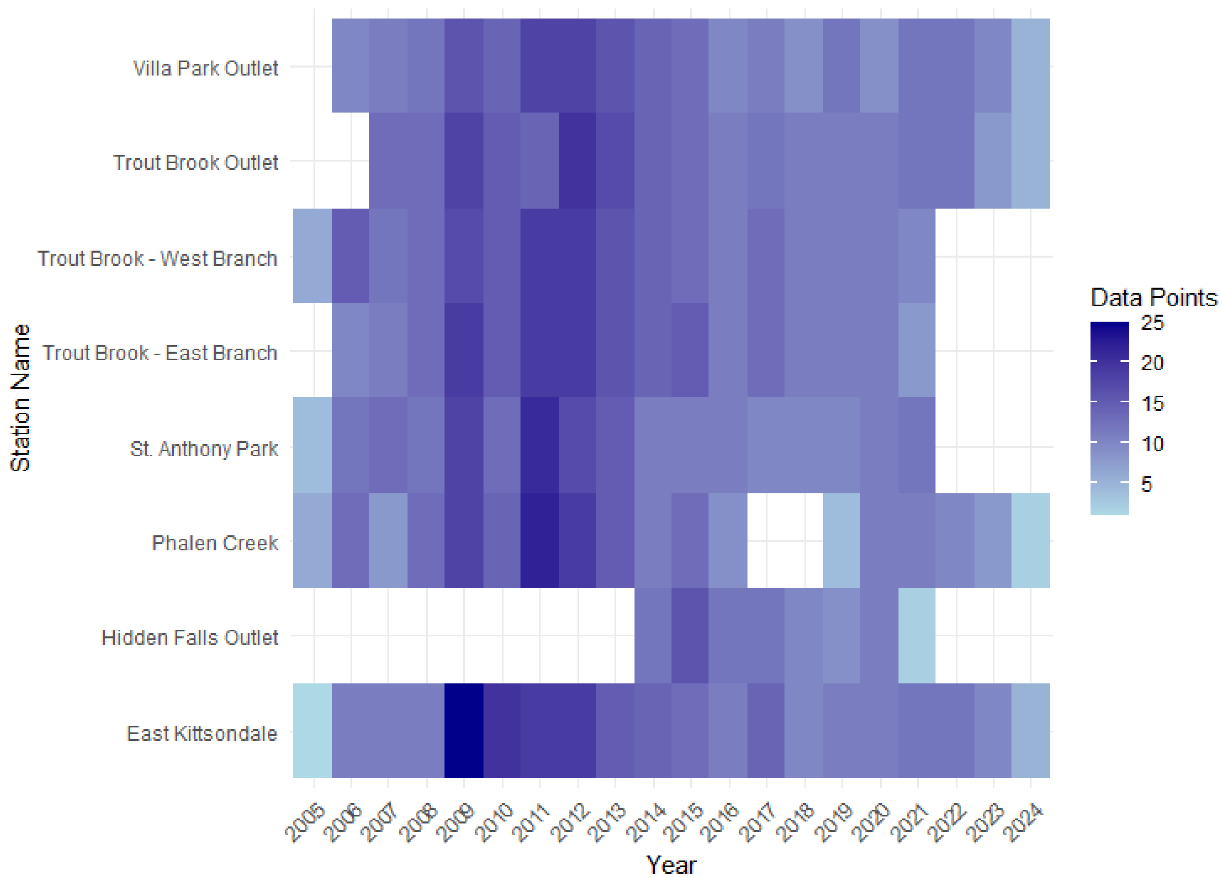


Figure 22. *Availability of data during baseflow at stormwater sites. Color indicates the number of data points available for each site across each year, with darker colors indicating more data availability and lighter colors indicating fewer data points collected. No color indicates no sample was collected in that year. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, and broom.*

2.2 Seasonal Analysis – Active Stormwater Sites

Using the Mann–Kendall trend test, we looked at active monitoring sites to see if there were any seasonal increasing or decreasing trends across the entire period of record and across flow types. Chloride concentrations at all active sites show variability in increasing trends by both season and flow type (Figures 23-26).

2.2.1 Spring Seasonal Analysis

In the spring season (Figure 23), only stormflow at Villa Park Outlet has a statistically significant increasing trend, and only baseflow at Trout Brook Outlet has a statistically significant increasing trend.

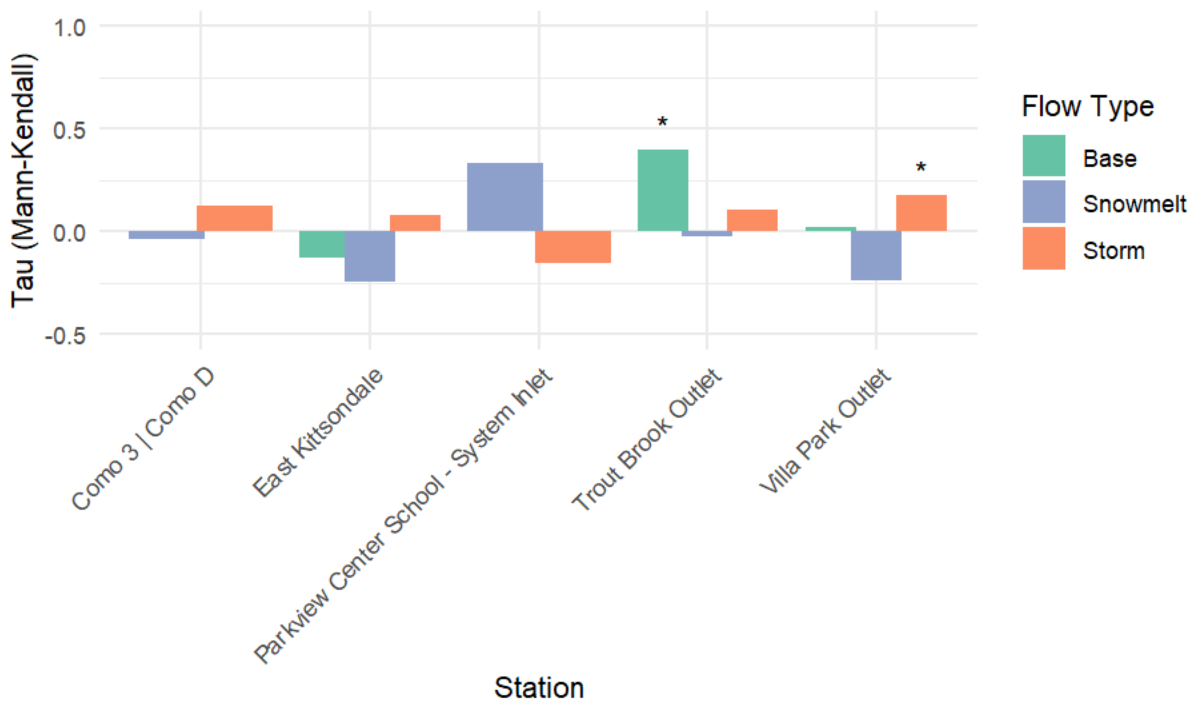


Figure 23. *Spring season Mann–Kendall results for active stormwater sites. Asterisks (*) indicate trends where p-values are <0.05. Flow types are color-coded: green = baseflow, blue = snowmelt, and orange = stormflow. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall.*

2.2.2 Summer Seasonal Analysis

In the summer season (Figure 24), stormflow chloride concentrations show a statistically significant increasing trend at Villa Park Outlet, whereas baseflow chloride concentrations show a statistically significant increasing trend at both Villa Park Outlet and Trout Brook Outlet. In the summer season, there is no snowmelt data collected; therefore, it has been removed from the figure legend.

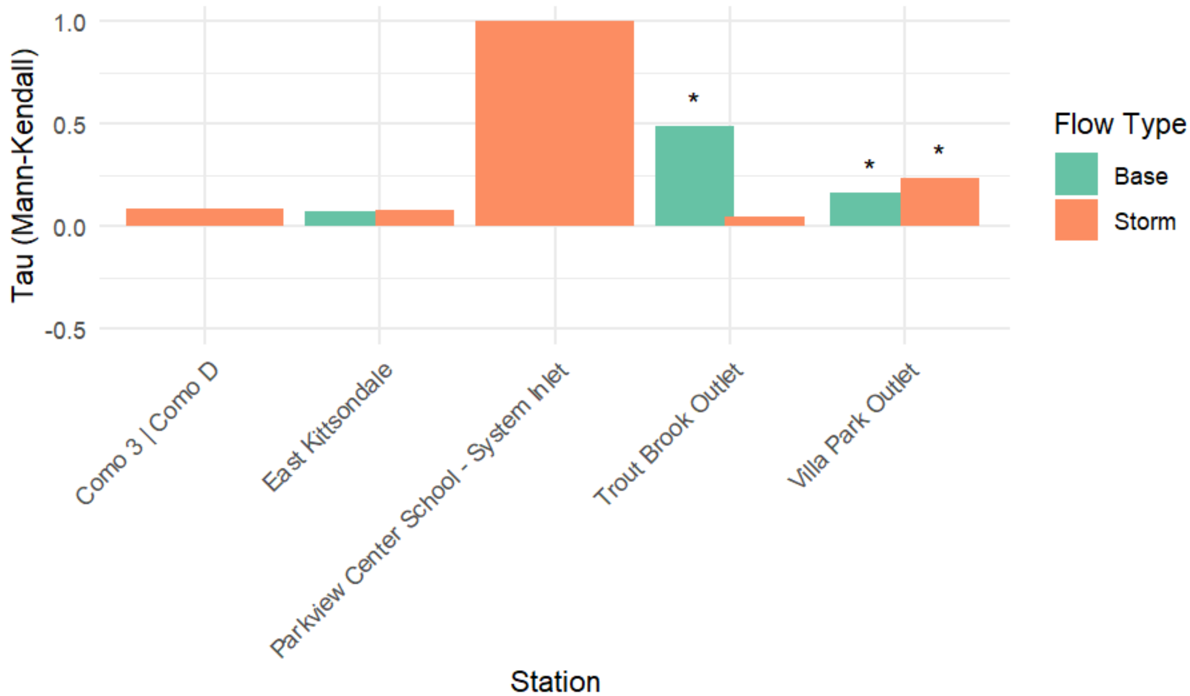


Figure 24. *Summer season Mann–Kendall results for active stormwater sites. Asterisks (*) indicate trends where p-values are <0.05. Flow types are color-coded: green = baseflow and orange = stormflow. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RcolorBrewer, purrr, trend, and Kendall. Note: all Parkview Center School – System Inlet samples were measured as <5mg/L, resulting in a Tau value of 1.0.*

2.2.3 Fall Seasonal Analysis

In the fall season (Figure 25), only baseflow chloride concentration at Trout Brook Outlet show a statistically significant increasing trend. In the fall season, there are no snowmelt data collected; therefore, this flow type has been removed from the figure legend.

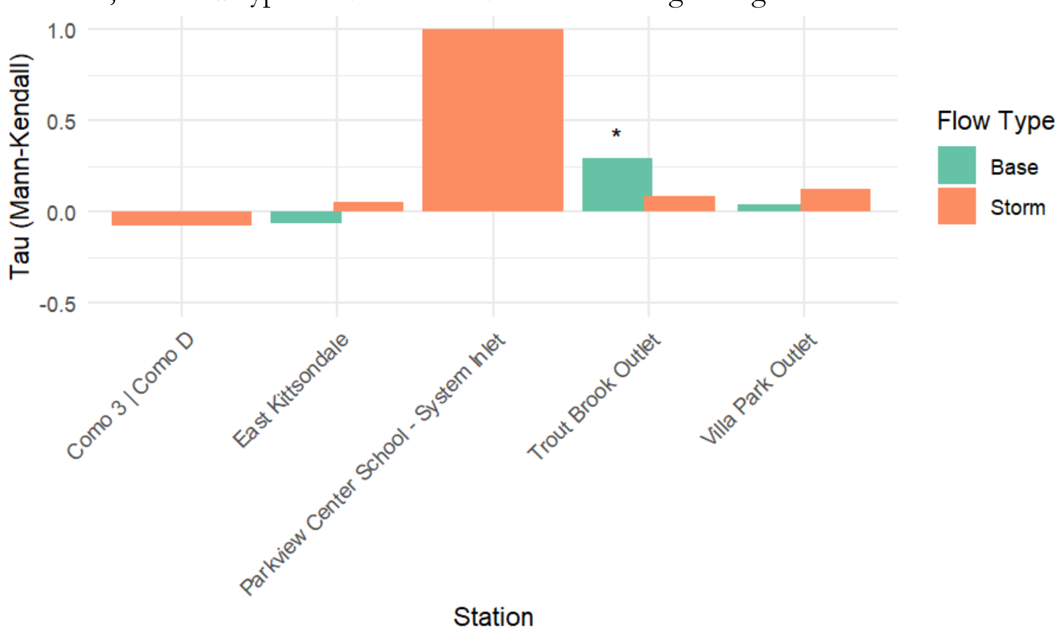


Figure 25. Fall season Mann–Kendall results for active stormwater sites. Asterisks (*) indicate trends where p-values are <0.05. Flow types are color coded: green = baseflow and orange = stormflow. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall. Note: all Parkview Center School – System Inlet samples were measured as <5mg/L, resulting in a Tau value of 1.0.

2.2.4 Winter Seasonal Analysis

In the winter season (Figure 26), there are no statistically significant trends across any flow type at any active site. In the winter season, there are no storm data collected; therefore, it has been removed from the figure legend.

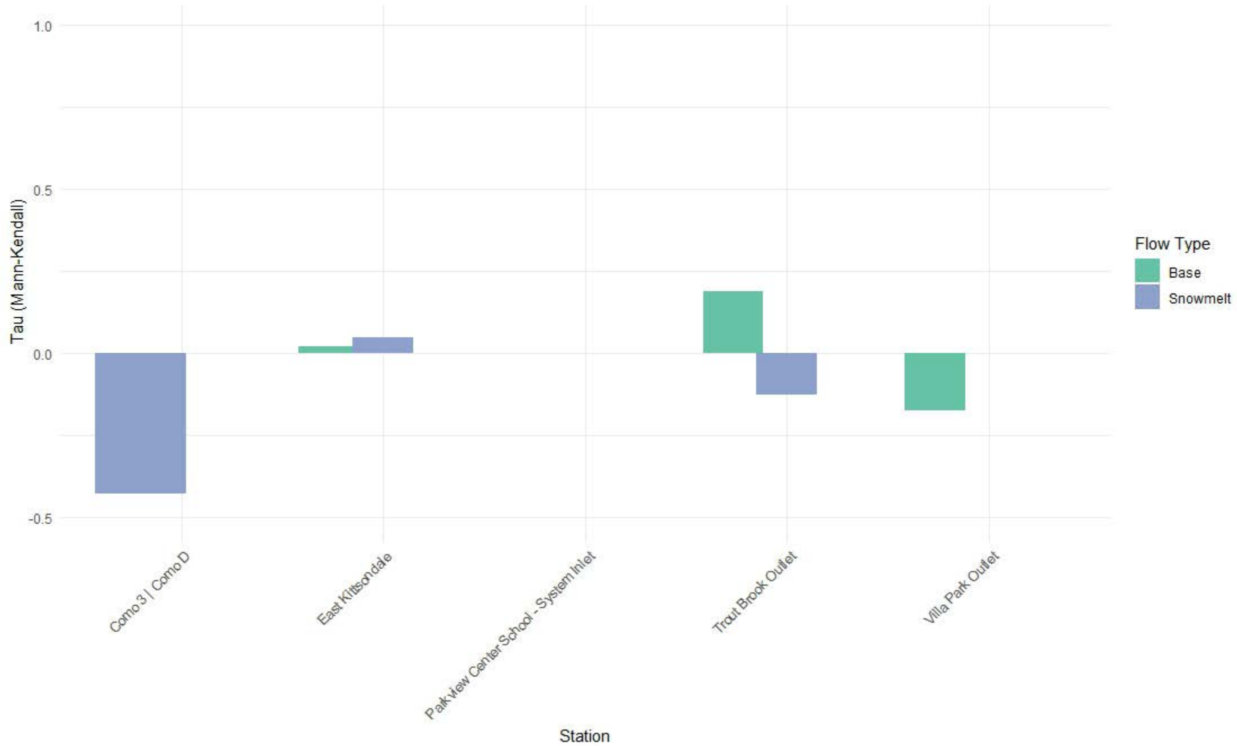


Figure 26. *Winter season Mann–Kendall results for active stormwater sites. Asterisks (*) indicate trends where p-values <0.05. Flow types are color coded: green = baseflow and blue = snowmelt. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RcolorBrewer, purrr, trend, and Kendall.*

3. Aggregated Site Analysis

3.1 Comparison of Stormwater Data to MPCA Chloride Standard

Additional visualizations were prepared for all stormwater monitoring sites (both active and inactive) to show a comparison of stormwater monitoring site data to the thresholds for the MPCA chloride standard (Figures 27 and 28). For the chronic exceedances, East Kittsondale had the highest number of exceedances captured over the period of record, followed closely by Trout Brook – East Branch (Figure 27). The majority of all chronic exceedances have been measured during baseflow conditions. For acute exceedances (Figure 28), East Kittsondale again had the highest number of exceedances captured over the period of record, as well as the most number of baseflow exceedances among all sites. The majority of all acute exceedances have been measured during snowmelt conditions. Storm samples exhibited the lowest number of both chronic and acute exceedances.

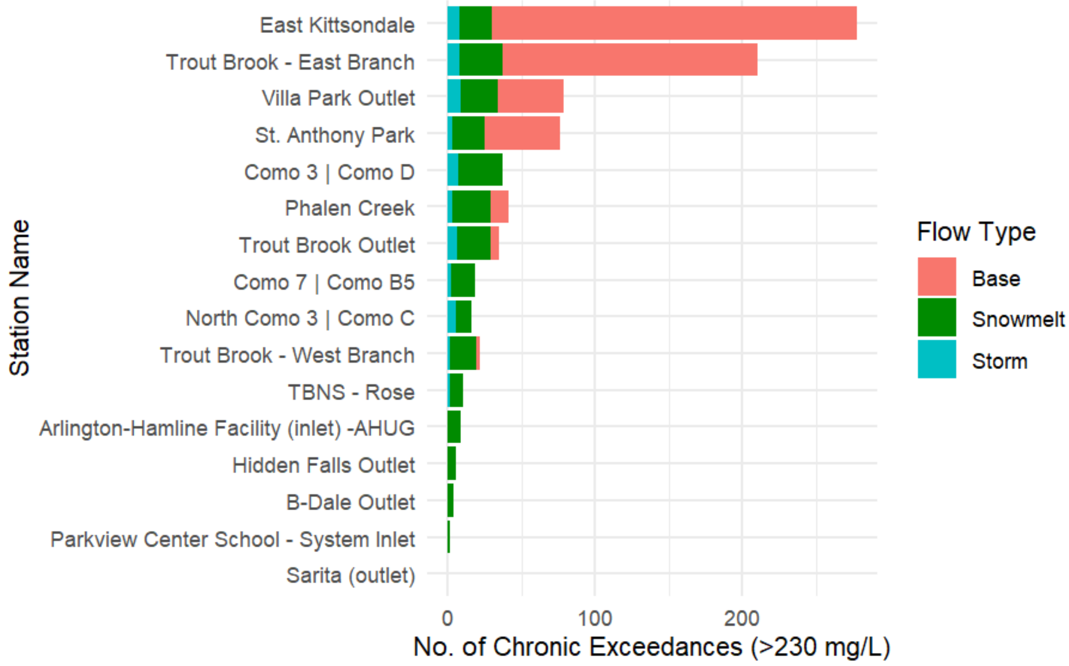


Figure 27. All inactive and active sites with the highest number of occurrences where discrete sample concentrations exceeded the chronic aquatic life criterion (230 mg/L). These exceedances are shown for context only; the criteria apply to classified lakes and streams, not to stormwater conveyances. Data are color coded by sample flow type: red = baseflow and blue = snowmelt. R packages used for this figure include ggplot2, dplyr, and tidyverse.

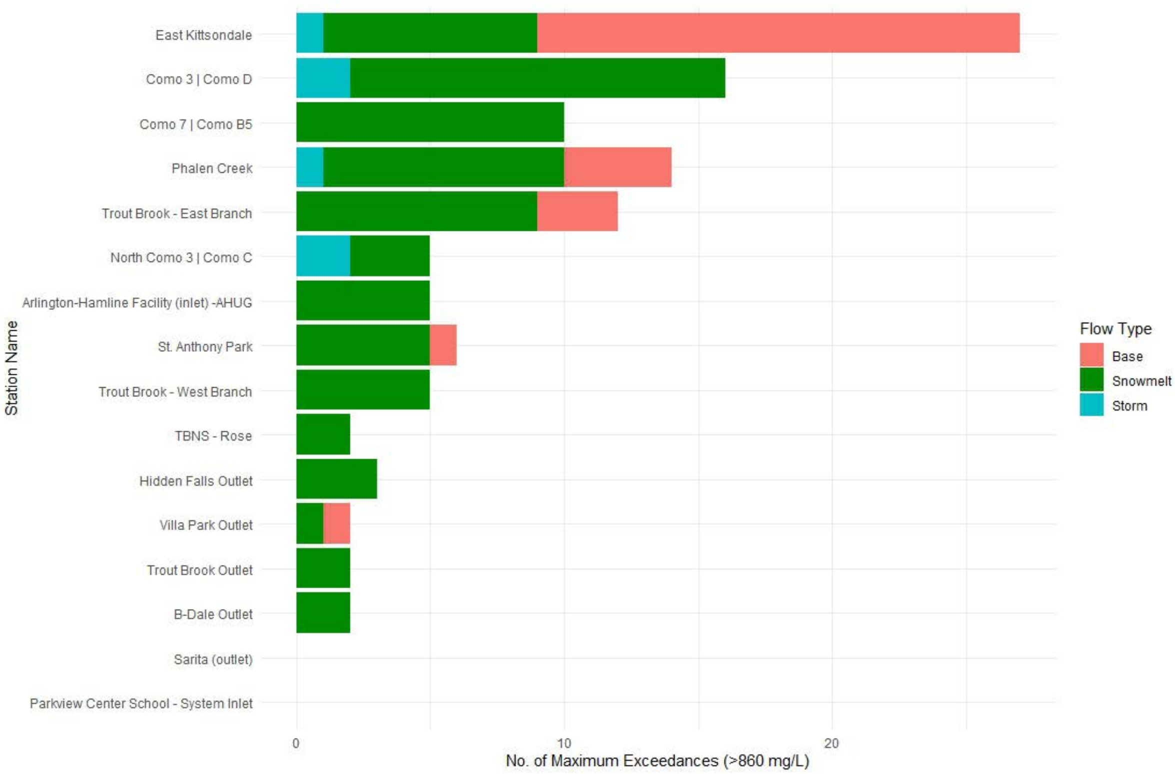


Figure 28. All inactive and active sites with the highest number of occurrences where discrete sample concentrations exceeded the maximum aquatic life criterion (860 mg/L). These exceedances are shown for context only; the criteria apply to classified lakes and streams, not to stormwater conveyances. Data are color coded by sample flow type: red = baseflow and blue = snowmelt. R packages used for this figure include ggplot2, dplyr, and tidyverse.

3.2 Seasonal Analysis – Inactive Stormwater Sites

In addition to active site seasonal analysis in the Stormwater Data section, all inactive stormwater sites were run through the Mann–Kendall trend test for each season for each individual site period of record. Figures 29 – 32 show the results across the three main flow types: baseflow, snowmelt, and storm flow. Each individual plot represents one of the four seasons.

3.2.1 Spring Seasonal Analysis

In the spring season (Figure 29), baseflow chloride concentrations exhibited statistically significant increasing trends at Trout Brook–West Branch, St. Anthony Park, and Phalen Creek but a statistically significant decreasing trend at Trout Brook–East Branch. Storm chloride concentrations showed a statistically significant increasing trend at Hidden Falls Outlet but a statistically significant decreasing trend at Como 7 | Como B5 and Arlington-Hamline Facility inlet (AHUG). Only one site, St. Anthony Park, had a statistically significant increasing trend in snowmelt chloride concentrations.

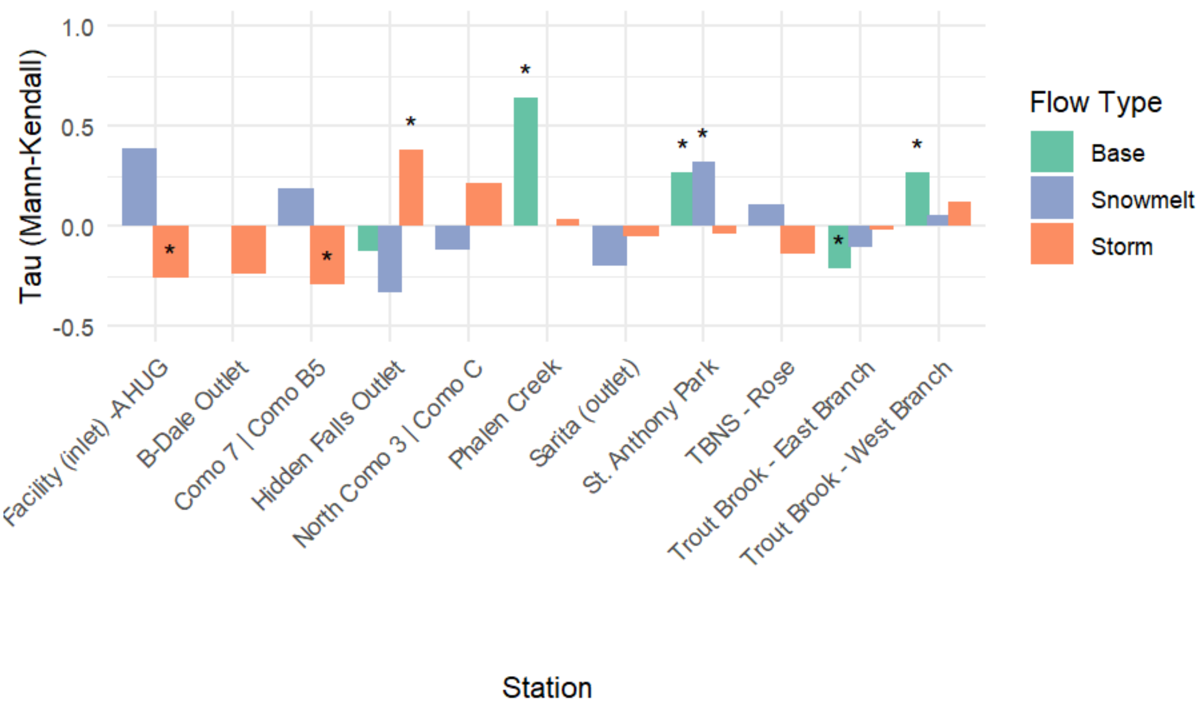


__Figure 29.__ Mann–Kendall results for inactive stormwater sites during the spring season. Asterisks (*) indicate trends where p-values are <0.05. Flow types are color coded: green = baseflow, blue = snowmelt, and orange = stormflow. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RcolorBrewer, purrr, trend, and Kendall.

3.2.2 Summer Seasonal Analysis

In the summer season (Figure 30), baseflow chloride showed a statistically significant increasing trend at St. Anthony Park, Phalen Creek, and Trout Brook–West Branch. Stormflow chloride concentration showed an statistically significant increasing trend at TBNS–Rose and Trout Brook–West Branch, but a statistically significant decreasing trend at B-Dale Outlet and AHUG.

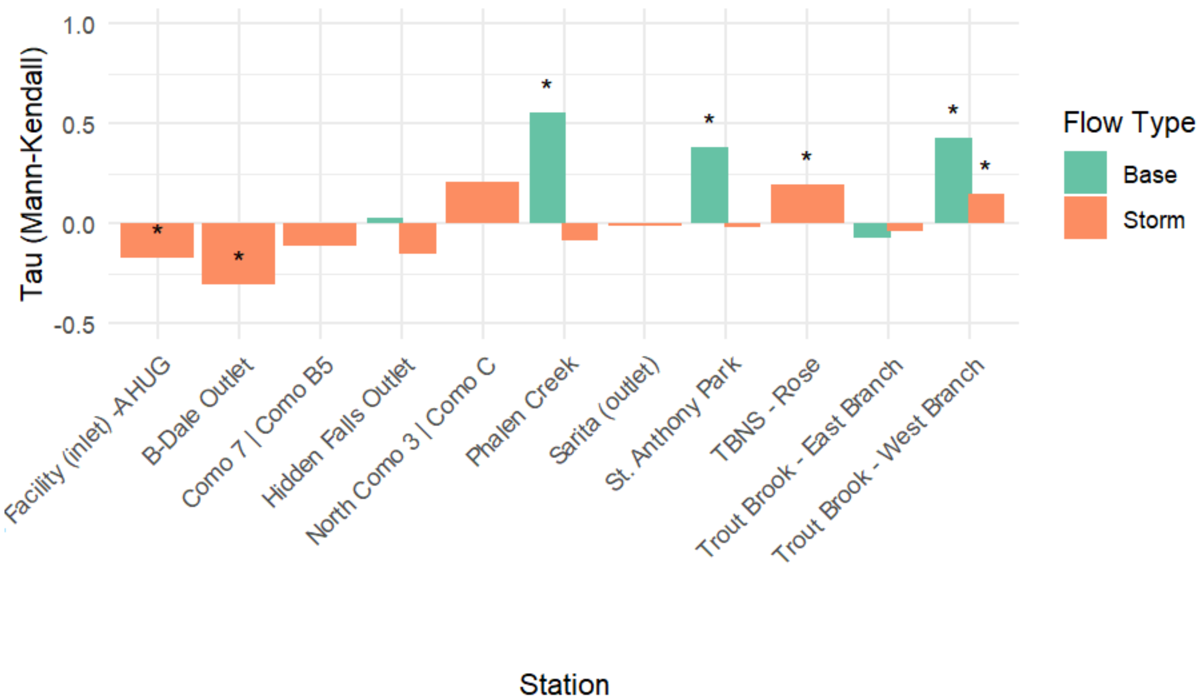


Figure 30. *Mann–Kendall results for inactive stormwater sites during the summer season. Asterisks (*) indicate trends where p-values <0.05. Flow types are color coded: green = baseflow and orange = stormflow. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall.*

3.2.3 Fall Seasonal Analysis

In the fall season (Figure 31), statistically significant increasing trends in baseflow chloride concentrations were observed at Trout Brook – West Branch, St. Anthony Park, and Phalen Creek. For stormflow, St. Anthony Park exhibits a statistically significant increasing trend while Como 7 | Como B5 exhibits a statistically significant decreasing trend.

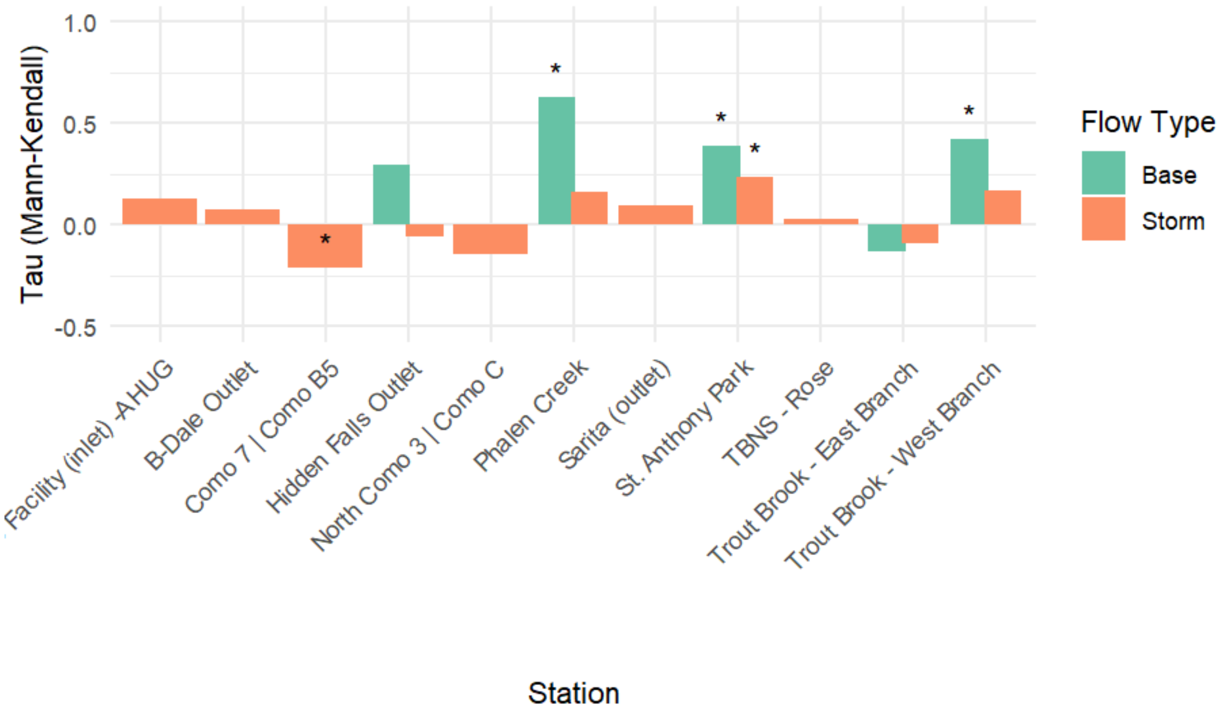


__Figure 31__. Mann–Kendall results for inactive stormwater sites during the fall season. Asterisks (*) indicate trends where p-values are <0.05. Flow types are color coded: green = baseflow and orange = stormflow. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall.

3.2.4 Winter Seasonal Analysis

For the winter season (Figure 32), only two sites had statistically significant increasing trends: Phalen Creek and Trout Brook–West Branch during baseflow conditions.

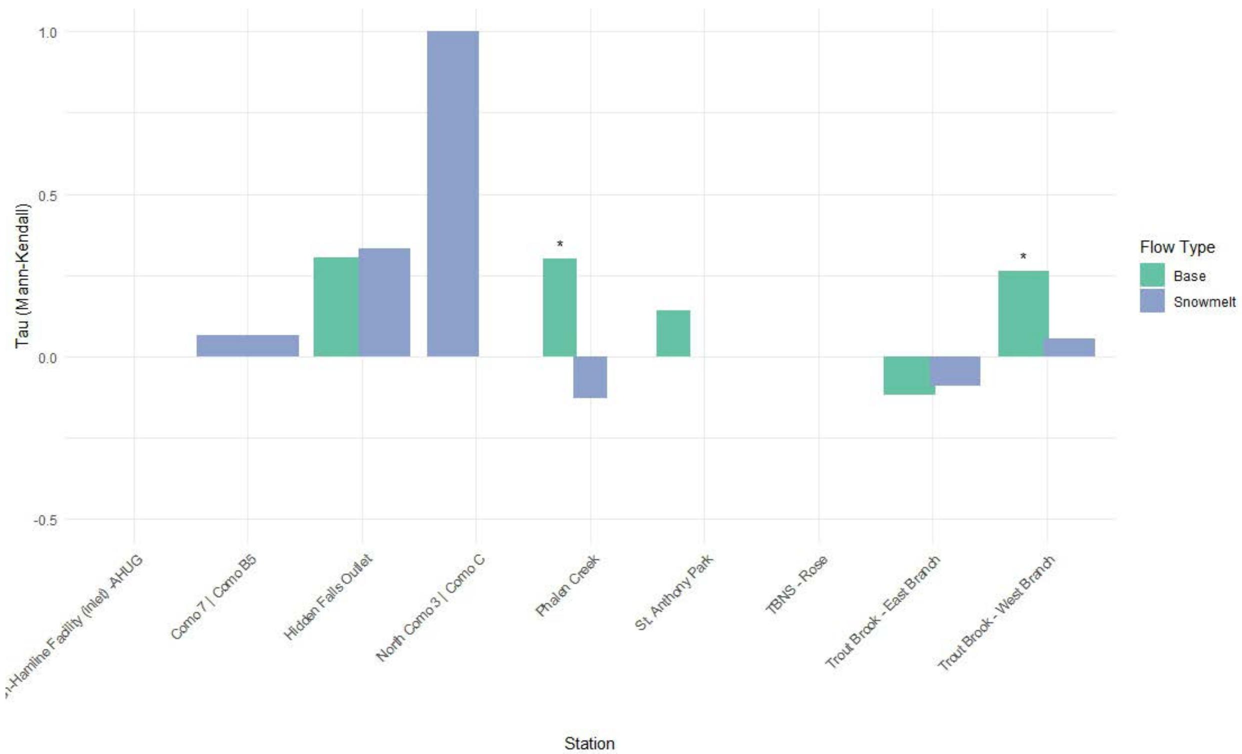


Figure 32. *Mann–Kendall results for inactive stormwater sites during the winter season. Asterisks (*) indicate trends where p-values are <0.05. Flow types are color coded: green = baseflow and blue = snowmelt. R packages used for this figure include ggplot2, dplyr, tidyverse, lubridate, broom, RColorBrewer, purrr, trend, and Kendall. Note: North Como 3 only had a single snowmelt sample collected in the winter season, resulting in a tau value of 1.0.*

SUMMARY

There are increasing, significant trends in chloride concentrations at a few of the lake sites over their individual periods of record and over the past 12 years of record where data collection years overlap (2011–2023). Across all data, McCarrons, Como, and Loeb lakes have shown the most statistically significant trends over time, though at varying depths. The rate of change differs when looking at the full period of record or just the past ~12 years of record, which may indicate that the rate of change is changing over time.

Although seasonal data were limited at some lake sites, all but Little Crosby Lake showed statistically significant trends in at least one season. Seasonal analyses revealed more nuanced trends than depth-specific linear analyses across the full monitoring period. Further investigation into why certain depths or seasons exhibit divergent trends at the same site may be warranted.

In stormwater systems, chloride concentrations increased over time under baseflow, snowmelt, and stormflow conditions at multiple sites. Villa Park Outlet and Trout Brook Outlet had increasing concentrations across multiple flow types and seasons, and could be invested further. Chloride concentrations exceeding the MPCA's aquatic life criteria were observed at both active and inactive monitoring sites. The majority of all chronic exceedances have been measured during baseflow conditions. The majority of all acute exceedances have been measured during snowmelt conditions. Storm samples exhibited the lowest number of both chronic and acute exceedances.

REFERENCES

Minnesota Pollution Control Agency (MPCA). "Chloride Standards." Minnesota Pollution Control Agency. Accessed April 18, 2025. https://www.pca.state.mn.us/business-with-us/water-quality-standards.

U.S. Environmental Protection Agency (USEPA). "National recommended water quality criteria – Aquatic life criteria table. EPA Office of Water. 1988. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table.

Appendix B: Methods for Estimating Areas of Potential Chloride Application for CRWD Impervious Surfaces by Land Use and Surface Type

Technical Memorandum

Young Environmental Consulting Group, LLC

To: Britta Belden, Division Manager
Sarah Wein, Water Resource Project Manager
Capitol Region Watershed District (CRWD)

From: Christopher Ross, Senior GIS Analyst
Della Schall Young, CPESC, PMP, CTF, Principal Scientist

Date: April 16, 2025 (Revised September 22, 2025)

Re: Methods for Estimating Areas of Potential Chloride Application for CRWD Impervious Surfaces by Land Use and Surface Type

Young Environmental conducted a Geographic Information Systems (GIS)-based analysis of impervious surfaces within the Capitol Region Watershed District (CRWD). This work supports the CRWD's Chloride Pollution Prevention Plan by evaluating impervious surfaces where chloride is likely to be applied during winter weather events across land uses and surface types. Young Environmental used two primary methods: (1) spatial delineation of chloride-receiving impervious surfaces by drainage area and simplified by land use categories and (2) lane mile estimations by roadway ownership type (MnDOT, County, and Municipal). In the following sections, we describe the data sources, GIS processing methods, classification logic, and outputs that inform prioritization at the sub-watershed scale.

Data Sources

The GIS analysis relied on the following spatial datasets to characterize impervious surfaces and roadway infrastructure within the CRWD:

- Road centerlines—Metropolitan Council (live service), used for roadway classification and lane mile estimation
- Land use—Metropolitan Council (2020), developed by the Metropolitan council and interpreted from 2020 aerial imagery in conjunction with county parcel data
- Transportation structures—Ramsey County (2021), polygon features identifying sidewalks, parking lots, alleys, and driveways
- Drainage areas—the CRWD (2024), used to spatially summarize chloride-contributing surfaces by sub-watershed

We combined and processed these datasets to estimate the distribution of chloride applications based on land use, surface type, and ownership.

Data Preprocessing for Land Use

Although data sources are useful when initially received, it is often necessary to edit the data to make derivative products and prepare for further analysis.

Land Use Simplification

The land use data contain 22 generalized land use classes developed by the Metropolitan Council. For the purposes of our analysis, we combined land use classes to simplify the dataset and reduce the fractional outputs for further analysis. The following list details the land use simplification strategies along with justification at the preprocessing stage:

- **Residential**—Single-family detached, single-family attached, multifamily, seasonal or vacation, manufactured housing park, and mixed-use residential are all residential categories.
- **Agricultural**—Farmstead, agricultural, and extractive are combined because there is little impervious surface.
- **Commercial**—Retail and other commercial, office, and mixed-use commercial are used for provision of goods and services but are specifically nonresidential.
- **Institutional**—Only institutional land that is used primarily for religious, governmental, educational, social, cultural, or major health-care facilities is included.
- **Parks**—Parks, recreational or preserves, and golf courses are combined to represent all parks and green spaces.
- **Industrial**—Mixed-use industrial, industrial, and utility are merged because they are all industrial.
- **Transit**—Major highway, airport, and major railway are combined to encompass the major transit routes.
- **Undeveloped**—Undeveloped is its own category and represents land not used for a defined purpose.
- **Open water**—Open water is excluded from this analysis with the logic that there cannot be impervious surface on the water; therefore, open water would not impact the calculations.

Transportation Structures Segmentation

Transportation structures constitute a polygon feature class with attributions that differentiate sidewalks, parking lots, and driveways. For ease of entry into a geoprocessing model, we exported each category into separate feature classes.

Road centerlines represent a single line for each road segment. For use in our processing model, we first need to separate the roadways by their classification to achieve feature classes for municipal, county, and MnDOT roadways. Once we achieved the three feature classes, we used the following buffers to generate polygons that accurately represent the impervious area of the roadways:

- Municipal roads = 20 ft.
- County roads = 25 ft.
- Minnesota state roads = 30 ft.
- Interstate = 50 ft.

We merged Minnesota state and interstate roads into "MnDOT" before further processing because MnDOT would apply chloride to both roadway types. We visually compared these new polygons to the transportation structure polygons to confirm low or minimal overlap.

Land Use Clipping

Following preprocessing, impervious surface segmented data were ready for integration with land use classifications. We used a pairwise-clip geoprocessing operation to spatially intersect each chloride-receiving impervious surface type (sidewalks, driveways, parking lots, and roadways) with the simplified land use dataset. This produced feature classes identifying the extent of each impervious surface type within each land use category.

Land Use Impervious Model

We developed the land use impervious model (Figure 1) to automate the processing of impervious surface data by drainage area and land use. The model performs the following steps iteratively for each drainage area:

1. Select and clip: A pairwise clip is performed between each impervious surface layer (e.g., sidewalks) and the simplified land use data within the selected drainage area.
2. Calculate area: The model calculates the acreage (or square footage) of each surface type within each land use category.
3. The model processes surface types in the following order:
   - Sidewalks
   - Parking lots
   - Driveways
   - Alleys
   - Municipal roads
   - County roads
   - MnDOT roads

We exported these outputs as summary tables and combined them into a master spreadsheet for further analysis and prioritization.

Land Use and Surface Type Examples

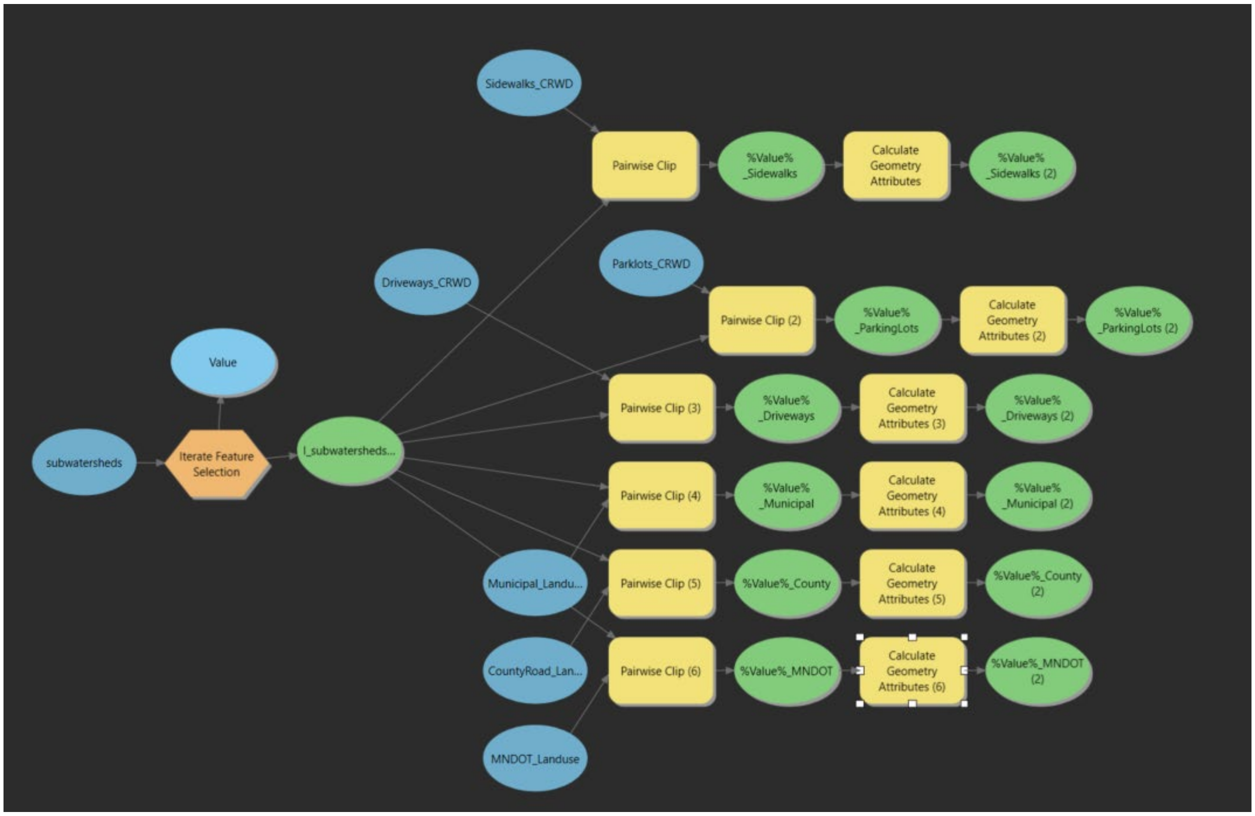
The following list includes brief examples of the surface type and land use combinations:

- **Residential**
  - Sidewalks—Sidewalks along a neighborhood street
  - Driveways—Household driveways typically leading to a garage
  - Parking Lots—Multifamily housing such as apartment complex parking lots
  - Alleys—Alleys providing access to driveways between municipal streets
  - Municipal Roadways—Roadways providing access to residential areas
  - County Road—County roads running through residential areas
  - MnDOT Road—Minimal occurrence due to overlaps in land use boundaries

- **Agricultural**
  - Agricultural impervious totaled less than 20 acres across all surface types for all drainages and was mostly represented by overlaps between roadways and agricultural land use.
- **Commercial**
  - Sidewalks—Sidewalks along commercial land use properties such as retail stores or office complexes
  - Driveways—Minimal occurrence due to overlaps in land use boundaries
  - Parking Lots—Parking lots for retail and office businesses
  - Alleys—Minimal occurrence due to overlaps in land use boundaries
  - Municipal Roadways—Roadways providing access to retail and office buildings
  - County Road—County roads providing access to retail and office buildings
  - MnDOT Road—Overlapping areas of MnDOT rights-of-way and commercial areas near freeways
- **Institutional**
  - Sidewalks—Sidewalks or trails through school grounds and along streets
  - Driveways—Minimal occurrence due to overlaps in land use boundaries
  - Parking Lots—Parking lots for schools and universities
  - Alleys—Minimal occurrence due to overlaps in land use boundaries
  - Municipal Roadways—Roadways providing access to schools and universities
  - County Road—County roads providing access to schools and universities
  - MnDOT Road—Minimal occurrence due to overlaps in land use boundaries
- **Parks**
  - Sidewalks—Sidewalks and trails in parks and golf courses
  - Driveways—Minimal occurrence due to overlaps in land use boundaries
  - Parking Lots—Parking lots providing parking access to parks and golf courses
  - Alleys—Minimal occurrence due to overlaps in land use boundaries
  - Municipal Roadways—Roadways providing access to parks and golf courses
  - County Road—Roadways providing access to parks and golf courses
  - MnDOT Road—Minimal occurrence due to overlaps in land use boundaries
- **Industrial**
  - Sidewalks—Sidewalks along streets adjacent to industrial buildings
  - Driveways—Minimal occurrence due to overlaps in land use boundaries
  - Parking Lots—Parking for access to industrial buildings
  - Alleys—Minimal occurrence due to overlaps in land use boundaries
  - Municipal Roadways—Roadways providing access to industrial buildings
  - County Road—County roads providing access to industrial buildings
  - MnDOT Road—Minimal occurrence due to overlaps in land use boundaries
- **Transit**
  - Sidewalks—Sidewalks and trails overlapping with highways
  - Driveways—Minimal occurrence due to overlaps in land use boundaries
  - Parking Lots—Rail yards and rail rights-of-way
  - Alleys—Minimal occurrence due to overlaps in land use boundaries
  - Municipal Roadways—Municipal roads overlapping highways such as bridges and ramps
  - County Road—County roads overlapping highways such as bridges and ramps

  - MnDOT Road—Interstate and state highways
- **Undeveloped**
  - Undeveloped land use in this analysis is mostly the result of overlapping boundaries. The most significant occurrence in our analysis is in areas identified as parking lots, even though they may still be under development or simply open areas.

Figure 1. Land Use Impervious Model Diagram



Data Preprocessing for Lane Miles Analysis

We conducted lane mile analysis to validate the calculations in the above Land Use Impervious Model, and to assist with potential calculations of chloride contributions from roads maintained by MnDOT, Ramsey County, and municipalities. The Metropolitan Council Road Centerline Dataset served as the base layer for roadway geometry.

Preprocessing steps included the following:

- Clipping to the CRWD boundary: We clipped the regional road network to the CRWD boundary to isolate relevant road segments.

- Roadway classification: We assigned road segments to three ownership categories based on the route system attribute:

  - MnDOT roads: Includes state highways and interstates

  - County roads: Managed by Ramsey County
  - Municipal roads: Managed by city public works departments

- Lane count attribution: We created a new “Lanes” field to track the number of travel lanes per segment. Initially, we populated lane counts using default values (typically two lanes), and then manually reviewed and updated them for high-volume corridors:

  - Interstates: 3–5 lanes per direction
  - County arterials: 2–4 lanes
  - Municipal streets: 1–2 lanes, adjusted by context

- Dissolve operation: After we verified lane counts, we performed a dissolve to aggregate roadway segments by ownership type and lane count, simplifying geometry for processing.

This prepared dataset formed the basis for estimating total lane miles and supported subsequent load estimation by road type.

Lane Mile Model

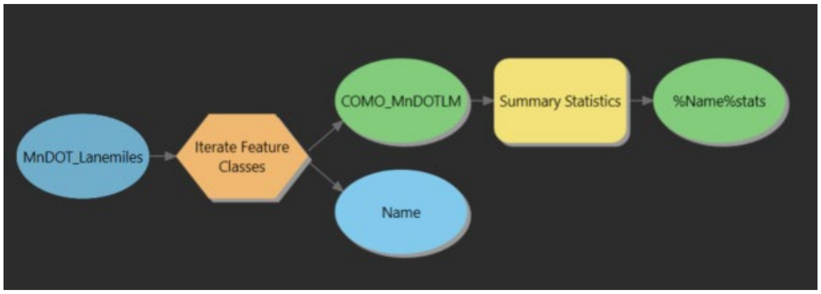
We developed the lane mile model (Figure 2) to automate future chloride-relevant calculations for roadways by ownership and sub-watershed. It processes each drainage area iteratively using the following steps:

1. Roadway selection: Within each drainage area, road segments are selected by ownership category (MnDOT, county, or municipal).
2. Clipping: Selected road segments are clipped to the drainage boundary.
3. Linear distance calculation: The model calculates the total length of road segments in miles.
4. Lane miles calculation: Linear miles are multiplied by the number of lanes to yield lane miles.
5. The lane mile summary statistics model (Figure 3) aggregates lane mile (and can also aggregate future calculations for chloride load) results across all drainages to generate summary statistics by ownership type and sub-watershed. These outputs provide a spatially resolved estimate of road salt application potential, supporting targeted winter maintenance strategies and sub-watershed prioritization.

We conducted manual verification of roadway classifications and surface alignment to ensure confidence in the results and minimize overlap or omission errors.

Figure 2. Lane Mile Model Diagram

Figure 3. Lane Mile Summary Statistics Model Diagram



Appendix C: Spatial analysis results for CRWD and each major CRWD subwatershed

Appendix C: Spatial analysis results for CRWD and each major CRWD subwatershed

		Major CRWD Subwatershed Area (acres)																Total (acres)
Surface Type	**Land Use**	Como	Crosby	Davern	Downtown	East Kittonsdale	Goodrich - Western	Hidden Falls	McCarrons	Mississippi River Blvd	Phalen Creek	St Anthony Hill	St Anthony Park	Trout Brook	Urban	West Kittonsdale	West Seventh	CRWD
Sidewalks	Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	0.0	0.0	0.0	0.0	2.5
	Commercial	5.1	1.3	1.2	20.3	8.7	2.5	0.3	0.4	5.7	7.3	12.9	10.6	12.1	0.3	7.8	1.9	98.4
	Residential	51.6	24.2	39.6	15.4	97.6	25.3	1.1	8.8	116.9	58.0	109.9	62.1	105.8	16.8	36.7	14.5	784.3
	Industrial	0.1	0.9	0.4	0.3	0.7	0.0	0.6	0.1	0.3	2.8	1.6	9.1	9.3	0.0	1.1	1.6	28.9
	Institutional	8.2	3.2	3.8	19.0	8.5	2.5	0.1	2.7	27.0	11.4	29.5	46.5	45.7	1.1	3.6	2.1	214.9
	Parks	23.6	14.3	4.8	14.2	2.2	1.7	1.3	2.4	8.5	7.4	7.6	5.9	20.5	0.9	2.0	2.6	119.9
	Transit	0.2	3.3	0.5	8.9	1.6	1.4	0.0	0.2	0.0	1.0	2.5	3.8	8.6	0.2	1.0	2.1	35.3
	Undeveloped	0.2	0.6	0.2	1.8	0.2	0.5	0.6	0.1	0.5	3.9	2.4	0.4	5.1	0.3	0.7	0.9	18.4
Driveways	Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.1	0.0	1.0
	Commercial	1.2	0.0	0.2	0.7	2.0	0.3	0.0	0.0	0.6	0.9	0.5	0.1	1.7	0.1	0.2	0.4	8.9
	Residential	79.3	22.2	53.7	6.1	71.4	21.8	0.1	44.9	81.6	55.9	90.9	63.8	164.2	22.2	24.9	15.6	818.6
	Industrial	0.2	0.1	0.1	0.0	0.1	0.0	0.3	0.0	0.2	0.2	0.2	0.9	2.3	0.0	0.2	0.6	5.4
	Institutional	0.3	0.0	0.2	0.9	1.1	0.3	0.0	0.0	0.8	0.5	1.3	3.1	1.4	0.1	0.3	0.4	10.7
	Parks	0.2	0.1	0.0	0.0	0.1	0.0	0.6	0.0	0.1	0.0	0.2	0.1	0.4	0.1	0.0	0.0	1.9
	Transit	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.9
	Undeveloped	0.1	0.5	0.0	0.3	0.0	0.1	0.1	0.0	0.3	1.0	0.8	0.1	1.9	0.3	0.2	0.1	5.8
Parking Lots	Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.7
	Commercial	40.6	12.4	28.5	32.1	59.7	8.5	4.7	5.4	23.0	40.0	96.0	83.1	132.8	0.8	63.4	5.9	636.9
	Residential	14.0	7.7	18.3	10.2	13.7	8.5	1.4	10.4	12.3	12.0	38.8	48.3	61.1	2.0	10.4	5.5	274.6
	Industrial	0.2	20.4	9.3	1.4	10.4	0.0	0.3	0.0	0.0	24.8	30.0	193.6	197.1	0.0	32.4	40.9	560.8
	Institutional	11.8	6.5	10.0	22.9	19.2	4.9	0.0	10.2	39.5	26.6	61.3	193.3	65.7	1.4	12.6	7.8	493.7
	Parks	16.0	10.8	3.6	3.0	1.8	0.4	0.3	0.6	3.8	1.1	4.6	1.3	9.0	1.2	0.6	0.6	58.7
	Transit	0.0	0.1	0.6	6.0	0.8	0.0	0.0	0.0	0.0	0.2	22.4	55.6	2.1	0.0	2.3	0.0	90.1
	Undeveloped	0.0	0.3	0.2	2.3	0.5	1.7	30.1	0.0	1.9	3.7	9.7	5.7	5.1	0.0	5.8	0.3	67.3
Alleys	Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
	Commercial	0.2	0.1	0.0	0.2	2.1	0.3	0.0	0.0	2.5	1.6	2.3	0.3	1.0	0.0	1.5	0.0	12.1
	Residential	16.6	9.8	12.2	0.8	41.0	7.5	0.0	0.0	55.8	27.5	39.5	19.6	34.8	4.9	14.3	3.2	287.5
	Industrial	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.2	0.5	0.4	0.0	0.0	0.0	1.5
	Institutional	0.2	0.1	0.1	0.0	0.1	0.4	0.0	0.0	0.9	1.5	1.9	0.3	0.6	0.0	0.7	0.1	6.9
	Parks	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.2	0.1	0.1	0.3	0.2	0.0	0.0	1.3
	Transit	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.5
	Undeveloped	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	1.4	1.0	0.2	1.2	0.1	0.2	0.0	4.5
Municipal Roads	Agricultural	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.2	6.8	0.2	0.0	0.8	0.0	8.4
	Commercial	4.2	5.1	5.0	30.3	16.9	3.8	0.0	0.2	7.7	14.2	18.6	20.1	24.4	1.2	14.7	3.9	170.3
	Residential	172.3	68.3	124.3	30.0	215.5	56.5	2.9	69.2	250.7	139.1	239.9	168.1	337.2	46.4	82.8	35.6	2,038.8
	Industrial	0.3	6.0	1.6	0.7	4.4	0.0	0.7	0.0	0.4	8.2	3.1	32.2	36.6	0.0	4.7	6.6	105.5
	Institutional	8.3	5.1	7.8	21.3	16.0	5.3	0.1	2.9	22.4	16.5	32.9	81.9	39.1	1.8	7.0	3.6	272.0
	Parks	30.1	24.2	19.0	10.9	20.1	2.7	3.2	3.0	39.7	15.2	11.0	19.0	26.4	2.7	3.1	3.6	233.9
	Transit	0.9	24.3	7.1	25.6	25.7	5.4	0.1	12.3	0.0	7.5	34.6	32.6	70.5	2.8	8.9	7.1	265.4
	Undeveloped	0.7	2.1	3.6	4.0	1.5	1.1	19.2	1.9	1.2	12.7	6.4	2.8	22.7	1.3	3.0	1.5	85.7
County Roads	Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	6.3	0.1	0.0	0.0	0.0	6.6
	Commercial	10.2	0.5	0.1	0.0	4.2	0.7	0.3	1.4	8.8	2.0	20.1	11.0	15.9	0.0	4.9	0.5	80.4
	Residential	18.6	4.4	9.8	0.0	11.7	2.7	0.5	10.6	16.8	8.3	21.2	16.7	33.5	0.0	4.6	0.8	160.3
	Industrial	0.7	0.0	0.0	0.0	0.5	0.0	0.0	0.2	0.1	0.2	5.1	11.5	7.3	0.0	0.6	1.3	27.5
	Institutional	2.1	0.0	0.3	0.2	1.9	0.3	0.3	1.6	5.5	0.8	8.4	9.3	10.6	0.0	1.6	0.4	43.3
	Parks	7.7	0.1	1.8	0.8	1.0	0.0	0.0	0.4	2.3	2.8	11.7	2.3	7.7	0.0	0.8	0.0	39.4
	Transit	0.1	0.8	0.3	15.4	0.5	0.6	0.0	1.9	0.0	0.0	9.4	9.6	10.5	0.0	3.7	7.1	59.8
	Undeveloped	0.3	0.9	0.0	0.0	0.2	0.1	0.0	0.4	0.7	0.9	6.3	1.2	6.2	0.0	0.3	0.0	17.5
State Roads	Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Commercial	0.0	1.3	2.8	6.2	4.0	2.2	0.0	0.0	2.9	6.6	0.0	0.2	1.4	0.0	5.2	3.2	35.9
	Residential	0.3	2.2	2.6	1.6	2.3	2.3	0.0	0.0	6.5	5.7	0.0	3.9	0.0	0.0	3.1	2.8	33.4
	Industrial	0.0	0.2	0.7	0.0	0.3	0.0	0.0	0.0	0.5	0.9	0.0	0.0	0.0	0.0	0.0	0.5	3.0
	Institutional	0.2	1.0	0.1	1.5	0.4	0.2	0.0	0.0	2.6	2.9	0.0	6.4	0.0	0.0	0.6	0.5	16.5
	Parks	0.0	7.0	2.4	0.4	0.0	0.6	0.0	0.0	0.3	1.7	0.0	0.4	0.0	0.0	0.3	0.0	13.1
	Transit	0.0	26.3	5.1	23.6	30.4	8.1	0.0	20.0	0.0	19.1	42.3	29.2	97.6	6.3	18.4	0.1	326.4
	Undeveloped	0.0	0.1	0.0	1.2	0.2	0.7	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.8	0.4	4.4
Total		**527.2**	**319.1**	**381.7**	**340.7**	**702.1**	**182.1**	**69.2**	**212.3**	**751.3**	**557.7**	**1,039.9**	**1,283.6**	**1,638.6**	**115.5**	**393.0**	**186.8**	**8,700.9**

Appendix D: Chloride Management Plan Project – Task 2.2: Local, Regional, and International Literature Review, and Task 2.3: Review of Current Work Being Done by CRWD

Technical Memorandum

To:	Britta Belden, Division Manager Sarah Wein, Water Resource Project Manager Capitol Region Watershed District (CRWD)
From:	Nick Voss, Water Resources Scientist Della Schall Young, CPESC, PMP, CTF, Principal Scientist
Date:	January 14, 2025
Re:	Chloride Pollution Prevention Plan—Task 2.2: Local, Regional, and International Literature Review, and Task 2.3: Review of Current Work Being Done by CRWD

This memorandum provides an overview and analysis of chloride management strategies derived from Task 2.2 and Task 2.3. As Young Environmental collaborates with the Capitol Region Watershed District (CRWD) on a Chloride Management Plan, it is essential to understand the existing literature and ongoing efforts in this field. Chloride contamination poses significant risks to freshwater ecosystems, vegetation, infrastructure, and drinking water supplies. The diverse sources of chloride pollution complicate mitigation efforts, necessitating a comprehensive review of effective strategies and best practices. To gain a broad perspective, we have examined local, regional, and international documents. This summary highlights key findings from approximately two dozen documents on chloride management, categorized for ease of reference (See Table 1). The table presents information on the documents researched, with the last two columns detailing Young Environmental's assessment of each activity's relevance to the CRWD. Additionally, it evaluates the current efforts of the district, identifying strengths and areas for improvement.

Task 2.2: Local, Regional, and International Literature Review Summary

Chloride pollution is a persistent and growing issue in urban areas, even when road salt and other chloride applications are used correctly and efficiently. Chloride is a nondegradable pollutant, meaning that once it enters the environment, it accumulates over time, with severe implications for water quality, aquatic ecosystems, infrastructure, and vegetation. This challenge is exacerbated by increasing reliance on deicing salts in urban, cold-weather climates, driven by public safety concerns, liability pressures, and climate change impacts.

To inform CRWD's chloride management strategies, Young Environmental reviewed foundational documents and emerging literature that highlight best practices, challenges, and innovative solutions for reducing chloride pollution. Resources reviewed include the following:

1. Minnesota Statewide Chloride Management Plan Report (2021): A statewide framework for chloride reduction focusing on monitoring, public education, training, and regulatory recommendations
2. Twin Cities Metropolitan Area Chloride Management Plan (2016) TCMA: Regional strategies for adaptive management, collaborative frameworks, and actionable

recommendations for urban chloride reduction

3. Shingle Creek Chloride TMDL Report (2006): A case study identifying chloride sources, monitoring trends, and implementing Total Maximum Daily Load (TMDL) strategies in an urban/suburban watershed
4. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Chloride (2011): Establishes chloride toxicity thresholds to protect aquatic ecosystems in urban watersheds
5. Impact of Deicing Salt on Maine Streams (2020): Highlights the ecological and groundwater impacts of deicing salts in urban runoff scenarios
6. Wisconsin Statewide Chloride Strategy (2022): Outlines financial incentives, training, and best management practices (BMPs) for reducing chloride usage statewide
7. Hennepin County Chloride Initiative Report (2020): Examines trends in chloride pollution and offers strategies to reduce its application while ensuring public safety by focusing on developing a strategic plan to promote BMPs among private applicators. The report included interview and survey responses from private applicator companies, providing their perspectives on the issues that will be considered as input in the development of the Chloride Management Plan.

In addition, supplementary materials were reviewed, offering insights into cross-jurisdictional collaboration, emerging technologies, and climate resilience in chloride management.

Chloride Management Challenges

The reviewed documents reveal that even when chloride is used appropriately and within recommended guidelines, it remains an environmental concern. Chloride's persistence in the environment means that even small amounts contribute to cumulative pollution. This issue is compounded by the following factors:

- Cumulative impact: Correctly applied chloride still washes into surface water and infiltrates groundwater, leading to persistent environmental accumulation. The Minnesota Statewide Chloride Management Plan highlights that water bodies with minimal chloride application still face exceedances of chronic and acute water quality standards due to historical accumulation.
- Public safety vs. environmental health: Balancing safe winter roadways and walkways with chloride reduction remains a significant challenge. The TCMA identifies liability concerns as a primary driver of overapplication, even when best practices are implemented.
- Climate resilience: Increasing freeze–thaw cycles, as noted in the Wisconsin Statewide Chloride Strategy, are driving more frequent and intensive applications of deicing salts, even in areas adopting advanced salt management practices.

Trends in Chloride Pollution

The persistent nature of chloride pollution is reflected in several key trends:

1. Long-term accumulation: Chloride concentrations continue to rise in lakes, streams, and groundwater, even in areas with reduced application rates. Documents like the Shingle Creek Chloride TMDL Report show that chloride concentrations exceed water quality standards in urban watersheds, even with monitored reductions in road salt use.
2. Seasonal spikes: Chloride levels peak during winter months, as described in the TCMA, highlighting the immediate impact of deicing salt on water bodies.
3. Groundwater contamination: Studies like the Impact of Deicing Salt on Maine Streams

emphasize the migration of chloride into groundwater, impacting drinking water supplies and aquatic ecosystems.

4. Reliance on road salt: Despite advances in salting technologies, liability concerns and unpredictable winter conditions continue to drive heavy chloride use.
5. Challenges of mitigation: Documents like the Hennepin County Chloride Initiative Report show that while advanced salting techniques and alternative deicers reduce chloride inputs, they cannot fully address the long-term accumulation in water systems.

Roles in Chloride Management

CRWD is well positioned to play a critical role in chloride management by coordinating regional efforts and fostering collaborative partnerships. The reviewed documents suggest the following roles for CRWD and related stakeholders:

- Monitoring: Expand and refine monitoring programs to track chloride concentrations and identify priority areas for intervention.
- Education and outreach: Lead public awareness campaigns targeting private contractors and residents, emphasizing the environmental costs of chloride pollution.
- Policy advocacy: Support state and municipal policy changes, including liability protection for certified applicators and incentives for adopting chloride reduction technologies.

Strategies for Partners Consideration

Although chloride management is inherently challenging because of its environmental persistence, the reviewed resources present several strategies for CRWD to consider supporting through partner implementation:

1. Enhanced monitoring: Use tools like conductivity loggers and targeted sampling to better understand chloride trends and prioritize intervention areas, as highlighted in the Shingle Creek Chloride TMDL Report.
2. Public awareness campaigns: Develop and support initiatives like “Low Salt, No Salt Minnesota,” as described in the Minnesota Statewide Chloride Management Plan Report, to reduce reliance on chloride for deicing.
3. BMPs: Encourage the implementation of structural solutions such as permeable pavements and stormwater retention systems alongside nonstructural approaches like prewetting and brining technologies.
4. Adopt alternative deicers: Encourage applicators to evaluate the feasibility of using less harmful alternatives, as recommended in the Wisconsin Statewide Chloride Strategy.
5. Policy development: Advocate for regulations that balance public safety with environmental protection, including liability protection for certified applicators.

Recommendations for CRWD’s Consideration

Given the challenges of managing chloride pollution, CRWD may consider adopting a multifaceted approach:

- Expand its chloride monitoring framework to capture long-term and seasonal trends in priority areas.
- Engage municipalities, private contractors, and community groups in chloride reduction

initiatives.

- Explore incentives for adopting advanced technologies and alternative deicers.
- Collaborate with state agencies and regional partners to advocate for policies that protect public safety and reduce chloride pollution.

Chloride remains an environmental concern even when used correctly, highlighting the need for innovative and collaborative approaches to its management. The accompanying spreadsheet summarizes roles, strategies, and best practices from the reviewed literature to guide CRWD in refining its chloride management efforts.

Task 2.3: Review of Current Work Being Done by CRWD

CRWD is actively addressing the challenges of chloride pollution through a range of strategic initiatives aimed at reducing the environmental impacts of road salt and de-icing agents. This summary reflects information derived from CRWD's 2021–2030 Watershed Management Plan, public-facing materials, and related program documents.

A key component of CRWD's strategy is its monitoring program, which has been in place for over 20 years. The program collects chloride data from water bodies like Como Lake and storm sewers like the Trout Brook Interceptor, revealing rising chloride concentrations that necessitate further intervention. Monitoring data not only tracks the effectiveness of reduction efforts but also provides critical insights for adaptive management to address emerging challenges.

To combat chloride use, CRWD sponsors MPCA Smart Salting Training for Public Works employees of all CRWD municipalities, and has also sponsored MPCA Smart Salting Training for Property Management for Saint Paul Public Schools. These sessions emphasize correct salt application practices, which helps reduce over-application while maintaining safety.

Public engagement plays a significant role in CRWD's approach. Through public awareness campaigns, the district educates residents and businesses about the environmental consequences of excessive salt use. These campaigns provide practical tips, such as shoveling snow before applying salt and sweeping up excess salt for reuse, to encourage more responsible practices.

Finally, CRWD regulatory staff field concerns from community members about excessive salt applications through its Illicit Discharge Detection and Elimination program, and has considered amendments to the District water quality and stormwater management rules that would incorporate chloride reduction through either direct applicator maintenance training or improved site design to reduce the need for salting on permitted sites.

This summary highlights CRWD's holistic approach, integrating insights from its 2021–2030 Watershed Management Plan. By combining monitoring, education, innovation, and partnerships, CRWD is making strides to reduce chloride pollution and protect the watershed for future generations.

Attachment

- Table 1: CRWD Chloride Framework Research Summary (2024)

Literature Review

1. BCWMC. (2023). Parkers Lake drainage project final report. Bassett Creek Watershed Management Commission.
2. Canada–United States. (2012). Great Lakes Water Quality Agreement: Protocol amending the agreement between Canada and the United States of America on Great Lakes Water Quality, 1978, as amended in 1983 and 1987. Washington, DC.
3. Canadian Council of Ministers of the Environment. (2011). Canadian water quality guidelines for the protection of aquatic life: Chloride. Winnipeg, MB.
4. Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN.
5. Environment and Climate Change Canada. (2024). Code of practice for the environmental management of road salts: Annual overview of data reported (2019–2022) in the context of national targets. Gatineau, QC.
6. Fortin Consulting, Inc. (2014). The Real Cost of Salt Use for Winter Maintenance in the Twin Cities Metropolitan Area. St. Paul, MN: Minnesota Pollution Control Agency.
7. Illinois Water Quality Standards. (2023). Environmental protection: Water quality standards. Pollution Control Board.
8. Iowa Department of Natural Resources. (2023). Chloride water quality standards factsheet. Des Moines, IA.
9. Iowa Department of Natural Resources. (2023). Toolbox for chloride limits compliance. Des Moines, IA.
10. Kreiter, A.L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.
11. Maine Department of Environmental Protection. (2020). Impact of deicing salt on Maine streams: A DEP issue profile. Augusta, ME.
12. Maryland Department of the Environment. (2024). Chloride pollution reduction strategies. Baltimore, MD.
13. Michigan Department of Environment, Great Lakes, and Energy. (2021). Chloride Water Quality Implementation Plan. Lansing, MI.
14. Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.
15. Minnesota Pollution Control Agency. (2020). Statewide chloride management plan summary. Minnesota Pollution Control Agency.
16. Minnesota Pollution Control Agency. (2021). Statewide chloride management plan report. Minnesota Pollution Control Agency.
17. Mullaney, J.R., et al. (2009). Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States. USGS.
18. New Hampshire Department of Environmental Services. (2020). Best Management Practices and Salt Use Minimization Efforts. Concord, NH.
19. Pennsylvania Department of Environmental Protection. (2012). Rationale for the Development of Ambient Water Quality Criteria for Chloride. Harrisburg, PA.
20. Queensland Department of Environment and Resource Management. (2011). Salinity management handbook (2nd ed.). Brisbane, QLD: The State of Queensland. ISBN: 0 7242 7412 X.
21. Rhode Island Department of Administration. (2014). Road Salt/Sand Application in Rhode Island. Providence, RI.

22. Seeley, M. (2019). Climate change in Minnesota: A hydrologic perspective. University of Minnesota.
23. Wenck Associates, Inc. (2006). Shingle Creek Chloride TMDL Report.
24. Wisconsin Department of Natural Resources. (2022). Statewide Chloride Strategy. Madison, WI.
25. World Health Organization. (2017). Guidelines for Drinking-Water Quality. Geneva, Switzerland.

Table 1: CRWD Chloride Framework Research Summary (2024)

Document	Trend (presented or paraphrased)	Issues/Impacts/Resources Evaluated	Goals and Drivers		Actions/Activities	Relevance to CRWD (High, Medium, Low, Unknown)	Notes
			Guiding Principles	Goals	Actions (Suggested or Paraphrased)		
List the document and publishing entity	*List most relevant chloride trends noted in document or paraphrased*	*Subject or Topic*	*Highest level guidance/purpose of the document*	*High level goals identified in document (will be a judgement call re: principle vs. goal vs. objective)*	*What actions is the entity going to lead*	*Qualitative assessment of how relevant this info is to CRWD's effort*	*Additional notes of relevance*
Queensland Department of Environment and Resource Management. (2011). Salinity management handbook (2nd ed.). Brisbane, QLD: The State of Queensland. ISBN: 0 7242 7412 X	Salinity risks linked to hydrology and land use.	Salinity risks, groundwater, soil health.	Understand and Monitor Salinity Risks.	Develop early detection systems.	Use conductivity tests and salinity maps.	Low	CRWD's work involves managing urban hydrology.
Queensland Department of Environment and Resource Management. (2011). Salinity management handbook (2nd ed.). Brisbane, QLD: The State of Queensland. ISBN: 0 7242 7412 X	Land use changes increase salinity.	Vegetation loss, groundwater depletion	Integrate salinity management.	Create integrated land management plans.	Revegetate at-risk areas with trees and crops.	Low	Land management overlaps with watershed practices (municipal).
Queensland Department of Environment and Resource Management. (2011). Salinity management handbook (2nd ed.). Brisbane, QLD: The State of Queensland. ISBN: 0 7242 7412 X	Prevention is cost-effective over reclamation.	Hydrology, salinity in urban settings	Adopt preventative approaches.	Avoid hydrologic imbalances.	Monitor and adjust irrigation practices.	Moderate	Cost-effective prevention aligns with CRWD goals.
Environment and Climate Change Canada. (2024). Code of practice for the environmental management of road salts: Annual overview of data reported (2019–2022) in the context of national targets. Gatineau, QC	Excessive salt use degrades water resources.	Chloride in road salt, urban watersheds	Optimize salt application.	Increase salt efficiency in road maintenance.	Adopt prewetting and efficient salt spreaders.	High	CRWD requires efficient salt use for ecosystem health.
Environment and Climate Change Canada. (2024). Code of practice for the environmental management of road salts: Annual overview of data reported (2019–2022) in the context of national targets. Gatineau, QC	High risk near sensitive zones	Sensitive zones, chloride benchmarks	Protect salt vulnerable areas.	Identify and protect chloride sensitive areas.	Implement salt management for vulnerable zones.	High	Sensitive watersheds need strategic salt controls.
Environment and Climate Change Canada. (2024). Code of practice for the environmental management of road salts: Annual overview of data reported (2019–2022) in the context of national targets. Gatineau, QC	Inefficient salt use harms ecosystems.	Salt storage, urban stormwater quality	Promote sustainable practices.	Improve sustainability in salt usage.	Mandate annual reviews of salt plans.	Medium	CRWD supports sustainable urban practices.

Document	Trend (presented or paraphrased)	Issues/Impacts/Resources Evaluated	Goals and Drivers		Actions/Activities	Relevance to CRWD (High, Medium, Low, Unknown)	Notes
			Guiding Principles	Goals	Actions (Suggested or Paraphrased)		
Canadian Council of Ministers of the Environment. (2011). Canadian water quality guidelines for the protection of aquatic life: Chloride. Winnipeg, MB	Chloride toxicity thresholds impact aquatic life.	Freshwater ecosystems, chloride toxicity	Establish Protective Chloride Thresholds	Establish and enforce protective limits.	Apply acute and chronic chloride criteria.	High	Chloride limits are critical for local waterbodies.
Canadian Council of Ministers of the Environment. (2011). Canadian water quality guidelines for the protection of aquatic life: Chloride. Winnipeg, MB	Sensitive ecosystems need tailored strategies.	Endangered species, habitat risks	Launch site-specific risk mitigation.	Develop localized chloride limits.	Engage stakeholders for site-specific thresholds.	Medium	Localized chloride limits align with CRWD concerns.
Canada–United States. (2012). Great Lakes Water Quality Agreement: Protocol amending the agreement between Canada and the United States of America on Great Lakes Water Quality, 1978, as amended in 1983 and 1987. Washington, D.C.	Holistic approaches address cumulative threats.	Climate change, invasive species	Adopt ecosystem-based management.	Address threats through an ecosystem approach.	Coordinate across agencies and stakeholders.	High	CRWD benefits from ecosystem management expertise.
Canada–United States. (2012). Great Lakes Water Quality Agreement: Protocol amending the agreement between Canada and the United States of America on Great Lakes Water Quality, 1978, as amended in 1983 and 1987. Washington, D.C.	Shared water issues require cooperation.	Transboundary pollution, collaboration	Strengthen binational collaboration.	Foster cross-border pollution solutions.	Establish shared monitoring and planning.	High	Transboundary collaboration is applicable to CRWD.
Maine Department of Environmental Protection. (2020). Impact of deicing salt on Maine streams: A DEP issue profile. Augusta, ME	Urban runoff elevates chloride levels.	Urban chloride sources, aquatic species	Reduce chloride pollution from urban runoff.	Limit chloride discharge in urban watersheds.	Train municipal staff in deicing BMPs.	High	Urban runoff is a major issue for CRWD watersheds.
Maine Department of Environmental Protection. (2020). Impact of deicing salt on Maine streams: A DEP issue profile. Augusta, ME	Chloride harms aquatic species and habitats.	Chloride toxicity, ecosystem health	Protect sensitive aquatic species.	Preserve biodiversity in aquatic systems.	Monitor aquatic ecosystems regularly.	High	Aquatic biodiversity aligns with CRWD priorities.
Iowa Department of Natural Resources. (2023). Chloride water quality standards factsheet. Des Moines, IA	Toxicity is linked to hardness and sulfates.	Municipal effluents, water softeners	Adopt flexible standards.	Use flexible, site-specific chloride standards.	Allow flexible compliance based on chemistry.	Medium	Flexible standards help address urban variability.
Iowa Department of Natural Resources. (2023). Chloride water quality standards factsheet. Des Moines, IA	Water softeners and industries contribute chloride.	Industrial chloride sources, reduction	Encourage source reduction.	Minimize upstream chloride sources.	Optimize home water softeners regionally.	Medium	Source control fits within CRWD programs.

Document	Trend (presented or paraphrased)	Issues/Impacts/Resources Evaluated	Goals and Drivers		Actions/Activities	Relevance to CRWD (High, Medium, Low, Unknown)	Notes
			Guiding Principles	Goals	Actions (Suggested or Paraphrased)		
Iowa Department of Natural Resources. (2023). Toolbox for chloride limits compliance. Des Moines, IA	High costs demand alternative solutions.	Compliance, municipal effluent reuse	Develop innovative compliance tools.	Enable cost-effective compliance solutions.	Recycle effluents for no discharge uses.	Medium	Effluent reuse could be explored in CRWD areas.
Iowa Department of Natural Resources. (2023). Toolbox for chloride limits compliance. Des Moines, IA	Local data improves management precision.	Water chemistry, chloride thresholds	Promote data-driven adjustments.	Tailor chloride reduction to local conditions.	Collect long-term chloride and water hardness data.	Medium	Data-driven approaches support CRWD projects.
Maryland Department of the Environment. (2024). Chloride pollution reduction strategies. Baltimore, MD	Adaptive strategies reduce environmental salt.	Applicator training, chloride controls	Implement adaptive management.	Promote efficient salt practices statewide.	Train and certify road salt applicators.	High	CRWD can apply adaptive salt reduction tactics.
Maryland Department of the Environment. (2024). Chloride pollution reduction strategies. Baltimore, MD	Stormwater permits emphasize salt reduction.	Salt plans, urban stormwater management	Mandate salt management plans.	Mandate comprehensive salt management plans.	Enforce MS4 permit compliance for chloride.	High	CRWD enforces MS4 permits, including chloride plans.
Wenck Associates, Inc. (2006). Shingle Creek Chloride TMDL Report.	Chloride levels exceed chronic and acute standards in multiple reaches.	Road salt application, Como and McCarrons Lakes chloride exceedances	Prioritize reduction of chloride levels to meet standards.	Achieve compliance with MN water quality standards for chloride.	Implement deicer alternatives, optimize equipment, and monitor reduction strategies.	High	Urban water bodies face similar chloride impairments; strategies align with addressing impaired water quality.
Wenck Associates, Inc. (2006). Shingle Creek Chloride TMDL Report.	MPCA nondegradation policy protects existing water quality in streams and lakes.	Mississippi River and tributaries	Ensure nondegradation of water bodies meets standards.	Maintain chloride levels in nonimpaired water bodies.	Develop best practices for salt storage and public education campaigns.	Moderate	Prevents chloride impairments, ensuring sustainable management of CRWD's water resources.
Wenck Associates, Inc. (2006). Shingle Creek Chloride TMDL Report.	Public awareness campaigns like "Low Salt, No Salt Minnesota" are effective.	Private property deicing practices, public education initiatives	Strengthen community engagement and education.	Increase stakeholder participation in chloride reduction programs.	Host workshops on winter maintenance and environmentally friendly deicing.	High	Engaging stakeholders reduces pollution at the source, enhancing compliance and effectiveness.
Wenck Associates, Inc. (2006). Shingle Creek Chloride TMDL Report.	Monitoring data shows seasonal chloride exceedances during winter deicing.	Seasonal runoff, unmonitored subwatersheds	Implement targeted monitoring and adaptive management.	Establish systems to track chloride levels and identify hotspots.	Deploy conductivity loggers and adapt strategies based on annual monitoring reports.	High	Data-driven management is essential to address seasonal chloride dynamics effectively.
Wenck Associates, Inc. (2006). Shingle Creek Chloride TMDL Report.	Salt storage and maintenance significantly influence chloride loading.	Municipal deicing practices, BMP implementation	Align municipal operations with chloride reduction goals	Reduce municipal stormwater chloride contributions.	Adopt BMPs for deicing and set lane mile-based salt benchmarks.	Moderate	Collaborative approaches enhance chloride management across municipalities.

Document	Trend (presented or paraphrased)	Issues/Impacts/Resources Evaluated	Goals and Drivers		Actions/Activities	Relevance to CRWD (High, Medium, Low, Unknown)	Notes
			Guiding Principles	Goals	Actions (Suggested or Paraphrased)		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Chloride levels increasing; impaired status for chloride (2014)	Water quality monitoring	Adaptive management	1. Reduce chloride levels to meet state water quality standards.	Conduct biannual water quality monitoring to track chloride concentrations.	High	Chloride levels in Como Lake exceed state standards, requiring iterative adjustments based on monitoring data and emerging technologies.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Establish iterative review cycles.	Update chloride reduction strategies every three years based on monitoring results.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Regional chloride impacts; MPCA TMDL emphasizes collaboration	Public/agency engagement	Collaborative stewardship	1. Build partnerships with local agencies.	Partner with MPCA and local agencies to implement regional chloride BMPs.	High	Regional efforts such as the Twin Cities Metro Area Chloride TMDL highlight the need for collective action and resource sharing to address chloride pollution.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Engage community stakeholders in chloride reduction.	Engage community groups like District 10 to promote stewardship programs.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Overapplication of salt due to lack of training	BMP implementation	Sustainable practices	1. Promote efficient salt application techniques.	Conduct winter maintenance training for municipal staff and private contractors on efficient deicing practices.	High	Improper deicing contributes to chloride pollution; training and equipment calibration are crucial to reducing salt use while maintaining public safety.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Minimize salt use while ensuring public safety.	Promote calibration of equipment to avoid overuse of salt.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Stormwater runoff delivers chloride to the lake.	Structural BMPs	Long-term infrastructure development	1. Implement structural BMPs to manage chloride runoff.	Install infiltration basins and permeable pavement systems to capture chloride-laden runoff.	Medium	Green infrastructure solutions such as infiltration basins can intercept chloride-laden runoff, addressing one of the primary sources of pollution.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Increase green infrastructure deployment.	Incorporate green infrastructure solutions into future development plans.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Low public awareness about chloride impacts	Community engagement	Public education and behavior change	1. Increase public understanding of chloride pollution.	Conduct public workshops to educate residents about the impacts of chloride pollution.	High	Community understanding of chloride pollution is essential for behavioral change; outreach can empower

Document	Trend (presented or paraphrased)	Issues/Impacts/Resources Evaluated	Goals and Drivers		Actions/Activities	Relevance to CRWD (High, Medium, Low, Unknown)	Notes
			Guiding Principles	Goals	Actions (Suggested or Paraphrased)		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Encourage community adoption of BMPs.	Develop and distribute outreach materials promoting sustainable deicing practices.		residents to adopt sustainable practices.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Lack of deicing policy and accountability for salt use	Regulatory framework	Policy and regulation development	1. Establish municipal chloride application regulations.	Advocate for policies limiting chloride application rates in municipal and private sectors.	High	Current practices lack enforcement and guidelines for chloride use. Developing policies can institutionalize sustainable practices and ensure compliance with reduction targets.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Develop enforcement mechanisms.	Establish reporting requirements for deicing practices to ensure compliance with regulations.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Increasing chloride levels but uneven spatial distribution	Data and analytics	Integrated monitoring	1. Monitor chloride levels seasonally and annually.	Deploy monitoring equipment to capture seasonal variations in chloride inputs.	High	Chloride pollution hotspots need identification to prioritize interventions. Long-term monitoring ensures timely adjustments to strategies based on real-world effectiveness.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Identify hotspots for targeted interventions.	Analyze spatial data to prioritize chloride reduction efforts in high-input areas.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Urban runoff exacerbates chloride transport.	Climate resilience	Infrastructure resilience	1. Prepare infrastructure for increased deicing needs.	Update stormwater infrastructure to handle increased freeze–thaw cycles and deicing needs.	Medium	Climate change impacts, such as increased freeze–thaw cycles, amplify deicing needs. Incorporating resilient infrastructure prepares for future scenarios while reducing chloride pollution today.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Address climate-induced impacts on runoff.	Retrofit aging systems to incorporate chloride-reducing technologies.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Inefficient salt spreading equipment	Technology upgrades	Technology adoption	1. Use smart technologies to optimize salt application.	Procure and deploy smart salt spreaders to reduce overapplication.	Medium	Advancing the use of modern technologies such as smart salt spreaders ensures minimal salt usage without compromising public safety.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Reduce chloride use via advanced equipment.	Implement pavement sensors to monitor real-time conditions and optimize deicing efforts.		

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Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Significant chloride input from private lots and roads	Public–private partnerships	Public–private collaboration	1. Partner with private entities to reduce chloride use.	Establish programs encouraging private businesses and HOAs to adopt chloride BMPs.	High	Residential and private property management contributes to chloride runoff. Partnering with businesses and HOAs (homeowners associations) fosters sustainable practices beyond municipal domains.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				2. Engage HOAs in sustainable deicing.	Provide incentives for private entities to invest in smart deicing technologies.		
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN	Lack of funding for structural BMPs and chloride BMP adoption	Economic support strategies	Financial incentives	1. Offer grants for BMP implementation.	Create grant programs for infiltration systems in high-priority areas.	Medium	Providing financial incentives such as grants or subsidies encourages local governments and private entities to adopt BMPs, supporting regional chloride reduction goals.
Capitol Region Watershed District. (2019). Como Lake Management Plan. St. Paul, MN				Subsidize smart deicing equipment for private users.	Provide financial support for municipalities to procure smart salt spreading equipment.		
Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.	Rising chloride levels in surface and groundwater	Chloride in stormwater, surface water, and groundwater	Sustainable chloride use	Reduce chloride usage.	Optimize road salt application practices.	High	Aligns with CRWD's efforts to reduce chloride impacts, especially in impaired water bodies like Como Lake and McCarrons Lakes.
Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.	Seasonal chloride peaks during winter months	Engagement with municipalities, public, and private applicators	Stakeholder collaboration	Increase awareness and compliance.	Conduct public education campaigns.	High	CRWD depends on partnerships and public education to improve municipal and private salt application practices.
Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.	Persistent chloride in the environment	Chloride accumulation in lakes, groundwater, and stormwater systems	Performance-based adaptive management	Protect and restore impaired and at-risk water bodies.	Establish monitoring programs.	High	Monitoring is essential for tracking trends, evaluating chloride reduction strategies, and protecting aquatic life in CRWD's jurisdiction.
Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.	Urbanization and road density contributions	Exploring sustainable chloride-reduction measures and alternatives	Cost-effective, sustainable practices	Develop sustainable, cost-effective alternatives.	Fund research into alternative practices.	Medium	Although CRWD can advocate for cost-effective alternatives, its implementation depends on stakeholders.
Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.	Climate change impacts on chloride management	Freeze–thaw cycles increasing salt application demands				Medium	Long-term planning for climate resilience is relevant, but the immediate focus is on existing chloride sources and management.

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Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.		Adjusting strategies to respond to observed chloride trends			Implement adaptive management strategies.	High	Adaptive management aligns with CRWD's data-driven approach to adjusting strategies based on monitoring results.
Minnesota Pollution Control Agency. (2016). Twin Cities Metro Area Chloride Management Plan.		Chloride toxicity affecting fish, invertebrates, and aquatic plants				High	Protecting aquatic life aligns directly with CRWD's mission to improve water resources and manage chloride impacts effectively.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Chloride concentrations in water bodies exceed standards and persist in the environment.	Ecosystems, water quality	Balance public safety with environmental stewardship.	Reduce chloride use.	Promote MPCA Smart Salting training to teach best practices (e.g., calibration, liquid deicers).	High	CRWD must manage pollutant loads while addressing public safety concerns.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Urban stormwater ponds retain significant chloride, impacting downstream ecosystems.	Urban water management			Monitor and assess chloride levels in stormwater and prioritize high-impact areas for intervention.	High	Stormwater systems are a key focus of CRWD's management activities.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Chloride harms aquatic life, affecting fish, macroinvertebrates, and amphibians.	Biodiversity and ecosystem health	Promote environmental awareness and stewardship.	Protect aquatic ecosystems.	Collaborate with local organizations to reduce chloride loads impacting aquatic habitats.	High	CRWD oversees ecosystem health within its jurisdiction, which chloride directly threatens.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Vegetation damage and soil salinization from chloride affect runoff and ecosystem balance.	Linked terrestrial systems			Support education campaigns addressing the impacts of oversalting on vegetation and soils.	Medium	Vegetation health indirectly affects runoff and water quality managed by CRWD.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Rising chloride concentrations in monitoring wells exceed drinking water standards.	Groundwater contamination	Protect vital water resources from persistent pollutants.	Protect groundwater quality.	Develop programs to reduce chloride application rates near groundwater-sensitive areas.	High	CRWD integrates groundwater protection into broader water resource management strategies.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Soil compaction from chloride increases runoff and reduces infiltration.	Stormwater management	Ensure infrastructure resilience in chloride-affected environments.	Improve stormwater infiltration.	Promote landuse practices that mitigate soil impacts from salt.	High	Soil compaction affects infiltration and runoff, critical for CRWD's stormwater management goals.

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Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Chloride causes corrosion of bridges, sidewalks, and infrastructure.	Public stormwater systems		Minimize infrastructure damage.	Encourage contracts prioritizing salt efficiency and reduced application.	Medium	Infrastructure impacts are indirect but relevant where chloride affects stormwater systems.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Increased freeze–thaw cycles lead to greater salt use.	Climate adaptation	Adapt to changing climatic conditions.	Adapt to changing conditions.	Incorporate climate resilience strategies into long-term chloride management plans.	Medium	Climate trends are relevant to long-term water resource planning but less immediate for CRWD's current efforts.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Drinking water sources are at risk of chloride contamination.	Public health and water quality	Protect human health by ensuring safe water supplies.	Safeguard public health.	Support outreach on the risks of chloride to drinking water supplies.	High	Protecting drinking water aligns directly with CRWD's goals for water quality.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Public safety concerns drive excessive salting practices.	Public safety	Balance public safety with sustainable environmental practices.	Balance safety and sustainability.	Educate applicators on safe, reduced salt alternatives that protect public safety.	Medium	Balancing safety and chloride reduction is indirectly relevant for CRWD's outreach efforts.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Legal fears drive overuse of salt, discouraging best practices.	Institutional and legal barriers	Encourage collaborative governance to address systemic barriers.	Support systemic policy change.	Advocate for liability laws for certified Smart Salting applicators.	Medium	CRWD can collaborate on policy advocacy but has limited direct control over legislative efforts.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Contracts based on outcomes, not volume, could reduce oversalting.	Operational efficiency			Encourage municipal contracts that focus on efficient salt use.	Medium	Contracts influence salt use indirectly but could align with CRWD's chloride reduction goals.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Applicators and the public lack understanding of chloride impacts and solutions.	Public education	Promote widespread understanding of chloride's impacts on water resources.	Increase public and applicator awareness.	Reframe messaging to emphasize personal impacts and downstream effects of chloride pollution.	High	CRWD is well positioned to lead public outreach campaigns on chloride reduction.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	The public assumes stormwater is treated before reaching water bodies.	Watershed education			Educate communities on stormwater's direct entry into water bodies and the role of chloride pollution.	High	Public understanding is critical to supporting CRWD's chloride management strategies.

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Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Local governments, businesses, and watersheds work in silos.	Multistakeholder engagement	Support coordinated and unified chloride reduction strategies across stakeholders.	Strengthen collaborative approaches.	Partner with stakeholders to align chloride reduction strategies and resources.	High	Collaboration is central to CRWD's mission and chloride management goals.
Kreiter, A. L. (2020). Hennepin County Chloride Initiative: Developing a strategic plan to increase adoption of best management practices with private applicators.	Limited alignment of isolated programs impedes broadscale solutions.	Shared resource alignment			Facilitate coordinated chloride management efforts among municipalities, applicators, and organizations.	High	Aligning programs enhances CRWD's effectiveness in implementing chloride management plans.
Michigan Department of Environment, Great Lakes, and Energy. (2021). Chloride Water Quality Implementation Plan. Lansing, MI.	Chloride and sulfate impair aquatic ecosystems, affecting freshwater mussels and fish populations.	Numeric standards, NPDES permits	Align WQS with chloride benchmarks to protect aquatic ecosystems.	Develop chloride specific WQS through NPDES permits.	Integrate chloride benchmarks into permits. Train stakeholders on chloride reduction strategies.	High	Supports CRWD's regulatory framework to incorporate chloride standards in urban and natural watershed management.
New Hampshire Department of Environmental Services. (2020). Best Management Practices and Salt Use Minimization Efforts. Concord, NH.	Half of chloride in watersheds stems from private property deicing.	Urban runoff, private property deicing	Optimize salt use through BMPs while maintaining public safety.	Reduce salt use by 25%–45% in urban and private areas.	Promote Smart Salting training. Mandate Salt Minimization Plans for new developments.	High	Practical BMPs align with CRWD's focus on urban deicing and public private collaboration.
Fortin Consulting, Inc. (2014). The Real Cost of Salt Use for Winter Maintenance in the Twin Cities Metropolitan Area. St. Paul, MN: Minnesota Pollution Control Agency.	Road salt causes \$803–\$3,341 per ton in damages to infrastructure and ecosystems.	Financial impact of road salt	Minimize economic and environmental costs of chloride use.	Reduce salt use by 10%–70%.	Transition to brining and advanced technologies. Calibrate equipment to minimize overapplication.	High	Regional analysis aligns directly with CRWD's goals of reducing urban chloride impacts while offering economic benefits to stakeholders.

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Mullaney, J. R., et al. (2009). Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States. USGS.	Chloride concentrations are rising in urban and agricultural areas due to deicing and irrigation practices.	Chloride trends, GIS mapping	Monitor and manage chloride trends in water resources.	Expand monitoring programs to track trends and prioritize action areas.	Use GIS tools to identify hotspots. Conduct targeted sampling in rural and urban areas.	Moderate	Supports CRWD's monitoring and data-driven decision-making efforts for chloride hotspot management.
Wisconsin Department of Natural Resources. (2022). Statewide Chloride Strategy. Madison, WI.	Chloride levels are increasing in surface and groundwater, with urban runoff being a major source.	Public–private collaboration, financial assistance	Address chloride pollution through multisector partnerships.	Implement TMDLs and BMPs through cross-sector collaboration.	Develop Smart Salting initiatives with municipalities. Secure grants for equipment upgrades like brining systems.	High	Comprehensive multisector strategies closely align with CRWD's need for collaborative solutions and funding for BMPs.
Pennsylvania Department of Environmental Protection. (2012). Rationale for the Development of Ambient Water Quality Criteria for Chloride. Harrisburg, PA.	Elevated chloride disrupts osmoregulation in aquatic species, leading to stress and mortality.	Aquatic species health, ecological balance	Develop state-specific chloride criteria for aquatic life protection.	Adopt chloride standards based on ecological data.	Conduct research to localize chloride criteria. Target reduction efforts in ecologically sensitive areas.	Moderate	Offers scientific basis for ecological impacts of chloride, supporting CRWD's arguments for stricter controls.
World Health Organization. (2017). Guidelines for Drinking Water Quality. Geneva, Switzerland.	High chloride levels affect drinking water taste and infrastructure durability.	Drinking water quality, taste, and safety	Ensure safe drinking water through chloride management.	Maintain chloride levels below WHO-recommended thresholds.	Monitor drinking water sources for chloride contamination. Raise awareness on minimizing salt use near drinking water sources.	Low to Moderate	There is limited direct relevance, but this provides context for public health considerations, especially in source water protection.
Rhode Island Department of Administration. (2014). Road Salt/Sand Application in Rhode Island. Providence, RI.	Improper salt storage contributes to runoff, causing water quality degradation.	Salt storage and runoff prevention	Balance public safety and environmental protection in salt storage practices.	Improve salt containment and handling practices.	Standardize municipal salt storage practices.	Low to Moderate	Highlights storage issues that could support CRWD's recommendations for local municipalities, though the focus is state-specific.

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					Implement runoff prevention measures at storage sites.		
Illinois Water Quality Standards. (2023). Environmental protection: Water quality standards. Pollution Control Board.	Meeting numeric standards for chemical constituents and chronic toxicity in waterways is challenging.	Chloride TMDL for Como Lake and McCarrons Lake; mixing zone management	Comply with state and federal standards.	Achieve compliance with numeric standards by 2030.	Implement stricter permitting for industrial discharges.	High	CRWD operates as an MS4 co-permittee, requiring compliance with chloride-related TMDLs and standards to avoid regulatory penalties.
Illinois Water Quality Standards. (2023). Environmental protection: Water quality standards. Pollution Control Board.				Reduce mixing zone exceedances in priority areas by 50%.	Expand monitoring of mixing zones in sensitive habitats.	High	
Seeley, M. (2019). Climate change in Minnesota: A hydrologic perspective. University of Minnesota.	Increased precipitation and extreme weather events are leading to more freeze–thaw cycles and deicing salt applications.	Infrastructure retrofits; climate modeling for stormwater runoff impacts	Climate resilience	Retrofit 25% of stormwater infrastructure by 2030.	Develop localized climate models.	High	CRWD must adapt to climate changes that exacerbate chloride runoff, impacting infrastructure and water quality.
Seeley, M. (2019). Climate change in Minnesota: A hydrologic perspective. University of Minnesota.				Integrate climate impact analysis into watershed plans by 2026.	Invest in flood mitigation strategies, focusing on urban hotspots.	High	
Minnesota Pollution Control Agency. (2020). Statewide chloride management plan summary. Minnesota Pollution Control Agency.	Chloride levels in Minnesota's lakes and rivers are increasing due to urban runoff and winter maintenance.	Road salt management; alternative deicing materials for winter maintenance	Chloride pollution reduction	Reduce road salt application rates by 30% within five years.	Expand public education on chloride reduction strategies.	High	Chloride impairments in Como and McCarrons Lakes are directly tied to urban road salt use, requiring strategic reduction measures.
Minnesota Pollution Control Agency. (2020). Statewide chloride management plan summary. Minnesota Pollution Control Agency.				Promote alternative deicing materials across 70% of municipalities.	Implement pilot projects using alternative deicing materials.	High	
Minnesota Pollution Control Agency. (2021). Statewide chloride management plan report. Minnesota Pollution Control Agency.	Chloride concentrations are rising in the Twin Cities Metropolitan Area surface waters.	Smart Salting training; chloride monitoring for Como Lake and McCarrons Lake	Evidence-based chloride management	Develop TMDL plans for 25 high-risk water bodies by 2028.	Establish mandatory Smart Salting training programs.	High	CRWD relies on data-driven approaches for chloride monitoring and adaptive management in impaired and high-risk areas.
Minnesota Pollution Control Agency. (2021). Statewide chloride management plan report. Minnesota Pollution Control Agency.				Monitor chloride in 50 waterbodies by 2026.	Expand data sharing platforms for chloride trends.	High	

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BCWMC. (2023). Parkers Lake drainage project final report. Bassett Creek Watershed Management Commission.	Collaboration improves outcomes for chloride reduction and stormwater management projects.	Public workshops for Smart Salting; collaborative BMP development	Stakeholder engagement	Increase stakeholder participation by 40% by 2026.	Facilitate workshops on BMP integration for chloride reduction.	Medium	Public engagement enhances implementation but is secondary to technical efforts for chloride reduction and compliance.
BCWMC. (2023). Parkers Lake drainage project final report. Bassett Creek Watershed Management Commission.				Complete two chloride reduction projects using public engagement lessons.	Develop engagement templates based on project feedback.	Medium	

Appendix E: Examples of Current Chloride Reduction Solutions

Examples of Current Road Salt Reduction Solutions

Examples of current road salt reduction solutions under the major themes of education and communication, training, regulatory initiatives, policy initiatives, monitoring and data analysis, winter maintenance improvements, infrastructure design, financial support, research, and partnerships.

- **Education and Communication**
  - The "Low Salt, No Salt Minnesota" campaign offers a toolbox of education and communication resources to help with outreach to applicators to reduce road salt use (Clean Water Minnesota [CWM], 2025).
  - In the fall of 2025, the Minnesota Pollution Control Agency (MPCA) debuted a Chloride Reduction Program website (MPCA, 2025b) in addition to their Chloride Outreach and Education website (MPCA, 2025a) to offer resources for educational materials, outline training opportunities and financial assistance, and encourage partnership and collaboration.
- **Training**
  - The MPCA offers Smart Salting Trainings and certification for: Roads, Parking lots & sidewalks, Property management, and Community leaders (MPCA, 2025c). These trainings aim to improve operator effectiveness while maintaining safety. The trainings also help municipal separate storm sewer system (MS4) permittees to fulfill the MS4 training requirements.
  - Many watershed districts in the metro area help to fund these trainings for partners in their areas.
- **Regulatory**
  - Nine Mile Creek (NMCWD), Valley Branch (VBWD), and Riley-Purgatory-Bluff Creek (RPBCWD) Watershed Districts all include chloride management in their Stormwater Rules by requiring stormwater permittees to have a chloride management plan and a smart-salting certified applicator (NMCWD, 2023; RPBCWD, 2019; VBWD, 2023).
  - The MPCA regulates MS4 permit holders by including chloride-specific requirements in their most recent MS4 permit, issued on November 16, 2020 (MPCA, 2023). This included requirements for:
    - Distribution of education materials focused on chloride impacts on water resources and practices to reduce salt use.
    - Annual training of all staff performing winter maintenance operations.
    - A written Snow and Ice Management Policy.
    - Proper salt storage.
    - Use of regulatory mechanisms to require proper storage at commercial, institutional, and other non-permitted facilities.
    - Maintaining a written or mapped inventory of salt and snow storage locations.

        - Those who have a chloride waste load allocation (WLA) guided by an approved TMDL must document the amount of deicer applied each winter maintenance season and must conduct an assessment of the permittee's winter maintenance operations to reduce the amount of deicing salt applied.

- **Policy**
    - In 2024, Nine Mile Creek Watershed District staff submitted a resolution to MN Watersheds titled "Regulatory approaches to reducing chloride contamination" to show the support of watershed organizations for regulatory approaches at either the state, county, city, or watershed organization level as a solution to chloride overuse (NMCWD, 2026b).
    - Minnesota Watersheds and other Minnesota organizations have worked for legislation to provide limited liability legislation for property owners and maintenance companies who are Smart Salting certified by the MPCA to aim to reduce the amount of salt used by certified commercial applicators in Minnesota.
    - One route being discussed to regulate the work of private contractors is to create an occupational licensing program through a city/county/state policy that requires all winter maintenance contractors that may apply salt in their work to obtain a license to perform this work. This is similar to licensing requirements for electricians, plumbers, and pesticide applicators (Sniegowski et. al., 2025).

- **Monitoring and Data Analysis**
    - Most watershed districts and water management organizations have monitoring programs that have been tracking chloride conditions in their respective water resources over time. The Minnesota Pollution Control Agency, Metropolitan Council Environmental Services, and Minnesota Department of Natural Resources, as well as various County environmental departments, have also been monitoring the health of our local, county, and state water resources. These datasets are essential to understanding the extent of the chloride problem in area water resources, determine which water bodies are impaired, create total maximum daily loads (TMDLs) for water quality improvement, and will allow managers to understand trends and changes in lake and stream health with future chloride reduction.
    - The Coon Creek Watershed District is partnering with the US Geological Survey on a monitoring and modeling project to better understand the interaction of groundwater and surface water chloride in the Coon Creek Watershed with the goal of using this information to determine realistic load reduction targets, identify loading hotspots, target solutions, and track long-term trends and progress (Dauphinais et al., 2025).

- **Winter Maintenance Improvements**
    - Numerous improvements in technology and best management practices have allowed both large roadway applicators and small-scale applicators to improve snow removal and efficient salt use. Multiple reports outline these strategies which

include: improved mechanical removal (e.g. better plow blades, implementing best practices for plowing operations), the use of temperature sensors to understand real-time pavement temperature, adding brine as a tool, improved event forecasting, better equipment calibration, improved decision-making for choosing the property material and estimating timing of snow and ice control, and better tracking of salt use (Local Road Research Board [LRRB], 2022; Minnesota Department of Transportation [MnDOT], 2019; MPCA, 2020). For example, the Minnesota Statewide Chloride Management Plan highlights the addition of brine as a tool for large roadway ice management as a major milestone in salt use between 2000 and 2020 (MPCA, 2020).
    - Multiple cities are leading the way in being proactive in their winter maintenance strategies, which allows for more proactive and less reactive decision-making with respect to salt use. This includes strategies such as improving mechanical snow removal, implementing brine programs, and better defining the level of service that will be provided for different types of paved surfaces.
    - Some cities are evaluating the use of winter street sweeping to remove excess salt leftover from winter storm or thawing events.

- **Infrastructure Design**
    - Bolton & Menk, Inc created a Low Salt Design (LSD) Guide to outline the ways that we can better design our infrastructure in cold climate areas to reduce the need for salting in the winter, such as creating intentional and efficient snow storage areas that reduce meltwater sprawl and considering pavement alternatives (Bolton & Menk, Inc., 2025a).
    - The City of Hopkins has included a low-salt design checklist in their sustainable building policy that was adopted in 2025, which includes recommendations from Bolton & Menk's LSD guide and leverages financial incentives to gain traction among developers (City of Hopkins, 2025).
    - The City of Bloomington Public Works Department has been reducing salt use through their WISE (Winter Intendance and Salt Elimination) program that includes improved infrastructure design with strategies like minimizing obstacles in parking lots that prohibit efficient plow operations and improved snow storage (Distal, 2025).

- **Financial Support**
    - The MPCA offered chloride reduction grants in 2024 for source reduction projects using a chloride reduction action plan. The MPCA also offers loans for chloride reduction through their small business environmental assistance loans and Clean Water Partnership loan program (MPCA, 2025b).
    - Nine Mile Creek, Ramsey Washington Metro (RWMWD), and South Washington (SWWD) Watershed Districts all offer grants for chloride reduction practices to organizations in their respective districts as part of their larger grant programs (NMCWD, 2026a; RWMWD, 2026; SWWD, 2026).

- **Research**
    - Institutions like the University of Minnesota and state departments like the MN Department of Transportation are at the forefront of research on alternatives to traditional road salt, examining both their potential for use as well as their environmental impacts (Gulliver et al. 2022; University of Minnesota Center for Transportation Studies [UMN CTS], 2022).
    - Research projects and large-scale analyses continue to demonstrate the transport of chloride through watersheds and the detrimental effects of chloride on our water resources, the environment, and infrastructure (Herb, 2017; Janke & Finlay, 2025; Small, et al., 2025; McDivitt, 2019)
- **Partnerships**
    - The Hennepin County Chloride Initiative (a collaboration between multiple watershed districts, watershed organizations, and cities in Hennepin County with support from the county and the MPCA), collaborated to create the "Low Salt, No Salt Minnesota" program (CWM, 2025).
    - The newly established "Cold Climate Center of Excellence for Stormwater Infrastructure Technologies" (CCCESIT) is being co-led by the University of Minnesota (UMN) and the University of New Hampshire in partnership with the National Municipal Stormwater Alliance with an overarching goal of advancing the science and awareness of how stormwater (including snowmelt) is managed year-round in states with cold climates (UMN, 2025).
    - Bolton & Menk, Inc. organize an annual Salt Symposium: a day-long virtual event that allows for professionals from various backgrounds to come together and share success stories, challenges, and new research in chloride reduction and management (Bolton & Menk, Inc., 2025b).
    - Winter Salt Week is a collaboration of organizations across the United States that work to raise awareness of salt pollution and partner to highlight solutions for reduction through a one-week virtual event in January (Wisconsin Salt Wise, 2025).

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Appendix F: Summary of Themes from CRWD Chloride Plan Issues and Roles Identification Workshops and Activities

Technical Memorandum

To:	Britta Belden, Monitoring and Research Division Manager Sarah Wein, Water Resources Project Manager
From:	Nick Voss, Water Resources Scientist Suzy Lindberg, Communications Manager Della Schall Young, CPESC, PMP, CTF, Principal Scientist
Date:	December 10, 2024
Re:	Summary of Themes from CRWD Chloride Plan Issues and Roles Identification Workshops and Activities

To begin the establishment of the Capitol Region Watershed District (CRWD) Chloride Management Plan, the CRWD, in partnership with the Young Environmental consultant team, intentionally designed an engagement plan by identifying key groups to provide feedback throughout plan development, and determine the best ways to engage each group.

To begin this engagement plan, the first step worked on identifying the main issues to reducing chloride use in CRWD and potential roles for CRWD to engage in to help reduce chloride use in the District. The main goals of this step were to: 1) provide all groups with a clear understanding of the negative impacts of chloride use in the District, and 2) identify the main issues with managing chloride use and potential roles the District should take to reduce chloride use from each group's perspective.

This memo describes the process for identifying issues and roles with each group outlined in the engagement plan, methods to synthesize the data from all engagement activities, and the overall outcomes and themes of all activities. These results will be used to develop plan goals and objectives, which will form the backbone for the plan and guide the development of implementable actions.

INTRODUCTION

Engagement Groups

The following groups were included in the issues and roles identification portion of the engagement process.

Group	Description	Engagement Type
Board of Managers	As the primary decision-makers within CRWD, the five-member Board of Managers guides the District to implement the projects	**Workshop & Presentation:** November 6, 2024

Group	Description	Engagement Type
	and programs laid out in the CRWD Watershed Management Plan.	**Co-Facilitated:** Sarah Wein and Della Schall Young
Community Advisory Committee (CAC)	The CAC represents a group of environmentally minded residents who meet monthly to assist CRWD's Board of Managers and Staff and strengthen the connection between CRWD and District residents.	**Workshop & Presentation:** November 13, 2024 **Co-Facilitated:** Sarah Wein and Britta Belden
CRWD Staff	CRWD staff use their technical expertise, practical experience, and institutional knowledge to carry out the goals and objectives in the CRWD Watershed Management Plan through CRWD projects and programs.	**Workshop & Presentation:** October 29, 2024 **Co-Facilitated:** Sarah Wein and Britta Belden
Technical Advisory Group (TAG)	This group of partners includes municipal, state, and county agencies; external experts; and practitioners to provide technical guidance and feedback. At the first workshop, the TAG was represented by the City of Saint Paul, Ramsey County, Metropolitan Council, and the Minnesota Pollution Control Agency.	**Workshop & Presentation:** October 30, 2024 **Co-Facilitated:** Sarah Wein and Della Schall Young
General Public	The general public was included to gather their input on key issues and solutions. It was also critical for the project team to determine the level of public understanding and concern with chloride as an emerging issue.	**Survey:** An online survey was released and promoted from 10/22/2024 through 11/14/2024. **Events:** • September 30, 2024: MaryDale Festival • October 5, 2024: City of Saint Paul Snow Summit • October 8, 2024: Minnesota Water Stewards Annual "Confluence of Stewards" event

Although the initial engagement plan also involved outreach strategies for businesses, commercial properties, and applicators that manage impervious areas throughout the CRWD, further discussion led the project team to the determination that in-person outreach would be too extensive for the current scope of work. The project team is incorporating recent survey results from applicators, which is available through another Twin Cities study led by Hennepin County, into the overall Plan. Those survey results are not included here in this document.

Workshops and Outreach

CRWD/Young staff conducted an issues and roles identification workshop with the CRWD Board of Managers, CAC, Staff, and TAG. During each workshop, each group was given a presentation that outlined the reason for the development of a CRWD Chloride Plan, the major environmental impacts of chloride use to District water resources, and the major challenges to reducing the use of salt in CRWD.

Next, workshop facilitators asked a series of questions designed to prompt discussion and extract key information from participants. The questions varied slightly depending on the audience and their role and were designed to gather critical information. Example questions included the following (specific questions are introduced in the results section of the memo):

1. What are the main issues/constraints/challenges to reducing chloride use in CRWD?
2. If there were no limitations, what would you do to reduce chloride pollution?
3. What should CRWD's role be in chloride reduction?
4. What can CRWD do to help or support your organization in chloride reduction?

Additionally, a survey was conducted that was used for tabling at three public outreach events, and the same questions were used for an online survey. The online survey was posted to the District social media channels, District newsletter, and sent to the Executive Directors of the Saint Paul District Councils for distribution to their respective residents. The questions asked were:

1. Tell us your level of concern about the following issues related to de-icing salt by ranking each issue "High", "Medium", or "Low":
    a. Water Quality: Salt can permanently pollute lakes, rivers, wetlands, groundwater, and drinking water.
    b. Animals: Salt can be toxic to birds, fish, and aquatic bugs. It can also sicken pets and hurt their paws.
    c. Plants and Soil: Salt can harm lawns, landscaping, trees, and aquatic plants. It can also contaminate soil.
    d. Personal Property: Salt can cause rusting on vehicles and damage shoes, carpets, and flooring.
    e. Public Infrastructure: Salt damages public infrastructure like concrete and asphalt pavements, and bridges.
2. What do you think should be done to use less salt or solve the chloride pollution problems in our watershed?

ANALYSIS METHODS

Raw Data

Once the engagement process was complete for each group, Young Environmental staff conducted an analysis to develop qualitative codes and themes for answers to the discussion questions in all workshops. To do this, each piece of data (i.e. answer) was first assigned its own identifying number and a phrase that associates the piece of data with the workshop and the question that it pertains to. By examining and coding each response, Young staff could move on to consolidate all individual workshop responses into overall codes and themes.

Results and Themes

Using the raw workshop data, Young Environmental generated a list of codes and subcodes to reveal a sequence in the responses. Codes were counted and tracked by their response number to rank them according to the most prominent responses in the data. The list of codes for each question was gathered and combined in a synthesis of all workshop responses.

This synthesis contained the most prominent codes that arose for each question, and the top three codes were used to generate the qualitative themes overall. When a theme was rich in data and nuance, subthemes were included and organized with both a number and letter. Keywords, anchored quotes, and pie charts were included for each question to support reviewers in understanding the meaning captured by the themes.

Finally, a summary of the public outreach survey was included to summarize the multiple-choice question results and prominent codes that arose from the public event and survey data.

RESULTS

Synthesis of Workshop Results

The following tables and charts express the sequence of coded data that was discovered in the analysis as well as the top three prominent themes grounded in the coded data.

Question 1: What emerging trends in chloride use, perception, behavior, technology, etc. are you observing?

Workshops in data pool: TAG and staff.

Sample code from top-occurring code: "Education—more people are starting to understand the problem; however, what messaging/interactions will reach different groups."

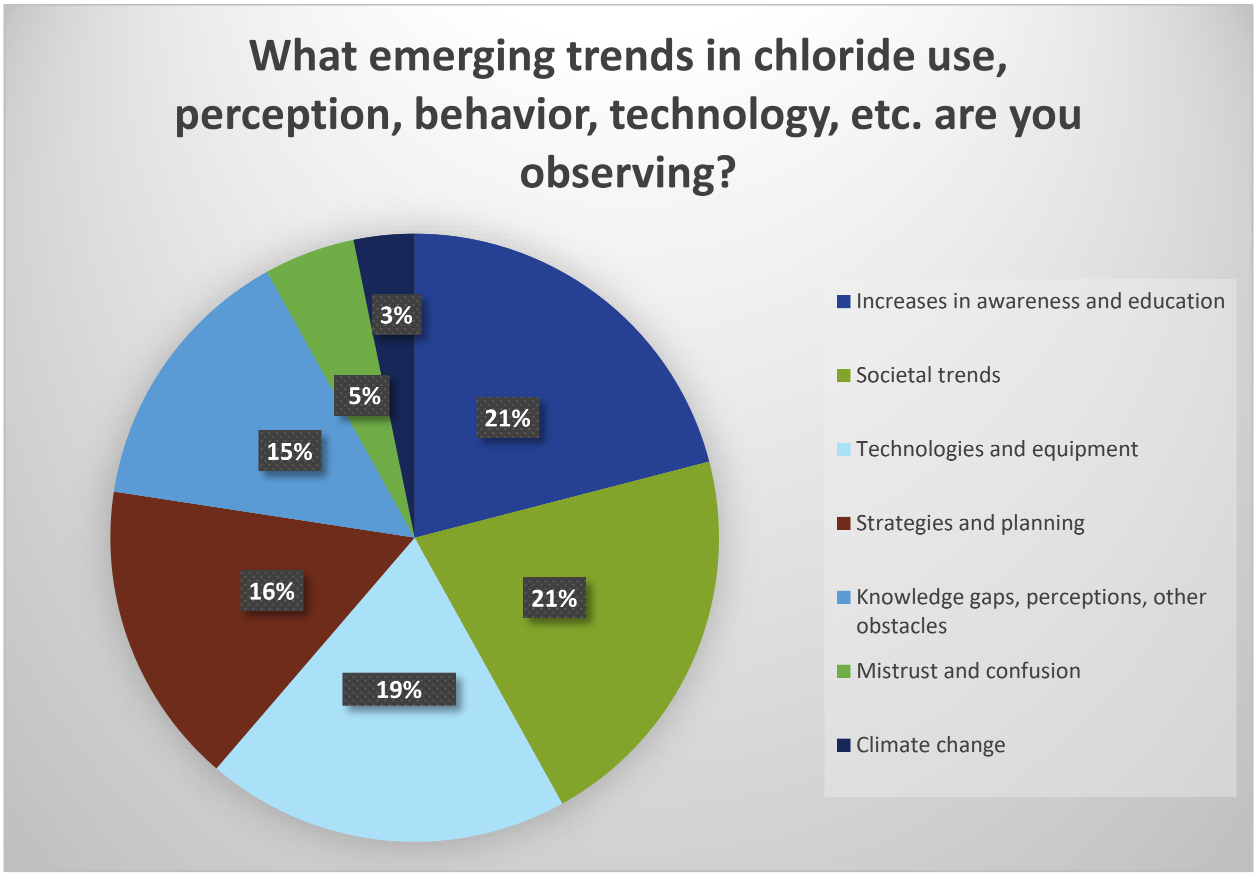
Keywords from top-occurring code: More awareness, more discussion, increase in education, complaints, context, types of trainings, and levels of service.

Themes:

1. Increased education and understanding also appear to come with an increase in specific training and higher receptivity to context.

2. There is an expressed desire to improve in the midst of many societal complications such as liability and high demands for public safety.
3. Technology allows for improvements but comes with costs and considerations of accessibility.
    a. Use of technology and equipment allows a proactive approach to chloride application.
    b. Technology and equipment are improving application rates, but their associated costs are increasing.
    c. There can be limited access to advanced equipment, yet infrastructure damage increases.

Qualitative code	Occurrence	Percentage
Increases in awareness and education	13	21%
Societal trends	13	21%
Technologies and equipment	12	19%
Strategies and planning	10	16%
Knowledge gaps, perceptions, other obstacles	9	15%
Mistrust and confusion	3	5%
Climate change	2	3%



Question 2: What are the main issues, constraints, and challenges to reducing chloride use in CRWD?

Workshops in data pool: All.

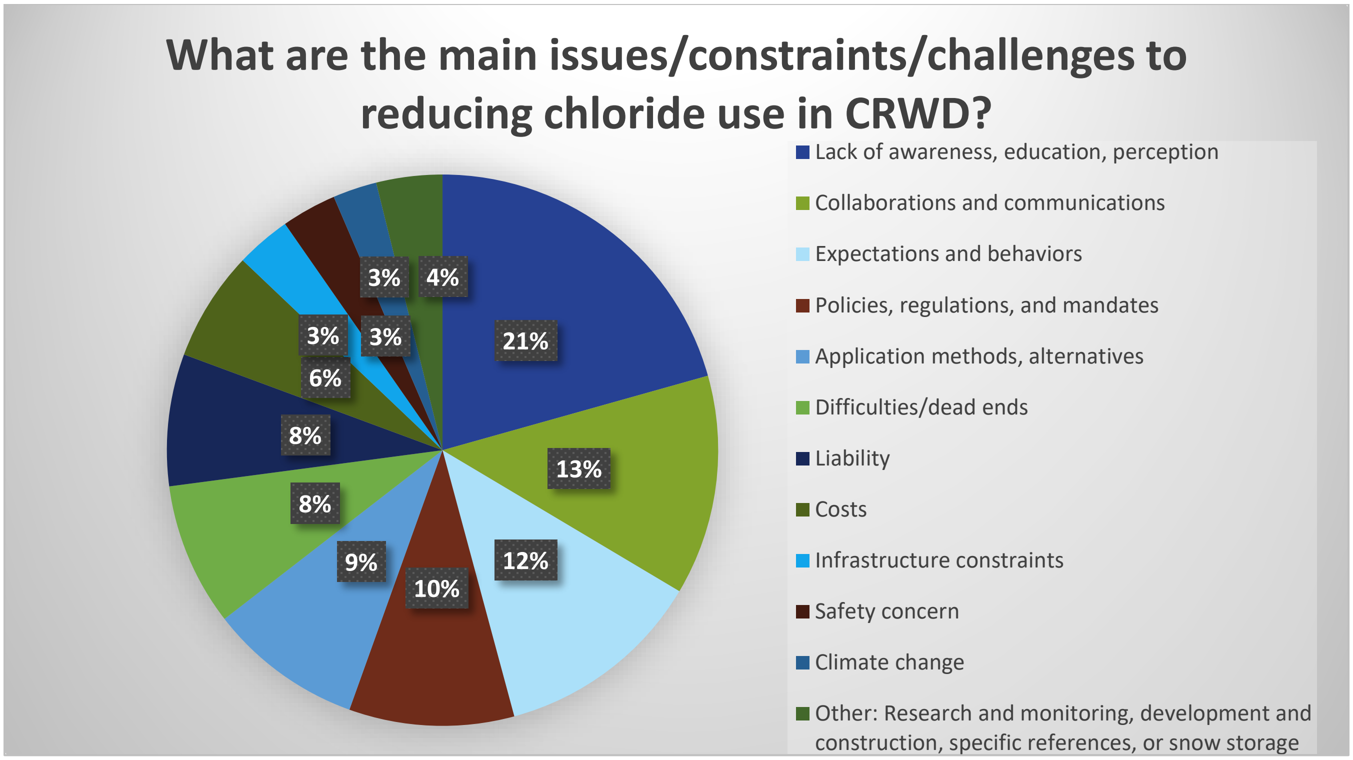
Sample quote from top-occurring code: "There is a lack of education/information about when to use salt, how much, and how too much causes permanent pollution and damage."

Keywords from top-occurring codes: Perception, lack, appropriate, information, use, alternatives, no alternatives, tailoring, toolkits.

Themes:

1. A lack of education and awareness as well as issues around public perception of chloride, lead to increased chloride use.
2. There are needs and pressures around leadership and governance, especially in terms of how they relate to trades and contractors.
    a. Communication should span different trades and agencies while promoting shared participation and buy-in.
    b. Communication should be consistent and clear and should clear up misinformation.
3. Expectations drive behavior, foster a culture of immediacy, and contribute to overuse of chloride.

Qualitative code	Occurrence	Percentage
Lack of awareness, education, perception	32	21%
Collaborations and communications	20	13%
Expectations and behaviors	19	12%
Policies, regulations, and mandates	15	10%
Application methods, alternatives	14	9%
Difficulties/dead ends	13	8%
Liability	12	8%
Costs	10	6%
Infrastructure constraints	5	3%
Safety concern	5	3%
Climate change	4	3%
Research and monitoring (other)	2	1%
Development and construction (other)	2	1%
Specific reference (other)	1	1%
Snow storage (other)	1	1%



Question 3: What is your organization's role in chloride reduction and management?

Workshops in data pool: TAG.

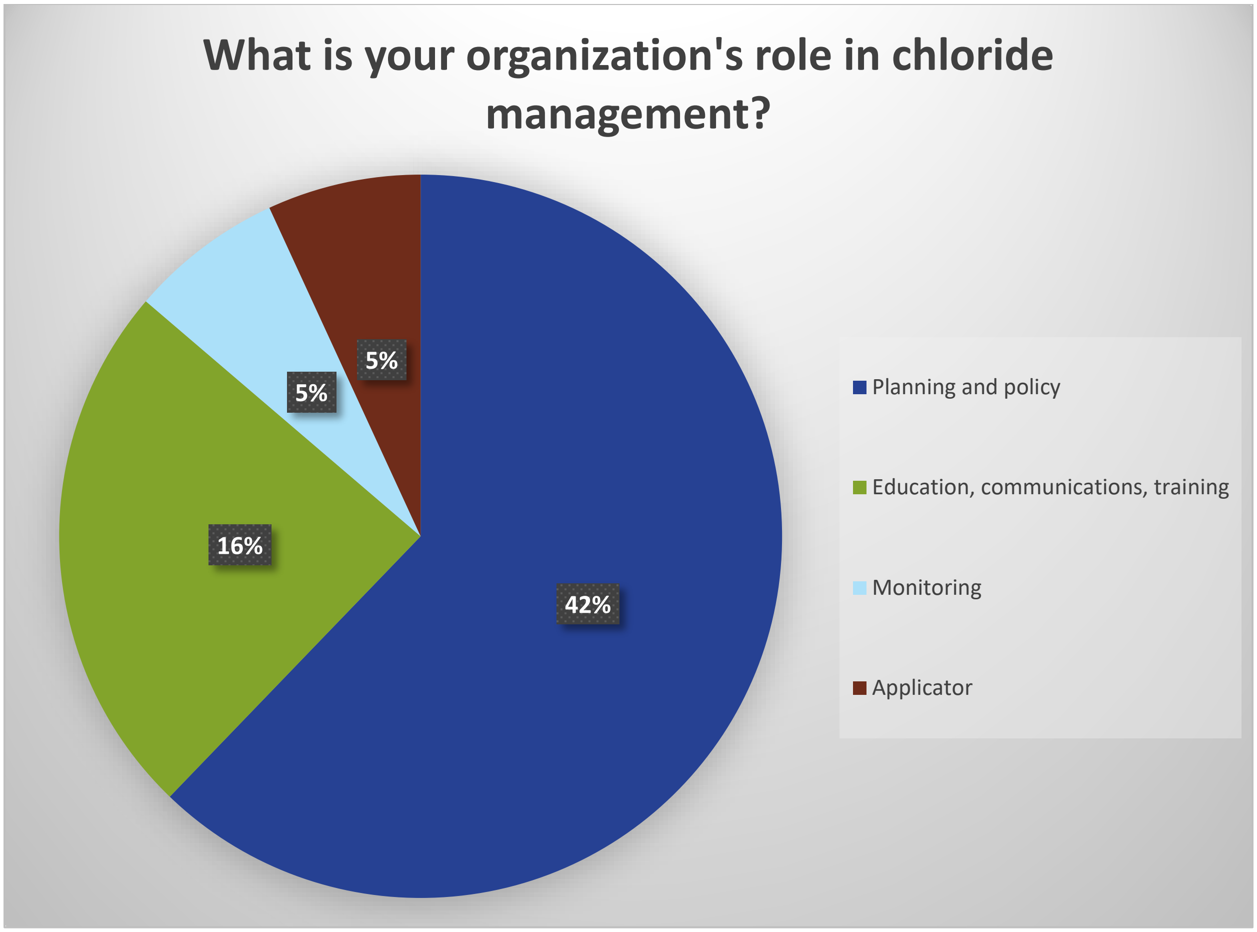
Sample quote from top-occurring code: "Policy establishment."

Keywords from top-occurring codes: Policy, mapping, working, not working, learning, recommendation, plans, design, equipment, partnerships, technology.

Themes:

1. Form plans and policies that utilize tracking, advances in equipment and technology, chloride management plans, and an ongoing assessment of what's working and what isn't.
2. Provide education and training with an emphasis on proper application and impaired waters.
3. Tie together monitoring of water and aquatic plants. Applicators should focus on proper application and the use of techniques to assess conditions and needs for maximum benefit.

Qualitative code	Occurrence	Percentage
Planning and policy	8	42%
Education, communications, training	7	16%
Monitoring	2	5%
Applicator	2	5%



Question 4: What should CRWD's role be in chloride reduction?

Workshops in data pool: All.

Sample quote from top-occurring code: "Education. Education to old and new appliers conveying what's in it for them. Making chloride issues available for Minnesota transplants to understand. Education to home consumers conveying what's in it for them."

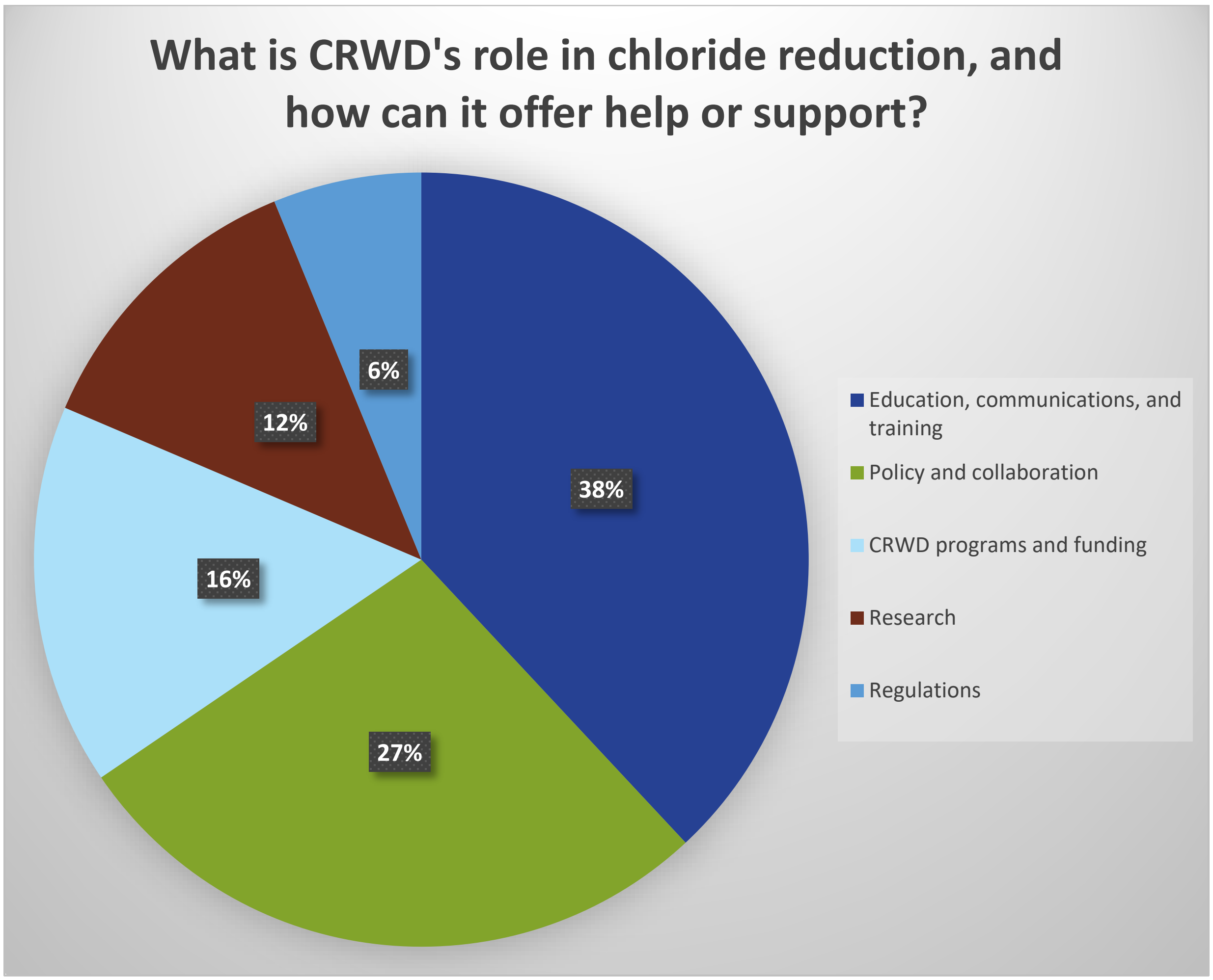
Keywords from top-occurring code: Education, communications, idea sharing, outreach, service, expectations, training, diversification, creative, audience, case studies, share practices.

Themes:

1. There is a broad emphasis on education campaigns that are grounded in data and what's current.
   a. Lead campaigns that are supported by creative ideas yet grounded in case studies, and also cater to specific audiences from staff to the public to applicators.
   b. Improve existing training programs, or make training for applicators a requirement.
2. Drive policies and collaboration through partnerships, having conversations, and networking.
   a. Develop incentives and design strategies supported by partnerships.
   b. Be a supportive, helpful leader and advocacy figure, but also assign roles.

3. Provide programs and funding.
    a. Provide site plan review, grants, training, research efforts, and chloride reduction programs.
    b. Provide monitoring and analysis of that monitoring.
    c. Provide programs that deliver tangible services and infrastructure changes.

Qualitative code	Occurrence	Percentage
Education, communications, and training	43	38%
Policy and collaboration	31	27%
CRWD programs and funding	18	16%
Research	14	12%
Regulations	7	6%



Question 5: If there were no limitations, what would you do to reduce chloride pollution?

Workshops in data pool: All.

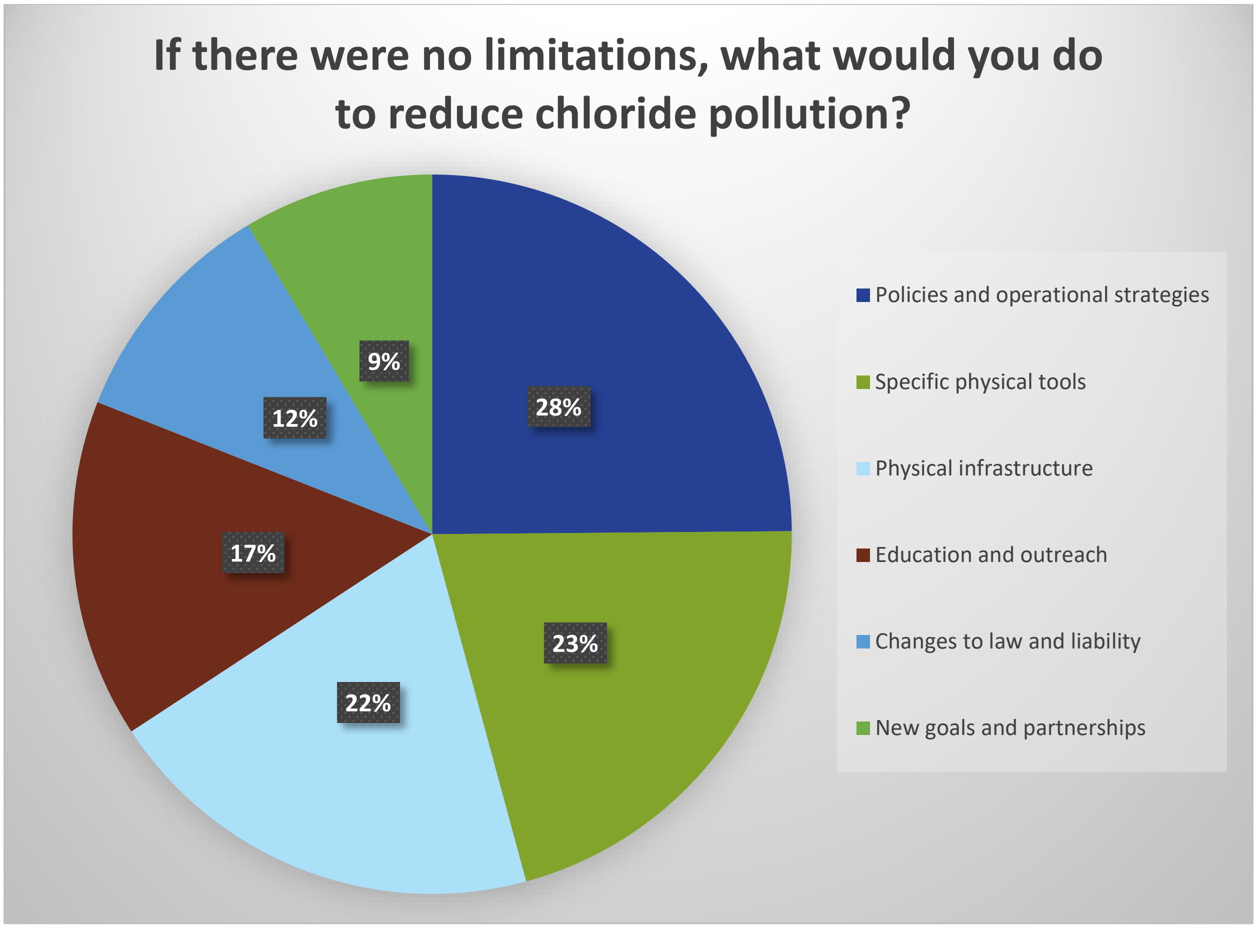
Sample quote from top-occurring code: "Require collection of salt spills within a certain time."

Keywords from top-occurring code: Require, support, sweep, lottery, pay, drivers, label, benefit, care, grants, plowing, business, mindful, inception, site visits.

Themes:

1. Develop policies and strategies.
    a. Policies around the use of waste products, street restrictions, and the use of lottery money
    b. A variety of strategy ideas such as warning labels, expanded plowing, and subsidizing alternatives
2. Provide tools, salt alternatives, and technology such as reverse osmosis or the wide issuance of free tools such as crampons.
3. Make changes to physical infrastructure such as heated surfaces, reduced pavement, or raised surfaces.

Qualitative code	Occurrence	Percentage
Policies and operational strategies	30	28%
Specific physical tools	22	23%
Physical infrastructure	21	22%
Education and outreach	16	17%
Changes to law and liability	11	12%
New goals and partnerships	9	9%



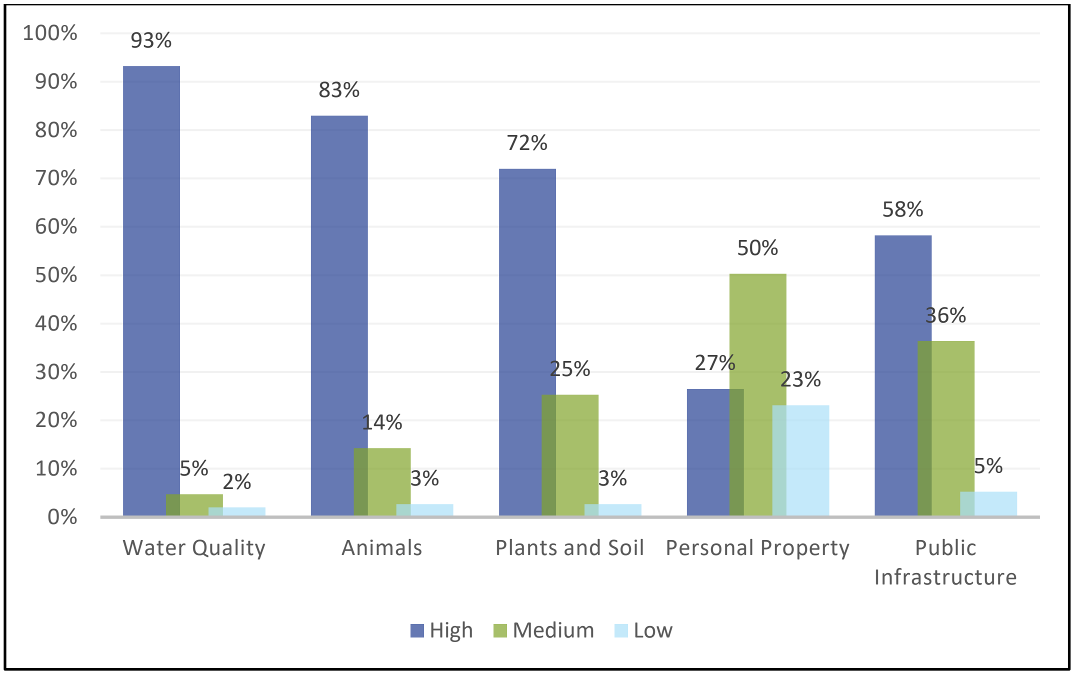
Synthesis of Public Survey Results

Through the three public events and public online survey data, we solicited input from 150 members of the public. The following charts/figures express the compiled results of the public events and public online survey data collected.

Question 1: Tell us your level of concern (high, medium, and low) about the following issues?

All public responses

Issue	High	Medium	Low
Water quality	93%	5%	2%
Animals	83%	14%	3%
Plants and soil	72%	25%	3%
Personal property	27%	50%	23%
Public infrastructure	58%	36%	5%



Question 2: What do you think should be done to use less salt or solve the chloride pollution problems in our watershed?

Public event responses: Major themes

- There should be more and better alternatives to chloride
- There should be more policies surrounding salt use and winter maintenance activities
- There should be more infrastructure in place to reduce the need to salt

Public survey responses: Major themes

- There should be more and better alternatives to chloride
- There should be more education containing information about salt application, impacts of salt use, and alternatives to salt
- There should be more regulations that limit the use of salt and promote better winter maintenance